वार्षिक प्रतिवेदन 2018-19

Annual Report 2018-19

CSIR-National Metallurgical Laboratory

Jamshedpur - 831007, India

Our sincere tribute to

Prof. EG Ramachandran (1925-2018)

A brilliant metallurgist, an outstanding teacher, a distinguished academician, and a visionary, Prof. EG Ramachandran passed away on February 14, 2018. Born in 1925, he obtained his PhD in 1947 (at the age of 22, an extraordinary accomplishment) from the University of Sheffield. Prof. EG Ramachandran's joining CSIR-National Metallurgical Laboratory in 1956 which coincided with Dr. Balraj Nijhawan taking over as the 1st Indian Director of CSIR-National Metallurgical Laboratory. These were initial days for a fledgling laboratory on which rested the country's dreams and hopes of building the metallurgical industry of India at par with that of developed nations. Prof. EG Ramachandran was one of the six Assistant Directors who was entrusted the leadership for laying the foundation and shaping the future of CSIR-NML. His association with CSIR-National Metallurgical Laboratory, Jamshedpur was for approximately 5 years, after which , he served the Department of Metallurgy, IISc, Bangalore, as a faculty member for 9 years, and then moved to IIT Madras in 1961 as the first Professor of the Department of Metallurgical Engineering. He was also the Director-in-Charge of IIT Madras for a small period.

Some of the best R&D work of Prof. EG Ramachandran were conducted at the CSIR-National Metallurgical Laboratory, Jamshedpur. It is bewildering that even after pursuing applied research; he could publish seventeen papers within span of five years, which included several in NATURE and Acta Metallurgica.

He was actively involved in establishing the Industrial Metallurgy Division in the Indian Institute of Metals and later became its President in 1980.

He will live on in the hearts of all his admirers including his students and peers.

Sources :

1.https://alumni.iitm.ac.in/wp-content/uploads/2018/02/Prof-EGR-Chair-an-appeal.pdf

2.Dr. S. Srikanth: "Prof. EG Ramachandran's Years (Oct 1956 – Oct 1961) at the National Metallurgical Laboratory, Jamshedpur"

CSIR-National Metallurgical Laboratory

The Inception

The foundation stone for National Metallurgical Laboratory was laid by Hon'ble Sri C. Rajagopalachari on 21st November, 1946. It was formally inaugurated and dedicated to the nation on 26th November, 1950 by Pandit Jawaharlal Nehru "in a spirit of hope and in a spirit of faith in the future'. The laboratory was an element of Sir Shanti Swaroop Bhatnagar's vision of providing India with a network of research institutions for taking the country ahead in science and technology. CSIR-NML played a significant role in the industrial revolution of India starting from 1950 especially in the areas of mineral processing, iron and steel making, ferroalloys and extraction of non-ferrous metals, notably magnesium. Asia's largest creep testing facility was also set up at CSIR-NML in the early 1970s and even today it ranks as the second largest creep testing lab in Asia.

"….But when I come to Jamshedpur it is not the past of India that comes up before me but some vision of the future comes before my eyes."

"I do not wish any worker to come to these laboratories merely with the aim of earning his living. What I wish is that our young men and women who come here should have a zeal for working out problems which would have great consequence. That would give vitality to these Institutes. They should realize that service to science is real service to India – no, even to the whole world – science has no frontiers".

…Pandit Jawaharlal Nehru

Research & Development

The Laboratory has kept pace with changing research scenarios and needs of the country. In the last few years, greater emphasis is given to industry sponsored research and, alignment with government program; namely, Make in India, Innovate in India, Strategic sector needs, Swatch Bharat, Societal and skill India, etc. The activities of the Laboratory touch upon several major sectors relevant to the growth of India, including iron and steel, power and energy, oil and gas, automotive, railways, strategic, societal, and others. We strive to create competitive advantage for our clients. Our high quality services have marked our presence around the world.

CSIR-NML envisions becoming a self-reliant, self-sufficient R&D laboratory by continuing providing feasible and sustainable solutions to the industries in the areas of metals, minerals and minerals. The laboratory strives to recreate its niche in the areas relevant for empowering the evolving India via catering to the needs of modern India.

Our Vision Statement

"To become a global leader and an internationally benchmarked laboratory in mineral and metallurgical research and development. To become a self-sustained technology centre in minerals, metals and materials."

Organizational Structure

President, CSIR
Shri Narendra Damodar Modi

Vice President, CSIR
Dr. Harsh Vardhan

Director General, CSIR
Dr. Shekhar C. Mande

Director CSIR-NML
Dr. Indranil Chattoraj

Research Council

Management Council

Advisors

Dr. R. Kumar
Management

Dr. S. Tarafder
(w. e.f. 1st March, 2019)
Management

Dr. S. K. Das
NKN &ICT

R&D Divisions and Units

Dr. S. Tarafder
Head-MTE

Dr. R. Singh
Head-MNP

Dr. S. G. Chowdhury
(w. e.f. 1st March, 2019)
Head-MTE

Dr. A. Sinha
Head-AMP

Dr. D. Bandopadhyay
Head-MER

Dr. T. V. Vijayakumar
Head-MC

R&D Support Divisions

Dr. A. Mitra
Head-RPBD

Dr. S. K. Mandal
Head-KRIT

Mr. P. K. Dhawan
Head-ENG

HRG & Functionaries

Dr. S. K. Mishra
Head-HRG

Mr. N. K. Singh
SPO

Mr. S. R. Hembram
COA

Mr. A. M. Pradhan
FAO

Dr. K. Bhattacharya
(w. e.f. 1st October, 2018)
COA

NKN & ICT (National Knowledge Network & Internet Communication Technologies), MTE (Materials Engineering Division), MER (Metals Extraction & Recycling), MNP (Mineral Processing), AMP (Advanced Materials & Processes), NML-MC (NML-Madras Center), RPBD (Research Planning & Business Development), ENG (Engineering), KRIT (Knowledge Resources & Information Technology), HRG (Human Resources Group), ADMIN (Administration), S&P (Stores & Purchase), F&A (Finance & Accounts)

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Research Council (RC)

Prof. Amol A Gokhale (Chairman)
IIT, Bombay
Former Director, Defence Metallurgical Research Laboratory (DMRL), Hyderabad

Dr. Gautam K. Dey (Member)
Former Associate Director, Materials Group, Bhabha Atomic Research Centre (BARC), Mumbai

Prof. V.S. Raja (Member)
Institute Chair Professor, Department of Metallurgical Engineering and Materials Science, IIT Bombay

Mr. Vinay Mahashabde (Member)
Chief Technology Officer (Products), Tata Steel, Jamshedpur

Dr. Vilas D. Tathavadkar (Member)
Senior Vice President, Aditya Birla Science and Technology Company, Raigarh

Dr. R.N. Patra (Member)
Former chairman IRE, Mumbai

Prof. S.K. Bhatnagar (Member)
Department of Cell Biology, College of Biotechnology, SVBP University of Agriculture & Technology, Meerut

Dr. R.R. Hirwani (Member)
Former Head, CSIR-Unit for Research and Development of Information Products (URDIP), Pune

Dr. K. Muraleedharan (Member)
Director, CSIR-Central Glass & Ceramic Research Institute, Kolkata

Dr. Arun K. Bhaduri (Member)
Director, Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam

Prof. B.K. Mishra (Member)
Director, IIT Goa

Prof. Dipak Mazumdar (Member)
Ministry of Steel Chair Professor, Department of Materials Science & Engineering, IIT Kanpur

Dr. Girish Sahni
DG-CSR & Secretary DSIR

Dr. I. Chattoraj (Member)
Director, CSIR-National Metallurgical Laboratory , Jamshedpur

Impressions

Wonderful campus. Neatly maintained. People are energetic. I wish to be here for some more time.

Harish Hirani
CSIR-CMERI
13 - 4 - 2018

Warm & dedicated people in such a cold working subject with such energy & enthusiasm great results are bound to be observed.

H. M. Bangur
Managing Director
Shree Cement
11- 05 - 2018

NML, a great and unique organization in the glorious history and a very important role to play in all sectors of growth of nation (starting from health to wealth) no civilization without "metal" NML to be taken as a vital R & D organization for the nations growth. Thank the Director for giving me the opportunity to take part in the Foundation Day.

T. C. Rao
EX-CSIR
26 - 9 - 2018

Very impressive laboratory for the future development of processes devoted to recycling of metal, thinking of a real sustainable development in the world.

S. Pellet Rosetaing
ICSM (France)
27- 9 - 2018

FOREWORD

CSIR-National Metallurgical Laboratory (NML), Jamshedpur has continued to perform well and in tune with the expectations of our stakeholders. In the past financial year, a number of major projects were undertaken and their execution initiated. The national mission programme on Advanced Ultra Super Critical (AUSC) Power Plant Technology, coordinated by IGCAR, Kalpakkam, has CSIR-NML as one of the major research partners. In this programme, CSIR-NML is executing four projects addressing materials qualification and NDT protocols. Additionally, and in the same theme, three research projects, Creep-fatigue interaction behavior of ODS-austenitic steels and ODS-iron and nickel aluminides, Development of Advanced NDE based Diagnosis and Prognosis Protocols for AUSC Power Plants, High Temperature Oxidation and Hot Corrosion behavior of selected materials for Clean Coal Technologies for Power Plant Applications, were also initiated. The latter projects are sponsored by DST, with ARCI, Hyderabad as the coordinating organization. The first pilot plant in the country for amorphous steel production, for use in transformers and other applications, will be set up soon by CSIR-NML, through funding provided by the Ministry of Steel.

The implementation of the various tasks planned under the International Program "Twinning on Capacity Building to transform the Metals Industry Development Institute of Ethiopia" has been started. CSIR scientists from five different laboratories have visited Ethiopia and initiated several modules under this program. Another international project, "Development of an effective extraction and separation technology to selectively extract rare earth elements from Waste Electrical and Electronic Equipment", being conducted through a sponsorship mediated by IFCPAR (The Indo-French Centre for the Promotion of Advanced Research), under Bilateral cooperation in Science and Technology, is being actively pursued.

CSIR-NML developed a technology for production of DRI from mill scale and lean grade coal in Tunnel Kiln by using iron ore fines and non-coking coal. Till date no process has been developed to utilize mill scale and lean grade coal for production of DRI in Tunnel Kiln without pre-induration of pellet. We have also been able to mark our presence in the areas E-waste management. As a part of this initiative, a couple of processes and technologies have been developed at CSIR-NML and are readily available for technology transfer. A Know-how for extraction of precious metals (Au, Pt and Pd) from the metallic concentrate of PC-PCBs has been transferred. Several projects have been carried out and processes developed in the matters of recovery of Germanium as metal/salts from secondary resources, Graphene based membranes from Graphite ore for desalination, feasibility studies on recovery of barite from drilling mud by flotation, development and transfer of a technology for the production of electrolytic zinc powder from zinc dross and development of high strength Zn-based biodegradable alloys for orthopaedic applications. CSIR-NML has provided consultancy on setting up the first pilot plant for sodium production. This is soon to be up-scaled to commercial production facility with CSIR-NML's help and advice.

The external cash flow (ECF) generated was very good, crossing Rs. 45 Crores in the reporting year. However, we could not meet the target of filing 25 patents, having filed 20 patents only. 7 copyrights were also filed. 5 new technologies were developed against a fiscal target of 8. The publications were stagnant at around 120 with an average impact factor of 2.17. Both these figures, especially the latter (impact factor) needs significant upward revision, if we want to have a global standing.

For the society, CSIR-NML continues its small but significant contributions. Detailed Project Report (DPR) for technological intervention for 5 Bell and Brass metal clusters of West Bengal are in progress, in association with the Technology Facility Centre (TFC). CSIR-NML is actively pursuing skill development activities targeting skills upliftment of the underprivileged, through a CSIR grant programme as well as on its own. Scientific dissemination for students continues through the School Interaction Programs as well as "Jigyasa".

I extend our heartfelt gratitude and appreciation to our esteemed clients, members of our Research Council, and numerous other friends and mentors, for providing continuous support and advice. I will reiterate the sense of pride and privilege I feel to be a part of CSIR-NML and to be able to work with a group of talented and dedicated individuals.

(Dr. Indranil Chattoraj)
Director, CSIR-NML

IMPACT

Science & Technology in Ancient India

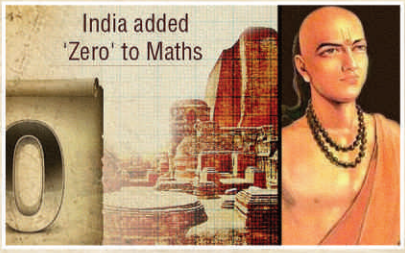
"India is not only at the origin of everything; intellectually, religiously or politically and even the Greek heritage seems pale in comparison."

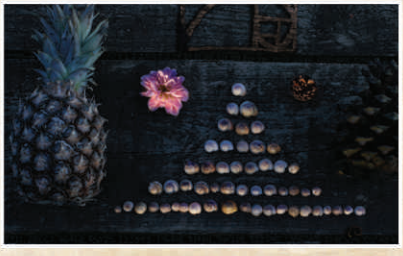
Frederich Von Schlegel

"We owe a lot to the ancient Indians, teaching us how to count. Without which most modern scientific discoveries would have been impossible."

Albert Einstein

Ancient Indian scientific & technological achievements have left a mark on every scientific field that are dealt with in the modern world. Presenting a compilation of a few such achievements /contributions, that were leading at their times…





https://www.thebetterindia.com/63119/ancient-india-science-technology/;
https://www.themysteriousindia.net/ancient-india-inventions-science-technology/ ; Wikipedia
https://www.google.com

Impressions

Today is my first visit to NML to deliver 125th birth ceremony lecture of M.N Saha. I am impressed by the ambience of the lab. Scientist and people are nice. Best wishes to all of them.

Sankar K. Pal
Indian Statistical Institute
Kolkata
05 -10 - 2018

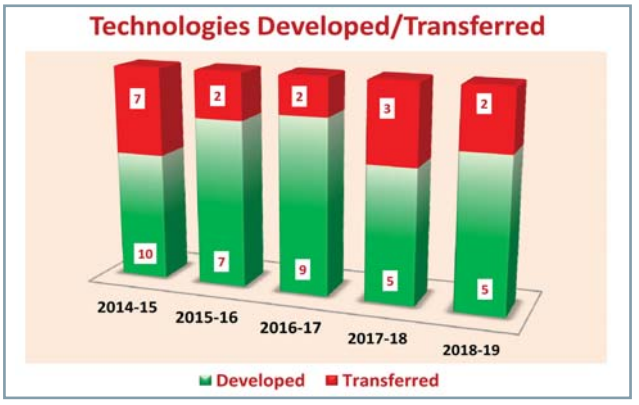
Very rewarding experience of visiting the lab after nearly 23 years. Excellent progress. I am particularly impressed with indigenously developed instruments and device.

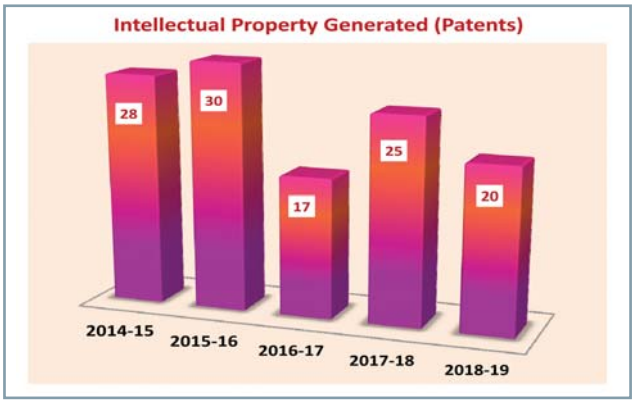
E. S. Dwarakadasa
Indian Institute of Science and Karnataka Hybrid Micro Devices Ltd.
29 -11- 2018

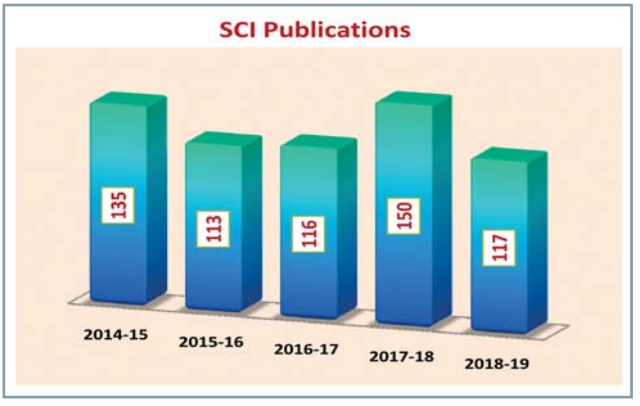
I am coming to NML after a couple of years. Always a pleasure to come here and have always been inspired by the work done here. Given the importance of R & D & technology for the future of the country we need to encourage all scientific minds to explore the limits of their potential and create conditions for the same. All the best to Team NML.

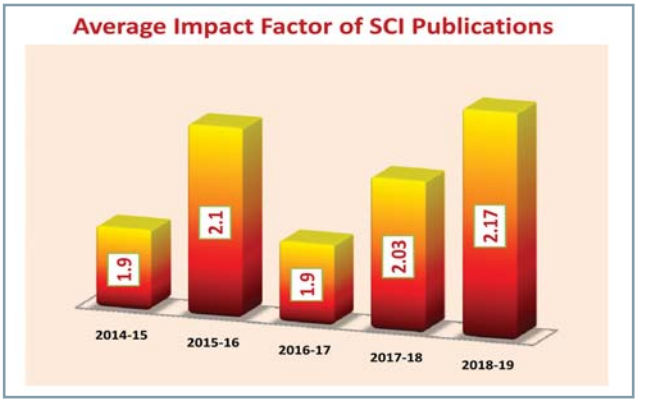
T. V. Narendran
Managing Director
Tata Steel
18 - 01- 2019

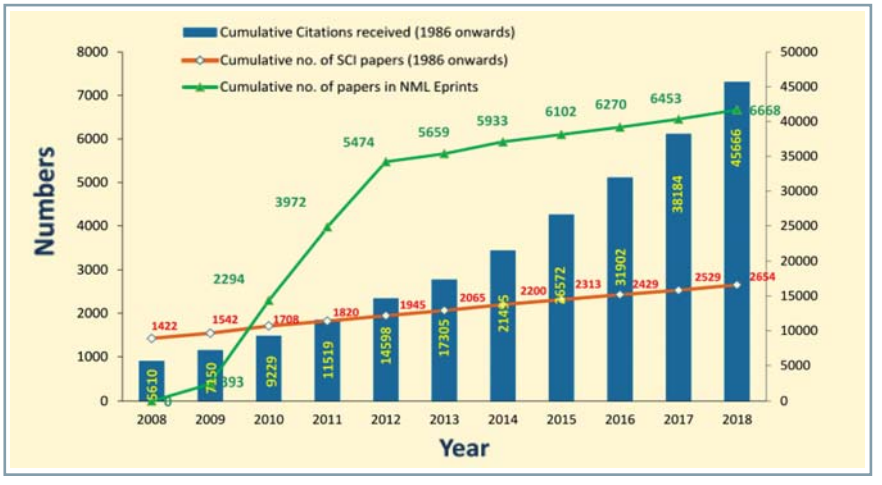
R&D OUTPUT











Source : Web of Science/Scopus/Google Scholar as on 31.01.2019

CSIR-NML Technology Profile

Mineral Processing

Column Flotation Technology

The column flotation technology is a new mineral beneficiation method developed on strong scientific principles for processing of fine low grade ores and minerals. The merits of the technology include improved metallurgical performance in terms of grade and recovery, effective cleaning of froths, small foot print, low capital investment, less operation and maintenance costs with user friendly controls. Improved metallurgical performance is due to: (i) less entrainment and entrapment, (ii) Independent control of operating variables, (iii) Froth washing provision and (iv) Control over bubble size - effective in fines collection. The Reduced operating & capital costs as a result of: (a) No moving parts & Lower energy consumption, (b) Lower reagent consumption, (c) Substantial reduction in floor area - vertical configuration and (d) One stage of column flotation generally replaces multi stage conventional flotation. The technology is fully commercialized for both, laboratory and industrial columns. The following industrial columns are in operation: M/S Indian Rare Earths Ltd., Chatrapur, Orissa (Sillimanite), 150 tons/day; M/S Indian Rare Earths Ltd., Chavara, Kerala (Sillimanite), 150 tons/day; M/S Andhra Barites Co. Ltd., Kadapa, Andhra Pradesh (Barites), 700 tons/day; M/S W Minerals Ltd., Srikakulam, Andhra Pradesh (Sillimanite), 150 tons/day*; M/S Oren Hydrocarbons Pvt Ltd., Chennai, Tamilnadu (Barites), 1000 tons/day.

Beneficiation of Low-grade Tungsten Ores

The technology is based on the novel integrated process flow-sheet involving beneficiation of low- and lean-grade ores and hydrometallurgical extraction of tungsten from wolframite concentrate. The concentration of the lean ore is achieved basically by gravity and magnetic separation techniques followed by hydrometallurgical extraction of tungsten from wolframite concentrate to obtain ammonium para-tungstate

Beneficiation of Low-grade Iron Ores

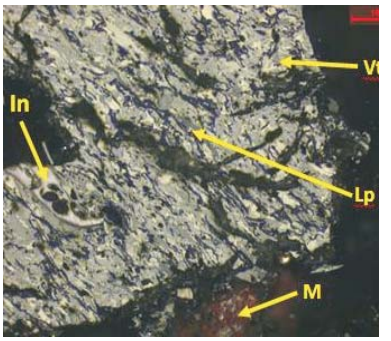
The technology is based on processing of low-grade iron ores primarily involving washing, gravity and magnetic separation. The products are calibrated lumps, sinter and pellet-grade concentrates suitable for iron & steel making. The intermediate products are recycled towards maximization of iron recovery. It has been commercialized for ore from Bolani and Gua Mines of SAIL

Recovery of Chromite Values from Tailings/Slimes Produced by Chromite Ore Beneficiation Plant

The technology exploits the difference in density of the chromite ore and the associated gangue minerals for their separation using fine gravity separator. The technology was developed at bench scale and subsequently validated through pilot scale trials. It produces marketable chromite concentrate with final tailings assaying< 10 % Cr_2O_3 meeting IBM guidelines for disposal of tailings. It has several advantages viz.(i)Additional resource generation(ii)Creation of additional space for storage of tailings and (iii)Reduces potential damage to environment.

Dry beneficiation of non coking coal for application in thermal power and DRI

This technology is utilized for ash reduction in high ash non-coking coal by dry processing for use in thermal power and DRI applications, and for De-shaling of high ash non-coking coal. Its salient features are(i)Producing clean coal with less than 34% ash with high yield (ii)No need of process water (iii)Prevents generation of coal slime water (iv)Requires relatively less floor area compared to (v) conventional wet processing (vi)Less power consumption per ton of coal compared to wet processing of coal



Beneficiation of dumped low-grade iron ore fines for iron and steel making

The process is based on upgradation of dumped low-grade iron ore fines involving scrubbing-washing-classification of the dumped fine ore followed by gravity and magnetic separation of classified materials. The process ensures optimum recovery of iron values through closed loop operation and processing of intermediate products. The technology has been commercialized and a plant with capacity of 1.35 mtpy has been commissioned.

Phosphate Concentrate

The process technology is based on separation of phosphate containing minerals from low-grade ore by froth flotation. The product is suitable for the manufacture of phosphoric acid and phosphatic fertilizers.

De-ashing of high non-coking coal

The process is based on treating the high-ash thermal coal for reducing the ash level by adopting the gravity concentration and flotation techniques. The ash level can be reduced to 10-15% from a feed of 30-35% ash depending on the coal characteristics.

Metals, Materials and Alloys

After 90 days at the power plant

Erosion resistant steel for underwater components of turbine hydrogenerators

The developed alloy steel is multiphase steel and exhibits TRIP effect; hence it can be used at room temperature as well as lower temperatures. The steel is developed through normal casting and heat treatment process. It has similar hardness and tensile strengths as that of presently used cast 13%Cr-4%Ni steel and has higher impact toughness (3 times as that of the 13%Cr-4%Ni) at room temperature as well as zero degree temperature. This steel exhibits higher erosion resistance as well as cavitation resistance as required for underwater components of turbine hydro generators.

Biomimetic Electrospun Collagen - Graphene Nanocomposites

The process relates to manufacture of graphene nano-composites through exfoliation of natural graphite using collagen. It bypasses the graphite oxide route, hence results in lesser defects. Spinning of graphene- collagen with PVA polymer is used to form fibres with varied applications. Yield varies from 0.03-0.05% as compared to the reported best of 0.3%.

Biphasic Calcium Phosphate Block

The product, a novel three dimensional load bearing biphasic calcium phosphate nanocomposite is osteoinductive. It can induce the stem cells to differentiate into new bone forming cells. So the nanocomposite can be used for bone healing and synthetic bone graft. The mechanical compressive strength of the 3D BCP is in the range of 6-26 MPa analogous to cancellous bone. The Process has been transferred to M/s G. Surgiwear Ltd, Shajahanpur.

Biomimetic Polymer Base Hydroxyapatite Block

The product is a novel three dimensional load bearing polymer- hydroxyapatite nanocomposite. It has been synthesized through biomimetic route. The process is in situ, simple and cost effective. It does not involve any toxic cross linker and works at near ambient conditions. The application of the nanocomposite is as a load bearing synthetic bone graft. The compressive mechanical strength of the nanocomposites is in the range of 2-12 MPa. The Process has been transferred to M/s G. Surgiwear Ltd, Shajahanpur.

High Carbon High Chromium White Cast Iron with Improved Wear Resistance for Grinding Media Applications

The grinding media so developed is used for grinding clinker for cement production. The developed GM has better wear rate than existing product in market.The Process has been transferred to M/s Shree Cements.

Coatings and Lacquers

Anti-Tarnishing Lacquer for Silver and Copper-based Alloys

Anti-tarnishing lacquer is a one component fast drying interior lacquer for use on brass, copper, bronze and silver surfaces. It prevents tarnishing (blackening) and provides a durable finish resistant to water, acid and alkali environments. The formula contains active corrosion inhibitors chemically bonded to acrylic polymer backbone, hence prevents tarnishing of copper, brass, bronze and items for long durations of several years. The lacquer is nontoxic (Lead and Cadmium free) when dry and can be applied by spraying, brushing, or dipping and takes 10 minutes to dry. Post treatment like baking is not required. The product has been commercilised by (i) M/S. Mahashraya Chemicals (P) Ltd., Balasore, Odisha and (ii) M/s Multicoat Surfaces (P) Ltd., Kolkata.

Cyanide free process for leaching and recovery of gold

The Salient features of this process are (I) Cyanide free Gold leaching process as fast as conventional cyanide process (2-5 min) (ii) Close loop process of gold leaching and recovery (iii) Operated at room temperature (iv) Gold plated on any surface can be recovered without damaging the base material. The Process is implemented at TITAN Company Ltd, Watch Division, Hosur, Tamil Nadu.

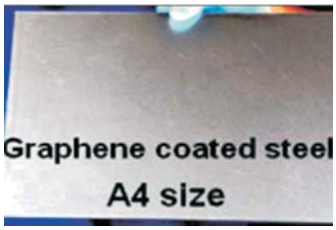
Cyanide free alkaline electrolyte and electrochemical process for rust removal from plain carbon steel components

The Salient features of this process are(I) Very fast electrochemical rust removal process (1-2 min) (ii) Alkaline cleaning process – No hydrogen embrittlement and cleaned surface is passivated to prevent immediate rusting (iii) Electrolyte is free from toxic elements like cyanides (iv) Operation at room temperature (v) Very small components (screws) and big components can be cleaned. The Process is implemented at TITAN Company Ltd, Watch Division, Hosur, Tamil Nadu.

Zn-Ni-Cu Coatings for Anti-Bacterial and Fuel Tank Applications

The salient features of Zn-Ni-Cu coated steel are (I) Improved corrosion resistances in foul fuel media as well as in the presence of microbial attack (ii) Antibacterial properties of the coated steels (iii) The coatings do not require hexavalent chrome passivation (iv) It is easy to scale up. It is used in Anti-bacterial applications (Acs, Refrigerators, Windows, Air coolers), Automobile fuel tank.

Without coatingZn-Ni-Cu Coated Steel



Graphene Coated Steel

A simple process consisting of dip coating followed by heating in inert atmosphere is available for the production of graphene coated steel. The same process can also be extended for graphene coating over other substrates, like quartz. The graphene coated substrates produced using this process improves the anti-corrosion properties of bare steel as well as can be used as atransparent conductor.

Nano-Composite Hard Coating

The developed nano-composite Ti-Si-B-C coatings exhibit excellent mechanical properties, good tribological properties with low coefficient of friction. The coating also shows excellent resistance to chemical corrosion (salt spray 500 hrs, no degradation) and oxidation resistance up to 800°C.

Iron and Steel making

Highly Metallised Low Sulphur Directly Reduced Iron (DRI) from Iron Ore Slime and Rejected/Middling Coal

The process utilizes ~100% waste raw materials to yield a value added product. This invention is useful for converting steel plant wastes such as iron ore slime/fines, middling and rejected coal containing more than 25 % ash into a highly metallised (Metallisation > 96%) low Sulphur (0.006%S) DRI. The DRI produced from these waste raw materials is suitable as a substitute of scrap for induction furnace, electric arc furnace and basic oxygen furnace for steel making.

Highly Metallised Directly Reduced Iron Cylinders (DRIC) from lean grade raw materials

The product (DRI-C) developed by this process can be used as a feed / substitute of scarp for melting in Induction Furnace(IF), Basic Oxygen Furnace(BOF) and Electric Arc Furnace(EAF) for production of steel. The process utilizes ~100% waste/lean grade raw materials to yield a value added product. This invention is useful for converting steel plant and mining waste such as iron ore fines/slime with lean grade coking coal or non-coking coal (>32% ash) into a highly metallised (metallization >96%) low Sulphur (0.008%S) DRI Cylinders are suitable for induction furnace, electric arc furnace and basic oxygen furnace steelmaking.

Highly Metallised Directly Reduced Iron (DRI) from mill scale and lean grade non coking coal in Tunnel Kiln

The process utilizes mill scale and lean grade non-coking coal for production of highly metalized DRI through Tunnel Kiln. This invention is useful for converting mill scale generated in primary and secondary sector of iron and steel industries into highly metalized DRI. Lean grade non-coking coal left in the mine heads are utilized as a reductant for conversion of mill scale into DRI. DRI produced from this process have very high degree of metallization (Metallisation > 92%) and are suitable as a feed for induction furnace, electric arc furnace and basic oxygen furnace for steel making.

Fluxed sinter through micro-pelletization

A fluxed sinter using 100% ultra-fine waste oxide material generated in steel plant, viz. LD sludge, BF flue dust and lime fines (10 to 55%) through micro-pelletization for their recycling. The micro-pellets are hard (CCS: ~10 kg/pellet) to withstand cold handling. Sintering is possible neither using any external heat nor any coke breeze and the waste material itself is the heat source. The produced sinter is suitable for using in both iron and steel making processes.

Cold bonded carbon composite pellets for utilization of iron ore micro - fines and carbon bearing fines

This process produces micro-pellets with high C content which will be used in sintering of iron ore for reduction of coke breeze consumption and in smelting reduction process. The salient features of the process are (i) this is a cold bonding process, so it is energy efficient; curing time is very short (5-10 min), (ii) It utilizes iron ore micro-fines and coal fines or coke fines or carbon containing waste fines in iron making or sintering, (iii) the micro-pellets provide energy to the sinter bed for reduction in coke breeze consumption. 38-48 % reduction in coke breeze has been found when 38 % blast furnace flue dust containing pellets were mixed with iron ore in sintering (12 kg scale), (iv) Since it is a composite pellet, it can be reduced faster than normal pellets and (v) $C0_2$ in steel plant's waste gas is utilized in strengthening of pellet.

Pellet-Sinter Composite Agglomerate (PSCA) of iron oxide fines for use in Blast Furnace

In Pellet-Sinter Composite Agglomerate (P-SCA), iron oxide pellets are embedded into the sinter mass. P-SCA for use in blast furnace has been developed with Indian iron ore to utilize the micro-fines in sintering. It also uses steel plant's waste materials viz. LD sludge; mill scale, etc (5-10%) with iron oxide microfines. The process yields a very good quality sinter even at the lower basicity that is usable in blast furnace. It increases the fines acceptability (30% above normal) improving permeability and decreases energy consumption (-20%) and flux consumption.

Briquetting of ore fines

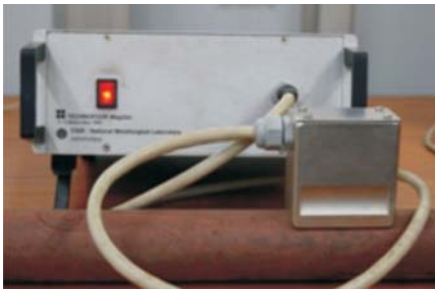
This technology produces briquettes of ore fines with suitable binder through briquetting press. Ore fines and industrial waste can be utilized for metal production through this technology. The technology utilized is a green technology for utilization of ore fines as well as waste products of industry such as mill scale, flue dust etc. Greenhouse gases and other harmful gases are not generated through this technology.

Devices and Process Intermediations

Wide Metallic Glass Ribbon Processing Unit

The device is used for the production of different types of alloy using melt spinning system. The liquid metal is poured on a water cooled Cu-wheel which can rotate at a speed of 1000 -3000 rpm. The system can be operated in normal and controlled atmospheres. The type of alloys that can be prepared through this melt-spinning system are (a) Glassy magnetic alloys: Fe-Si-B, Fe-Ni-B, Co-Si-B; (b) Nanostructured magnetic alloys: Fe-Nb-Cu-Si-B,Fe-Co-Nb-Si-B; (c) Brazing alloys: Cu-Ni-Mn, Ni-Fe-Cr-B-Si; (d) Ferromagnetic shape memory alloy: Ni-Mn-Ga, Co-Ni-AI. No hazardous gases are emitted. The technology islicensed for manufacturing to M/s Vacuum Techniques Pvt. Ltd., Bangalore

MagStar: A Portable Magnetic Hysteresis and Barkhausen Emissions based Electromagnetic Device for Non-Destructive Evaluation of Steel Structure/Component



The developed NDE device can be used for evaluation of microstructural changes during heat-treatment/ ageing, determination of ferrite volume fraction, evaluation of ferromagnetic phases and its correlation with mechanical properties and residual stress analysis. The developed magnetic NDE device is suitable to use on-site to assess the extent of damage accumulation in components after extended period of service at high temperature. The developed magnetic NDE device is able detect the extent of creep and fatigue damage that is experienced by steel components. The device is suitable to evaluate carburization depth at the inner surface of the process heater tube used in petrochemical industry. The device is suitable to detect the damage of initially non-magnetic process heater tube wherein magnetization appears at the inner surface due to carburization during in-service operation in petrochemical industry. It is suitable to detect the presence of magnetic phase in non magnetic materials. The technology has been licensed for manufacturing to M/s Technofour, Pune.

Ultra-β: A Portable Nonlinear Ultrasonic Device

It is a portable, site worthy damage parameter measurement set-up based on higher harmonic analysis of ultrasonic signal. Moreover, the modification in the design of the commercially available system based on higher harmonic analysis of ultrasound wave makes it applicable to in-service components assessment for other structural damage evaluation like fatigue, creep, etc. It assesses as well as quantifies the pitted area which could be useful to predict the crack initiation site in the structure in service. The device is used in damage assessment viz. fatigue, creep, corrosion pitting of Industrial components.

MagSys : A Portable Giant Magneto-Impedance (GMI) based magnetic sensing device for NDE applications

The device can be used in petrochemical industries where properties of stainless steel based component changes due to carburization, for detection of presence of magnetic phases in non-magnetic steel that take place during in-service operation or manufacturing process, and for detection of low magnetic field. MagSys is a portable magnetic sensing device where nanostructured Fe-Co based magnetic wires of diameter 80-120 micron prepared by in-rotating water quenching technique is used as a core material in the probe head. This magnetic wire material exhibits Giant Magneto-Impedance (GMI) properties. The output signal of the sensor is proportional to the magnetic field generated by the test object. If there is change in composition, microstructure or residual stress of the test object due to in-service operation, the magnetic properties also change and hence the output signal of the sensor.

FlawGuard: A cost effective device for defect detection in wire during cold drawing

The device can be used for online surface and subsurface defects, viz. transverse cracks, weld joint, craw feet, detection in wires during cold drawing. This system works based on the principle of encircling coil differential probe eddy current. This should be installed in the drawing line and wire passes through the core of the probe. Probe diameter can be changed based on the wire diameter. Features of the present system are (i) Test material diameter: 1.5 mm - 2.5mm, (ii) Operating frequency: 10 Khz, (iii) Depth Resolution: 200 pm, (iv) Drawing line speed: up to 12 m/s, (v) LCD display, (vi) Software for data logging to identify defect location, (vii) Interfacing through LAN, (viii) Analog output for further signal analysis, (ix) Alarm: LED & Buzzer, (x) Standalone as well as laptop based, (xi) Power Requirement: 220V/50Hz and (xi) Weight: 1.5 Kg; Dimension: 300 x 300 x 100 (all in mm).

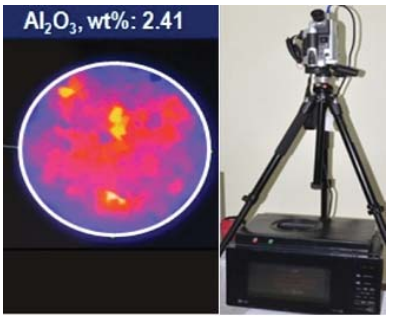
Energy efficient brass and bell metal melting furnace

The technology focuses on new fuel efficient brass melting furnance. The existing traditional brass melting furnaces are fuel inefficient, and the operators are exposed to toxic flue gases and high suspended particulate matter (SPM) resulting in serious health hazards. These also contribute to atmospheric pollution. The CSIR-NML furnaces have advances like a) ~ 20% reduction in coke consumption; b) ~ 80% less suspended particulate matter (SPM) and Zn vapour in flue; c) Reduction in melting cycle which results in 25% increase in productivity; d) Minimum alteration of existing operating practices of traditional brass melting furnace; e) Construction by using locally available materials.

Ultrasonic Flow Gauge: A device for fluid flow rate measurement through a narrow tube

Propellant availability onboard is one of the main factors determining the spacecraft life. It is essential to gauge the propellant accurately for estimation of spacecraft end-of-life (EOL) and to optimize mission strategy. The developed ultrasonic flow gauge can be integrated in the spacecraft for onboard propellant gauging. It can also be used as a gas and liquid flowmeter. Light weight, low power consumption, analog as well as digital output ports, test points in the circuits, capable of measuring flow rate from 0.1 LPM to 6 LPM are the major salient features of this device.

Microwave-IR Sort: Rapid, reliable, non-invasive technology for iron ore compositional analysis



The technique can be used for detection of alumina, silica, iron in iron ore, alumina in bauxite and moisture in coke. The IR Thermography based method of the present invention is a useful tool for detection of alumina-rich iron ores and has the potential for estimation of composition for other commodities as well. This is a fast, low cost and non-invasive technique for compositional analysis of iron ore. This method can be considered to be an alternative for known chemical analysis methods which are time-consuming and cumbersome. This inventive method apart from dry processing is also a quick method for indirect chemical analysis of ore due to which the delay time can be saved and production can be increased. From the developed calibration curve, the alumina content in the ores can be determined within a duration of just 60 seconds and the quality of the feed grade can be estimated from the alumina percentage. Implementation of the method in the beneficiation process in operating mines would lead to more systematic and improved decision making inputs to effective planning and control leading to resource optimization in a safe and environment friendly manner. Real time analysis of feed grade to the plant operators allows effective process optimization for achieving targeted production and grade.

Annealing Simulator Device for annealing of steel specimens under desired environmental conditions for testing and characterization

The equipment is an integrated annealing simulator device for annealing under desired conditions for testing and characterization of steel specimens. The device can be used in (i) varieties of unique annealing simulations, (ii) batch as well as continuous annealing of steel samples, (iii) heat treatment under controlled atmosphere as and when required, (iv) precise control on the heating and cooling rates in annealing simulation, (v) Flexible control on the soaking time during annealing simulation, (vi) annealing simulation of several specimens in one go, (vii) faster data acquisition device for temperature recording for entire cycle of annealing simulation and (viii) precision environmental control on annealing simulation.

Portable Automated Ball Indentation (PABI) System for *in-situ* evaluation of mechanical properties of metallic components

The device has the ability to estimate hardness, yield stress, yield ratio, tensile strength, strain hardening constant and fracture toughness- all in just one test. Other features of the device are (i) Ball impression is less than an mm in diameter making it a nearly non-destructive test, (ii) hardness mapping of non-uniform samples like weld zone and HAZ, (iii) adaptor for bench testing of small sample, (iv) adaptor for field testing of large components, (v) stress or strain controlled test modes, (vi) estimation of multiple properties with one run, and, (vii) software controlled operation and analysis. The technology has been Licensed to M/s Ducom Instruments, Bangalore.

Closed Loop Corrosion Test Rig Equipment for Flow Assisted Corrosion Study

"Closed loop corrosion test rig" is indigenously designed by CSIR-NML. The equipment has the facility to control and monitor dissolved oxygen (50-5000ppb), and the flow rate of the media during experiment. Provision exist for extra sensors for monitoring other parameters. It is attached with two type of test rig for metallic coupon exposure as well as electrochemical studies using on-line potentiostat under flow condition. Closed loop corrosion test rig was developed as an equipment to study the electrochemical and corrosion behavior of metallic materials under flow simulated media with controlled dissolved oxygen and different flow rates at a constant temperature. This study is required for the pipeline material evaluation specifically dealing with oil, marine water and other liquid media.

Value Additions to Industrial Wastes & Lean Sources

Paving Blocks from Fly Ash, Blast Furnace Slag, Steel Slag, etc.

The process produces pavement blocks of different shapes and sizes and different colours and designs. These paving blocks can be used in pavement, patio, lounge, garden, park, petrol pumps, etc., and are suitable for light to medium load. It meets IS 15658:2006 specification and can be produced in different shapes and sizes with properties equivalent to M15 - M35 grade concrete. It uses ambient temperature synthesis and generates 30% less $C0_2$, and 35% lower embodied energy than conventional equivalent product. The product meets USEPA 1311 specification for toxicity. Also, due to 35% lower $C0_2$ emission and 35% less embodied energy, it falls in the category of green process. Due to use of waste and byproduct, it qualifies for 1 point in LEED certification for green building.

Geopolymer Cement

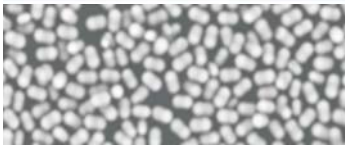
Geopolymer cement is new type of alumino-silicate binder and is considered as an alternative to Portland cement which is produced from two major industrial wastes, fly ash and granulated blast furnace slag. During synthesis, the alumino-silicates present in feedstock undergoes polymerization and polycondensation resulting into hard ceramic like material with good longevity. The salient features of the product are (i) meets the properties of Portland pozzolana cement as mentioned in IS 1489:1991, (ii) ~10% more durable than OPC and are fire resistant upto 900°C, and, (iii) uses ambient temperature synthesis and generates 70% less $C0_2$ than Portland cement.

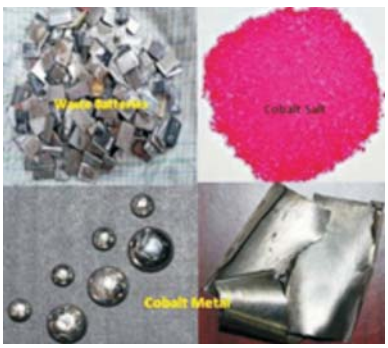
Yellow Tungsten Oxide and Tungsten Metal Powder from Heavy Alloy Scraps

The process is related to recovery of high pure products (YTO, W-metal powders & other metal salts/powders) from waste/end-of-life WC-hard metal tool bits/drill bits/inserts, and heavy metal alloy scraps/swarf. The salient features of the process are (i) purity of YTO & W-powder is >99.9%, (ii) High pure cobalt salt is a by-product, (iii) process recovers all the metals from WC scraps with >95% recovery efficiency and (iv) processing cost ~ Rs. 400/kg of tungsten powder (excluding scrap cost).

Ferrite and Pigment grade high purity monodispersed Iron Oxide from waste chloride pickle liquor and other iron rich sources

High purity mono dispersed hematite particles of very uniform sizes and shapes can be produced by low temperature aqueous synthesis route in large quantities with a yield of almost 100% starting from very inexpensive and impure iron sources such as blue dust, scraps, pickle liquors, crude iron oxide, high iron containing residues, etc.The mono dispersed hematite particles of different shapes such as cubic, spindle, ellipsoidal, spherical, peanut type particle can be produced by this method. Different shapes of uniform size mono dispersed hematite particles of size ranging from 200 - 2000 nm can be produced.



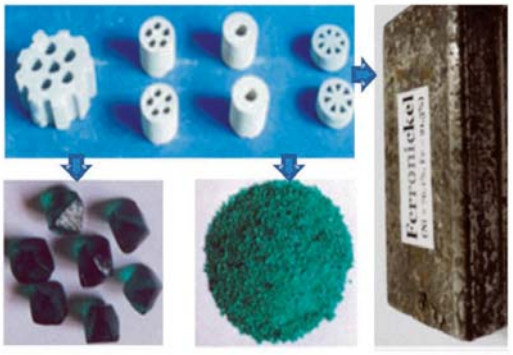


Recovery of Cobalt from Discarded Li-ion Batteries of Mobile Phone

This is a process for the dissolution of metals from discarded lithium ion batteries (LIBs) of mobile phone. Diluted sulfuric acid in presence of an oxidant was used to leach out -70-80% cobalt along with other metals in 60 min at elevated temperature. Leach liquor generated was further processed through solvent extraction, precipitation, crystallization/electro-winning techniques to recover cobalt as salt/ metal.

A Process for Recovery of Lead from Zinc Plant Residue

The washing of residue as a part of pre-treatment step dissolves part of zinc and copper, which can be recovered by recycling the liquor in to the main leaching stream from where the lead containing residue is generated. The remaining acid in the washing stage can be reutilized during original raw material leaching. The lead recovery from the washed residue using sodium chloride is a very cheap option for lead dissolution. The process operates at low temperatures and low acid concentrations, and therefore special material of construction is not required. Due to higher molecular weight of lead, the iron requirement by weight for cementation is much less. The process requires much less capital investment and can be operational in medium and small scale. The process involves lesser number of unit steps.



Recovery of Nickel from Spent Nickel Catalyst

Nickel catalysts used in various operations become spent after several cycles of use, for which a very simple and innovative process is developed at NML for recovery of nickel. The processing step consists of direct acid leaching in presence of a promoter followed by impurity removal to produce nickel salt/metal. The novelty of the process is that, it gives very high nickel recovery (99%) under the moderate conditions in presence of a little quantity of a promoter without which it is found to be very poor even at higher temperature and acid concentration. High purity alumina is produced from the process as a part of leached residue.A smelting process is also developed for recovery of nickel as ferronickel from variety of spent catalyst containing nickel in the range 8-25%. Various grades of ferronickel with nickel content in the range 20% to 80% have been produced. Nickel sulphate is extensively used in electroplating, organic chemical synthesis, metal coloring, dye mordant, manufacturing other nickel salts, Ni-Cd battery. The Sulphate process has been transferred to M/s SMC Technology, Malaysia.

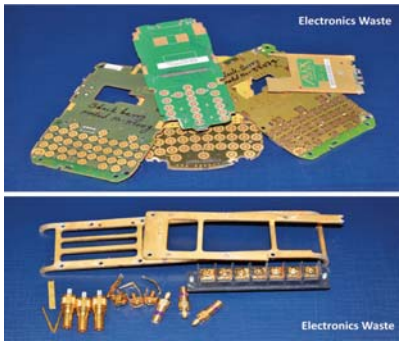
Fe-Ni/Co-Mo Metallic Alloy & Saleable Alumina rich slag leach residues of Ni-Mo/Co-Mo spent Catalysts.

Fe-Ni/Co-Mo alloy | Calcia-alumina slag

Hydrometallurgical treatment of spent hydro-refining catalysts generate residues containing significant amount of Ni (2- 5%), Co (2 – 5%) and Mo (0.5 – 1%). These residues are presently dumped or underutilized in construction related industries. The pyro-metallurgical process developed at CSIR-NML is able to recover more than 90% of these metals as saleable alloys, besides generating calcium aluminate type slag for cement applications. The product may be used for economic recovery of valuable and strategic metals such as Ni, Co and Mo from waste source such as processed spent hydro-refining catalysts. The main advantage of this process is generating alloys (Fe-Ni-Co-Mo) which can be directly used in specialty steel manufacturing

Ferric sulphate from copper slag

The process is to treat the slag to recover products of commercial importance such as ferric sulphate and silica powder. Ferric sulphate is an important ingredient for arsenic removal from toxic waste stream of copper industries and very fine silica powder produced will find number of applications. The novelty of the process is the complete conversion of siliceous slag in sulphate system to value added products. The process does not generate any solid or liquid effluent/wastes. The process is useful for partly solving the ecological and environmental issues with an added economic advantage by utilising the dump slag generated in the copper plants. The Technology has been licensed to M/s Sterlite Copper, Tuticorin.



Recovery of Gold from waste mobile phones and scraps of various equipments

This is a process for the dissolution of metal from the PCBs of waste mobile phone, small parts of various equipments containing gold on the outer layer. Chemical leaching followed by adsorption/ cementation with subsequent heat treatment was used to recover 99% gold.

Recovery of Neodymium as a value added product from waste hard disk of personal computers

This is a process for the recovery of neodymium as value added product from magnets of discarded hard disk. Under optimized condition, sulfuric acid leaches 98% Nd, 97% Fe, 60% Ni and 7.5% B. Acid leaching was followed by selective precipitation of Nd and leaching of the precipitate with 5-20% HF solution.

Technologies Commercialized/Impact Making Technologies

Commercialization of the Process for Production of Pigment Grade Iron Oxide from Waste Chloride Pickle Liquor by M/s Rang Sarjan Chemicals, Gujarat

CSIR-National metallurgical Laboratory developed a simple process for production of highly dispersed red iron oxide of uniform size and shape from a variety of waste sources including waste chloride pickle liquor. The major processing steps consist of oxidation of ferrous iron followed by conversion to desired grade iron oxide. The process does not involve any prior purification steps. The process parameters are so tuned that a particular size and shape could be engineered to produce desired color grade iron oxide. The process produces very uniform size iron oxide in the range 100-2000 nm of different shapes and color. Due to highly dispersed and very uniform nature of the particles, the produced iron oxide gives very high color purity and matches with the color of different standard grade high end iron oxide available in the market.

The process was demonstrated and transferred to M/s Rang Sarjan Chemicals, Gujarat for production of high grade iron oxide from waste chloride pickle liquor. From the chloride pickle liquor of M/s Rang Sarjan containing about 200 g/L ferrous iron and other impurities, highly dispersed iron oxide particles of different sizes ranging from 100 nm to 600 nm were produced under different conditions of precipitation. Both reduced tone and mass tone of the produced oxides were tested and found to be of much superior in quality with respect to pigmenting properties.

Figure 1: Continuous counter current chlorination unit for waste chloride pickle liquor

Figure 2: 15000 liter capacity precipitation reactor for Iron oxide

M/s Rang Sarjan Chemicals set up a pilot plant at their site and tested the process at a pilot scale. They ran the pilot plant for production of desired grade iron oxide for several months for confidence building. Simultaneously, they set up a 1000 metric ton capacity commercial plant. They have already started commissioning trial and are in the process of stabilising various unit operations for smooth commercial production and further expansion to 3000 metric ton.

Transfer of know-how for a process for production of highly metallized DRI from mill scale and lean grade coal to M/s. Shree Mahabir Refractories Work, Ranchi

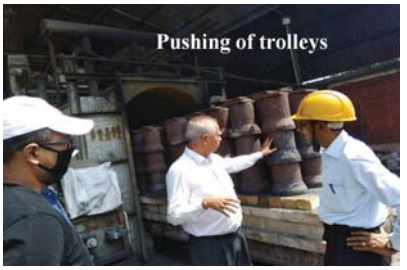
Mill scale is generated in steel plant at the rate of about 2% of the produced steel and is available as a secondary material containing approximately 72% Fe. Presently, more than 1.4 million tons of mill scale is being generated annually in India and is expected to reach about 3.0 million tons by 2020. In an integrated steel plant, almost 85% of the mill scale generated is consumed in-house via sintering. The balance part of the mill scale with particle size less than 0.5 mm is heavily contaminated with oil and is dumped for land filling as waste, which involves with disposal cost and environmental pollution. These mill scale may be utilized for DRI making.

It is a fact that India has a vast coal reserve. However,only 13% out of it is coking and the rest is non-coking or lean grade coal. DRI making technology can utilize these non coking coal. However, the conventional coal based Directly Reduced Iron (DRI) making process requires high grade ferruginous lump ore or indurated pellets.

DRI making from mill scale utilizing lean grade non coking coal may be an important route for waste utilization. Till date no process has been developed to utilize mill scale and lean grade coal for production of DRI in Tunnel Kiln without pre-induration of pellet.

In view of above, an initiative was taken by CSIR-National Metallurgical Laboratory, and a technology has been developed for production of DRI from mill scale and lean grade coal in Tunnel Kiln. The Know-how has been transferred to M/s. Shree Mahabir Refractories Work, Ranchi.

Essential hardware such as pelletizer (20 ton /hr. capacity), Ball mill (1 ton/hr. capacity), Rail tracks for loading and unloading of raw materials and product are being installed. Commercial production will start in the near future.



IMPACT ON SOCIETY

CSIR-NML has initiated several programmes to reach out to the society through upgrading traditional technology and implementing appropriate innovation relevant to social/rural sector. CSIR-NML has developed fuel efficient and eco-friendly furnace for brassware artisans replacing their traditional coke fired furnaces which are grossly fuel inefficient and polluting. CSIR-NML developed furnace resulted in: (i) Reduction in energy consumption by 25%; (ii) Reduction in melting cycle time by 20%, (iii) Increase of productivity by 25%, (iv) Significant reduction in pollution and cooler working ambience.

Brass & Bell metal artisans of Odisha, West Bengal, and Jharkhand were trained by CSIR-NML to adopt energy efficient brass and bell metal melting furnace and innovative process to improve their product quality.

A survey on Silver/Brass/Bronze/Bell-metal clusters at Salem and Thanjavur District of Tamilnadu was conducted.

150 brass melting artisans including 10 women were trained to improve their livelihood and to work in a congenial environment.

Artisans were trained to use energy efficient bell metal melting furnace.

Jigyasa-School-NML Interactive programme

SNIP programme has been designed to give students, teachers and professionals an exposure to modern laboratory environment and to develop scientific temperament, for their career development. This programme is being carried out at CSIR-NML since June 2011 and since then, a total 17,567 students from 211 schools along with teachers have participated in this programme and derived the benefits.

During 2018-19, a total 867 students and 58 teachers from 20 schools have visited the laboratory under INDSS-NIP, TECNIP & JIGYASA. A separate programme on "IISF Outreach Programme" was organized at CSIR-NML. This programme was similar to Jigyasa-SNIP, in which a total 250 students and 10 faculties were invited. A science exhibition was also organized in which students made scientific models and demonstrated them. It was observed that during laboratory visits students and faculties showed keen interest on R&D in the area of minerals, metals and materials science. School-NML Interactive programme during its 8 years span of time has drawn a wide publicity and appreciation from the schools/general public and is very well covered by the press and media as well.

Human Resource Development: Skill Training Initiatives

The program aims :

- To utilize CSIR knowledgebase and infrastructure for contributing to national skill mission
- To implement special up-skilling/training programs for societal benefits
- To implement identified skill/training programmes of national skill mission
- To promote entrepreneurship/ technopreneurship in CSIR through skilling, training of trainers and Incubation facilities

Topics covered under Skill Training Programs (STP) in 2018-19

- Soft skills for quality improvement
- Training on Welding
- Entrepreneurship development on e-waste management

STPs Organized		
Title of the Training	**Date of Training Programme**	**No. of Participants**
1. CSIR Integrated Skill Training Initiative Soft Skills for Quality Improvement (SSQi 2019)	February 27-28 2019	42
2. CSIR Integrated Skill Training Initiative Entrepreneurship Development On E-Waste Management (EDEM 2019)	March 12-15 2019	23
3. Advanced Training Program (on Manual Metal Arc Welding and Gas Cutting)	February 22 to March 22 2019	10

Performance Targets Achieved in 2018 - 2019

	Objectives	Planned	Achieved
1.	Total External Cash Flow (ECF)^	40 Crores	45.55 Crores
1a	Grant in Aid (a part of total ECF)	15 Crores	8.86 Crores
1b.	Industrial ECF (a part of total ECF) I. Foreign Sponsored II. Public Sector Units (PSUs) III. Private Industries including Testing	25 Crores 1 Crore 15 Crores 9 Crores	37.13 Crores 1.43 Crores 28.91 Crores 6.35 Crores
2.	Customer Satisfaction Index	4.5	4.7
3.	SCI Publications	120	117
4.	Patents	25	20
5.	Copyrights	5	7
6.	Technologies to be Developed#	8	5
7.	Technologies to be Transferred*	5	2

^*Cash flow generated from sponsored projects from private industries, PSU and government agencies.*

#Technologies Developed:

- Development of high carbon high chromium white cast with improved wear resistance for grinding media application
- Recovery of chromite value from chromite ore beneficiation plant trailing /Slimes
- Production of highly metallised directly reduced iron (DRI) from mill scale and lean grade non-coking coal in tunnel kiln
- Closed loop corrosion test rig equipment for flow assisted corrosion study
- Hot rolled low alloy steel with high strength, Impact toughness and abrasion resistance

*Technologies Transferred:

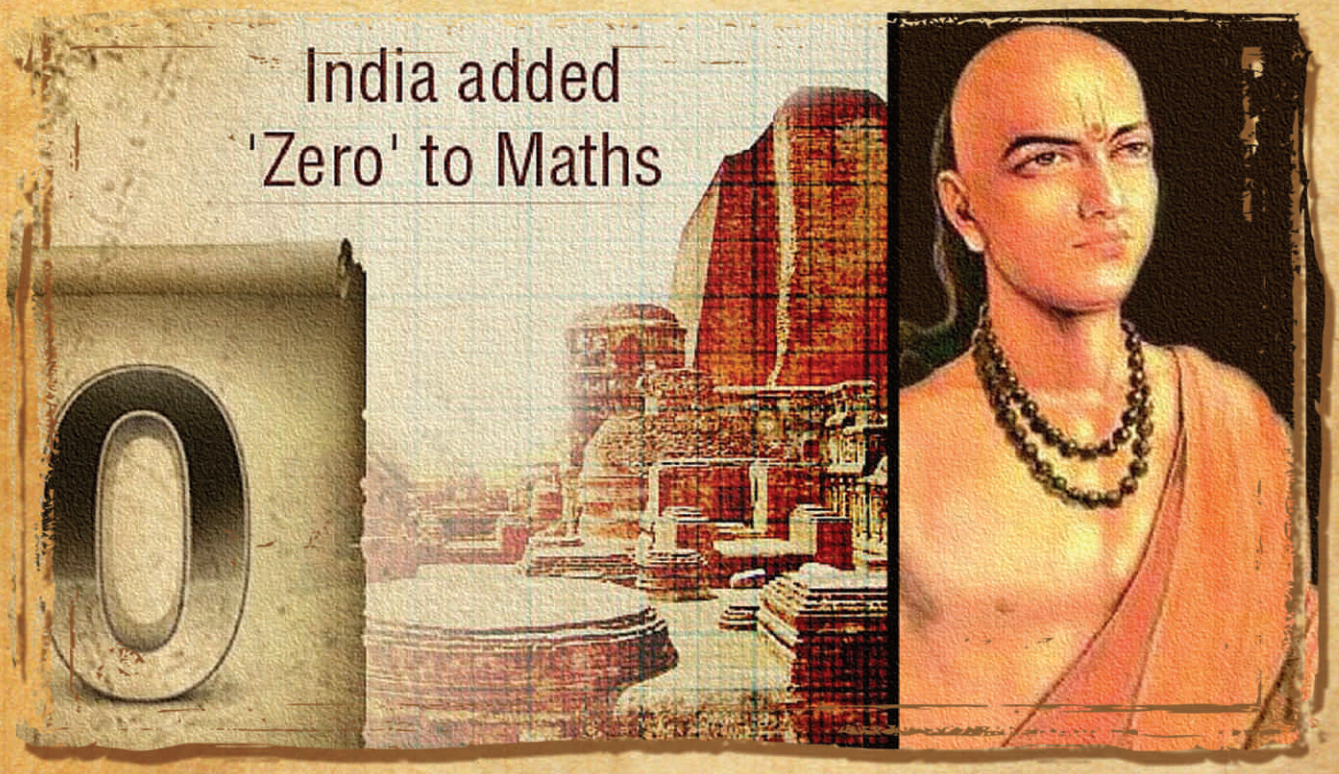
- Process for production of Highly Metallized DRI from Mill Scale & Lean Grade Non-Coking coal in Tunnel Kiln; transferred to M/s. Shree Mahabir Refractory Works, Ranchi
- Device for fluid flow rate measurement through a narrow tube transferred to M/s. Electronic & Engineering Co.(I) Ltd., Mumbai

Performance Targets planned for 2019-2020

	Objectives	Planned
1.	Total External Cash Flow (ECF)	42 Crores
1a	Grant in Aid (a part of total ECF)	17 Crores
1b.	Industrial ECF (a part of total ECF)	25 Crores
	I. Foreign Sponsored	2 Crore
	II. Public Sector Units (PSUs)	17 Crores
	III. Private Industries including Testing	10 Crores
2.	Customer Satisfaction Index	4.7
3.	SCI Publications	120
4.	Patents	25
5.	Copyrights	5
6.	Technologies to be Developed	6
7.	Technologies to be Transferred	5

MISSION PROJECTS

Science & Technology in Ancient India



The Idea of Zero

Mathematician Aryabhata was the first person to use zero and it was through his efforts that mathematical operations like addition and subtraction started using the digit, zero. He Played a vital role in Place value system and zero, Approximation of π, Trigonometry, Indeterminate equations, and Algebra.

Science & Technology in Ancient India

FLAGSHIP PROJECTS

Recycling of tungsten based heavy alloy scraps for production of high pure tungsten powder

Tungsten is a strategic metal and has critical applications in defense, mining, communications, and other sectors. Global tungsten supply is dominated by Chinese monopoly and the Indian tungsten demand (~1500 metric tons/year) is mostly met through imports. In order to lessen the import burdens, it is important to develop indigenous technologies for recycling of available scraps. The main objective of this project was to develop process flow-sheet at a pilot scale (100 kg/day scale tungsten powder production) and perform detailed techno-economic evaluation for commercial production of tungsten from tungsten based heavy alloy scraps and turnings generated in the various defense establishments of our country.

The technology for tungsten recycling developed at CSIR-NML for production of W-powder from tungsten based heavy alloy scraps is superior in many aspects than various contemporary technologies; such as: lower capital investment (~50% with similar plant capacity), lower unit operating cost (~60% lower than conventional processes), higher tungsten recovery (98% against about 90%); all of which results in a higher ROI. The recycling process was initially developed at a bench scale and subsequently scaled up to 100 kg/day scale scrap processing by using newly established state-of-the-art W-recycling pilot plant (Figure 1). The pilot plant trials generated more than 200 kg W-powder till date, out of which 50 Kg W-powder has been supplied to the sponsor for evaluation. The supplied powder was tested by the sponsor by manufacturing the actual penetrator and evaluating its mechanical properties. It has been found that the W-powder produced at CSIR-NML by recycling of W-heavy alloy scrap, meets all the desired physical and chemical properties.

Figure 1: Glimpses of 100 kg/day W-extraction pilot plant

Technology for beneficiation and extraction of tungsten from mine waste sample

Due to non-availability of high-grade primary tungsten deposits in India, most of the demand of tungsten has been met through imports. Chinese monopoly in global tungsten supply, its high and fluctuating international prices places us in a situation, where development of indigenous technologies for production of this metal from domestically available resources becomes imperative. Scheelite ($CaWO_4$) and wolframite [$(Fe,Mn)WO_4$] are the two most common tungsten mineral constituents of the economic ore deposits. As far as India is concerned, there is no economic ore deposit of tungsten. The tenor values of tungsten mineral deposits that are economically mined elsewhere in the world are generally ~1.5% WO_3. Indian occurrences are very low-grade with tenor values in decimals only (0.1% or less). The major rock formations containing wolframite are located in Degana (Rajasthan), Khobna-Kuhi (Maharashtra), and Bruggubanda-Tapaskonda (Andhra Pradesh). A potential deposit is also reported in Almora (Uttar Pradesh) with some deposits of minor importance from Balda, Deva Ka Bara and Pali (Rajasthan), Agargoan and Kolari-Bhaonri (Maharashtra), Bankura (West Bengal),

Madurai (Tamilnadu), Attapadi (Kerala) and Gadag (Karnataka). In addition, there are some deposits of minor importance, and also concentrations of scheelite are found in gold ores of Kolar and Hutti in Karnataka. The total reserve of tungsten ore in India is estimated to be 87.4 million tonnes. The low tenor of the tungsten ores, fine dissemination and friable nature of tungsten bearing minerals, pose a daunting challenge to the metallurgists to develop a suitable technology for the exploitation of Indian deposits which is of strategic importance to the country. The sponsor of the project has been interested in exploitation of lean-grade tungsten ore for recovery of tungsten. And the sponsor has instructed CSIR-NML to work on the gold ore tailings, a mine waste sample, towards development of process technology for beneficiation and extraction of tungsten.

After thorough characterization of the waste sample, it was found that the tungsten bearing mineral was scheelite, with very low abundance. The gangue minerals were mainly silicates consisting of quartz, plagioclase, biotite, perthite, amphibole, etc., oxides such as a spinels, rutile, chromite, and magnetite, and sulphides such as arsenopyrite, pyrite, chalcopyrite, pyrrhotite, etc. Bench scale beneficiation experiments were carried out involving gravity and magnetic separation, and conceptual flowsheet for processing the low tungsten containing scheelite material was developed. The validation of the bench scale result was carried out through pilot scale trials. Bulk pre concentrate was generated through pilot scale campaigns and subsequently the pre-concentrate was used for extraction of tungsten. The pre-concentrate was further processed by hydrometallurgical routes for production of high pure APT at bench scale level. Initially the pre-concentrate was subjected to alkali leaching followed by solvent extraction of tungsten from leach solution. A detailed study for optimization of various parameters such as ratio variation, pH, effective concentration of organic solvent and stripping agent, number of stages required for efficient extraction and stripping, was carried out. The strip solutions obtained during scale-up SX trials was mixed thoroughly and was taken for APT crystallization through evaporation under reflux condition. The evaporated solution (with about 90% volume reduction) were allowed to cool under stirring condition to crystallize APT. Chemical analysis of the crystallized APT was confirmed to be >99.9% purity. APT was further subjected to direct high temperature hydrogen reduction inside a tubular furnace having controlled gas flow facility to get the high pure tungsten metal powder with 99.9% purity (Figure 2).

Figure 2: Tungsten powder produced from mine waste sample by beneficiation and hydrometallurgical extraction at CSIR-NML

Study on the interface layer formation during hot dip galvanizing of advanced high strength or dual phase steels for automotive applications

The increasing demands of light weight vehicles to reduce fuel consumption and emissions are forcing the automotive industries to use various advanced high strength steels (AHSS). The steels should have desired elongation and high work hardening rate to provide high strength with excellent ductility, formability and vehicle crashworthiness, so that the safety issues are not compromised. In order to maintain structural integrity and satisfy consumer durability expectations, the corrosion protection is becoming increasingly important for using thinner cross section of these AHSS. The continuous galvanizing process is among the most cost effective means of achieving this objective, and hence, galvanizability is crucial.

Hot dip galvanizing of advanced high strength (AHS)/ dual phase (DP) steels was carried out using binary Zn–Al, Al-Si as well as ternary Zn–Al–Mg baths for the development of high quality coated steels for automotive industries. A laboratory hot dip process

simulator (HDPS) was procured and installed (Figure 3) to study the effect of various process parameters on the formation of adherent coatings on the substrate. The understanding of interface layer formation mechanism during hot dip galvanizing of steels and optimization of process parameters and alloying elements for the formation of adherent coating was achieved. However,

Figure 3: Hot Dip Process Simulator installed at CSIR-NML

the poor reactive wetting between the liquid zinc and the surface of AHS/DP steels due to selective oxidation of the alloying elements, that are commonly used in these steels, is a major challenge to the steel industries. These oxides are not easily reduced by conventional atmospheres employed in continuous galvanizing line. In addition, the specific thermal cycle required to achieve their microstructure may not be compatible with the current continuous hot dipping process. Therefore, commercial viability of producing hot dip galvanized AHS/DP steels requires lab scale simulation of the galvanizing or galvannealing processes. The development of bare spot free GI and GA coatings on DP-980 AHSS using Fe precoat has possibility to use commercially. The scale up and other issues will be taken care of. Due to IPR issues, the use of Al-Si coating for hot stamping is restricted and with the development of Al-Si-Cu-Mg-X alloy, it will be possible to use it commercially

In this project, A Hot Dip Process Simulator (HDPS) was installed and several coatings developed using HDPS on AHSS substrates were:

- GI and GA coatings on DP 590, DP 780 and DP 980 grades of AHSS
- A new Al-Si-Cu-Mg-X alloy coatings for hot stamping applications
- Zn-Al-Mg coatings on DP-590

Two related projects executed using the installed HDPS were as follows:

(I) Development of technology to eliminate wettability issues in HSS and AHSS in CGL2 annealing furnace by optimisation of dew point control

The study aimed at developing a better understanding of the effect of dew point on alloy segregation on steel substrate during intercritical annealing prior to dipping. During hot-dip galvanizing there can be problems with poor reactive wetting due to the selective oxidation of the alloying elements. Complex chemistry, coverage, size, distribution and morphology of the oxides, play critical role in the deterioration of reactive wetting. The annealing atmosphere may preferably oxidize minor alloying elements (Mn, Cr, Si, Al, etc.) commonly employed in high strength steel, though it is able to reduce iron oxides. The mechanism of selective oxidation depends on oxygen partial pressure, which is controlled through dew point. It is, therefore, an imperative to develop a better understanding of the role of segregation of minor alloying elements on the selective oxidation, which is a function of intercritical annealing gas composition and dew point. Wettability issues in HSS grade have to be eliminated by optimization of annealing schedule and dew point control. In this project, a detailed thermodynamic study was carried out using the simulation software package, ThermoCalc, to investigate the amount and type of oxides present on the strip surface after annealing prior to dipping, by varying annealing temperature and annealing atmosphere (dew point). Experiments were carried out using IFHS 350 grade steel substrate with varying annealing conditions (temperature: 780 to 830°C & Dew point: +10 to -50°C) using Hot Dip Process Simulator (HDPS) and specimens were characterized after annealing prior to dipping as well as after hot

dipping in galvanizing bath. Suitable annealing conditions were found out for developing good quality coating on IFHS grade steel by eliminating the wettability issues (Fig. 4). In general, coating quality was improved with low annealing temperatures and low dew point or high annealing temperatures and high dew point conditions.

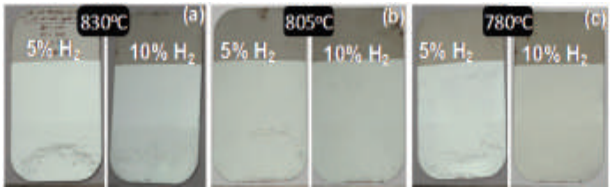


Figure 4: Photographs of hot dip galvanized specimens. Good quality coatings were obtained at (a) 830°C with +10°C dew point; (b) 805°C with -10°C dew point & (c) 780°C with -30°C dew point

(ii). Development of Al-Si-X (x= Mg/Na/other element) coatings on hot forming grade steel

The project objective was to develop Al-Si based coatings on hot forming grade steel substrates for better formability and corrosion resistance by: (a) Designing bath composition with addition of Mg and other elements and (b) Optimizing the hot dip process parameters. In hot sheet metal forming of high strength steels, the blank is austenitized in the temperature range of 850-950°C for about 3-10 minutes. Thereafter, forming and quenching take place in a water cooled closed die. During austenitization, oxide scale formation and decarburization on the steel surface necessitate an intermediate step of blank pre-coating. Hot dip coating is an effective and inexpensive method to improve high-temperature oxidation resistance during hot forming. The thermally stable and formable Al-Si based hot dip coating lead to cost reduction by eliminating descaling step. During austenitization of the aluminized steel, melting of the Al–Si based coating may occur. This may lead to production stoppages and cost escalation due to die damage during subsequent hot forming. During austenitization, formation of high temperature intermetallic compounds, iron diffusivity and coating thickness, play pivotal role in the stability and formability of coating. Coating failure may occur due to the formation of several cracks in the coating during hot forming operation. This is mainly due to the presence of brittle intermetallics which have different thermal expansion behavior compared to the substrate steel. It is therefore imperative to design bath composition and optimize hot dip coating process parameters for developing desired formable, high temperature oxidation and corrosion resistant coating. In this project, a new bath composition was designed based on Al-Si alloy with addition of Mg and other elements. Three different bath compositions were selected for developing aluminized coating based on extensive literature and patent search as well as thermodynamic analysis using the simulation thermodynamic software package, FactSage, keeping in view the maximum bath temperature of 650°C. Based on the detailed characterization and high temperature behavior of the coatings, the bath composition was finalized. Hot dip experiments were carried out with varying strip entry temperature and dipping time for a fixed bath temperature (650°C) to achieve good quality adherent coating on the steel sheets supplied by the sponsor. Defect free good quality adherent aluminized coating, with optimized bath composition and process parameters, was obtained. The developed coating will provide high temperature oxidation and corrosion resistance and better formability for the hot forming grade steels and can withstand up to 930°C during hot bending test (Figure 5).

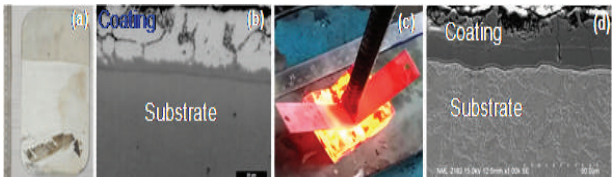


Figure 5. (a) Photographs of aluminized specimens; (b) Cross-sectional optical image of coated specimen; (c) Specimen during hot bending test; (d) Cross-sectional SEM image of coated specimen after hot bending test

Impact on society/industry

- The development of GI and GA coated AHSS (DP-590 and DP-980) will benefit the automotive industries. At present, most of the automakers are not using GI and GA coatings and instead using organic paints. Due to high corrosion resistances of these coatings, the consumers will be benefitted. Another benefit to the society will be on low CO_2 emission due to reduction of vehicle weight.
- The creation of HDPS facility will help the steel industries of India to simulate the process parameter at a lab scale and develop new coatings.

Advanced Ultra Super Critical Power Plants – Research on Materials Selection

Advanced ultra-super critical (AUSC) power plant with enhanced steam temperature and pressure is planned for implementation in India. Such power plants will have much improved plant efficiency and significantly reduced carbon foot print. CSIR-NML has been tasked with a few major responsibilities particularly in the matter of materials selection for such power plants which will see much higher temperatures. The activities under this program of national importance at CSIR-NML are as below :

1. Generation of creep data of AUSC Rotor (Alloy 617 M forged) and casing (alloy 625 cast) materials

This project aims at evaluating the creep rupture behavior of Alloy 617M (forged) and Alloy 625 (cast) materials at temperatures of 600, 650, 675, 710 and 750°C at stress levels which give a nominal rupture life of 500, 1000, 5000 and 10000 h. Tests will be conducted using constant load creep/stress rupture test methods. Better understanding of creep rupture behavior of these alloys will help in design and integrity assessment of pressurized components made from these alloys for the advanced ultra supercritical power plant program in India. Creep curves (strain -time behaviour), rupture time data, isochronous stress-strain curves, 1% strain creep strength and Norton-Bailey coefficients will be evaluated. In addition, post test metallographical characterization (fractography and optical/SEM micrography) of ruptured specimens will also be studied. Out of 32 specimens provided (16 for each alloy) 16 tests have been completed (500 and 1000 h expected life level). 14 tests for 5000 and 10,000h expected life are under progress.

2. Evaluation of creep crack growth (CCG) behaviour for SS304HCu base material

This project will generate the creep crack growth (CCG) data (da/dt Vs C*) of SS304HCu stainless steel tube material at various temperatures as part of round robin test exercise for Indian advanced ultra-supercritical power (AUSC) plant project. SS30HCu is a candidate material for boiler tubes. Any pre-existing defect or incipient damage during service conditions can lead to crack extension due to synergistic interaction of creep and fracture mechanisms. Evaluation of material behavior for creep or fracture alone is inadequate to assess the material performance, since the contributions to life limiting factors is due to more than one mechanism. This work includes the evaluation of the creep crack growth (CCG) behavior of the material at temperature regimes relevant to the component. The work includes assessment of creep crack growth behavior of indigenously developed 304HCu for advanced ultra super-critical boiler application.

3. Evaluation of creep crack growth (CCG) behaviour for 10Cr- Alloy 617 BMW weld joint

This project will to generate the creep crack growth (CCG) data (da/dt vs C*) of 10Cr-Alloy 617 bi-metallic weld (BMW) joint at various temperatures. Any pre-existing defect or incipient damage during service conditions can lead to crack extension due to synergistic interaction of creep and fracture mechanisms. The weld heterogeneity will increase the propensity of such defects. Evaluation of material behavior for creep or fracture alone is inadequate to assess the material performance, since the contributions to life limiting factors is due to more than one mechanism. The work also includes assessment of creep crack growth behavior of indigenously developed 10Cr-Alloy 617 BMW.

4. Development of Advanced NDE-based techniques for creep damage evaluation of AUSC power plant materials

In the Indian AUSC programme, Inconel 625 and 617M have been identified as candidate materials for some of the key components. AUSC power plants materials will be subjected to high levels of stresses, creep, fatigue and creep-fatigue interaction, and varied extent of fire-side corrosion and steam oxidation. Since these are new materials, there are no reported literatures on non-destructive evaluation (NDE) to assess the progression of such damages, which are essential for design and the condition monitoring to ensure structural integrity during service. This project aims to understand the inter-relationship between the NDE parameters and the material microstructure during creep by applying various non-destructive techniques with an emphasis on velocity and attenuation of ultrasound wave, non-linear ultrasonics and electromagnetics in the two materials. Special attention will be given to the development of on-line monitoring and inspection methodologies to assess life-limiting aspects (e.g. material degradation, creep-fatigue damage, etc.) and thereby improve plant availability. Special attention will be given to the design and development of high-temperature sensors, techniques and procedures for online monitoring of damage and continuous life-prediction. Alloy 617M in the form of a bar of dimension 150 mm x 90 mm x 69 mm has been received. Machining and preparation of 15 flat samples for creep test have been completed. Ultrasonic Measurement using ultrasonic (UT), Non-linear Ultrasonic (NLU), UT imaging (UTI) and Eddy Current (EC) on as-received samples have been completed. Creep test condition has been selected from the AUSC creep matrix of alloy 617 M and in one sample interrupted creep test is in progress with a creep condition of 305 MPa stress and 650°C temperature. Till now 472 hours of creep in 10 interruptions have been completed. At each interruption, UT, NLU, UTI and EC measurements have been carried out. For EC measurement, couple of contact sensors have been fabricated In-house and tested and are being used for the measurement. Substrate for eddy current sensors operable at high temperatures (~1100°C) has been acquired. Interrupted creep test at 165MPa and 750°C temperature followed by NDE measurements at each interruption will be carried out on three samples. Along with single sample interrupted in various cycles, test will also be carried out on multiple samples, each interrupted at a particular creep exposure time. These samples will be used for microstructural analysis to establish the correlation of variation of NDE parameters with microstructural degradation. Beside development of NDE data, sensors operable at high temperatures will be fabricated for online degradation study of power plant components.

Amorphous Electrical Steel (AES) for energy applications

CSIR-NML is currently engaged in "Pilot scale development of amorphous electrical steel for energy applications" sponsored by Ministry of Steel, Government of India. The project will target production of rapidly quenched ribbons of 25-30 micron thickness and width around 100mm. The detailed process scheme for the production of rapidly quenched ribbons has been drawn. The procurement process for the pilot plant equipment is in progress.

Activities on modeling and simulation of the water cooled quenching wheel which is an important component for the pilot scale production of wider ribbons, are being carried out. Efforts are also being made on selection of industrial grade raw materials including ferroalloys and high purity silicon to produce laboratory scale amorphous ribbon. One of the major problems of amorphous alloys over their crystalline counterpart is the low saturation induction. Considerable research work is in progress for improving saturation induction by incorporating Iron rich phosphorous containing nanostructured materials. Research is also being carried out for application of amorphous and nanostructured ribbons as magnetic fillers in microwave absorbers.

Twinning on capacity building to transform Metal Industry Development Institute (MIDI), Addis Ababa, Ethiopia

The Council of Scientific and Industrial Research (CSIR) has entered into an agreement with the Metal Industries Development Institute (MIDI), Ethiopia to implement a "Twinning Program on Capacity Building to Transform Metal Industry Development Institute (MIDI)". The agreement was signed by the Director of NML, Jamshedpur on behalf of CSIR, India and the Director General of MIDI on 7th June 2017 (Figure 6). The

Figure 6: Agreement signing ceremony between Metal Industry Development Institute (MIDI), Ethiopia and Council of Scientific and Industrial Research (CSIR), India. Mr. Workneh Delelegn, Director General of MIDI and Dr. Indranil Chattoraj, Director of CSIR-NML are signing the agreement.

financial compensation to the twinning partners (CSIR laboratories) for the twinning program for three-year duration is ~US$ 6 million. This multimillion dollar international project is one of the largest programs between a CSIR institute and a foreign entity. Five CSIR laboratories (NML, CMERI, CEERI, CSIO and CLRI) are involved in implementing the program and CSIR-NML is the Coordinating Nodal Lab for the program. These five laboratories, complementing each other and together, provide the ideal knowledge and expertise fountainhead for MIDI to embark on its capacity and capability building. They will share their domain expertise in the matters of organization, structure, functional efficiencies, metals processing, manufacturing and post-processing, through twinning with MIDI. The principal objective of this transformation program is to enhance the competitiveness of the metal and engineering industry through speeding up the transformation and development of the sector, through a transformation of MIDI into a globally competitive center of excellence in the field of metals and metals manufacturing.

The team of experts from CSIR-NML visited MIDI during 2018-19 (from April'18 to March'19) for execution of the planned activities as per the PMC. Following activities /training programmes were conducted by NML experts at MIDI in Ethiopia -

(i) One week (18-24 August, 2018) training on 'Benchmarking & Best practices in metal industry' was imparted at MIDI

(ii) One week (25-31 August, 2018) training on 'Entrepreneurship development' was imparted at MIDI

(iii) Finalisation of Master's Programmes with Academic Institutes (i.e. Addis Ababa Institute of Technology and Addis Ababa Science and Technology University) and MIDI was carried out during 18-31 August, 2018.

(iv) Activity leaders of facility infrastructure creation visited MIDI for one week (October 1 to October 7, 2018) to finalise the site for the integrated facility infrastructure centre and equipment for the centres.

(v) GAP analysis and man-power competency of MIDI under the activity 'Reorientation and restructuring of MIDI' was carried out from November 19 to December 15, 2018.

(vi) Industrial database creation activity was carried out from November 19 to December 15, 2018.

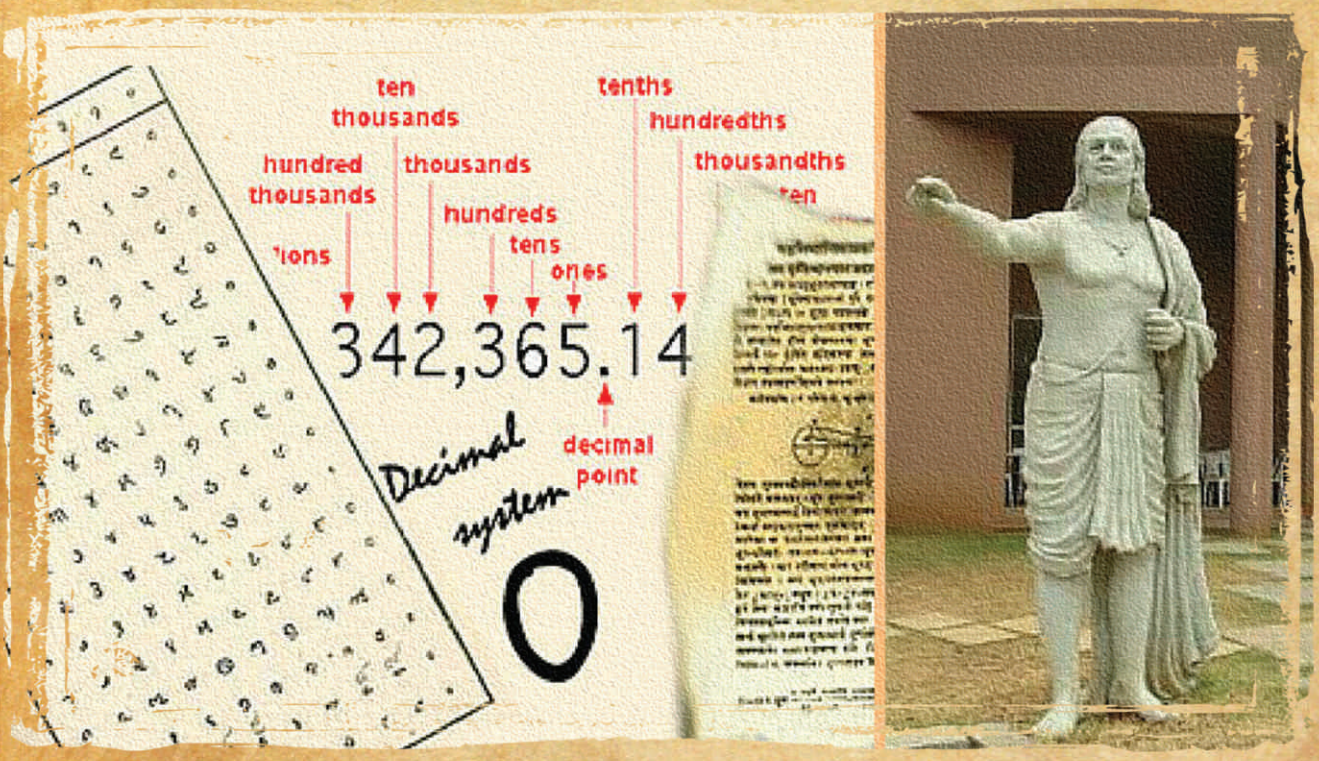
(vii) Expert database creation activity was carried out from November 19 to December 15, 2018.

(viii) Facilities database creation activity was carried out from November 19 to December 15, 2018.

(ix) Facility Infrastructure creation activities (Chemical Analysis Laboratory; Welding Laboratory; NDT Centre and Metallography / Materials Characterization Laboratory) were carried out from January 19 to February 02, 2019.

RESEARCH AREAS

Science & Technology in Ancient India



The Modern Numeral System

The country that first used the largest number of these numeral forms is India. 1, 4, and 6 are found in the Ashoka inscriptions (3rd century BCE); the 2, 4, 6, 7, and 9 appear in the Nana Ghat inscriptions about a century later; and the 2, 3, 4, 5, 6, 7, and 9 in the Nasik caves of the 1st or 2nd century CE.

Science & Technology in Ancient India

ADVANCED MATERIALS AND PROCESSES (AMP)

Advanced Materials and Processes (AMP) Division was constituted with a mandate of R&D of advanced materials & processes / techniques for the improvement of materials & components' performances and mitigation of environmental problems related to novel materials and its related industrial sectors. The division comprises three research verticals, namely Surface Engineering (SE), Non-Destructive Evaluation and Magnetic Materials (NDE&MM) and Functional Materials (FM). The division seeks to identify novel ideas in the form of materials, methods, sensors and devices to transcend the current state-of-the-art, to meet upcoming technological challenges of the industrial and strategic sectors. The three research groups, endeavor to understand how research might be directed towards real progress in terms of better performance, higher stability, facile processing and easier, faster and lower cost of production of materials and its evaluation in their specific domain, namely, Energy, Space, Defense, Iron and Steel, Oil & Gas as well as Biomedical sectors. Ongoing research program of the division includes (i) Functional nanomaterials and structures for energy application, (ii) Light weight functional alloys for biomedical and engineering application, (iii) Environmental friendly coatings for aerospace, (iv) Coating on advanced high strength steel through HDPS, (v) Self-healing coating for corrosion prevention, (vi) Development of NDE protocols for damage assessment using magnetic and acoustic techniques, (vii) Design and development of devices and sensors for industrial applications and (viii) Development of amorphous / nanocrystalline magnetic materials and special alloys. Different ongoing projects under the above mentioned programs are being sponsored by more than 15 funding agencies, , majority of them being the different business houses (Tata Steel Limited, Boeing, John Keells (Sri Lanka), Bajaj, Bharat Forge, Titan, JSW, TYASHI, etc.) along with line ministeries and strategic sectors (MoS, NTPC, ONGC, ISRO, IGCAR, BARC). AMP division has a number of state of the art facilities in its domain areas; software CIVA for electromagnetic and ultrasonic simulations and Scanning Electrochemical Microscope have been new additions during the FY 2018-19. On the research translation front NDE &MM group has transferred a technology of a "device for fluid flow rate measurement through a narrow tube" to Electronic & Engineering Co. (I) Ltd., Mumbai, during December-2018. Another technology entitled "Sensing device for inline coating thickness measurement of Galvanized Wire" has also been developed and is likely to be transferred during 2019-20. AMP division is significantly contributing in two ongoing major projects namely (i) Installation and commissioning of pilot plant for Amorphous electrical steel production and initial experimental trial and (ii) Advanced NDE techniques for creep damage assessment of AUSC power plant materials.


Team AMP

During the period of this report, scientists from AMP division published 17 papers in SCI journals and 5 papers in non-SCI journals. Scientists of the division also filed 12 patents and 1 copyright. On the human resource development front, one doctoral student graduated this year and 8 doctoral

students are being trained. Similarly, 12 students completed their M. Tech. under the guidance of scientists of the division and 11 M. Tech. students are still continuing their dissertation.

MoU has been signed between CSIR-NML and Liquid Propulsion Systems Centre, ISRO, Bangalore for realization of electronic package for ultrasonic flow meter for onboard Propellant gauging of spacecraft. Another MoU has been inked between CSIR-NML and M/s Surgiwear to develop high strength and controlled biodegradable Mg / Zn based alloys and zinc coating on Mg alloys for orthopedic application. On the academic front, agreement has been signed between CSIR-NML and Shiv Nadar University, Greater Noida, to work jointly in the field of surface modification of biodegradable alloys and jointly train the doctoral students.

Functional Materials

Induction active sole plate for iron press

The objective of the project was development of sandwiched sole plate for induction heating of iron with cooling rate of 5°C / min. In induction heating, temperature is generated by eddy current loss; for the eddy current loss the sole plate should be active in the presence of electromagnetic radiation. In general, sole plate made of ferrous metals is active in induction heating method. CSIR-NML developed the sandwiched sole plate where the bottom plate is aluminum metal (non-ferrous) of 3 mm thickness. Our special design makes the sole plate active when the electro-magnetic radiation is exposed. Besides, the sandwiched plate is filled with metal oxide powder that helps in storage of heat. The main challenge of any research on pressing irons is to maximize energy savings and make it more user friendly, for example, a cordless iron (Figure 1). Currently two different models of iron have been made and tested by the laboratory and the sponsor is developing the induction heating system. The developed sole plate design has the following features:

- 3 mm thick Al plate (non-ferrous) can be used at the bottom of the sandwiched plate, which is unique in design
- Heat retention capacity is high, heat loss < 5°C /min

Impact on society/industry

Energy saving and user-friendly iron press is expected to be available in the market. Test of the sole plate indicates that it saves around 50 % energy.

Figure 1: Induction active sole plate

Collagen-graphene composites for energy devices

The objective of the project was to synthesize and characterize iron oxide, hydroxyapatite and silver on graphene-collagen colloidal composites and electrospinning them into fibers for use in energy devices. The graphene has been functionalized using collagen protein and further used as a template for the synthesis of iron oxide, silver and hydroxyapatite composites. These composites were then electrospun to form fibers and heat treated at 140°C. The heat treated fibers were then directly used as electrodes in aqueous electrolytes and cyclic voltammetry was done. The measurement of specific capacitance (F/g), energy density (Wh/g) and power density (W/g) was done. Charge-discharge studies were also done and attempts have been made to make a prototype (Figure. 2). Future work will focus on a prototype super capacitor.

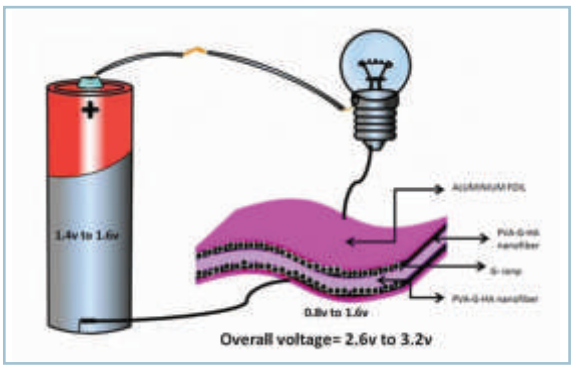


Figure 2: Prototype being perfected

Impact on society/industry

All fiber flexible super capacitors can revolutionize the world of energy device

Synthesis and characterization of Biocompatible Mg Alloys

The project aims at the development of Mg-based bio-implants which are both biocompatible and biodegradable. Biodegradable implants are new generation metallic biomaterials which degrade within the body after the healing process is over thus avoiding revision surgery. The mechanical properties of currently used polymeric bio-degradable implants are not suitable for load bearing applications, and the degradation products of polymers lead to inflammatory tissue responses. Therefore, metallic bio-degradable alloys having higher hardness, strength, toughness, and biocompatibility are thought of as potential substitutes for biodegradable polymers. In this project Mg-based alloys will be developed which can be used as bio-degradable implants, which produce degradation products that are non-toxic and can be readily excreted by the human body.

Keeping this in view, a series of MgY, MgGd, MgGdY, MgGdYZnZr and MgZnMn alloys were prepared and investigated for their microstructure, structural, mechanical and corrosion characteristics. The ultimate tensile strength (UTS) of the developed alloys in as-cast condition varied from 76 MPa to 447 MPa; Mg10Y, Mg10Gd10Y and Mg6Zn1Mn exhibited UTS above 200 MPa and the highest UTS (447 MPa) was shown by Mg10Y. The elongation of Mg10Y and Mg10Gd10Y were 3.5 and 1.5 % respectively. Mg6Zn1Mn alloy possessed UTS values between 200 to 236 MPa and an elongation of 9 to ~18 % in the as-cast condition. Mg6Zn1Mn alloy billet weighing 6 kg was solutionised at 500°C for 8 hours in Ar-atmosphere and machined to get billets weighing ~5.5 kg (Figure 3). Among these alloys, the

Figure 3: Solutionised Mg6Zn1Mn alloy billets for extrusion

biocompatibility of Mg10Y and Mg10Gd10Y alloys was not examined but Mg6Zn1Mn alloy is biocompatible. Focus of this study has been on enhancing the mechanical property of the biocompatible Mg6Zn1Mn alloy through mechanical processing. This alloy was extruded at 275°C with an extrusion ratio of 3.875 and the extruded sample showed a UTS of 276 MPa and an elongation of 26 %.

A patent has also been obtained on the process for preparing "A high strength as-cast Mg-Y alloy". The future work will concentrate on extrusion experiments at a higher extrusion ratio to further enhance the strength.

Impact on society/industry

A successful outcome of the project i.e. the planned technology to produce high strength Mg alloys with desired degradation rate, will set a new path in the area of orthopedics.

Non Destructive Evaluation and Magnetic Materials

Development of energy efficient magnetic nanocomposite materials (Indo-Russian project (DST-RFBR))

In this collaborative project with National University of Science and Technology (NUST), Moscow, Russia, the development of Energy Efficient Magnetic Nanocomposite Materials is the objective. The Russian group is led by Dr. Sergey Kaloshkin, Director, Institute of New Materials & Nanotechnologies, Moscow. The project involves preparation of nanostructured materials by both the groups in their laboratories, exchange of samples for characterization and joint publications. In the ongoing research work, a series of FeB(P)SiNbCu alloy ribbons have been prepared by melt spinning technique. The XRD pattern (Figure 1) for the alloy series show complete amorphous nature of the ribbons. The influence of P addition on the stability of as-quenched amorphous structure and crystallization behaviour were studied using DSC thermograms (Figure 2). The DSC thermograms exhibit double exothermic peak indicating crystallization of a-Fe and $Fe_3(B, P)$ phases respectively. With increase in P addition, the primary and secondary crystallization onsets T_{x1} and T_{x2} increase till 6 at% P beyond which it remains stable.

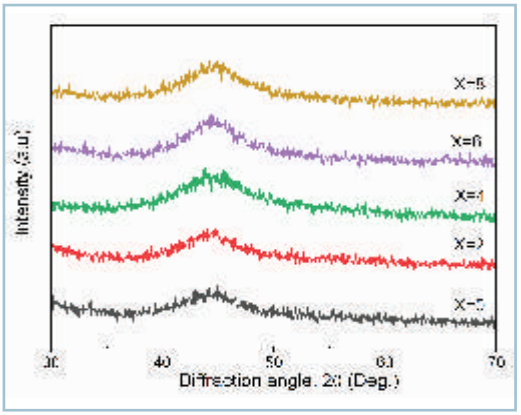


Figure 1: XRD patterns of as-quenched ribbons of $Fe_{81}B_{15-x}P_xSi_2Nb_1Cu_1$ alloys

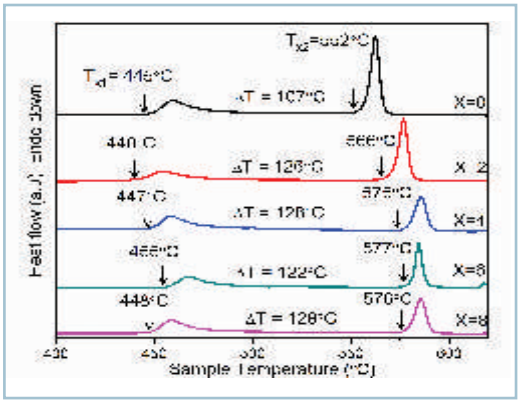


Figure 2: DSC thermogram obtained for as-quenched ribbons of $Fe_{81}B_{15-x}P_xSi_2Nb_1Cu_1$ alloys

Investigation of sensitization behaviour of austenitic stainless steel using magnetic techniques

The present study aimed at quantifying the magnetic behaviour of SS304LN in the sensitized condition using magnetic techniques available. A study on the sensitization behaviour of AISI 304LN has been carried out and the following conclusions can be drawn from the present study: (i) Sensitization leads to the formation of a magnetic phase due to the depletion of Cr in the Fe-Cr-Ni matrix resulting in the formation of Ni-Fe matrix (ii) the magnetic behaviour of the Ni-Fe matrix is complex depending on the Cr-carbide layer thickness near the grain boundary (iii) a super paramagnetic phase is formed (iv) the Curie and the blocking temperatures of the magnetic phase depend on the volume fraction of the Cr-depletion resulting from sensitization. At high enough values of % DOS these values are in the range of 200–250 K. This study in effect concludes that the sensitization in SS304LN exhibits a ferromagnetic behavior at high values of DOS. However a detailed magnetic characterization is needed before the magnetic technique can be used as an alternative for estimating the sensitization in austenitic stainless steel.

Modification of microstructure and

mechanical properties by high-intensity ultrasonic treatment of high-strength steels

Ultrasound vibrations have been known to improve the quality of large sized castings when liquid metals transform into solid shapes. The important advantages of the application of vibration to solidifying castings are: (i) grain refinement, (ii) homogeneity of structure and properties, (iii) reduced micro-segregation resulting in shorter heat-treatment times and improved resistance to corrosion. However, the application of Ultrasound waves in modifying the structure and properties of solid-state metallic materials appears to be relatively less common in industry. In this work, an attempt has been made to study the changes in mechanical properties of IF and mild steel grades of steels both of which are cold rolled through ex-situ high intensity ultrasound treatment. Results of change in hardness due to ultrasound treatment for different times have been correlated with micro-strain through XRD and grain sizes using EBSD. Ultrasonic treatment was done

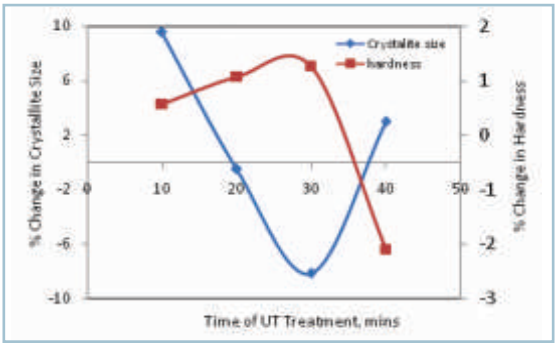


Figure 3: % Change in Hardness and Crystallite size with ultrasonic treatment in IF-CR steel

for 10 min, 20 mins, 30 mins and 40 mins in cold rolled (CR) and cold rolled then annealed (CRAn) IF steel and Low Carbon (LC) steel samples using a 4.5 kW ultrasonic generator and at a frequency of 20 kHz. For IF-CR and IF-CRAn samples, it was found that there is an increase in hardness till 20 mins of UT treatment, after which it decreases. 20% change in hardness was observed for IFCRAn steel sample when treated for 20 mins. Whereas for LC-CR sample, hardness decreased till 30 mins of UT treatment and an increase was observed for 40 mins treatment. EBSD and XRD analyses were made to correlate the hardness variation results with changes in grain size. EBSD analysis showed refinement of grains with the ultrasonic treatment. Variation of hardness and crystallite sizes with ultrasonic treatment for IF-CR steel is shown in Figure 3.

Development of Iron based rapidly solidified alloys from high phosphorous pig iron (HPPI)

An exploratory research project has been undertaken to develop rapidly solidified amorphous alloys utilizing industrially available high Phosphorous Pig Iron (HPPI) material. The major objective of the project is the utilization of HPPI as raw material for the preparation of multicomponent alloys in the form of ribbon through melt-spinning technique, and subsequent structural, thermal and magnetic property evaluations. The melt spinning of four alloys including HPPI, were carried out at different wheel speeds of 1400, 1700, 2100 and 2500 rpm mimicking various melt quenching rates. The X-ray Diffractometry, Differential Scanning calorimetry, fluxmetery and magnetometry techniques were employed in characterizing the as-quenched ribbons. The HPPI ribbons exhibit amorphous + crystalline and amorphous matrix for 2100 and 2500 rpm wheel speeds, respectively (Figure 4). Whereas the modified alloys (FeCSiPBCrMo and FeCSiPBCrNbMo) exhibit

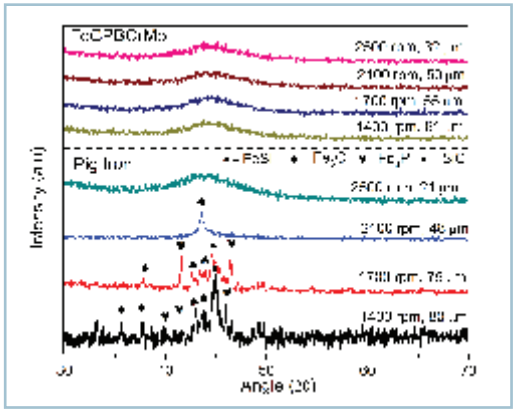


Figure 4: XRD patterns of HPPI and modified alloy ribbons depicting ease of amorphization.

complete amorphous matrix even at lower wheel speed of 1400 rpm. The DSC thermogram for HPPI and modified alloy ribbons exhibit multistage crystallization process. The fully amorphous ribbons impart favorable combination of soft-magnetic properties having low coercivity (6-20 A/m) and high saturation magnetization in the range of 1-1.3 T (See Figure 5). The investigation outlines a methodology for evaluating the glass forming ability (GFA) of new alloys through melt-spinning technique and a way of correlating the ribbon microstructure to that of water atomized powders. The study illustrates the potential scope of utilizing industrial high Phosphorous Pig Iron as input material for preparing amorphous magnetic cores and coatings. The collaborative work resulted in a joint patent.

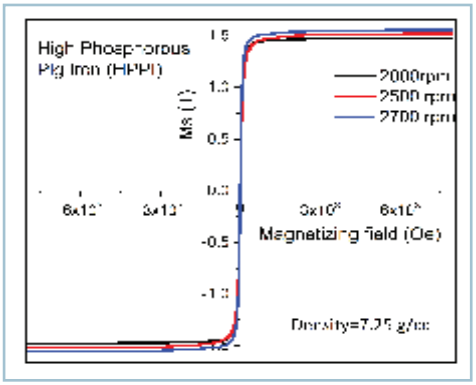


Figure 5: Saturation magnetization (Ms) of HPPI ribbons prepared at different wheel

Development of process for real time temperature mapping of 4 faces of the billet mould using densely multiplexed Fiber Bragg Grating (FBG) sensors

Billet casting is used worldwide for the production of long products such as concrete reinforcement bars (rebar), high carbon springs, mild steel wires and electrodes. Casting of these steels has been done at the collaborator Steel LD Shop #1 since the inception of Continuous Casting there. Casting of rebar grades is done in two sections of 130mm^2 and 150mm^2 at all three billet casters at LD1. Rhomboidity (off squareness/ obliquity) and cracks are two billet defects noticed in this grade which accounts for most of the rejections at LD1. Previous studies have identified the solidification pattern in the mould to be the sole cause for the cracks and one of the primary causes for rhomboidity. The objective of the present project is to record live mould wall cold face temperatures of a billet casting mould, across the face and on all four faces, for at least two moulds, by embedding FBG sensors. The activities consist of i) FBG Sensor fabrication in suitable single mode fiber, packaging and temperature calibration; ii) Array of FBG sensor insertion, installation in the caster and real time data capturing; and iii) data compilation for further modeling.

Evaluation of density/ homogeneity of TC Rings of rolls through NDT technique

Processing steps of Tungsten-Carbide (TC) rolls may cause density variation and residual porosity. Generally, TC rings are received from various vendors having different binder and are inspected at the shop floor for dimensional checking and for physical damage, before cutting or grooving. It is very difficult to relate Roll breaks or poor pass life or variation in wear pattern, with the roll quality in terms of density, homogeneity, etc. Any TC roll containing more than allowable levels of porosity results in less dense products and inferior performance. The objective of this project is to develop ultrasonic based non-destructive test technique for homogeneity study of TC rolls on site. Ultrasonic velocity is dependent on density of any material. Ultrasonic imaging for velocity mapping from the top surface was carried out on a few TC rings with various binder amounts. Figure 6 shows the velocity variation in two TC rings with two different binder percentages

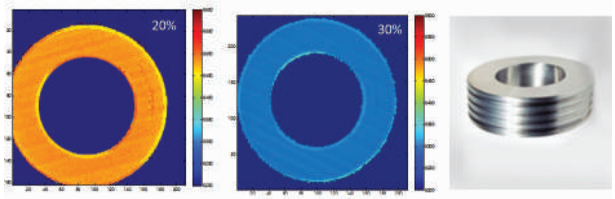


Figure 6: Variation in UT velocity with binder amount

along with a digital image of a TC ring. Variation in velocity with binder percentage is clearly visible in the images. Thereafter, ultrasonic tests in a contact mode were carried out on a large number of TC rings supplied by various vendors and having different binder percentages. From all the measured data, calibration curve for velocity against binder % has been developed with a correlation factor of 0.98. It was found that the sound velocity decreases with binder %.

Development of online temperature monitoring system for blow pipes in blast furnaces using FBG sensors

Blow pipes are critical parts of blast furnaces as the hot blast which is injected by tuyeres is drawn from bustle pipe through blowpipes. Basically, it feeds the tuyeres with hot blast and pulverized coal. As these hot blast and pulverized coal are injected, they make the blowpipe more vulnerable for wear and thermal cracking. Crack/wear in refractory exposes the blow pipe to high temperature which can lead to sudden failure of blow pipe. Such failures not only affect the productivity in terms of breakdown, but it also causes safety threats. Hence there is a need to monitor the condition of the blowpipe on a continuous basis to avoid such unexpected failures. The present project aims to develop a methodology to monitor the health of blowpipe during service by sensing the real-time temperature using FBG sensors and to control the operation of the unsafe/critical blowpipe from a remote location in order to avoid any catastrophic failure. A fundamental study and investigations have been made to ascertain the basic requirement of the sensors with respect the dimension, sensitivity, and fibre selection, based on the temperature range and signal processing system. Fabrication of FBG sensor-arrays as per the requirement and subsequent protection / encapsulation of the sensors for deployment in a blow pipe have been carried out. An application specific signal processing and the data logging / analysis software and interfacing protocol has been developed and implemented along with alarming option in order to avoid any sudden failure due to rise in temperature. The entire system with two arrays, each having three FBG sensors, has been successfully commissioned on January 25th, 2019 at H-blast furnace of sponsor for real-time condition and temperature monitoring of blow-pipe from the control room and is still in operation (Figure 7 a & b). Development of such system will help to avoid any unexpected shutdown due to blow pipe failure which accounts for the huge production losses and other casualty.

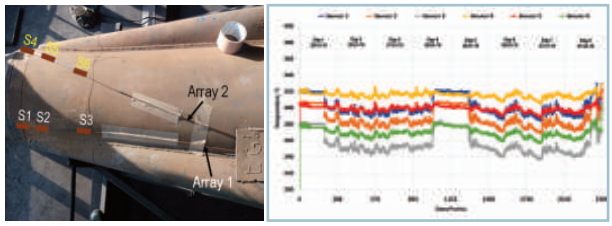


Figure 7: (a) Position of six embedded sensors on the surface of a blowpipe; (b) Real time temp data for 8 days from the date of installation

Laboratory scale processing and technology transfer of 18 karat low melting point gold alloys for jewellery application.

Lowering the melting point and increasing the hardness are two major challenges for 18 karat gold alloys applicable to special type of jewelleries. The objective of this project is to process 18 karat low melting point gold alloys in the form of rods, rings and granules through rubber mold. New types of 18 karat gold alloys were designed and developed through arc melting and casting in the form of rods by suction casting, which have melting point in the range of 350-470°C, and hardness of 210-310 Hv. Initially the alloys were prepared in the form of 3, 4 and 6 mm diameter rods inside a copper mould. For industrial applications, the alloys are to be cast in rubber moulds of different shapes like rings, studs, etc. The present research targets to cast the rings of aforementioned low meting point alloys inside the rubber mould. After several attempts, one alloy was successfully cast as a ring without any damage of the rubber mould. There are more trials going on to prepare rings for commercial purpose.

Smart sensing system for cold drawn high end wires

The presence of cracks/discontinuities such as seams, cracks, pits, slivers, weld-line defects and internal discontinuities in metallic wires and the failure to detect these during the wire drawing process often leads to long term production interruptions, significant economic losses and lower quality of final product. Undetected wire defects result in failure at the customer end during subsequent processing or while in use. It is desirable not only to detect the quality of the wires in terms of defects during the manufacturing stage itself followed by diversion of defective spools but also to provide real-time feedback on product quality during production - even at high speeds. Although a few sophisticated systems are available globally, these are prohibitively expensive for large scale implementation. In fact, cost-effective, tailor-made systems are imperative for multiple line applications. CSIR-NML has already developed *FlawGuard*™, a low-cost device for sensing wire defects at high speed. Based on the principle of eddy-current (EC), this device has found ready acceptance with the biggest wire manufacturer in India and has been in regular operation since May 2017. Satisfaction with the performance of the device has resulted in the customer's request for up-gradation of the system beyond just defect detection and identification. Keeping this in view, this project aims to develop the next generation of *FlawGuard*™ incorporating a smart sensing system with remote monitoring and decision making capability on the quality of the wires. Additionally, the system would be capable of measuring the uniformity of the zinc coating on-line. Such a facility is non-existent in galvanising wire lines and will address the long-standing issue of proper production of galvanised wire. Non availability of low cost inline GI coating thickness measurement, make the producer handicapped to assess the required thickness in all the production lines during drawing. Over-coating of Zinc leads to a huge economic loss whereas undercoating is not acceptable by the customer. Implementation of the developed system will address these issues too.

After completion of the electronics and sensor fabrication for inline coating thickness measurement of galvanised wire, one trial has been made at the client's plant, to study its suitability in the line. Figure 8 shows placement of sensor in one of the galvanising lines along with the sensor output voltage in the display. Calibration of sensor output voltage with coating thickness is being carried out using the Hot Dip Galvanising Process Simulator.

Figure 8: Placement of sensor in one of the Galvanising lines along with the sensor output voltage display

Development of magnetostrictive sensing device for structural integrity evaluation of pipes

Pipelines form an integral part of industries in transporting fluids. The inspection and maintenance of these pipelines is very important to prevent any catastrophic failure. Non-destructive testing (NDT) by guided wave ultrasonic is an advanced technique for long range pipeline inspection where sensors have been placed in one location and information on the health of few meter length pipe can be monitored. In the guided wave ultrasonic based pipeline inspection, the reflection from the defect gives relevant information. Generally, PZT transducers are in use for guided wave ultrasonic inspection, which are bulky and very expensive. Another alternative is Magnetostrictive sensor (MsS), where polycrystalline alloys are used for generation and detection of guided ultrasonic wave. Light weight, portability and low cost are the advantage of using MsS as the sensing element for guided wave ultrasonic. This project aims to use rapidly quenched amorphous ribbon prepared by melt spinning technique as the sensing element. The proposed

project aims to study the effect of different type of defects like saw cut, corrosion, pits, holes and welds with a sensor configuration suitable for field application. The dimensional effect of these defects on MsS signal will be investigated. Based on the experience gained through laboratory experimentation, an MsS sensing device will be fabricated through an external party. Thereafter, experimentation will also be carried out using the developed magnetostrictive sensing device on pipes with different types of defects.

Evaluation of residual stress in shot peened steel subjected to fatigue using magnetic Barkhusen emission technique

Some of the critical aeronautical components include landing gears and bearings of aeronautical engines are made of ferromagnetic steel. These components are subjected to extreme service conditions. The landing gear is shot peened to introduce compressive stresses for enhancing fatigue life. Due to successive landing, the above components experience fatigue which reduces the compressive residual stress. Thus, assessment of the stress level in the landing gear and bearings through NDE techniques is essential for safe running of aircraft. As these components are ferromagnetic in nature, magnetic NDE techniques may be suitable for assessment of damage. High strength low alloy steel 4340M is a candidate steel for the landing gears. The project was sponsored by the client with an objective towards assessment of residual stresses in shot peened 4340M steel subjected to fatigue damage using Magnetic Barkhausen Emission (MBE) techniques. The advantage of the technique is that it can probe to longer depths (few tens of micrometers) compared to x-ray residual analysis. Moreover, the MBE equipment is portable and can be easily carried to the site for inspection and monitoring. The steel samples were normalized at 870°C for 1 hour. Some of the samples were shot peened and subjected to fatigue tests at two different stress levels, namely, 36% and 60% of yield stress. Interrupted fatigue tests were carried out to measure the variation in MBE signal and x-ray residual stress values with fatigue cycles. MBE and x-ray residual stresses measured for 36% YS shot peened sample subjected to interrupted fatigue cycles (Figure 9)

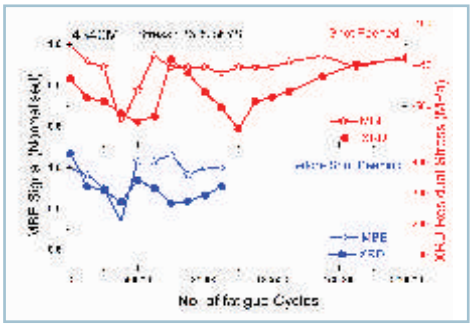


Figure 9 : Variation of normalized MBE signal and XRD residual stress for samples before and after shot peening subjected to fatigue cycles at stress levels of 36% of yield strength.

showed the distinct effect of enhancement in fatigue cycles to failure. The MBE signals have been normalised with respect to the values without fatigue exposure. At 36%YS the samples failed at 90,000 and 2,00,000 fatigue cycles before and after shot peening respectively. The influence of shot peening on enhancement of fatigue life was observed. The Barkausen signal showed similar variation with the change in residual stress determined from x-ray residual stress measurements. Similarly, at a much higher stress value of 60%YS, the samples failed at 44,072 and 83,381 cycles in pre-and post shot peened samples (Figure 10). The measurements of Barkhusen emission signal show the feasibility of measuring the variation in stress state of the sample during fatigue exposure.

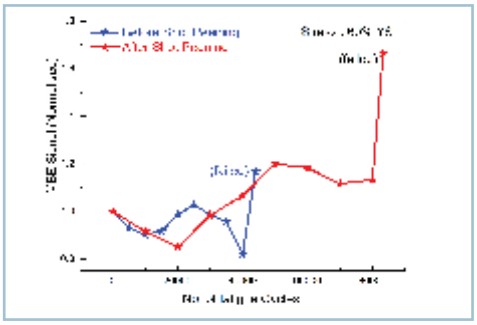


Figure 10: Variation of normalized MBE residual stress for samples before and after shot peening subjected to fatigue cycles at stress levels of 60% of yield strength.

ASAP: Advanced electromagnetic sensors for assessing property scatter in high value steel

The development of new materials for automobiles emphasizes fuel economy through vehicle weight reduction, which can be achieved by increasing strength-to-weight ratios of developed alloys. Generally, all automotive steels are processed through a sequence of hot rolling, cold rolling and subsequent annealing treatment to achieve required steel microstructures and properties. All these stages are monitored by destructive techniques like microstructural observation, hardness measurement, etc. Magnetic parameters, such as, coercivity, permeability, remanance, induction, power loss, are structure sensitive due to the variation of magnetic domain patterns with microstructural parameters (dislocation density, grain size, precipitation, etc.). Therefore, the magnetic parameters measured through electromagnetic sensors are effective in monitoring microstructural phase changes during processing and service of steels and its components. In this project two types of automobile steels, dual phase (DP) and interstitial free (IF) are characterized through microstructures, mechanical properties and electromagnetic parameters. The basic microstructure of these steels was initially ferrite matrix with a dispersion of pearlite phase in DP steel and large TiN, and fine titanium carbosulphide particles in IF steel. The strength and ductility of DP steel depend on the volume fraction of different phases like, ferrite, martensite, bainite, etc., while the mechanical behavior of IF steel is controlled by recrystallized microstructure of cold rolled steel. The aim of this project is to study the linkage between electromagnetic sensor signals and materials property for these two high value steels in order to exploit appropriate signals for microstructure characterization. With increasing martensite fraction, DP steel becomes magnetically harder, resulting in higher coercivity and lower permeability and RMS voltage. Magnetic flux density of DP steel shows a tendency to increase with ferrite fraction. The RMS voltage shows a small change with changing the soft magnetism of steels for varying phase fraction. At the recovery stage, the IF steel becomes about 60% magnetically softened, while it loses 20% of hardness (Figure 11). In contrast, during the recrystallization stage, this steel loses 20% of magnetic strength and 60% of mechanical strength. Due to its non-destructive nature, the measurement of magnetic parameters is a versatile method for monitoring microstrucutral phase change of DP steel and recovery and recrystallization behavior of IF steel. The system used in this investigation allows assessment of strip or plate samples with no machining or surface preparation requirements.

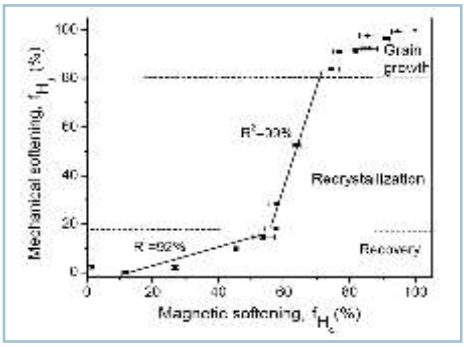


Figure 11: A relation between mechanical and magnetic softening of IF steel at the recovery stage

Development of methodology for identification of secondary (used) CRGO strips using electromagnetic sensor

The Cold Rolled Grain Oriented (CRGO) 3.5wt% Si-steel is extensively used as a core material for distribution and power transformers. The processing of the material which forms cube-on-edge Goss texture towards the rolling direction, is very critical for enhancing the magnetic property. However, the material property deteriorates in course of service. It is felt that some on-site non-invasive measurement techniques need to be developed to find the damages in CRGO steel sheet. The aim of the present project is to establish a non-invasive electromagnetic measurement technique for evaluation of damage in CRGO steel. Four categories of new (good) and three types of service exposed (damaged) CRGO sheets have been investigated in this research project through different destructive

(microscopy, texture, core loss) and non-destructive (electromagnetic) experimental techniques with an objective to establish non-invasive electromagnetic measurement technique for evaluation of damage in CRGO steel. It was observed that the damaged CRGO sheets demonstrate higher coercivity and core loss and grain boundary broadening compared to new CRGO sheets. The Goss texture is less spread in case of new CRGO sheet compared to service exposed (damaged) samples. Magnetic texture is evaluated by coercivity variation at different angular position with respect to the rolling direction, and the coercivity is found to be higher in transverse direction due to hindrance of magnetic domain movement (Figure 12).

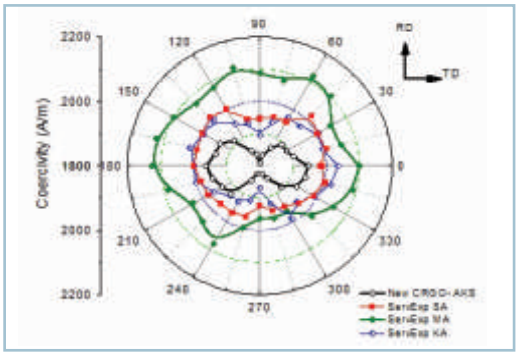


Figure 12: Variation of Coercivity in RD and TD of new and service exposed CRGO sheets

Electronic packages for ultrasonic flow meter for on-board propellant gauging of spacecraft

Spacecraft propellant gauging is one of the important activities that allow estimating the amount of propellant available onboard in a spacecraft. The propellant availability dictates the life of the spacecraft; also the data related to the propellant availability determines the mission sequence and decisions. This project is the 2nd phase of an activity. In the 1st phase CSIR-NML has proven its capability in designing a system for determining the fluid flow rate in a narrow tube as per the requirement of Liquid Propulsion System Centre (LPSC) of ISRO. CSIR-NML has already transferred this technology to an Indian manufacturer. The objective of this second phase is to fabricate four systems using flight qualified electronics. Qualification tests of the devices for continuous and pulsating modes for further use in Indian spacecraft will be carried out on ground in space environment. The electronic package development includes pulser, receiver, onboard storage and signal processing so as to enable acquisition, analysis and delivery of data from spacecraft to the ground stations.

Surface Engineering

Study of benefits of Cr micro-alloying/ modification of microstructure for enhancing corrosion resistance of carbon steel for water injection pipeline

The objectives of the project are: 1. Fabrication of a closed loop system for corrosion study in a flowing simulated sea water condition with different controlled O_2 levels. 2. Evaluating and optimizing the chemical dosage along with the inert gas flow for removing dissolved oxygen. 3. Corrosion evaluation of the line pipe steel under the influence of varied O_2 concentration using coupon exposure, open circuit potential measurements, and other electrochemical methods. 4. Alloy development with different Cr additions (Base alloy + 2 compositions). 5. Assessment of Cr additions on corrosion performance in the presence of oxygen. 6. Assessment of weldability of developed alloys and selected corrosion studies of welded parts.

Corrosion is a serious concern in the petroleum industries especially in production, transportation and storage, and refinery operations. Water injection through pipeline is most commonly used to pressurize the bed so as to increase the oil recovery. Mostly, sea water is used as an injection fluid which causes severe corrosion of the pipeline. Low/medium carbon steel is extensively used as a pipeline material. The normal life of currently used mild steel based pipes is ~15 years; however, failures are observed after 4-10 years of

service which is mostly due to corrosion. One of the prominent causes of premature service failure is higher oxygen levels which promotes pitting corrosion. Attempts are being made to enhance the service life time of the water injection pipeline by increasing the Cr contents of alloy steel. It is a pre-requisite to obtain O_2 level below 20 ppb during pressurized water injection to avoid its oxidizing effects in the presence of chloride. However, sometimes oxygen level shoots up and may reach as high as 2000 to 4000 ppb. It is thus important to understand the influence of O_2 contents varying from 250-4000 ppb on the corrosion of steel and to investigate the critical oxygen level in order to avoid pitting/ crevice corrosion. Such critical O_2 concentration would however be different for steel differing in the alloying constituents and need detailed experimentation. The design, fabrication and installation of an indigenous equipment "Closed loop corrosion test rig" for corrosion study in flow simulated sea water with different controlled O_2 levels has been done for the purpose. The equipment is attached with two type of test rig for coupon exposure as well as electrochemical studies using online potentiostat under flow condition. The equipment has the capability to monitor dissolved oxygen and the flow rate of the liquid during experiment. No critical issue with the developed alloys concerning welding was found. Corrosion evaluation of exposed coupons at different oxygen levels (viz. 4000, 2000, 1000, 500 and 250ppb) inside the closed loop was also completed. The potentiodynamic test in the test rig under flow condition has been done. It was observed that corrosion resistance increases due to low amount of chromium alloying.

A patent “A closed loop system for simulating and monitoring corrosion properties in continuous flow” has also been filed in India. Six-month coupon exposure of welded samples and potentiometric corrosion evaluation in the test rig under different flow condition will be carried out; and comparative data evaluation and recommendation of the suitability of alloy for extended life of the pipeline will be assessed.

Impact on society/industry

Present data show that the low amount of chromium alloying will extend the life of the water injection pipeline. The "Corrosion test rig" is developed as an indigenous affordable equipment for flow assisted corrosion study.

Self healing coating for corrosion protection of Steel and Aluminium alloys

The objectives of the project are: 1. Design and synthesis of chemically modified cationic, anionic & zwitterionic polymers that have intrinsic anticorrosive properties and high affinity towards steel surfaces. 2. Formulation of a self-healing coating following layer by layer and capsule based approach.

Development of self-healing coatings which automatically repair and prevent corrosion of the underlying substrate, when the coating develops defects due to mechanical reasons or climatic or temperature changes, is a thrust area of research worldwide. The focus of the present proposal is to develop smart self-healing anticorrosion coatings for steel and Aluminium alloys following layer-by-layer and capsule based approach. Novel cationic, anionic and zwitterionic functionalized polymers will be synthesized and they will be used as multiple layers and corrosion inhibitors will be used as the sandwich layer. Functionalization of the polymers will be done by incorporating corrosion inhibitors in the polymer backbone. In the capsule based approach, capsules of conducting polymer polyaniline (PANI) will be prepared and amine based corrosion inhibitors will be encapsulated. The capsules will be used in epoxy and polyurethane coatings to prepare self healing coating for corrosion protection of steel and aluminium alloys. The self-healing properties of the coating will be evaluated using Scanning Electrochemical Microscope (SECM), Localised electrochemical impedance spectroscopy (LEIS), standard electrochemical techniques, salt spray and outdoor exposure techniques. The self healing coating has potential application in pipelines, gas and oil tanks, bridges and industrial infrastructures. Currently, the zwitterionic polymer PGLBT (molecular structure shown in Figure 1.) has been synthesized and electrochemical and weight loss experiments in 1N hydrochloric acid medium has indicated that PGLBT has intrinsic corrosion inhibition properties and provides excellent corrosion inhibition

(93%). Further, other cationic, anionic and zwitterionic polymers with intrinsic corrosion inhibition property will be synthesized and used in multiple layers to produce self-healing coating on steel; and deposition of above polymers using layer-by layer approach to formulate self-healing coating will be done. Also, synthesis of polyaniline (PANI) microcapsules and encapsulation of corrosion inhibitors and formulation of self-healing coating by dispersing inhibitor encapsulated PANI microcapsules in epoxy resin will be done. The evaluation of self-healing performance of the developed coatings using electrochemical, salt spray and outdoor exposure techniques will also be carried on. Research outcome of this project could be a technology for formulation of a self-healing coating for corrosion protection of steel & Aluminium alloy. The self healing coating has potential applications in pipelines, gas and oil tanks, bridges and industrial infrastructure like sheds.

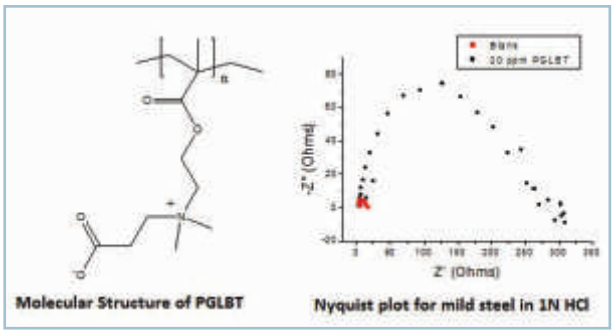


Fig.1. The Zwitterioninc Polymer structure and enhanced corrosion resistance due to its use on steel

Impact on society/industry

In selecting a construction material a compromise is made between the desired properties and price. Mild steel, despite its low corrosion resistance, is extensively used as a construction material in many cases primarily because of its low cost and ease of fabrication. Instead of using a more corrosion resistant expensive material like stainless steel, mild steel surface is often covered with a protective coating. Nowadays, protective coatings have to meet the legal requirements of avoiding use of harmful substances including hexavalent chromium, the main compound employed in such coatings, until recently. Consequently, there is a pressing need to develop environment friendly coatings without compromising on the product life cycle. Compared to normal barrier coatings, self-healing coatings present great advantage in that they provide maintenance free corrosion protection for longer durations. This is extremely beneficial for critical components like oil and gas tanks, pipelines, and bridges, where failure in coatings can result in loss of material and lives.

Development of Zn-Al-Mg coating with better resistance to surface blackening and powdering

The objectives of the project are: 1. To optimize Zn-Al-Mg coating composition on IFHS and CQDQ grade steel substrate and develop a secondary passivation coating on Zn-Al-Mg to avoid surface blackening for bare application in construction segments. 2. To improve powdering resistance of Zn-Al-Mg coating on IFHS and CQDQ grade steel for automotive applications through optimization of coating structure and hot dip process parameters.

The Zn-Al-Mg coating is used in construction and in automotive sectors. Improvement is required on durability, coating appearance, resistance to blackening, corrosion and powdering. Blackening occurs due to formation of ZnO-x in the presence of Al and Mg, on the outermost layer. The Zn-Al-Mg coating becomes charcoal gray impairing its commercial value significantly. In automotive applications, there is loss of particles from coating during forming operation that hampers coating quality and damages die surfaces. Further improvement of surface blackening and powdering resistance without deteriorating its workability and corrosion resistances are desired. In this project, the Hot dip coating process for Zn-Al-Mg coating, on the substrates of IFHS and CQDQ grade of steels, was optimized using hot dip process simulator (HDPS at NML Jamshedpur). The resistance of Zn-Al-Mg coating to surface blackening and powdering was improved (Figure 2) through optimization of the composition of hot dip molten metal bath of Zn-Al-Mg, addition of alloying element (Ni) and process parameter (Cooling rate of coating after dipping step). The controlled coating surface morphology (surface roughness (Sa), grain size), fine microstructural aspects

of constituent phases in coating (Zn-Al binary eutectic, ternary eutectic phase of Zn-Al-Mg_2Zn_{11} and controlled size, shape and fraction of Mg_2Zn_{11} phase) were characterized using optical and scanning electron microscopy (Figure 3), X-ray diffraction technique and electron probe micro analysis attached with wavelength dispersive spectroscopy (Figure 4). The performance of Zn-Al-Mg coating to surface blackening was characterized using UV visible spectroscopy with specular reflectance technique and exposing in humidity chamber test. Powdering resistance of Zn-Al-Mg coating was characterized using V-60 bend test. The optimized Zn-Al-Mg coating showed better resistance to surface blackening and powdering. This also resulted in an improvement of durability, coating appearance and corrosion resistance. Secondary protective thin film of lacquer on the developed Zn-Al-Mg coating was developed (Figure 5) and applied using dipping technique, which further improved the performance of Zn-Al-Mg coating with respect to durability, coating appearance, resistance to blackening, corrosion and powdering.

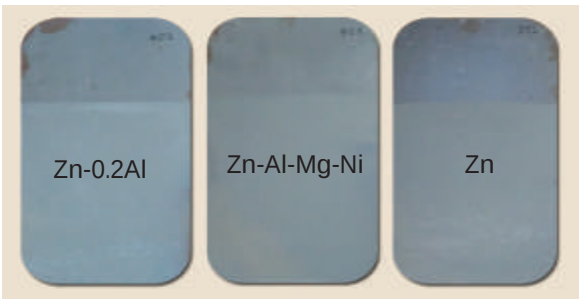


Figure 2: Images of different types of hot dip coatings using HDPS simulator at CSIR-NML.

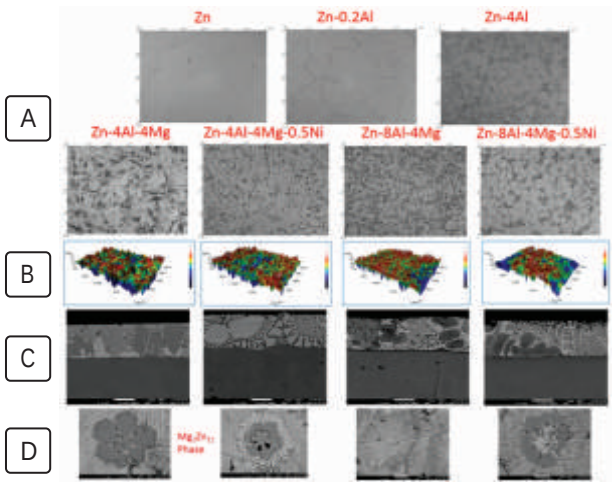


Figure 3: A) Optical micrographs of different types of Zn-Al-Mg coatings
B) Surface 3D profilography of different types of Zn-Al-Mg coatings
C) SEM images of transverse section of coatings
D) Modified Mg_2Zn_{11} phase in different types of Zn-Al-Mg coatings

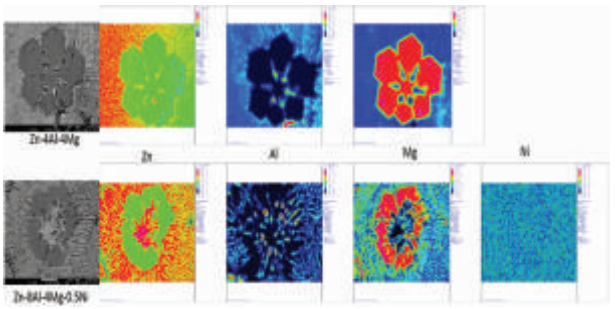


Figure 4: Element mapping of Mg_2Zn_{11} phase in Zn-Al-Mg coating using electron probe microanalysis attached with wavelength dispersive spectroscopy.

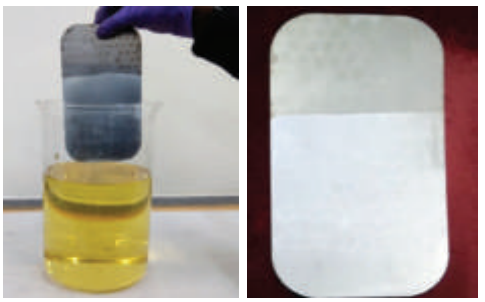


Figure 5: Images of secondary protective thin film of lacquer on Zn-Al-Mg coating by dipping technique.

Impact on society/industry

Hot dip coating process for Zn-Al-Mg coating on the substrate of IFHS and CQDQ grade of steels can be conventionally carried at industrial line of continuous hot dip coating line (CGL) using the optimized process parameters. The improved performance and quality of Zn-Al-Mg coating can increase the commercial value and reliability of coating in construction, structural and automotive applications.

Development of Fe flash coat for application in advanced high strength steel

The objective of the project is to develop Fe flash coat on advanced high strength steel with compact and uniform morphology, the study aims to optimize bath formulation and process parameters for Fe flash coat and thickness of Fe flash coat for subsequent efficient annealing and galvanizing processes. The Advanced high strength steels are being used for automotive applications. These steels are mostly alloyed with Mn, Cr, Al, Si, etc. They have a tendency to form oxides on the steel surface during annealing. This results in uncoated spots during subsequent galvanizing. To suppress surface selective oxidation of alloying elements and improve wetability, one of the methods is the use of a diffusion barrier flash coating on bare steel. Earlier study of Cu, Ni flash coat has been proven effective in defect free and corrosion resistant galvannealed coating but they are expensive. Cost effective development of Fe flash coat can control segregation and surface oxidation of alloying element. Therefore, there is need to optimize and design the Fe flash coating process to get compact and adherent Fe flash coat on advanced high strength steels. It will not only suppress the surface selective oxidation on steel but also improve the reaction kinetics of Fe-Zn phase formation during galvanizing and galvannealing process. In this project, a compact and uniform Fe flash coat on advanced high strength steel of grade DP590 at laboratory scale was developed through electrodeposition technique (Figure 6). Fe flash coat with good surface coverage and excellent adherence to steel surface was developed (Figure 7) through bath formulation for high throwing power with less time (1-3 sec) and optimization of process parameters such as current density, pH (5-6) and temperature (room temperature), etc. An optimized morphology and thickness (5 g/m^2-8 g/m^2) of Fe flash coating played an effective role in preventing surface segregation of alloying element in advanced high strength steel and in suppressing their surface selective oxidation during subsequent annealing process prior to hot dipping. It resulted in preventing the formation of any bare/uncoated spots in galvanized coating and galvannealed coating obtained using Hot Dip Process Simulator.

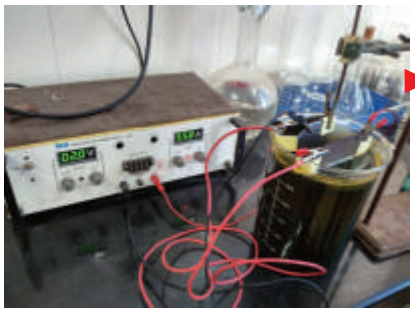


Figure 6: Experimental set up for electrodeposition process of Fe flash coating at laboratory scale at CSIR-NML.

Figure 7: Images of a) specimen of DP 590 steel b) Fe flash coating on DP 590 specimen using electrodeposition process with high current density c) uniform galvanized coating on Fe prior coated DP 590 specimen without any bare/uncoated spots d) good surface appearance of galvannealed coating on Fe prior coated DP 590 specimen without any bare/uncoated spots e) bare/uncoated spots on galvannealed coating on DP590 steel without any prior Fe flash coating.

Impact on society/industry

Application of Fe flash coating on continuous moving sheet using electrodeposition method after cleaning of cold roll steel sheet and before annealing process is industrially convenient, economically feasible and compatible for cold rolled sheets in hot dip coating production line. It provides good wettability of Zn or Zn alloy, thereby preventing the formation of oxides during annealing. This results in increased commercial value due to excellent surface quality of hot dip galvanized and galvannealed coatings without bare spots/uncoated spots. The improved performance and quality of Fe prior coated galvanized and galvannealed coating can increase the commercial value and reliability of coating in automotive applications.

METALS EXTRACTION AND RECYCLING (MER)

The division primarily deals with different facades of ferrous and non ferrous metals, value addition to as well as extraction from various industrial wastes, and chemical characterization of raw materials and products. The division consists of four major groups, namely, Ferrous Processing, Non-ferrous Processing, Secondaries and Resources Utilization and Analytical Chemistry. The Ferrous Processing group is largely involved in process innovation in agglomeration of iron ore fines and ferruginous wastes of steel plant, technology development on alternate routes for production of DRI from iron ore fines as well as other iron bearing wastes and preparation as well as quality improvement of different ferro alloys. The Non-ferrous Process group is actively pursuing research activities in harnessing secondary and lean grade resources for extraction of non ferrous metal values in either elemental form or as useful compounds, extraction of strategic metals for specialty applications, extraction of rare earth metals from primary and secondary resources. The Secondaries and Resources Utilization group is principally focusing on value addition to all types of industrial wastes by economically converting them to products for a variety of applications and also catering to the needs of cement industries. The Analytical Chemistry group is concentrating on three principle activities, including, chemical characterization of raw materials and products for both internal and external clients, chemical and structural characterization of coal from various major coal fields in India and production of Certified Reference Materials.

Through a series of brain storming sessions and keeping in mind the expertise domain, the division has identified a few areas for future research which include value addition to LD slag, improvement in utility of non coking/low grade coal, an umbrella program for treatment of E-wastes, and, development of new geopolymer material for specialty application. A brief description on few important research initiatives in the last financial year and their respective outcome has been presented below.

Team MER

Analytical Chemistry

Development of a beneficiation process of high ash low grade Indian coals based on micronization and oil agglomeration

Coal particle size and mineral matter have significant effects on coal combustion. Micronization of coal produces particles ≤ 20 microns which thereby increases the surface area-to-volume ratio enormously. Micronization of coal is proven to be advantageous for improvement of combustion; however, very little information is available for Indian coals in this matter. The study on micronization of Indian coals primarily consisted of two elements; 1) Comminution; and 2) Demineralization. Owing to structural heterogeneity and complexity, the proposed process was expected to vary with each coal. The project proposal included micronization and demineralization of six coals of different ash contents (14% - 35%). A complete characterization was performed prior to communition. After fine grinding, demineralization was attempted, using oil agglomeration. The proposed process of micronization and oil agglomeration proved successful in demineralizing most of the selected coals. Such a process for ash minimization, would be extremely beneficial in Indian industrial perspective, aiming at improvement of combustion properties. Out of the six coals chosen to be investigated, the ones from Bilaspur and IB valley areas failed to agglomerate, as shown in Table 1. The observation is in agreement with literature precedence wherein coals with higher moisture content did show poor agglomeration results. Interestingly, heat altered coal showed excellent results. These are specifically interesting due to their structural and chemical alterations owing to magmatic intrusion. Hence, the proposed process is a promising approach for coal beneficiation. The proposed process has been investigated six different coals varying in both ash and sulfur content. Three of the coals showed promising results, in particular the heat affected coal showed excellent mineral separation through the proposed process. We are currently optimizing the proposed process, for coals of different grades and mineral composition, in order to ascertain its robustness.

Table 1. Final result of the six selected coals for micronization and oil agglomeration

Coal	Ash (%)	Moisture	Volatile Matter	Agglomeration
Salanpur C	32.83	1.62	3.41	Excellent
Nimcha	14	0.69	36.89	Excellent
Tirap	3	4.59	40.48	Good
Bilaspur	35.5	5.79	21.71	No. Agglom.
IB Valley	23.01	5.31	27.78	No. Agglom.
Heat altered	28.60	1.47	7.21	Excellent

A further detailed study was carried out for the heat altered coal and the results are shown in Figure. 1, which essentially indicates insignificant effect of variation of pulp density on oil agglomeration.

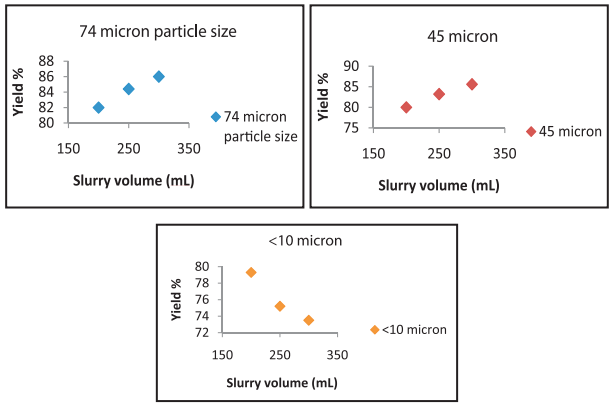


Figure 1: Insignificant effect of variation of pulp density on oil agglomeration

Impact on society/industry

An efficient beneficiation process, such as the proposed one, including ultra fine grinding and oil agglomeration is expected to have significant impact on efficient coal utilization in thermal power plants.

Distribution of Rare Earth elements in coal deposits of India : A potential resource

Today, there is considerable interest in the occurrence, mechanism, and, distribution patterns of Rare earth elements (REEs) in coal seam or coal ash due to the association of REEs with coal, which in turn can lead to large amount of REEs by treating the ash of these coals.

However, research on association of REEs in the Indian coal or coal by-products are not reported extensively. With the aim of finding a suitable extraction procedure of REEs from coal Ash, comparison of the seam wise distribution pattern of REEs of coal seams of different areas in India has been done to understand the association of REEs with coal. Coal samples from two different coalfields of Salanpur block of Asansol Coalfield and Sambaleshwari block of IB valley coalfield were collected and compared. Coal ash samples obtained from coal seams were treated by a laboratory developed procedure and the final solutions were analysed by ICP-MS for the estimation of REEs. Finally, the chemical fractionation, consisting of three successive extractions has been done to understand the leaching behaviour of REEs from coal ash. The chemical fractionation study shows that in Salanpur block of Asansol coalfield, the major portion of REEs are extracted by the ammonium acetate leaching as most of the REEs are associated with clays. Most of lighter rare earth elements (LREEs), in addition to a fair amount of heavy rare earth elements (HREEs) are obtained through ammonium acetate leaching (Figure 2) which is more favourable compared to water, HNO_3 and HCl leaching. Nd shows as high as 93% extraction followed by Ce (89%), Pr (72%) and Sm (78%). In case of Salanpur block, Asansol coalfield, the maximum concentration of LREE and HREE in coal ash has been found to be higher compared to coal seam samples of IB Valley coalfield. The present study reports that coal seams of Salanpur block, Asansol coalfield is one of the potential resources of REEs. Extensive studies of different coal seams of Indian coalfields are necessary to obtain other potential resources of REES.

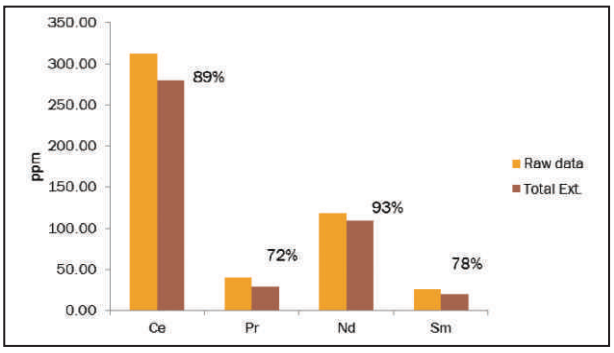


Figure 2: Extraction of LREEs in ammonium acetate compared to raw data.

Ferrous Processing

Development of a cost effective green technology for pre-reduction of chromite ore in tunnel kiln & production of high carbon ferro chrome in submerged arc furnace(SAF)

The main objectives of the project are : a. use of Chromite ore fines for making pellets; b. lowering the power consumption in production of ferro chrome with consequent reduction of the cost of production; c. reduction of carbon emission in the production of ferro chrome.

The process will use a Tunnel Kiln Furnace for pre-reduction of a mixture of chrome ore, solid reductant, fluxes and binder at around 1350°C-1400°C to form a Direct Reduced Ferro Chrome (DRFC). This DRFC can be further processed in an SAF furnace to produce high carbon ferro chrome. The tunnel Kiln consumes low energy as it is a closed furnace with much better heat transfer efficiency and utilization. In conventional SAF process, specific power energy for the production of high carbon Ferro Chrome is approximately 4500 kWH/Ton to 5000 kWH/Ton. In the proposed scheme of pre reduction of chromite ore in tunnel kiln furnace coupled with smelting reduction in SAF furnace, the overall energy requirement would be reduced to about 3500-4000kWH/Ton, thereby saving around 1000 kWH/Ton of electrical power equivalent. This translates to a saving in the production cost of high carbon Ferro Chrome of up to ₹ 7000/Ton.

Laboratory scale studies shows 25 to 35 % chromium metallization in reduced pellets (Figure 1) at 1500°C. Chromium metal recovery of reduced pellet has been achieved up to 90-92 % on melting in induction furnace. The fabrication of mixer and pelletizer has been completed. Next, the reduction of Chromite ore pellets in high temperature tunnel kiln, characterization of product and smelting reduction of reduced Chromite ore in 500kVA SAF have been planned.

Figure 1: Reduced Chromite ore pellets in tunnel kiln

Impact on society/industry

- Lowering the specific power consumption
- Reduction in carbon emission

Development of briquetting technique for utilization of steel plant solid waste

Several iron oxide fines such as Basic Oxygen Furnace (BOF) sludge, Blast Furnace (BF) sludge, Electro Static Precipitator (ESP) dust, sinter returns, BF flue dust, etc., are generated in different units of a steel plant. All these fines have a remarkable quantity of iron oxide. A significant portion of these is not used in steel plants till date because of their excessive fineness and inappropriate chemistry. It has been thought to use these fines in BOF converter as coolant if these fines are agglomerated properly. However, a suitable agglomeration technique is required. The present study aims at utilizing steel making sludge and other wastes, like, blast furnace sludge, ESP dust and sinter return, to produce briquettes. First, the process parameters for good quality briquettes have been optimized at a laboratory scale. The mix ratio, suitable binder and its quantity, etc., were optimized and cylindrical briquettes were produced in the laboratory, which can provide 280 kg/cm^2 cold crushing strength. Pilot scale study in 50 - 100 kg scale has also been conducted to make pillow shaped briquettes, 40 mm long, which showed cold crushing strength of 150 kg/briquettes (Figure 2). The largescale production of briquettes and subsequent plant trial to assess their performance has been planned which will be carried out at Bhilai steel plant.

Figure 2: Pilot Scale Briquettes

Production of DRI from steel plant wastes such as LD sludge, BF sludge and Mill Scale

A substantial quantity of BF sludge (28 -30 kg/ ton), LD sludge (15-16 kg/ton) and mill scale (2% of produced steel) are generated in an integrated steel plant during production and processing of steel. Only a minor portion of these fines are recycled in-house in steel plant. While, LD sludge and mill scale are secondary ferruginous materials containing more than 70% iron, BF sludge is a ferruginous (30-35% Fe) as well as carbonaceous (30-35%) material. Utilization of these materials in iron making are required. The conventional coal based Directly Reduced Iron (DRI) process used for production of DRI requires quality coal and high grade ferruginous materials in the form of lump or pellets. However, very little effort has so far been made to utilize BF sludge, LD sludge and mill scale. Keeping in view the above; an attempt has been made to develop a process for production of DRI briquettes utilizing BF sludge, LD sludge and mill scale. Since, India has very good source of non-coking coal, lean grade non-coking coal has been used in this study for production of DRI briquettes. BF sludge, LD sludge and mill scale were obtained from a steel plant and were characterized for their chemical composition. Briquetting parameters were optimized and briquettes were made under varying conditions with different percentage of mill scale, BF sludge and LD sludge. Reduction studies of briquettes were carried out with lean grade non-coking coal at different temperatures (1000 to 1250°C) and times (1 to 5 hrs) at a laboratory scale. Reduced briquettes were subjected to characterization such as crushing strength, XRD, optical microscopy, scanning electron microscopy and chemical analysis. DRI briquettes thus produced under optimized conditions have more than 87% metallization and are suitable for steel making in IF, EAF

and in BOF as coolant. Based on the laboratory scale findings, the apex committee for the project has recommended heat transfer studies to optimize the diameter of industrial saggers for commercial production of DRI briquettes in Tunnel Kiln. After optimization of diameter of saggers, pilot plant trial is expected to be carried out in a commercial Tunnel kiln for production of 200 tons DRI briquettes.

Development and fabrication of cannon liners for explosive testing

Cannoncare deployed for testing the explosives used in underground coal mines. It is made up of special steel and has three concentric parts. A pictorial representation of the cannon assembly has been presented in Figure 3 and the facility is available with CSIR-CIMFR, Dhanbad. This cannon assembly and the liners were imported 50 years back from a UK based organization and full technical information or know-how of manufacturing was not available with CSIR-CIMFR. The used cannon liners (inner membrane) are replaced with a new one, whenever it gets damaged after repeated firing of explosives. Generally, one liner can endure approximately 500-1000 number of shots. In view of the fact that the company, which provided the liners, no longer exists, CSIR-CIMFR tried to get it manufactured locally, using whatever technical information that was available. However, these liners failed to meet the requirements and showed limited service life (~ 20 shots). Hence, CSIR-CIMFR approached CSIR-NML for the development of an indigenous material as a substitute of the imported one and to help in fabricating new cannon liners from a third party. The issue of the development and fabrication of cannon inner member may be considered to be of national importance, as it has significant role in metal and mining industries. A small piece of material, cut from previously used imported inner member of cannon, was provided by CIMFR for preliminary assessment of the material.

The major objective of this project was to design alloy chemistry and optimize process (heat treatment) parameters to achieve the benchmarked mechanical properties for cannon liners. The project started with the investigation of the failed components (imported material collected from CSIR-CIMFR) and benchmarking of existing or used grades in-terms of composition, microstructure and mechanical properties.

The heat treatment conditions were initially optimized for 10mm thick samples and scaled up on an inch basis (as per industry thumb rule) and adopted for 40mm thick samples. The mechanical property of the in-house developed cannon liner steel is compared with the imported and locally manufactured cannon steel. It is evident from Figure 2 that the 15% decrease in the strength of in-house developed steel was compensated by 100% improvement in the charpy impact toughness and the uniform elongation. This may be attributed to the selection of lower reheating temperature, heavy reduction and higher austenization temperature, which avoids impurity segregation along the pre-austenite grain boundaries and hence toughened the tempered martensitic structure.

Cannon in service

Retired Cannon

Figure 3. Canon and Canon liner used for explosive testing

At present, M/s. MIDHANI Hyderabad is identified and order has been placed to manufacture the cannon liner steel. The cylindrical rod of alloy steel (1600 length x 220mm diameter) which is to be supplied by M/s. MIDHANI, Hyderabad, will be machined to required cannon inner membrane dimension and shrink fitted at M/s. Hindustan Engineering corporation, Ranchi. Thereafter, the fitted cannon will be placed for explosive testing field trial. Therefore, this project encompasses in-house development to actual field trial of a component.

Socio-economic impact of cannon liner steel

a. Import substitution and indigenization
b. Substantial cost reduction
c. Sustaining and reinforcing an important testing facility (explosive testing) of a CSIR / Indian organization

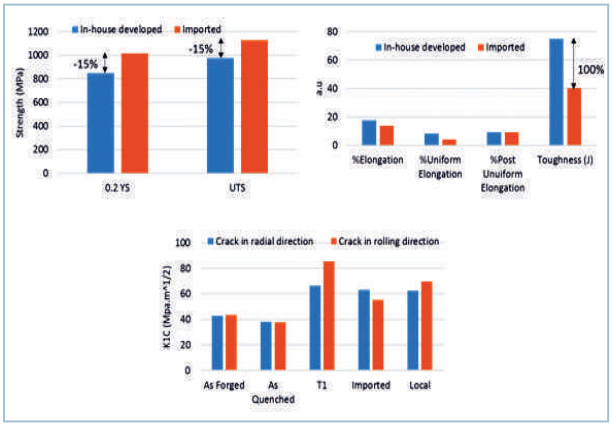


Figure 4: Comparative properties of developed and imported Canon liner

DIP mold simulator based method for qualification of casting powders for crack sensitive grade steels

Peritectic solidification in continuous casting have a great effect on the continuously cast slabs. The principal problems in continuous casting of such steel are (i) longitudinal cracking and (ii) sticker breakouts, and both of these problems are related to the horizontal heat transfer between the steel shell and the water cooled mould. Longitudinal cracking is a specific problem in medium (0.06–0.16%C) carbon steel grades due to the 4% difference in thermal contraction coefficients of the ferrite and austenite phases, which produces severe stresses in the shell that can only be relieved by cracking. Longitudinal cracks will occur in the surface of the solidified shell, if the meniscus region cannot conduct heat uniformly. It is known that the controlled rate of horizontal heat transfer minimizes the thickness of steel shell that is able to bear the contraction stresses, reducing thereby the tendency of formation longitudinal crack. It is usually achieved by obtaining a thick uniform slag shell, which is composition and property tailored to have high solidification temperature. Sticker break outs are caused by (i) lack of lubrication and (ii) creation of a shell (steel) with a low mechanical strength. Better lubrication and easy withdrawal of cast product can be achieved only by providing thin liquid slag shell, which in turn demands lower solidification temperature with minimum slag crystals. Therefore, mould powder to be used for peritectic grade casting, should be harmonized to manage the conflicts of both the function, namely, horizontal heat transfer and lubrication. The various properties of mould powder studied and known to affect its function are composition, viscosity, melting rate, crystallization rate, break temperature, melting temperature, basicity, macroscopic roughness, and, fluidity point.

At present several plant trials are needed to obtain an understanding on the behavior of mould powder, however, these plant trials not only incur significant operational costs but are also associated with a great risk of caster damages (break out, mould wear and stoppages). Moreover, it has been noticed that a chosen mould powder behaves differently even within its known working composition range. Therefore, a method has to be developed to evaluate the performance of mould powder. The dip mould simulator method proposed in this investigation will take into account the key properties of mould powder, steel to be cast and certain casting parameters like stroke, mould oscillation frequency, casting speed and cooling rate, to evaluate the suitability of casting of desired peritectic grade steel in the continuous caster. The work undertaken in this project can be categorized into (i) design and development of dip mould simulator, (ii) installation and commissioning of the dip mould simulator and (iii) assessment of two different mould powders using the simulator. The schematic representation of the dip mould simulator is provided in Figure 5. The dip mould simulator installed at CSIR-NML and the continuously cast molten wax under simulated condition during cold trial are represented in Figure 6, which confirms the replication of continuous cast surface using the simulator. In the upcoming months, it

is planned to perform high temperature experiments in the installed simulator using different mould powder to assess their performance. The feasibility of assessing the performance of mould powder will be further explored in the in-house available 20kg induction melting furnace. However, due to the limited volume of liquid metal and other dimensional constraints, simulation of high speed casting of liquid steels cannot be performed. Therefore, after successful establishment of this testing method in a 20kg Induction melting furnace, the dip mould simulator process for mould powder testing may be scaled up to 200-300 kg induction furnace. This may evolve into national testing facilities for qualification of mould powders for the critical steel grades.

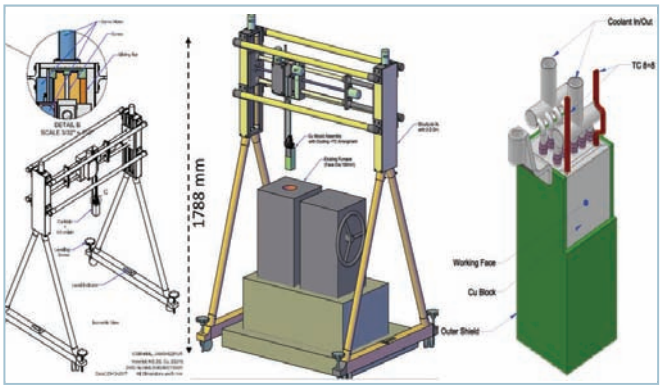
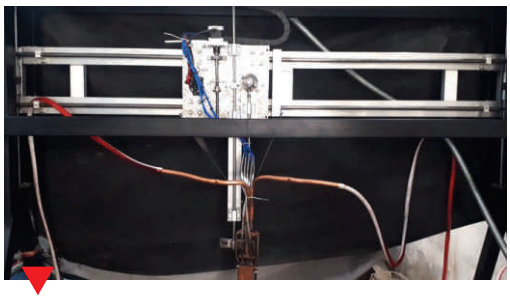


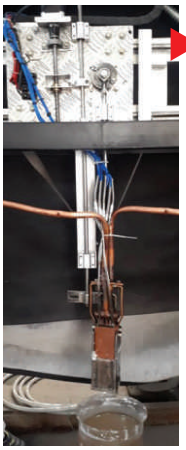
Figure 5: Schematic representation of the dip mould simulator

Socio-economic impact of development of Dip mould simulator

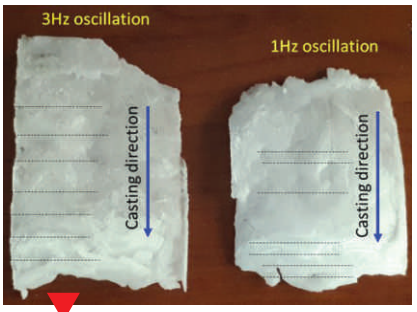
- Aids in selection of perfect mould powder for casting crack sensitive steel grades
- Optimization of continuous casting process especially the mould parameters
- Development of process for futuristic steels for critical applications
- Will be an unique national facility to study the initial solidification behavior of steel during continuous sting process



Dip Mould Simulator Installed at CSIR-NML



Dip Mould Simulator during Cold Trial Operation



Continuously cast wax

Figure 6: Dip mould simulator installed at CSIR-NML and the continuously cast molten wax under simulated condition during cold trial

Feasibility of recovering metal and spinel refractory from ferrochrome slag using vacuum arc furnace

Refractory spinel material can be made by changing the chemistry of ferrochrome slag. Chromiferrous slag waste discharge from ferro-chrome production can be used to produce spinel type ceramic sintered body by treating with the reducing agent, mainly coke, in the arc furnaces. In the present study, high carbon ferrochrome slag has been heated in vacuum arc furnace under reducing conditions above 1700°C while applying moderate vacuum, to recover magnesia-alumina containing spinel material after removing silica (<1%). The recoveries of the material/metal values such as, Mg and SiO from vapour phase, Spinel (Al_2O_3 and MgO) from slag phase and Fe-Cr-Si alloy from metal phase have

been found. Thermodynamic calculation for various process parameters has been done using FactSage. Actual optimization of these process parameters such as pressure, charge mix, charge ratios and the charging rate is being carried out at a pilot scale for producing the spinel material with <1% SiO_2. This study will help in utilizing ferro-chrome slag which is presently being dumped as waste material, in recovering value added materials.

Non-Ferrous Processing

Development of technology for commercial production of sodium metal

The project aims to provide complete technical assistance and consultancy for fabrication and operation of 3000A closed sodium cell at the site of the sponsor. The activity relates to the commercialization of CSIR-NML's technology. The indigenous close cell technology for production of sodium metal was developed by CSIR-NML up to a 500A capacity. Based on the CSIR-NML's technology, a pilot scale sodium metal production plant (3000A) was setup at the party's site. After successful operation of 3000A cell, the commercial scale (12000A) cell will also be setup to meet the captive demand of sodium metal of the sponsor, which is estimated to be 600 MTA. In this regard the party approached CSIR-NML to provide complete technical detail to initiate the sodium metal production facility at their site. Hence, a consultancy project was undertaken by CSIR-NML, Jamshedpur to set up commercial production of sodium metal facility at the party's site in a phase wise manner. CSIR-NML provided complete technical detail, plant layout, design of the cell, specification of the raw material and equipments, assistance during fabrication of the close cell, etc., at the site of the sponsor to operate a 3000A sodium cell (Figure 1). The sodium cell was fabricated indigenously, recently commissioned and operated successfully and produced substantial amount of high purity sodium metal (Figure 2). CSIR-NML provided the critical technical detail regarding the process of cell operation, material handling, initiation of the melter and cell, procedure for liquid transfer from melter to cell, addition sequence of raw material into the cell to maintain the bath composition and temperature, and also guided the technicians and operators during operation of the cell, and provided the safety measures. Based on the success of the 3000A cell operation, the party wishes to set-up commercial production (12000A each) of sodium metal plant at their site in the near future. The commercial production of sodium metal facility by the party will be the first sodium metal production plant in India.

Figure 1: Operational view of 3000A sodium cell

Figure 2: Collected sodium metal

Impact on society/industry

At present, there is no commercial sodium metal production facility available in India and its demand is met by import only. The development of an indigenous technology will make us self-reliant. The sodium metal required by the sponsor of the project is about 600 MTA, which is used as a primary raw material for production of pharmaceutical grade sodium hydride. The production of sodium metal by the party will fulfill their captive demand.

Development and transfer of a technology for the production of electrolytic zinc powder from zinc dross

The project has been undertaken at the request of the sponsor. CSIR-NML had demonstrated the process to

the client on a 1 Kg/day scale. After successful demonstration they financed for upscaling of the project on a 10 Kg/day scale. The installation and commissioning of equipment is being carried out. Thereafter, the sponsor will set up a plant to produce 1 ton/day zinc powder at their site with the help of CSIR-NML scientists. The process of zinc powder production from zinc dross is a simple electrolytic process where zinc dross is taken in a porous metallic container which acts as anode. Zinc is deposited on a stainless steel cathode. It is taken out, thoroughly washed and dried. The purity of zinc powder is 99.5% and it is suitable for industrial applications (Figure 3).

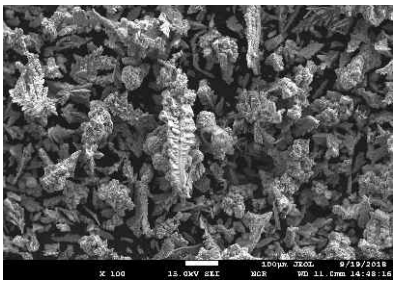


Figure 3: Zinc Powder

Smelting studies on ferrochrome slag

The project aims at the modification of ferrochrome slag produced by the sponsor. A pyrometallurgical approach based on smelting in electric arc furnace was attempted, and process optimization was carried out by varying raw material composition and smelting parameters like, time, power input, etc. Altogether, 30 smelting trails on a 2 kg scale in a 50 kVA electric arc furnace were carried out. The primary purpose of the smelting was to convert the Cr_2O_3-FeO-MgO-SiO_2-Al_2O_3 slag system into the MgO-SiO_2-Al_2O_3. Smelting tests were performed in a graphite crucible using carbon as well as aluminum as the reductant. The mass of metal and slag generated in each of the smelting tests were analyzed. Studies indicated that the ferrochrome slag could be converted into an alumina-rich slag which may find application as a refractory material. Our studies further indicated the need of a dust capture system for the collection of huge amount of dust generated in the smelting of alumina containing charge mix. Further work on the smelting of ferrochrome slag under vacuum is going on.

Figure 4. Smelting of ferrochrome slag in Arc furnace

To develop an effective extraction and separation technology to selectively extract rare earth elements from WEEE (Waste Electrical and Electronic Equipments)

The Objectives of the project are :

- Development of process parameters for selective recovery of rare earths metals from fluorescent lamps/ Neodymium Iron Boron magnet.
- Optimization of process parameters for the separation of rare earth ions (Nd, Pr, Dy) or (Eu, Tb) by solvent extraction using commercially available extractants at a lab scale.

Spent NdFeB magnets were crushed and ground, and characterized by chemical analysis, X-Ray diffraction (XRD) and scanning electron microscopy (SEM) to understand the chemical composition, mineralogy and morphology of the magnet powder. Chemical analysis by ICP-OES indicated that the sample contained around 30% of rare earths (Nd, Pr and Dy) and 67% iron. X-ray diffraction pattern of the spent magnet indicated the presence of Nd2Fe14B phase. Scanning electron micrograph of the sample appears like solid rock with no porosity. In order to selectively leach rare earth elements, the magnet samples were demagnetized, crushed, ground and further roasted in the presence of air to convert rare earth elements and iron into their respective oxides. The roasting parameters were optimized for complete conversion of metal oxide. Selective leaching of rare earth elements was carried out using mineral acid. At optimum leaching condition,

rare earths were selectively and quantitatively recovered from roasted NdFeB magnet powder. The leach residue obtained from leaching experiments will be characterized by chemical analysis, XRD and SEM. Solvent extraction and separation of rare earth elements (Nd, Pr and Dy) from the leach solution will be carried out using commercially available reagent. The developed process under this project has the potential to be utilized for commercial treatments of spent NdFeB magnet waste.

Recovery of vanadium from spent sulfuric acid catalysts

The objective of this project was to study the effects of leaching parameters on the extraction of vanadium from spent contact process catalysts of a sulfuric acid plant. The spent catalyst samples were subjected to acid followed by solid-liquid or liquid-liquid separation in an attempt to separate vanadium and its purification as ammonium metavanadate at bench scale and 1kg scale. With sulfuric acid using 20-30% solids, 96-98% V could be extracted. The leach liquor was subjected to selective sequential precipitation to extract vanadium as ammonium metavanadate (AMV). 98.6% pure AMV obtained, after calcination, resulted in 99% V_2O_5. The process was developed at 1kg at NML and demonstrated at 25 kg feed spent catalyst scale to the sponsor (Fig. 5).

Impact on society industry

150t annual generation of spent catalyst can yield ~8 ton vanadium, avoiding the monetary losses in landfills and decreasing environmental hazards.

Ammonium Metavanadate 98.6% V_2O_5

Snapshot Pilot Scale Demonstration at HZL, Udaipur

Figure 5: Vanadium recovery from spent catalyst

Secondaries & Resource Utilization

Development and transfer of process/know-how on red mud containing geopolymer paving blocks

The objective of the proposed work includes (a) evaluation of the sponsors red mud for geopolymer pavers, (b) production of 10 tons of paving blocks at pilot plant using optimized condition, and (c) technology transfer to the sponsor. The sponsor has alumina plants, has been accumulating large amounts of red mud, detrimental to the ecology and environment. Presence of Si and Al oxides and of Na_2O in the red mud (which is otherwise harmful) are useful in the geopolymer synthesis; besides, stabilization of harmful elements (if any) would happen during geoplymerization. Keeping these in view, the sponsor approached CSIR-NML, Jamshedpur for exploring the suitability of red mud in the process of making paving blocks. This projects aims at developing a process of geopolymer paving blocks using red mud in conjunction with fly ash produced at sponsor's end. The chemical analysis of red mud has been typical; alumina and silica have been significantly less than that required for geopolymerization while the Na_2O content has been between 6-7%. This limits the red mud usage in large amounts. The project has targeted to get a paving block (geopolymer) of M20 grade. Optimization of the process has been carried using standard concrete samples of size 70 mm cubes. In these optimization studies, instead of cement, a geopolymer paste consisting of red mud, fly ash, binder solution (a mixture of sodium silicate and sodium hydroxide solutions) is used, either alone or with small amount of ordinary portland cement (OPC). Different combinations of fly ash- red mud (varying from FA: RM= 100:0 to 50:50) have been tested; the OPC amount also has been varied. It has been found that the optimum ratio of red mud: fly ash is 20:80. Paver blocks of standard size were prepared using the optimized composition. Ratio of coarse aggregate: fine aggregate: geopolymer constituent was in the ratio 5:30:20 (red mud: fly ash=20:80). OPC used is 5% of the red mud + fly ash. 10 tons of red mud containing pavers have been prepared by vibro-casting. These pavers after curing for 28 days have been laid in the sponsor's premises. It has been found that laid pavers, after exposure to the atmosphere for a few weeks, are having white powdery material adhering to the exposed surfaces. This, efflorescence, is a consequence of formation on sodium carbonate on contact with the atmospheric carbon dioxide. Attempts are being made to minimize the efflorescence by different approaches.

Consultancy service on classification of fly ash for thermal power plant

The objective of the proposed work was to prepare a feasibility report for setting up of fly ash processing unit for a thermal power plant; this is to make the fly ash generated there acceptable to the cement industries. Utilization of fly ash, generated in thermal power plants, as a pozzolonic ingredient in blended cement enhances the sustainability of cement industries in terms of resource conservation (raw materials), and a reduced CO_2 footprint. Often, the particle size range of fly ash generated is wide- upto ~100 µm or above whereas the preference of cement industries, considering the reactivity/strength development, is for fly ash with particle size below 45 µm. This study is an attempt to assess the feasibility of separation of fly ash particles of the desired size range (-45 µm) from fly ash generated in order to enhance its acceptability/demand in cement industries. Two approaches viz. recovering only the fine fraction (-45 µm) present in the raw fly ash through classification, and targeting complete utilization of fly ash are considered; in the latter, the oversize fraction rejected during classification (former process) is ground in a ball mill to reduce its size to the desired levels.

Classification of fly ash is proposed in a battery of five classifiers as large volume of fly ash is to be processed. The set-up (from ESP) up to the intermediate silo remains unchanged; tapping of fly ash for processing is

through a diverter placed at an appropriate point on the transfer pipeline to the main silo. Processed fly ash is to be stored in three of the four existing silos; the fourth silo can be used to collect raw fly ash in case of any emergency/breakdown in the classifier circuit. To make the classifier oversize (unsuitable in blended cements) as well, secondary processing involving ball milling is included as an optional in the processing scheme. Flowsheets incorporating both options-primary and secondary processing- and plant layout are prepared and considered for cost economics. Details of main equipment and auxiliary items along with their specifications were provided to the sponsor along with load data and civil foundation data of major equipment. Financial aspects and power consumption details were worked out individually for each flowsheet.

Impact on society/industry

If implemented, significant resource conservation (cement industry) will happen along will reduced pollution.

Comminution studies of mixture of different type of cementitious materials.

The objectives of the project were a) fine grinding of different type of slag materials, b) activation of grinded slag material in presence of different fluxes for its use in cements industries. Iron and steel industries produce huge quantities of slag materials which require large amount of land for its disposal. This project aims at utilizing different type of slag material obtained from iron and steel plant such as LD slag, GBFS, etc., for its possible application in cement industries. Ultrafine grinding of these materials is required in association with other flux material such as lime, sodium hydroxide and sodium carbonate for mechanical activation. By re-using industrial slag material, alkali-activated slag (AAS) is one of the most promising precursors in large scale production and shows a huge potential to replace OPC. Replacement of clinker by slag not only offers energy savings and cost reduction compared to OPC, but also other advantages such as low heat of hydration, high sulfate and acid resistance, better workability, and good ultimate strength and durability. This project will study the grinding behaviors of the mixture of above materials with different type of fluxes to activate it for its application in cement industries. This study is performed with the target to produce activated ultrafine material having size below 75 micron using impact pulverization. Different processes will be studied and optimized. Future work will be undertaken for the activation of slag material with new flux mixture.

Impact on society/industry

This process utilizes the waste slag materials generated at iron and steel industries in huge quantities for cement industries. This will reduce or eradicate its disposal to barren lands which leads to environmental pollution.

Development of grinding aid for improving productivity of cement mill & development of performance improver to improve cement quality

The objectives are (a) To develop a customized grinding aid suitable for the cement clinker of sponsor, a reputed cement company, by which the productivity of grinding mill should improve, and (b) To develop a customized performance enhancer suitable for the cement clinker of sponsor by which the water demand (w/c ratio) of cement is reduced and consequently the compressive strength of cement is increased. Clinker grinding is one of the most important unit operations in cement making which has direct bearing on energy consumption, productivity and cement properties. Clinker grinding typically consumes 30-40% of the total energy required for cement making and thus any decrease in grinding energy keeping the output same, or any increase in output keeping the energy consumption same, is desirable. Cement grinding aids are the chemicals that are used to improve the grinding efficiency by decreasing the cement agglomeration during milling. Specific grinding aids have been developed for the Ordinary Portland Cement (OPC) and Portland Pozzolana Cement (PPC) of the sponsor. These grinding aids have been designated as PAC and TGC.

These grinding aids have been tested at lab scale ball mill using the OPC and PPC batch composition of the sponsor. Decrease in particle size has been noted when grinding aids were used. Also, the use of grinding aids has reduced the water requirement for standard consistency of cement and improved the compressive strength. The results have been revalidated at the sponsor's plant and were found to be matching with lab scale data. Further pilot scale trails are being carried out.

Major Technological & Scientific Targets Planned for 2019-2020

1. **Use of briquettes from steel plant wastes as partial replacement of scrap as coolant in BOF**
   - Characterization of raw materials, optimization of briquette making, evaluation of briquette properties
   - Preparation of briquettes in pilot scale under optimized condition and their characterization
   - Performance study in commercial BOF
2. **Commercialization of DRI making in tunnel kiln**
   - Identification of interested entrepreneur
   - Installation and commissioning of production units on turn-key basis
   - Hand holding for fine tuning of process
3. **Innovative material for restoration/ repairing of heritage structure**
   - Development of a new geo polymer material and its standardization
   - Identification of heritage terracotta and sandstone structure with the help of ASI
   - Repair/restoration of identified structure as per ASI protocol
4. **Extraction of rare earth metals from secondary resources**
   - Characterization of raw materials
   - Development of process flow sheet
   - Separation of individual rare earth metals using suitable reagent and technique
   - Characterization of products
   - Process optimization
5. **Commercial production of Sodium metal using fused salt electrolysis**
   - Preparation of package for upscaling of the process
   - Assistance towards selection, installation and commissioning of hardware
   - Technical assistance during commercial production and fine tuning of process parameters
6. **Production of EMD and EMM from Manganese ore**
   - Characterization of ore samples
   - Study on reduction and dissolution samples
   - Purification of manganese leach solution
   - Deposition of EMD and EMM
   - Characterization of products
7. **Extraction of strategic metals from secondary resources**
   - Identification of secondary resources and their characterization
   - Beneficiation of raw materials
   - Flow sheet development and product characterization
   - Optimization of the process parameters
8. **Analysis of 10,000 refereed sample and 10,000 core coal sample**
9. **Release of 3 Certified Reference Materials**

MATERIALS ENGINEERING (MTE)

The division focuses on different aspects of materials evaluation, characterization, and processing, and has the expertise and state of the art tools to do so. It is also involved in new alloys development, post-processing and metallurgical failure analysis of engineering components. The four groups in this division address different facets of these broad mandates.

The Microstructural engineering group has experts in microstructural characterization complemented by the entire array of necessary tools like batteries of electron microscopes, of X-ray diffraction techniques, and other high end characterization facilities. Apart from monolithic materials and alloys, this group also investigates similar and dissimilar joints. The group has some of the best national experts for failure analysis and carries out this activity for industries as well as defense and other strategic establishments. Using their understanding of the correlations of alloy chemistry, microstructure and properties, several customized alloys have been developed by this group. Alternate and optimized heat treatment protocols have been developed for betterment of materials properties.

The Materials Processing group deals with shape change processing including casting, rolling, forging, extrusion, and others. The group has at its disposal several simulators as well as actual forming platforms for the processing types indicated earlier. It also contributes to several social initiatives for metal artisans.

The Materials Mechanics group is primarily involved in evaluation of materials with regards to their ability to withstand fatigue, creep and fracture. It is endowed with the largest creep facility in India and one of the most sophisticated mechanical testing laboratories, anywhere. The group addresses the health of critical industrial and strategic components. It specializes in fatigue, fracture and creep degradations and estimation of remaining life of critical components. It has a major role in qualification of materials to be used for the Advanced Ultra-supercritical Power plants, which are activities under a national mission programme.

The Corrosion Engineering group focuses on corrosive degradations and their mitigation. The emphasis is on metallurgical issues in corrosion. The group is capable of conducting corrosion audit as well as long term corrosion tests on-site. Corrosion root-cause analysis is one of the expertise of this group. The group is also involved in qualification of materials to be used for the Advanced Ultra-supercritical Power plants, especially with regards to high temperature corrosion.

Corrosion Engineering

Corrosion auditing of steel plant using atmospheric corrosion exposure

The project aimed to assess the performance of mild steel by performing accelerated laboratory tests (simulated CO_2 & SO_2 exposures) and actual exposure at 21 different locations with varying environmental conditions of the plant. The project addressed :

- Estimation of corrosion rate of mild steel exposed at 21 different environmental conditions of the plant;
- Correlation of performance of mild steel with its chemistry / microstructure;
- Identifying corrosion products formed on the mild steel exposed at 21 different locations of the plant with the help of analytical techniques like EPMA, XRD and Raman Spectroscopy;
- Correlating corrosion products formed at different locations with the dominant industrial air pollutants;
- Understanding the mechanism of deterioration of mild steel in the Plant.

The selected mild steel was exposed for 15 months at locations selected by the sponsor. Some of the major findings obtained from 15 months exposure of mild steel coupons are:

1. The corrosivity index for all locations was determined. It was found that 55% of the exposure locations have low corrosivity index (C2), while 15% have medium (C3), 5% have High (C4), 20% have very High (C5) and 5% have Extreme (Cx) corrosivity.
2. Corrosion rates of mild steel specimen from different locations qualitatively corresponded with the visual appearance and rust formation on the specimens.
3. Characterization of corrosion products of mild steel exposed at different locations showed existence of lepidocrocite phase (a- FeOOH, which is an unstable and non-protective oxide of iron) and Fe_3O_4, on the samples exposed in high to extreme corrosive locations. The absence of maghemite (γ-Fe_2O_3, an oxide of iron which is most protective and stable) in the XRD patterns was also indicative of the higher corrosion rate.
4. SEM (BSE) of the top surface of the oxide scales clearly depicts that the higher surface roughness, and deep rooted or wide longitudinal cracks, resulted in increased corrosion rate.
5. Spallation of oxide scale has been noticed for a few specimens with consequent weight loss while most other specimens showed weight gain. The spallation occurred due to the non-adherent oxide and induced stresses.

Impact on society/industry

On the basis of the project report the sponsor has to take immediate action to apply paints/coating to the structure based on the corrosivity index measured and provided in the project report, which will help the sponsor not only to prevent atmospheric corrosion and further damage of the structural parts and threat to human life, but also minimize the economic losses due to it.

Development to improve corrosion performance and service life of aluminium alloy bracket

The objectives of the project were :

1. Failure examination of the service exposed bracket
2. Coating development for increased service life
3. Modification of Al-Si alloy for increasing corrosion resistance
4. Identification/development of descaling agent to clean the stainless steel drum

The integrity of bracket made up of cast Al-Si alloy is important for washing machine to attain its target service life. The bracket is fitted to the shaft at the centre and needs concentricity and perpendicularity to ensure desired rotational speed of the washer drum. Such components during operation encounter water and detergent used for clothes, and suffer from severe corrosion. Based on the variations in water quality across the country, bracket starts failing at different times, the least being around 3 months. Failure analyses of brackets which failed after different times were carried out. Corrosion across the thickness of all the brackets was found to progress by intergranular/ corrosion along the interdendritic regions subsequent to pitting, crevice, and uniform corrosion attack (Figure 1). A few brackets, which were in service for more than 12 months, suffered from a large thickness loss due to uniform corrosion. Owing to this, the strength of the component to tolerate fatigue during operation became inadequate and resulted in failure. Brackets which lasted less than 12 months, wherein the thickness loss is relatively less severe, were found to have failed due to poor ductility, due to high silicon and iron contents. Large iron rich phases are evident in the microstructure of such brackets.

To reduce the corrosion, PU and epoxy based coatings developed, were found to perform satisfactorily up to and more than 1200 hours in salt spray environment. Specimen, pretreated in Zirconium acid followed by Cr^{+3}

passivation, performed up to 2880 h in 3.5% NaCl Solution at pH~11; while other coatings failed in such environment. The modification of Al-Si alloys for corrosion resistance was made using Al-5%Ti-1%B and Al-10% Sr master alloy to see the effect of variation of Ti, B and Sr (0.05-0.5% Sr) in Al-Si alloy. The Al-Si Alloy added with 0.1% Ti and 0.01-0.02% B or 0.25% Sr showed corrosion rate <0.05 mm/y, which is similar to the rate experienced by fresh Al-Si bracket received from sponsor.

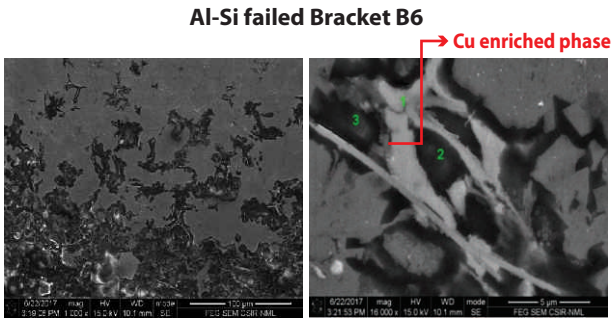


Figure 1: Corrosion propagated from along the grain boundary in a failed bracket

Remaining life assessment of DDH1 heater tubes

The stainless steel tubes installed in a Diesel Hydro De-Sulphurization (DHDS) unit had completed design life in service (>1,00,000 h). The sponsor requested CSIR-NML to work out the remaining life of the DDH1 Heater tubes, using non-destructive and destructive techniques, as per API 579/560/530. The remaining rupture life assessment (RLA) of heater tubes of its DDH1 unit deployed in sponsor's refinery was investigated. Heater tubes were made of SS321H alloy and had served for more than 100000 h (10^5h) of service life at an operating temperature of 480°C and average pressure of 56kg/cm^2. Three service exposed tubes with service life of 1,18,703 h (~14 years) were supplied for investigation. Tubes were subjected to visual examination, and dye penetration was applied to weld regions, to see physical defects. The susceptibility to sensitization and IGC (ASTM262 Practice E), microscopy, hardness, tensile strength, and stress rupture tests were also carried out. The visual examination and dimensional measurements with UT inferred no significant defects. Microstructural observations did not reveal any deleterious phases or gross microstructural changes (Figure 2). DL-EPR tests showed low or insignificant levels of sensitization in the

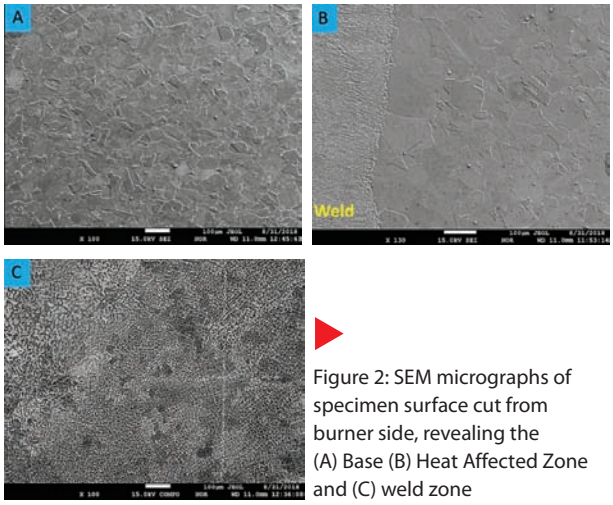


Figure 2: SEM micrographs of specimen surface cut from burner side, revealing the (A) Base (B) Heat Affected Zone and (C) weld zone

as received alloy tubes. The weld samples bent in the normal direction demonstrated susceptibility to intergranular corrosion by the occurrence of fissures. Hardness and tensile strength measurements indicated no loss of strength due to service exposure. The base metal revealed ductile to brittle transition temperature (DBTT) well below sub-zero temperature of -100°C while the weld samples showed DBTT of -10°C. The API 579 FFS-1 level-3 assessment using operating data of the past service and future operating period of 10 years showed no significant cumulative damage accumulation as per minimum Larson-Miller parameter (LMP) values calculated (using API579 and API530 approaches) for temperatures of 462, 500 and 600°C at pressure values of 56 and 69 kg/cm^2 (Figure 3). For an operating temperature of 625°C and pressure of 56 and 69 kg/cm^2, significant cumulative damage accumulation values were obtained. Stress rupture test (Level 4 analysis) of base and cross weld specimens, showed that at the existing operating conditions of 462°C and 56 kg/cm^2, based on API579 FFS-1 - API530

approach using min LMP values, the tube material had a further rupture life of 105 hours. At the pressure of 56kg/cm^2, 639°C was the maximum temperature for 10^5 h life. At 69kg/cm^2 pressure, 617°C was the maximum temperature for 10^5 h life. The stress rupture life of the tube material was good for further service of 10^5 h under existing operating conditions.

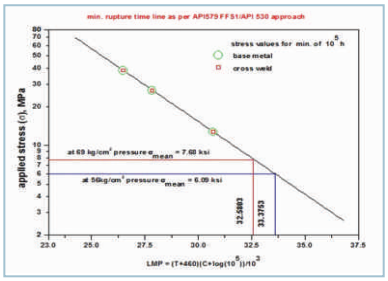


Figure 3: LMP plot for 10^5 h life determined based on API579 FFS-1 (2016) with 10^3 h life experimental data points for service exposed 321H tube material superimposed

Microstructure Engineering

Stacking fault energy of austenite phase in medium manganese steel : X-ray diffraction investigation

Stacking fault energy (SFE) of the austenite phase in a medium manganese steel (Fe-4.75Mn-0.18C-0.8Si-0.4Al wt. %) has been determined by X-ray diffraction (XRD) using the modified Reed-Schramm formalism. SFE determination involved XRD line broadening analysis of mean square strain due to dislocations and calculation of stacking fault probability (SFP, P_{SF}) from the analysis of diffraction peak shift due to both stacking faults and residual macrostress in the deformed austenite phase. Determination of stacking fault probability revealed significant change in the separation between two neighboring peak reflections (111 and 200) due to compressive residual macrostress as compared to corresponding change in peak separation due to stacking faults (Figure 1). Obtained SFE values were found to vary from 17 mJ m^{-2} to 29 mJ m^{-2} for the deformed specimens, annealed at an intercritical temperature for different durations for austenite stabilization prior to deformation (Table-1). SFP determination neglecting residual macrostress led to significant decrease in the SFE value of the austenite phase. Dislocations in deformed austenite phase were predominantly {111}<110> edge type and dislocation density was of the order of 10^{15} m^{-2}. Both X-ray diffraction and transmission electron microscopy observations suggested twinning-induced plasticity as the prevalent mode of deformation of austenite phase having SFE value ~29 mJ m^{-2} whereas transformation induced plasticity was found to be the major deformation mode for the specimen having SFE ~17 mJ m^{-2}.

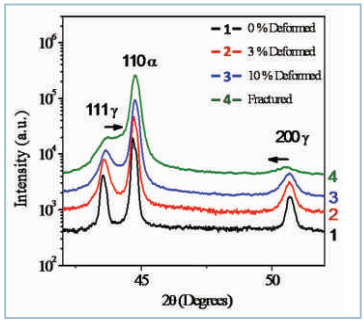


Figure 1: Opposite shift of 111 & 200 diffraction peaks of retained austenite phase in the deformed steel specimens (annealed for 4 hours prior to deformation) with respect to the undeformed steel specimen annealed for 4 hours confirms the presence of stacking faults (SF) in 3% deformed specimens

Table-1: SFE values of the austenite phase along with related microstructural parameters

Annealing time	($P_{sf} * 10^2$)	($\langle\varepsilon^2_{111}\rangle * 10^5$)	SFE (mJ m^{-2}) (With Stress)	SFE (mJ m^{-2}) (Without Stress)	Mn Wt. % in γ
2 Hours	1.62	2.21 (± 0.34)	17.26	12.27	6.5 (± 1)
4 Hours	1.06	1.99 (± 0.48)	29.19	20.69	8.7 (± 0.6)

Structure and magnetic properties of ball milled iron powders

Iron powder particles (mean particle size ~30μm, produced by sponsor through hydrogen reduction of iron oxide (Fe_2O_3) (Figure 2), which was supplied to CSIR-NML, was ball milled at cryogenic temperatures in order

to reduce the average particle size down to 20nm. Subsequently, structural characterization of the cryo-milled iron powder has been carried out by 'X-ray diffraction', 'Positron annihilation spectroscopy (PALS)' and 'Transmission electron microscopy'. Detailed magnetic properties of the nano-sized iron powder have been investigated by a Superconducting Quantum Interference Device (SQUID). Structural characterization confirms broadening of XRD line profiles of the bcc iron powder due to their small crystallite sizes (~20nm–50nm) (Figure 3) and the dislocations generated during the cryo-milling process. Typical dislocation density in the cryo-milled iron powder particles is $10^{15} m^{-2}$. The analysis of the 'Positron lifetime' data for the dislocations obtained through PALS is under progress. The SQUID magnetometer data of the nano-sized iron powder has been obtained, the analysis is yet to be concluded.

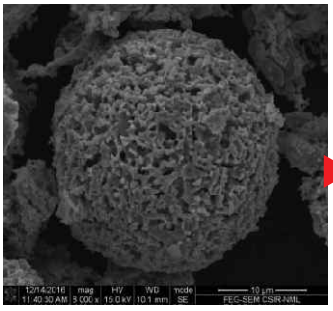


Figure 2: Scanning electron micrograph reveals the porous nature of the as-received iron powder

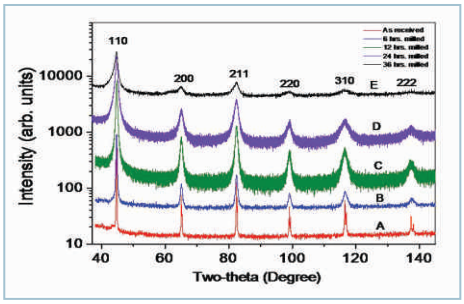


Figure 3: XRD patterns of BCC iron powder cryo-milled for various durations. Broadening of diffraction lines are clear in the XRD patterns for higher milling time.

Effect of continuous annealing line (CAL) parameters on ferrite+ martensite phase formation in DP steel

Effect of industrial continuous annealing conditions on 67% cold rolled steel intended for producing dual phase steel is reported in this study. The schematic of Continuous Annealing Line (CAL) schedule has been shown in Figure 4. The microstructure of two heat treatment schedules and the distribution of ferrite grain structure have been presented in Figure 5. Evolution of dual phase microstructure and bulk texture during two

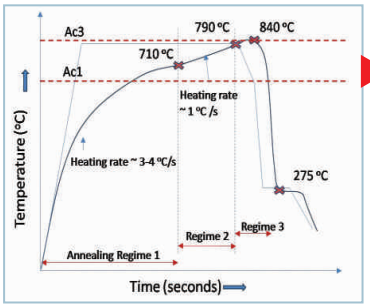
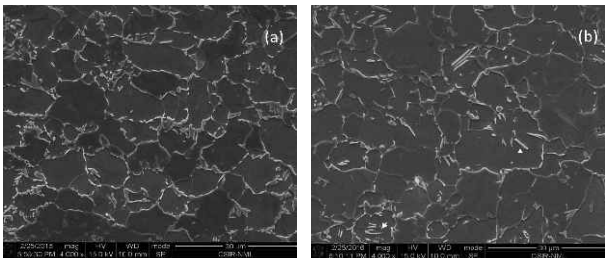


Figure 4: Schematic illustration of CAL with 60s of isothermal annealing at peak temperature 790 °C and *m*-CAL annealing cycle with different heating rates.



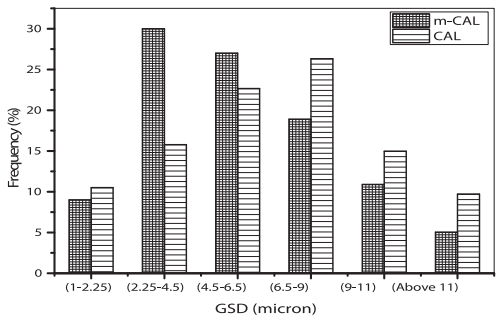


Figure 5: Microstructure of the processed steel showing a) formation of grain boundary martensite in the industrial CAL process, b) showing variation in martensite spatial distribution in *m*-CAL processed state (arrows show in-grain martensite), and c) distribution of ferrite grain size

different industrial continuous annealing process conditions was analysed using scanning electron microscope and x-ray diffractometer. Annealed dual phase steels were tensile deformed under quasi-static and dynamic deformation conditions. Deformed specimens were evaluated for bulk texture changes with respect to tensile deformation strain rates. The study revealed the effect of variation in industrial continuous annealing process on microstructure evolution, especially with respect to spatial second hard phase distribution and bulk texture. Depending on the heating rates and peak annealing temperature, the spatial distribution of martensite was found to change from predominant grain boundary type to "in grain" type. A variation in bulk texture intensity was also observed (Figure 6). The weak annealing texture of α- and α^{*} bcc texture fibres were found to improve dynamic tensile deformation characteristic of steel (Figure 7).

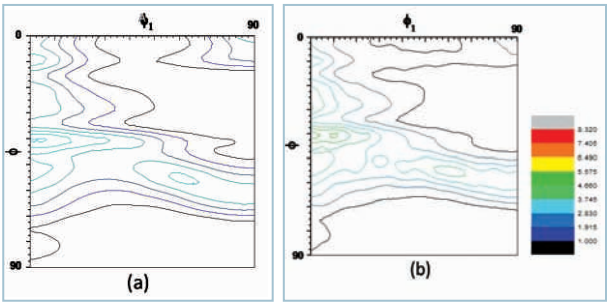


Figure 6: Constant$_2$=45° ODF sections of a) *m*-CAL and b) CAL annealed specimens show weak texture fibre intensities for *m*-CAL

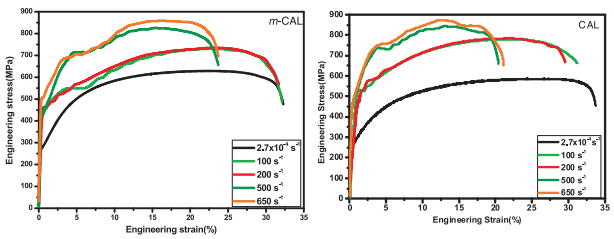


Figure 7: High strain rate engineering stress-strain plots showing a difference in strength and ductility in a) *m*-CAL and b) CAL DP steels.

Metallurgical and fractographic examination of 304LN and its weld under cyclic and monotonic loading in air/water and air environment

The work pertained to quantification of various microstructural aspects for qualification of the piping material of Advanced Heavy Water Reactor being designed at the sponsor's premises. The parameters which have significant role on fatigue damage of material under water environment are dissolved oxygen (DO), strain rate (or loading frequency), temperature, pH, sulfur content, electrolytic conductivity (EC), etc. The quantitative microstructural data-bases for the base material (i.e. SS 304 LN) have been generated. The grain size, inclusion rating, phases of the base materials have already been quantified. Quantification of deformation induced martensite (DIM) of the fatigue crack growth rate (FCGR) tested samples was carried out by XRD & EBSD techniques. Observation and measurement of striation spacing, micro-cracks/secondary cracks, crack paths, width of stretch zone on the fracture surface of base materials were carried under SEM. Micro-hardness profile along the growing cracks was done as well as characterization of the oxide scale near crack tip location was accomplished for base material. Quantitative microstructural data base will be generated for HAZ and weld materials in different environment conditions and different FCG loading frequency, temperature and strain rate.

Microstructural characterization of fusion boundary of ferrite- nickel based alloy in dissimilar metal weld

This investigation focused on:

- The effects of post weld heat treatment and different welding consumables on joint efficiency
- Exploration of different microstructural features like HAZ, Type-II and Type-I boundaries near interface
- The influence of carbon migration on microstructure across bond line

- The characteristics of martensitic layer adjacent to fusion boundary
- The nature of carbide precipitation

Eleven dissimilar materials welded (DMW) joints were investigated. The welding consumables were 309L SS, IN 182, IN 82, IN 52 and IN 152. Two of the joints were stress relief heat treated after buttering. Some of the joints were fabricated by narrow gap welding technique, where buttering was absent. Therefore, the variables were in the matters of welding consumables, heat treatment and welding methodology. The base materials used were low alloy steel (LAS) and 304LN stainless steel (304LN SS). In LAS, heat affected zone consisted of coarse grain ferritic region adjacent to the fusion boundary and fine grain ferrite-cementite structure away from fusion boundary. The width of this region was dependent on the nature of buttering / filler alloy and heat treatment. Close to the fusion boundary, Type-I boundary, Type-II boundary and martensitic layer were found (Figures 8 and 9). Width of the martensitic layer and the location of Type-I boundary were governed by the nature of filler alloy. Complex alloy carbides were formed near the interface due to carbon migration across the interface and the presence of string carbide formers like Cr, Nb and Fe in the filler alloys. Fusion boundary between 304LN SS and weld / filler alloy was practically featureless owing to structural compatibility (Fig. 10). Micro-hardness profile exhibited that sharp peak occurred near the fusion boundary between LAS and buttering material / filler alloy due to presence of martensite and alloy carbides (Figure 11). The weakest zone was with the buttering alloy / filler alloy away from fusion boundary. Crack initiation and propagation was completely within the buttering material / filler alloy (Figure 12). Overall assessment revealed that narrow gap welding provided better joint efficiency than conventional welding. During conventional welding Ni base buttering materials

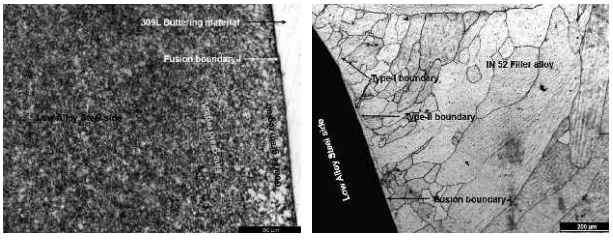


Figure 8: (a) Microstructure of low alloy steel near fusion boundary between LAS and buttering material (weld with 309L SS buttering followed by PWHT); (b) Structural heterogeneity of filler alloy near fusion boundary between LAS and filler material (weld with IN 52 filler alloy, followed by PWHT)

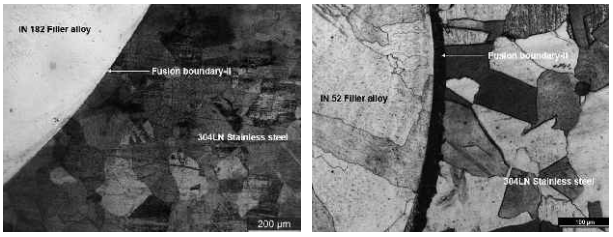


Figure 9: (a) Sharp interface between filler alloy and 304LN SS near fusion boundary – II (weld with IN 52 butering alloy, without PWHT); (b) Distinct interface between filler alloy and 304LN SS near fusion boundary –II (narrow gap weld with IN 52 filler alloy, followed by PWHT)

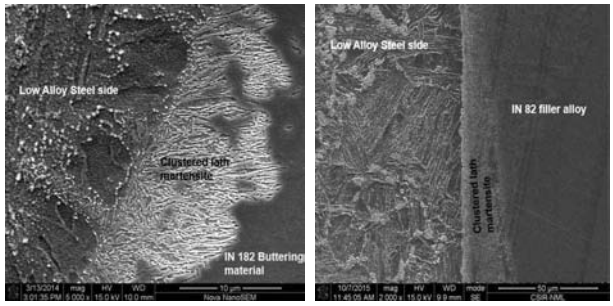


Figure 10: (a) Formation of lath martensite near fusion boundary – I (welded joint buttering with IN 82, followed by PWHT); (b) Presence of lath martensite near fusion boundary – I (narrow gap weld using IN 82 filler alloy, no PWHT)

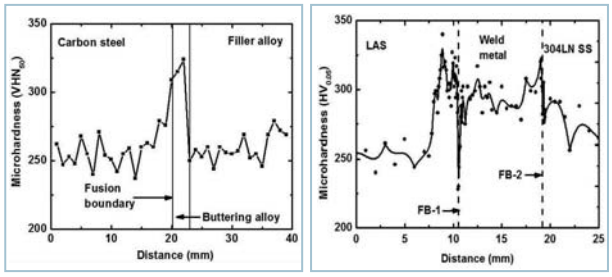


Figure 11: Microhardness profile across (a) fusion boundary – I (welded joint buttering with 309L SS, followed by PWHT); (b) both fusion boundaries (narrow gap weld with IN 82 filler alloy; no PWHT)

provided better joint efficiency than others. Post weld heat treatment provided marginal change in joint strength.

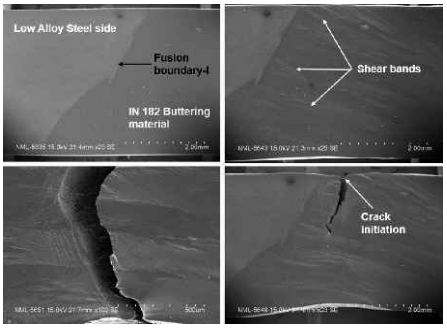


Figure 12: In-situ tensile test of welded assembly buttering with IN 182, followed by PWHT: clock wise images represent mounted samples, shear band formation near yield point, crack initiation after crossing and ultimate failure

Microstructural characterization & fractographic analysis of nuclear grade graphite

Three different grades of nuclear graphite namely A, B and C were investigated. The sources of these graphite grades were different. These materials consisted of a matrix, discontinuities like cracks / pores, and filler particles. Irregular shaped bright islands of filler particles were found distributed in a grey matrix (Figure 13). Most of the filler particles were surrounded by discontinuities (Figure 13a). The discontinuities appeared at the time of processing due to difference in thermal contraction co-efficient between matrix and the filler. Small near equi-axed discontinuities were

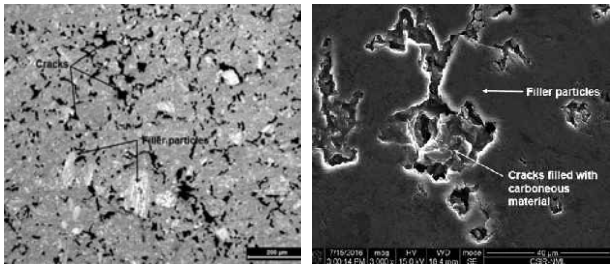


Figure 13: (a) Optical micrograph of nuclear grade graphite exhibiting (a) bright filler particles and dark discontinuities; (b) SEM image of nuclear grade graphite exhibiting cracks and filler particles

perhaps the outcome of gas evolution during fabrication of graphite. Overall distribution of discontinuities appears as irregular shaped bright islands. It has been noticed that most of the discontinuities were incompletely filled with carbonaceous mass (Figure 13b). The discontinuities were pre-dominantly inter-connected and isolated pores / holes were seldom observed. The filler fraction varied widely for Grade-A, from 6.3-17.8% (Figure 14), and for Grade-B, from 7.0-16.6%. Similarly, discontinuities also exhibited substantial change from sample to sample and for the Grade-A was 5.8-11.4%; and for Grade-B was 7.7-11.4%. In Grade-C, better homogeneity was observed, for filler fraction as well as the fraction of discontinuities. For Grade-A, individual

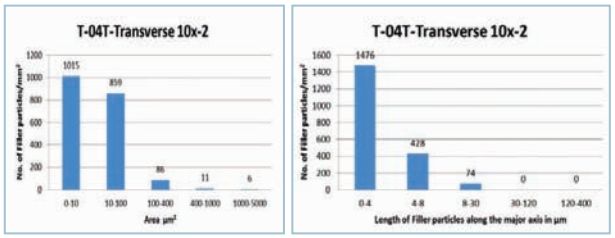


Figure 14: Distribution pattern of filler particles in nuclear grade graphite (A)

areas of filler particles were pre-dominantly $\leq 100\ \mu m^2$. Relatively large size filler particles are scarce. The same trend has been observed for Grade-B too. Grade-C in this respect exhibits much finer filler particles, as their average area is ~10 μm^2. The filler particles with area 10-100 μm^2 are small in quantity for Grade-C.

Individual length of filler particles was mostly ~4 µm. Most of the filler particles have lengths in the range of 4-8 µm; however, filler particles with length 4 µm and 8-30 µm were also substantial. Grade-C displayed similarity with Grade-A in this respect as average length of filler particles was 4 µm. Average aspect ratio of filler particles for Grade-A was ≤ 2.5. The same trend has been observed for Grade-B and C. Thus, individual area and length of filler particles might vary from grade to grade, however, the aspect ratios were similar. Discontinuities in nuclear grade graphite consist of pores and cracks. They have been characterized against

their individual length, aspect ratio and the orientation with respect to pre-defined axis. Mechanical tests involved tensile, compression, three point bend testing and four point bend testing. The fractographs indicated inter-particulate brittle fracture with limited ductility with some localized dimples, and significant cleavage (Figure 15). Pores and micro cracks (discontinuities) that formed during graphitization process have major contribution during fracture.

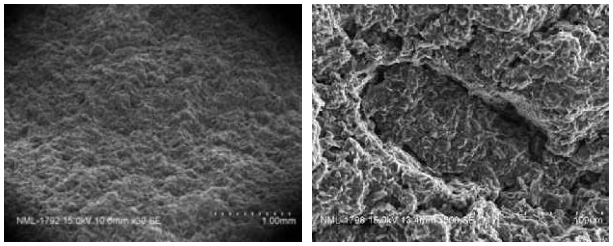


Figure 15: (a) Overall fracture surface and (b) Central part of fracture surface of nuclear grade graphite (Grade C) failed under tensile loading

Development of nano-size precipitates dispersed high strength steel with high hole expansion ratio (HER)

This project explored the reasons for embrittlement during processing of Ti-Mo micro-alloyed steel HS800 with the aim to achieve consistency in mechanical properties along with satisfactory HER.

Five different hot rolled heats were identified, with nominal compositions ranging as 0.04-0.083C, 0.0045-0.006N, 1.54-1.56Mn, 0.087-0.12Ti and 0.22-0.26Mo and mechanical properties in the ranges as follows : YS 665.5-773.5MPa, UTS 744-880.5 MPa, breaking strain 19.5-28% and YS/UTS 0.84-0.91. The thicknesses of slab and coil were 210 and 5-7 mm, respectively. The thermo-mechanical processing parameters were: 1186-1211°C soaking temperature, 179-186 mins soaking period, 902-917°C finish rolling temperature and 637-644°C coiling temperature. The gross microstructure exhibited ferrite matrix of grain size 3.2-5.4 µm (Fig. 16). Scattered cementite islands were present and the cementite fraction was 1.0-1.6%. Micro-alloyed precipitates were cubic (Ti,Mo)C (Fig. 17) with size range of 116-170 nm.

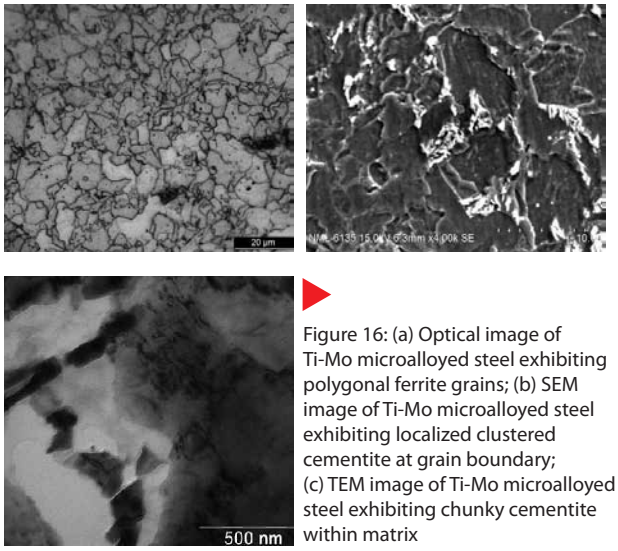


Figure 16: (a) Optical image of Ti-Mo microalloyed steel exhibiting polygonal ferrite grains; (b) SEM image of Ti-Mo microalloyed steel exhibiting localized clustered cementite at grain boundary; (c) TEM image of Ti-Mo microalloyed steel exhibiting chunky cementite within matrix

Considering the consistency in microstructure and mechanical properties in the desired range with YS/UTS of 0.9, a simulation study was carried out in Gleeble to identify the dissolution temperature of microalloyed precipitates. The selected temperatures were 1150, 1200, 1250 and 1350°C. Thermocalc simulations revealed that Ti-bearing precipitate started dissolving at 1000°C and might continue up to ~1450°C. Theoretical dissolution temperature of (Ti,Mo)C cubic precipitate was ~1240°C. To obtain consistent mechanical properties of TS $\geq$ 800MPa with YS/UTS ~0.85, and uniform elongation 15%, the second phase distribution should be coherent / semi-coherent with matrix and having a definite size range. In the present investigation, the slab re-heating temperature of ~1200°C was insufficient to dissolve completely the

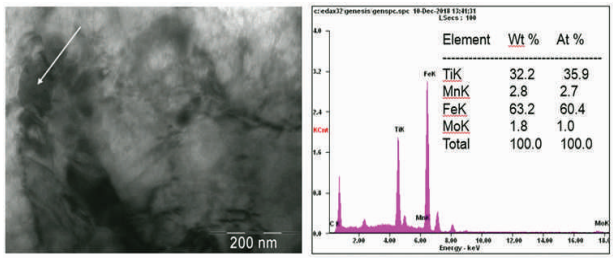
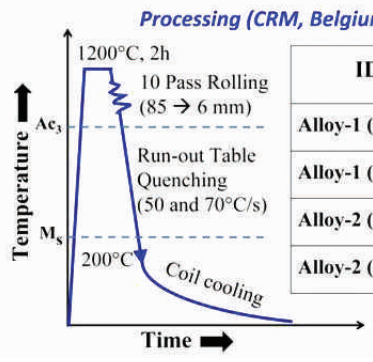


Figure 17: (Ti, Mo)C precipitate within ferrite matrix of the Ti-Mo microalloyed steel

micro-alloyed second phases; hence, they acted as precursor for further precipitation during processing. At the same time, they individually grew larger. This ultimately resulted in heterogeneous distribution of second phases and wide variation in mechanical properties.

Development of quenched and partitioned steel through hot strip mill route

The objective was to develop Quench and Partitioned (Q&P) steel through hot strip mill route with ultimate tensile strength (UTS) of 1200 MPa with 15% elongation and hardness of 450 BHN. Two low alloy steels (Alloy-1 and Alloy-2) containing a reduced amount of Si were designed. The quenching and non-isothermal partitioning process, which utilizes the heat remaining with the hot-rolled coil for carbon partitioning and subsequent austenite retention, was performed from different quench temperatures in the undeformed condition. The austenite retention (max. ~ 8 vol.%) was observed in Alloy-1, whereas Alloy-2 showed tempered martensitic structure. This indicates that alloy composition plays a vital role in microstructural development, i.e., whether carbon precipitate as carbides or partitions to austenite during Q&P process. Alloy-1, containing retained austenite, showed a significant improvement in the impact toughness and ductility of steel, in comparison to fully martensitic microstructure. However, the strength and hardness were compromised. Alloy-2 with tempered martensitic microstructure exhibited high strength and abrasion resistance with a compromise on impact toughness. Based on these results, Alloy-1, which showed austenite retention, was thermo-mechanically processed prior to Q&P to simulate the actual industrial processing. The alloy showed austenite retention and could achieve ~ 1350 MPa UTS, 300 BHN hardness, and 16 % elongation. After the lab scale validation of austenite stabilization and achievement of superior mechanical properties, both the alloys (Alloy-1 and Alloy-2) with a slight modification in composition were processed at a pilot scale (CRM, Belgium with 60 kg capacity) at different cooling rates after finish rolling (Figure 18). The resulting microstructure showed the presence of multi-phases such as ferrite, bainite, martensite, retained austenite, and carbides. One of the alloys (Alloy-1M) having retained austenite showed ~ 1000 MPa UTS, 280 BHN hardness, and 17% elongation. The other alloy (Alloy-2M) containing a mixture of carbides and martensite with an insignificant amount of retained austenite could achieve ~ 1550 MPa UTS and 450 BHN hardness; however, the elongation was reduced to 8.5%. The charpy impact toughness of the alloy containing retained austenite was found be ~ 2 times that of the alloy without retained austenite. The results validate austenite retention during hot-rolled coil cooling, and subsequent improvement in the mechanical properties.



Processing (CRM, Belgium) and achieved mechanical properties of developed alloys

ID	Hardness (HV-1)	UTS (MPa)	YS (MPa)	TE (%)	UE (%)	CIT_{RT} (J)	$CIT_{-40°C}$ (J)
Alloy-1 (50°C/s)	300±12	1003±67	660±56	13.3±2.2	7.9±1.0	49±5	42±4
Alloy-1 (70°C/s)	311±10	1024±23	656±26	17.0±0.8	10.0±0.3	58±6	48±9
Alloy-2 (50°C/s)	487±6	1508±34	1195±48	8.6±0.4	4.6±0.3	20±2	12±2
Alloy-2 (70°C/s)	495±5	1578±28	1277±24	8.5±0.9	4.1±0.7	26±4	18±5

CIT- Charpy impact toughness

Figure 18: Schematics of Processing employed in this study

Development of process technology for third generation Advanced High Strength Steel (AHSS)

An Integrated Steel Company, and CSIR-NML, have undertaken a collaborative assignment for development of third generation advanced high strength steel through quenching and partitioning process having high strength with enhanced ductility and good formability.

The scope of the study under this collaborative work would involve the following work elements:

- Design of alloy chemistries and heat treatment (quenching & partitioning) parameters
- Heat making and hot rolling at laboratory scale
- Dilatometry test and physical simulation of Q&P cycle in thermo-mechanical process simulator (Gleeble)
- Investigation of the microstructure after quenching & partitioning (Q&P) cycle simulations
- Cold rolling at a laboratory scale
- Q&P treatment on cold rolled sheet in prototype annealing simulator
- Evaluation of microstructure and mechanical properties of the cold rolled Q&P samples
- Analyzing results to establish structure – property correlation

In this ongoing project, alloy design using thermodynamics and kinetics study have been done and two alloys, Alloy 1 (low Mn, 1.75 wt.%) and Alloy 2 (high Mn, 3.5 wt.%) have been taken up for study. Figures 19(a) and (b) shows the property diagram of Alloy 1 and Alloy 2, respectively. The alloys were made at a 40kg scale followed by hot rolling to 4.5 mm thickness. Simulation was carried out for obtaining maximum retained austenite with varying quenching temperature, as shown in Figure 20. The hot rolled sheets were cold rolled to 1.3 mm thickness. After initial simulation, quenching and partitioning (Q&P) cycles were carried out on the cold rolled sheet in the

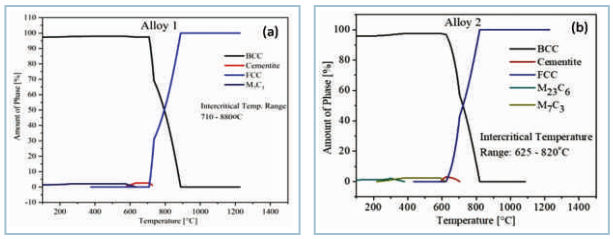


Figure 19(a) and (b): Property diagram of the Alloy 1 and Alloy 2 respectively

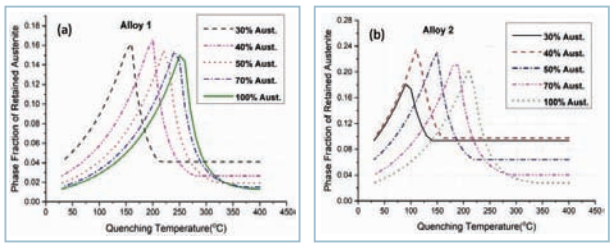


Figure 20 (a) and (b): Model calculation for obtaining maximum retained austenite with varying quenching temperature of the Alloy 1 and Alloy 2 respectively

prototype annealing simulator at NML. A fine lath like martensite-retained austenite microstructure was formed after the Q&P cycle as shown in Figure 21, having retained austenite fraction of around 20%. From the respective tensile stress-strain curves, it was observed that Alloy 1 demonstrated high elongation of 20%, YS of 570 MPa, and UTS of 870 MPa; while Alloy 2 demonstrated high strain hardening (YS/UTS: 0.42), YS of 500 MPa, and UTS of 1200 MPa. Work is being carried out on further improving the strength-ductility combination of the alloy. Quench and partitioned advanced high strength steel will enable end user to use thinner gauges, which would reduce overall weight of the vehicle leading to lower fuel consumption and greenhouse gas emissions.

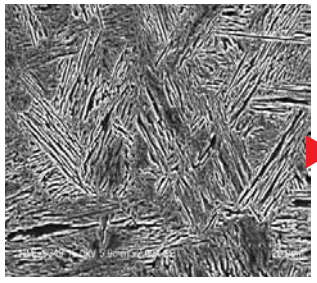


Figure 21: A fine lath like martensite-retained austenite was formed after the Q&P cycle

Improvement in the operational life of Manganese steel blow bars of limestone primary crusher

Manganese steel blow bars are used by the sponsor for crushing applications in limestone primary crushers. The capacity of such crushers is 1200 TPH. The feed to such crushers are the limestone run of mines, which may be up to 1 meter diameter in size, and contain hard quartz particles. The quality of limestone produced in the mines of the sponsor is lean, containing a larger fraction of quartz, which leads to early wear out of the Manganese Steel Blow Bars. A project was undertaken to improve the operational life of Mn steel blow bars either by suitable process change or by suitable alloy modification so that it can sustain the impact and abrasive conditions prevailing in the crusher.

In order to improve the operational life of the Blow Bars, initial damage assessment was carried out where samples from the worn out Blow Bars were subjected to extensive microstructural and mechanical characterization. Figure 22 shows the part of the worn

Figure 22. Worn out Blow Bar

out Blow Bar used for damage assessment. The demarcations 'lower part' and 'upper part' are made for cross sectional analysis of the wear side to reveal the wear mechanism in the material. Figures 23 and 24 show the cross sectional microstructures adjacent to the wear side of lower and upper parts respectively. These figures indicate prominent grain boundary cracking in lower parts due to heavy impact loading, and, prominent micro – cracking along carbides in the upper part due to severe abrasive conditions. Figure 25

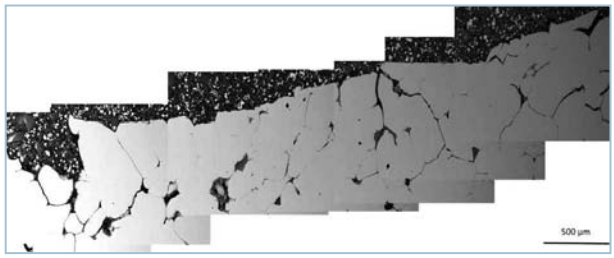


Figure 23. Cross sectional microstructures adjacent to the wear side of lower parts taken in backscattered mode in SEM

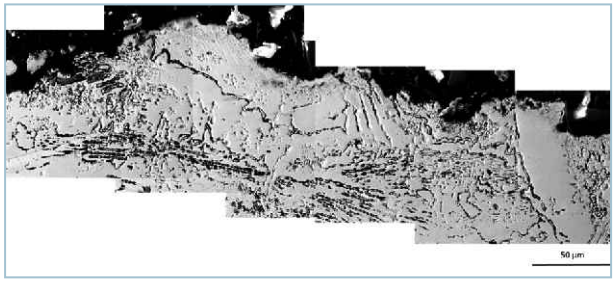


Figure 24. Cross sectional microstructures adjacent to the wear side of upper parts taken in backscattered mode in SEM

summarizes all the predominant mechanisms prevailing in the various parts of the wear side. The wear properties of the Blow Bars were poor due to the presence of long needle shaped carbides found along the grain boundaries. In order to improve the wear properties, the target was set to optimize the heat treatment condition so as to dissolve all the carbides and obtain a completely single phase austenitic microstructure. After a number of lab scale heat treatment studies followed by mechanical property evaluation, an optimized heat treatment schedule in the scaled up form was recommended for plant trial. After plant trials, the results were shared by the sponsor, which showed that the performance of the fully solutionized blow bars were poorer than the original cycle. Thereafter, a new alloy was developed with Si replacing the chromium in the existing grade, for which the scaled up optimized heat treatment was communicated along with the composition. The mechanical properties were found to be superior to those of the existing grade. This developed alloy has the combined effect of Si strengthening the austenitic

matrix, as well as the presence of fine innocuous distribution of carbides necessary for abrasion resistance. Various grades of Manganese steel are used for making wear resistant components, some of which may be replaced by the developed alloy as this alloy is cheaper due to absence of any major alloying element except Si.

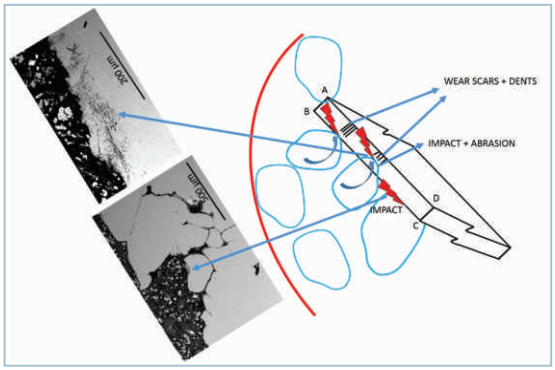


Figure 25. Predominant mechanisms prevailing in the various parts of the wear side

Annealing simulator integrated with online process control sensors for Run Out Table (ROT) process simulation

New generation advanced high strength steel development strongly depends on various metallurgical process controls during ***Run Out Table*** in hot strip mill and in ***Continuous Annealing Line*** processes. Expensive and time consuming industrial trials are made based on inputs from mathematical simulations or post-process evaluations. Therefore, development of industrial process parameter ***simulators*** is desirable for determining critical process parameters to avoid such time consuming expensive industrial trials.

Well known commercial experimental simulators, like, Gleeble by the Dynamic Systems Inc. USA, and Hot Dip Galvanising Process, Germany, etc., are very good for experimental process simulation. However, these equipment have limited simulation process parameter variables. Further, the cost of these simulators is very high (~ 6-13 crores). Most of these process simulations are possible on sub size samples, only. Any deviations from the available annealing simulation parameters are not possible or upgrading it is either expensive or requires support from the OEM.

The proposed research will create an opportunity for the development of indigenous experimental simulator along with the development of high temperature online process monitoring NDT sensors. The unique feature of the proposed simulator will be that the critical process control will be governed by metallurgical parameter changes rather than temperature measurements, which are commonly used. Therefore, it will provide better or more precise process control opportunities. This will be possible due to new electromagnetic sensor development capable of detecting phase changes. The development of electromagnetic/NDT sensors for online process control at high temperature will be one of its kinds. In addition to the sensor design and development, robotics for the online sensor arm, data acquisition and signal attenuation in industrial high temperature operating environments will be attempted in the project. Further, all these simulations experiments will be carried out on much large specimens compared to any used in commercial simulators. The simulator will be the integration of four stand-alone indigenously developed components; a) ROT b) Electro-magnetic NDT sensors c) Robotics for online sensor engagement with the specimen on ROT and d) indigenous software for real-time data acquisition, analysis, and process control. All four components have market potential as customized stand-alone items in addition to the integrated unit.

Materials Mechanics

Testing of pipe line material specimen to ascertain health of crude oil trunk

The objective of the project is to assess the health of service exposed API grade pipes.

The 1157 Km long crude oil pipe line in the North East region of India is in service beyond 50 years whereas pipelines in other parts of the country are in service for

around 38 years. These pipelines are made of API 5LX46 grade and API 5L grade B materials. The sponsor, an oil company, wanted CSIR-NML to check the deterioration in mechanical properties, if any, of 8" O.D., 14" O.D. and 16" O.D. pipe lines. It has been proposed that all the base, weld and HAZ will be evaluated for their chemistry, microstructure, mechanical, fracture and fatigue (S-N curve) behaviour and will be compared against the virgin condition. All the pipe sizes (8" O.D, 14"O.D. and 16"O.D.) will be considered in sequence for the three phases of this study. Phase I activities consists of chemical analysis, optical microscopy, scanning electron microscopy, tensile test, hardness test and sample preparation. Phase II activities include impact test, S-N curve generation and sample preparation. The Phase III activities would consists of NDE based crack size detection, fracture toughness (K_{IC}) testing, and fatigue crack growth rate testing and life base analysis.

Impact on society / industry

This project aims at health assessment of service exposed API grade pipes used for conveying oil. For this purpose mechanical properties and microstructures would be evaluated for both the virgin and service exposed API grade pipes. On the basis of recommendations made by CSIR-NML further decision would be taken by sponsor for the use of API grade pipes.

Investigations of toughness behaviour of simulated heat affected zone of SA508 and P91 steels

Welding is invariably used for fabrication of various components in nuclear power plants. High strength low alloy steel SA 508 Gr. 3 and P91 steel are used in fabrication of pipe lines which come out from the nuclear reactor, to transfer heat to the steam generator. SA508 steel has moderately high tensile strength of about 600 MPa and has excellent toughness even at sub zero temperatures. This steel is used in quench and tempered condition to induce required microstructure and mechanical properties. The heat affected zone created by welding, has different microstructure than the parent material. The heat affected zone width is quite narrow (few millimetres), but even in this zone the microstructure and mechanical properties have gradients due to thermal cycles in multi-pass welding. The welds between similar steels are given post weld heat treatment (PWHT), but these pipe lines are also welded with austenitic stainless steels at some points. Effect of welding, PWHT alters the microstructure and the consequent inhomogeneity in the material may lower the toughness of the joint. In this project, thermal cycles were computed analytically and captured during actual welding (Figure 1). These thermal cycles were imposed on the specimens through a thermo mechanical simulator (Gleeble), to generate similar microstructures in a wider zone. Some of these specimens were also given post weld heat treatment. After developing desired microstructures, mechanical properties were evaluated in various sub zones of the heat affected region. Mechanical properties evaluated were hardness, toughness, sub zero toughness, and fracture toughness, on miniature specimens. Micro structure and mechanical properties in various zones were compared and correlated. Effect of multi-pass welding was also evaluated.

Figure 1: Capturing of thermal cycles by inserting thermocouples during welding for Gleeble simulation
(a) Performing drilling operation (b) Spot welding of thermocouples (c) DAQ set up for thermographs (d) Chipping operation, further sub-sequent deposition.

P91 steel is used in steam generators and steam pipelines. This material experiences high temperature and should have very good creep resistance. To

optimize creep resistance properties, this material is used in normalized and tempered conditions. Various subzones in P91 steel weld HAZ were simulated in the Gleeble. The effect of heating rate on critical transformation temperature was also studied. Microstructure and hardness in various subzones ware evaluated. These samples were also subjected to PWHT, to understand its effect on evolved microstructure. Various investigations were carried out using optical microscopy, X-ray diffraction, scanning electron microscopy and transmission electron microscopy.

Materials Processing

Thermo-mechanical processing and heat treatment of low carbon steel

In this investigation, transformation textures in low carbon steel sheets have been studied in detail. Low carbon steel sheets are thermo-mechanically processed. During thermo- mechanical processing, the parent austenite phase develops a crystallographic texture, which is later inherited by the ferrite after transformation. Thus an orientation relationship exists between the crystallite reference axis of the parent and the product phase. The transformation directly influences the final microscopic properties. The development of hot rolled texture in ferrite basically depends on the deformation temperature and the extent of deformation in the austenite phase. It also depends on whether the austenite recrystallizes, or does not, before phase transformation. The steel plates are deformed to around 85-90% in the austenite region. Fine grain structures are obtained in low carbon steel sheets and the average grain size is around 15.4m (Figure 1a). On the other hand, moderate high strength low carbon steel develops pancake structure (Fig. 1b). In low carbon steel, hot band texture is weak and the main texture components are {001}<110>, {112}<110> and {332}<113> (Figure 1c). Hot band texture of high strength low carbon steel are very strong and the main texture components are {001}<110>, {112}<110>, {223}<110>, {111}<112>, and {332}<113> (Figure 1d).

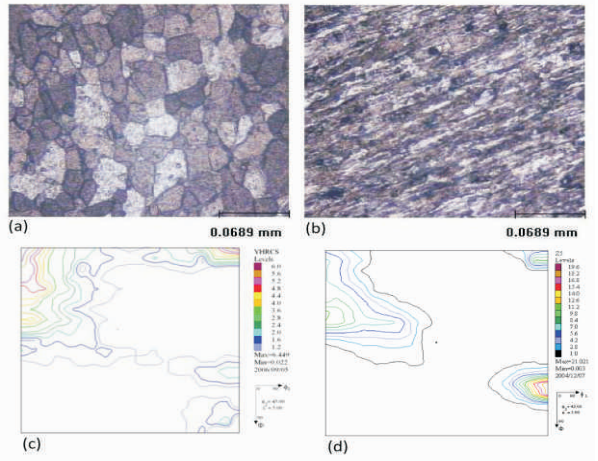


Figure 1: Microstructure and texture in thermo-mechanically processed low carbon steels

Optimization of the continuous annealing cycle for improvement of the mechanical property and microstructure of continuous annealed cold rolled dual phase (DP 590) steel

The study aims to develop DP590 steel with high formability, ductility and stretch flangeability from cold rolled full hard sheet and the optimization of the continuous annealing cycle. DP 590 sheet is used for making various components such as pillar (A&B), bumper beam, member (Floor, Cross, Reinforcement), rail roof, seat assembly, side sill, etc., of automotives. Mechanical property (YS, UTS and El) of DP 590 sheet is within customer specifications. However, there is inconsistency, particularly with respect to stretch flangeability (HER property), due to the development of cracks at different stages of forming. Therefore, there is a need for optimization of microstructure and mechanical properties for eliminating crack forming tendency. Keeping these in view, the sponsor contacted CSIR-NML for the optimization of the continuous annealing cycle for improvement of the mechanical property and microstructure of continuous annealed cold rolled dual phase (DP 590) steel.

In this work, cold rolled full hard strip supplied by the sponsor was used as a starting material for the

annealing experiments. These strips were first annealed using the Hot Dip Process Simulator (HDPS) available at CSIR-NML using process parameters used in the Sponsor's process line. Microstructure and mechanical properties of these laboratory annealed specimens were compared with the Sponsor's process line specimens obtained under identical annealing conditions for validation purposes. Thermal cycle analysis and new cycle design was performed based on thermodynamic and kinetic study. The plant designed thermal cycle for developing DP microstructure was divided into three stages. Detailed microstructure characterization and property evaluation was carried out for the specimens quenched after each thermal stages with varying process parameters (temperature, cooling rate, etc.). Some of the microstructures reveal a better distribution of fine martensite along the ferrite grain boundaries with enhanced properties (Figure 2). Based on the understanding developed at each thermal stage, new thermal cycles were designed.

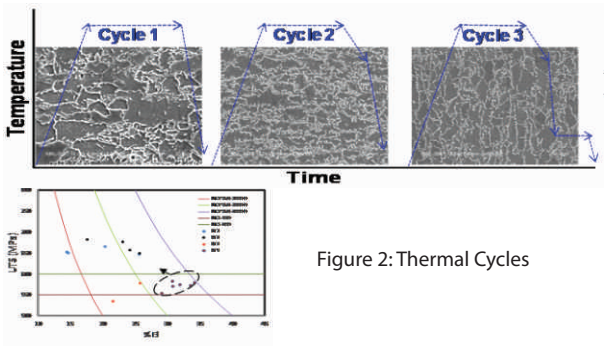


Figure 2: Thermal Cycles

It was observed that with the designed annealing cycle, desired HER property (76%), elongation (30-35%) and energy absorption capability (15-20 GPa%) were obtained. However, further improvement in strength (UTS: 560-580 MPa) is required. Some more optimization experiments need to be carried out in order to improve the strength and to reach a meaningful conclusion.

Impact on society/industry

The improvement of the mechanical properties in DP590 steel with respect to formability, ductility and stretch flangeability will help the industry to minimize the rejection at the customer end.

Optimization of Al-based metallic foams production method and development of metal foam

The project aims at the development of sandwich Al- and Al-alloy based sandwich foams for crash energy absorption applications. Closed cell Al-based metal foams are seen as good shock absorbers and are light weight, having density of around 0.4-0.6 g/cc. The objective was to develop a process for aluminum metal foam with various compositions and optimized process parameters, with delivery of around 50 samples of 50 mm x 50 mm x (6-10) mm sandwich foams to the sponsoring agency for testing. The process being employed for this development is powder forging and rolling followed by sintering and foaming of the precursor material (Figure 3). The powder of a given alloy is mixed with a foaming agent, TiH_2, in the present case, followed by forging and rolling. The purpose of the

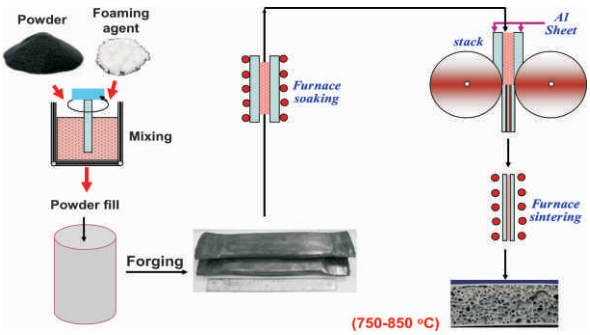


Figure 3: Process route

process is to embed the foaming agent particles within the sintered alloy powder. Upon heating to the foaming temperature, the foaming agent decomposes, releasing hydrogen gas. The sintering temperature needs to be kept below the decomposition temperature of the foaming agent so as to avoid decomposition and release of gas before full sintering. A uniform distribution of the gas evolution gives rise to uniformity in the pore distribution (Figure 4). The foam

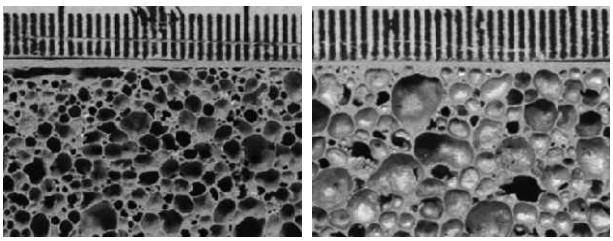


Figure 4: Pore structure

characteristics, in terms of porosity, pore size and density, depend upon the process parameters such as foaming agent content in the precursor, foaming temperature, foaming time and thickness of the precursor. In the present work, three different compositions are being attempted, e.g. pure Al, Al-Cu alloy and Al-Si alloy, and process parameters for each composition is to be optimized. One lot of samples of Al-Si alloy sandwich foams (Figure 5) have been supplied to the sponsoring agency and the test results showed shock attenuation of around 30%. The samples of other compositions are being prepared and will be supplied to the agency for further testing. It is expected to achieve a better shock attenuation by using other alloys systems. A successful completion of the project may lead to in-house facility creation by the sponsoring agency for the production of such sandwich foams.

Figure 5: Sandwich foams

Failure Analysis

Failure analysis projects were carried out for different sectors like Indian Railways, Oil and Gas, Steel etc. The objective of the investigations was to identify the root cause of the failure and suggest suitable remedies to mitigate or prevent such failures in future. It can also be an integral part of alternate material development and remaining life assessment of engineering components.

Metallurgical Investigation of derailed Sealdah-Ajmer Express (Tr.No.12987) coach parts and rails

Metallurgical failure investigation of the as received broken/damaged components (rail pieces, links, draw hook and wheel sets) of the derailed Sealdah-Ajmer Express (Train no.12987) was carried out through various non destructive and destructives tests such as visual examination, NDT, mechanical property evaluation, chemical analysis, microstructure analysis and Fractography by SEM. Chemical composition, mechanical properties and microstructure of the broken rails were found to be normal and conforming to the designated standard IRST-12-2009/Gr.880. Investigation reveals that the rail was broken because of rolling contact fatigue failure (Figure1). Fatigue cracks were originated from the gauge corner cracks generated on the contact surface between rail and wheel during service. Hence the primary cause of derailment is the fracture of the rail due to rolling contact fatigue. Gauge corner cracks were invariably present on the rail head at the contact surface between rail head and wheel. These gauge corner cracks were penetrated to the depth of ~10mm. These gauge corner cracks on rail head acted as the origins for fatigue failure due to the cyclic loading experienced by the rail during service. Moreover, chemical composition, mechanical properties and microstructure of the broken links of coach S-7 and pantry car (PC) were found to be normal and conforming to the designated standard IS: 5517.

Figure 1: Failed railway track

Links of coach S-7 and pantry car (PC) and other components were broken because of overload failure during the derailment process. Hence, failures of links are secondary in nature. Therefore, It is recommended to remove the gauge corner cracks by rail grinding before it grows critical and become the source of rolling contact fatigue.

Metallurgical Failure Investigation of Fractured Rails

Failure investigation of broken rails (Derailment of Train no. 12741, VSG-PNBE Express at Manikpur station of Allahabad on 24.11.2017) from North Central Railway, were carried out through visual observation, chemical analysis including hydrogen content, inclusion rating, NDT (normal UT and phase array), microstructure evaluation and mechanical properties evaluation (like tensile, hardness, impact). The results of qualifying tests conform to the standard requirements of IRST-12-2009/Gr880. The transverse fracture of rail pieces occurred due to fatigue aided by fretting action and thinning of foot at rail-clip location because of severe corrosion (Figure 2). The combined action of corrosion and thinning lead to fatigue crack nucleation and growth. The fractography showed initial crack propagation was due to fatigue leading to smooth fracture surface at thinned foot location followed by cleavage fracture propagation across the web and up to the head leading to transverse fracture. The longitudinal fractures were showing cleavage facets with river pattern due to overload. Therefore, It is recommended to inspect rails at rail clip locations periodically for thickness loss and also protect the surface of rails by painting/coating/ inhibitors.

Figure 2: Fractured railway track with thin foot

Root cause failure analysis of radiant tubes of furnace of HDGL/CRM-III at BSL/SAIL,Bokaro

Root cause failure analysis of radiant tubes of furnace of HDGL/CRM-III from BSL/SAIL, Bokaro was carried out through visual examination, chemical analysis, microstructure analysis, mechanical property evaluation and compositional analysis through Energy Dispersive Spectroscopy (EDS) and Wavelength Dispersive Spectroscopy (WDS) attached with Scanning Electron Microscope (SEM). Premature failure of several radiant tubes was reported within three month from the commissioning of the furnace (Figure 3). Visual examination revealed punctures (holes), circular groves (hot spots) on the outer surfaces and punctures (hole), conical hills and craters of reaction products on the inner surface of the tubes. Chemical composition, microstructure and mechanical properties of the radiant tubes were normal and conform to the specified standard (Inconel 601). SEM-EDS analysis of the outer surfaces shows deposits consist of iron, silicon, calcium, potassium, sodium, aluminium etc. and the inner surfaces shows deposits/ reaction products containing substantial amount of sulphur. Formation of nickel sulfides, chromium sulfides along with oxides of iron and chromium on the reaction products associated with holes, conical hills and craters were confirmed by XDR analysis. Moreover, the observation of chromium sulfides on the reacting interface with the tube metal confirmed that the damage to the radiant tubes is due to the sulphidation reaction from the inner side of the tubes. Ingress of sulphur through the inner surface is the root cause of failure of the tubes. The sulphur might have sourced from the mixed gas composition containing H_2S gas, tar and ash. It was recommended to control the sulphur deposition on the inner surfaces of the radiant tubes by controlling sulphur present in the fuel mixture.

Development to improve corrosion performance and service life of aluminium alloy bracket

The integrity of bracket made up of cast Al-Si alloy is important for washing machine to attain its target service life. The bracket is fitted to the shaft at the centre and needs concentricity and perpendicularity to ensure desired rotational speed of the washer drum. Failure analysis of failed brackets of Washing M/c at different time intervals was studied. Corrosion across the thickness of all the brackets has been identified to progress by intergranular/ corrosion along the interdendritic regions subsequent to the pitting, crevice, and uniform corrosion attack (Figure 4). A few bracket served for duration such as >12 months are noticed to suffer from a large thickness loss and failed predominantly by uniform corrosion. Owing to this, loss of strength of the component to tolerate fatigue during operation becomes inadequate and resulted in failure. Bracket serving <12 months wherein the thickness loss is relatively less severe, found failed due to poor ductility leading to mechanical fracture as these contained high silicon and iron contents. To reduce the corrosion, PU and epoxy based coatings were developed and found to perform satisfactorily to >1200h in salt spray environment. The modified Al-Si alloy with 0.1 % Ti and 0.01-0.02% B or 0.25% Sr showed a corrosion rate <0.05 mm/y, which is similar to the rate experienced by fresh Al-Si bracket received from M/s IFB Ltd.

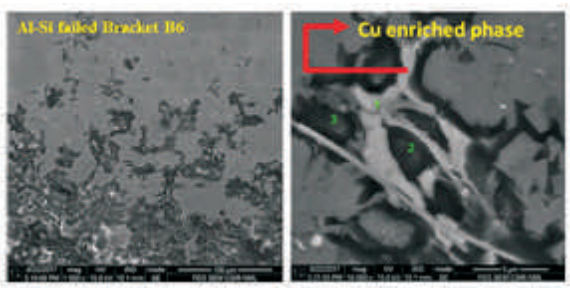


Figure 1: Corrosion propagated from along the grain boundary in a failed bracket

Remaining Life Assessment of DDH1 Heater Tubes

The remaining rupture life assessment (RLA) of heater tubes of its DDH1 unit deployed in BPCL-Kochi refinery was investigated. Three numbers of service exposed tubes (SS321H) with service life of 1,18,703 h (~14 years) were subjected to visual examination and dye penetration applied to weld regions to see physical defects. The susceptibility to sensitization and IGC (ASTM262 Practice E), microscopy hardness, tensile strength and stress rupture tests were also carried out. The visual examination and dimensional measurements with UT inferred no significant defects. Microstructural observations did not reveal any deleterious phases or gross microstructural changes (refer Figure 5). The weld samples bent in the normal direction indicated susceptibility to intergranular corrosion as the bent region contained fissures. The base metal revealed ductile to brittle transition temperature (DBTT) at sub-zero temperature of -100°C while the weld samples showed at -10°C. The API 579 FFS-1 level-3 assessment using operating data of the past service and future operating period of 10 years showed no significant cumulative damage accumulation as per minimum Larson-Miller parameter (LMP) values calculated. Stress rupture test of base and cross weld specimens, showed that at the existing operating conditions of 462°C /56 kg/cm^2, based on API579 FFS-1 - API530 approach using min LMP values, the tube material has further rupture life of 105hours. At the pressure of 56kg/cm^2, 639°C will be maximum temperature for 105 h life. At 69kg/cm^2 pressure, 617°C will be the maximum temperature for 105 h life. However, stress rupture life of the tube material was good for further service of 105 h under existing operating conditions.

Consultancy service for 500 MW Unit LP turbine rotor repair works

CSIR-NML provided necessary consultancy services to review the on-site repairing services of 500 MW Unit LP turbine rotor. This includes review of

(I) Failure analysis report and after assessment, suggestion for any additional investigations.

(ii) Chemical test, metallurgical and mechanical characterization of the rotor material, recommend for additional investigations and re-investigation of the material to establish correctness of the analysis.

(iii) NDT plan and micro-structural investigation plan of the milled surface and to witness the investigations at the works of the repairer.

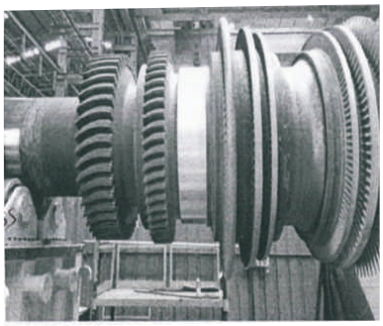


Figure 7: Stage of rotor machined and ready for weld built up

(iv) Weld Procedure Specification and heat treatment plans submitted by the repairer for weld built up.

The CSIR-NML team also witnessed the preparation of procedures like qualification test plate for weld built-up, pre and post weld heat treatment and recommended NDT, and mechanical characterization required for these test coupons after review of the repairer's plan. Assistance also provided to the sponsor to assure the quality of the repaired work by discussion at various stages.

Figure 8: Heating elements and insulation wrapped on the rotor for PWHT after weld built-up

Major Technological & Scientific Targets Planned for 2019-2020

1. Optimization of annealing cycle for a Dual Phase Steel
2. Hot corrosion study of 304H and IN 617 in simulated Indian coal AUSC condition
3. Creep data on Alloy 617 for Advanced Ultra Supercritical Technology

Team - MTE

MINERAL PROCESSING

The Mineral Processing Division (MNP) comprising Characterisation, Beneficiation and Agglomeration facilities has been around since the inception of CSIR-National Metallurgical Laboratory (NML) in 1950. An integrated mineral beneficiation pilot plant was installed in 1962 to study the feasibility of commercial exploitation of the techniques, process flowsheets and products developed in the laboratory. The Division is well equipped on modern lines to carry out planned research and development work on all types of ores and minerals for their rational utilisation and conservation.

Working closely with industry partners, innovations in mineral processing methodologies and state-of-art technologies have been developed with the objectives of the management of mineral resource base, and of enhancing productivity with sustainable environmental compliance. Expertise has been developed for new efficient processing options for beneficiation of ferrous, non-ferrous, strategic and industrial minerals and coal through the design and optimisation of processes. It has created confidence in the industry towards developing technology for converting waste to resource thereby enhancing mining life duly maintaining raw materials quality.

Based on the technical know-how provided by CSIR-NML a number of commercial beneficiation and agglomeration plants have been commissioned in the public and private sectors and it has contributed significantly to the development of mineral based industries. In addition to catering to the needs of mineral processing industry in India, CSIR-NML has maintained a strong international presence in mineral processing and has successfully executed a number of projects on samples of foreign origin from countries like Bhutan, Egypt, Syria, Sri Lanka, Sweden, Australia, Canada, Mali, Morocco, South Korea, Nepal, Zambia, UAE, Malaysia, Indonesia, Ukraine, Burma, Philippines, Oman, Uganda, Kazakhstan, Thailand, Ethiopia, etc. In recent times the division is focussing on Fine particle processing, Dry beneficiation, Mathematical modelling and simulation, Plant performance improvement and auditing, and Equipment development.

Team - MNP

Mineral Processing

De-ashing of high ash indian thermal non coking coal by dry beneficiation

Out of the Indian coal reserve of >300 billon tonnes, 86.6% is non-coking coal. High ash content in Indian non-coking coal is due to its inherent lithological association, intercalated shale of varied thickness and out of seam dilution through open pit mining. Combustion of high ash-low calorific coal results in incomplete combustion, low thermal efficiency, high operating & maintenance cost, erosion problems, difficulty in pulverization and excessive generation of fly ash with large amount of unburnt carbon. It requires beneficiation/washing/blending of coal in order to control the ash content to less than 34% which is mandated in power plants as per the regulation of Ministry of Environment and Forests, Govt. of India.

Out of the total non-coking coal used for thermal power, presently only about 20% is beneficiated coal. The wet washing of non-coking coal needs huge infrastructural and maintenance cost, of huge amounts of water and media, and there are environmental issues related to effluents discharge. Wet washing also adds moisture to clean coal, which is undesirable.

CSIR-NML has developed expertise and facility for dry beneficiation of non-coking coal. Technology/process flowsheet was developed for reducing ash in non-coking coal for application in thermal power plant and DRI, based on the studies carried-out at CSIR-NML.

With this expertise developed, CSIR-NML is working on development of technology for dry beneficiation of Indian high ash non-coking coal from different coalfields in collaboration with coal industries. In the present investigation, non-coking coal from Talcher coalfields has been studied and it was found that the ash content is around 41%. Detailed coal characterization, washability study and dry beneficiation based on air fluidization techniques have been carried out.

Typical result on coal sample from Talcher coalfields showing the effect of transverse angle of the separating deck on ash and yield of clean coal product is depicted in Figure 1. It shows that both yield and ash content of the clean coal decreases with the decrease of the transverse angle of the deck. Low transverse angle is favourable for achieving clean coal with low ash. At 34% ash level, product weight is about 75% and recovery of combustible is 87%. The organic efficiency is more than 90%. The product is suitable for application in thermal power plant. The scale of operation was 5-6 tph. The study has been extended for non coking coal from Ib Valley coalfields. The characteristic of this coal sample was found to be different from Talcher coalfields and appears to be difficult to wash. The work is in progress. Detailed coal characterization, washability study, dry beneficiation and development of process flowsheet for coal sample from Ib Valley coalfields, and techno-economic feasibility study will be carried out on the base process flowsheet developed. Dry beneficiation of high ash non-coking coal has been explored and it has significant prospects for commercial application towards the processing of high ash Indian non-coking coal for ash reduction.

Impact on society/ industry

- Conserves water
- Prevents generation of slime water
- Provides clean product with higher heating value
- Simple and compact process flowsheet
- Environmental friendly and cost effective

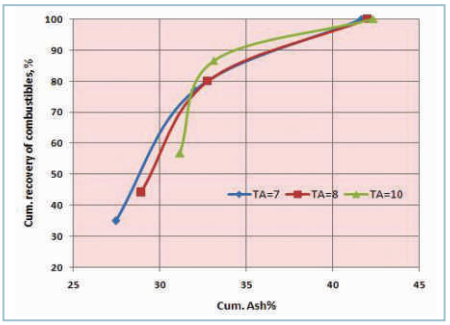


Figure 1: Effect of transverse angle of separating deck on yield and ash-content of clean coal

Studies on recovery of chromite values from Chromite Ore Beneficiation (COB) plant tailings

The objective of the project was development of a process technology for producing a chromite concentrate with 40 % Cr_2O_3 from COB plant tailings.

Chromium is one of the modern industry's essential elements and an important raw material for production of special steels and ferrochrome alloys. Around 90% of the mined chromite ore is converted into different grades of ferrochrome and almost 80% of it is consumed by the stainless steel industry. India has a total reserve of 322 million tonnes of chromite ores as per UNFC. The bulk of the reserves are located in the Sukinda valley of Odisha.

The good grade chromite ores are getting depleted due to utilisation over the years. Beneficiations of chromite ore generates a sizable amount of fines or slimes and are being lost to the tailings. The tailings contain 18 to 20% Cr_2O_3 value in it which needs to be recovered. Moreover, the tailings should contain < 10% Cr_2O_3 as per IBM guidelines. In this connection a chromite tailing sample was sourced from eastern India for characterization and beneficiation studies towards development of process/process flow-sheet for recovery of chromite values (Concentrate: 40% Cr_2O_3) from tailings. In the first phase, characterisation and conceptual flowsheet development through bench scale beneficiation was carried out; and in the second phase, pilot scale validation of the process developed was studied. The pilot scale validation was carried out following two routes: one using conventional gravity separator, and the second using the enhanced gravity separator. The process involved desliming followed by two stages of gravity/enhanced gravity concentration. The process technology was demonstrated and a feasibility report was prepared for putting up a commercial plant. The process technology is under implementation for commercial exploitation leading to recovery of chromite values from the tailings. The customer is working out the techno-economics of the process with a reputed consultant.

Impact on society/industry

- Recovery of chromite values from the waste or tailings provide additional raw material for use.
- Reduces pollution and also meets IBM guidelines with respect to tailing assay < 10% Cr_2O_3.

Deshaling and reduction of water consumption in wet beneficiation of coking coal

Beneficiation of coking coal is carried out by gravity and flotation techniques for ash reduction. In gravity process, usually heavy media bath, heavy media cyclone and jig are used for lowering the ash, and fines are processed by froth flotation technique. Presently, the coal at depth contains high ash and is difficult to wash. Beneficiation of this type of coal needs to be addressed based on their properties. In the present study the aim is to find the feasibility of the combination of dry and wet methods which can lead to improved metallurgical performance and water conservation. The deliverable of the study is a conceptual process flowsheet for beneficiation of coking coal with reduced water consumption. The coking coal sample received from West Bokaro Washery, Dhanbad having 32.5% ash was studied. The detailed characterization with respect to size and size-wise ash analysis, proximate analysis, calorific value and coal petrography were carried out. Washability studies of crushed coal sample of different top sizes were carried out to assess the possibility of dry de-shaling of the coal for producing a pre-concentrate (Figure 2). Attempt has been made to produce pre-concentrate with ash content of 26-27% by dry processing at coarser sizes. The pre-concentrate was further processed using a pneumatic table by reducing the size to -3mm and this produced a concentrate with ash content of 20%. The reject stream from dry circuits will be processed by using DMC and fines of -0.5 mm by froth flotation. The conceptual process flowsheet has been developed for processing of high ash Indian coking coal. In the present study, proof of concept has been developed for the viability of the combination of dry and wet processing of high ash coking coal.

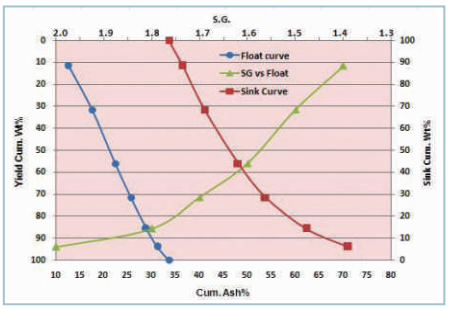


Figure 2 : Washability characteristics of -50+3mm coal sample

Encouraging results indicated that ash content of the high ash ROM coking coal could be reduced by 5-6 units by dry beneficiation which leads to improved efficiency and improved metallurgical performance of wet beneficiation. However, detailed beneficiation study is needed prior to commercialization of the process developed.

Impact on society/industry

- Dry beneficiation of high ash coking coal improves the feed quality prior to wet beneficiation
- Use of pre-concentrate generated by dry beneficiation process improves the efficiency of wet beneficiation process and metallurgical performance
- Net water consumption can be reduced by employing a combination of dry and wet methods for beneficiation of coking coal.

Modelling and Simulation Analysis of "Zawar" Comminution Circuit to increase its efficiency and throughput

The sponsor is operating a 1.5 MTPA Lead-zinc concentrator at Zawar (Balaria), Rajsamund district, Rajasthan. The ore is crushed and milled to desired size (P_{80}=106 micron) before subjecting to differential flotation process to produce separate lead and zinc concentrates. The crushing plant receives ore of -300 mm and reduces it to 80% passing 12-14 mm in two stages. The grinding circuit consists of ball mill operating in closed circuit with hydrocyclone. The comminution circuit was not able to achieve the rated capacity due to generation of rejects in ball mill during the plant operation. Modelling and simulation analysis was conducted for the comminution circuit to predict the optimum parameters of comminution. To find out the optimum parameters for comminution circuit, detailed survey was carried out and samples were collected at various points in comminution circuit to get ample data needed for the development of a steady state model. With the size distributions and percent solid at various points, mass balancing and model fitting has been undertaken and a mathematical model of the comminution circuit was developed (Figure 3). With the help of the developed mathematical model, the optimum process parameters were predicted to achieve desired throughput.

Impact on society/industry

Improvement in plant productivity.

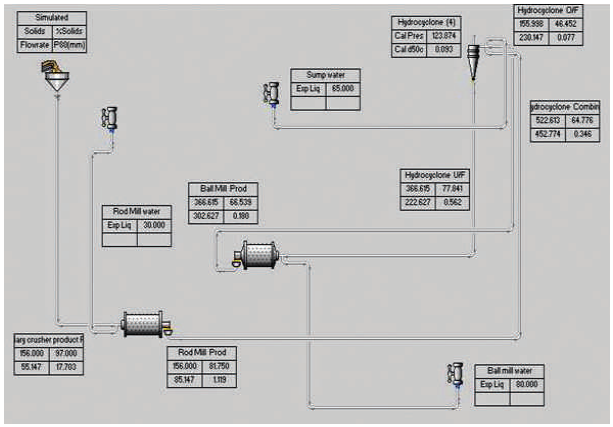


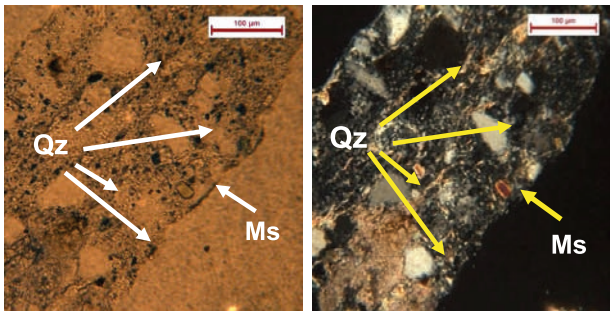
Figure 3: Schematic diagram of simulated grinding circuit.

Beneficiation of siliceous limestone for cement industry

The objective of the project was development of process for upgradation of low-grade limestone by reducing the silica content below 12% for its utilization in cement making industries. Limestone, a sedimentary calcareous rock, is mostly composed of calcite with some gangue minerals such as quartz, feldspar and mica. Limestone is extensively used in the cement and

metallurgical industries (iron and steel making). It is also used in the glass, food processing, papermaking, leather, wastewater treatment, adhesives, and construction industries. Grade wise, cement grade has leading share followed by SMS & BF grades and chemical grade. The cement grade limestone deposits are diminishing continuously because of continuous exploitation of high-grade limestone over the years. India has huge deposits of low-grade limestone spread across different states. Hence, many of the cement industries in India are looking for utilization of the existing low-grade siliceous limestone from their captive mines for conservation of mineral resources as well as sustaining environment. However, this siliceous limestone is not meeting the requirement of cement-grade limestone specification so it requires beneficiation for its utilization.

As received sample was analyzed and found to be composed of CaO 39.83%, MgO 3.51%, SiO_2 19.91% Al_2O_3 and LOI 33.57%. Mineralogical study showed that the major calcium bearing mineral is calcite while major gangue minerals are quartz and other silicate minerals (Figure 4). Detailed Studies were carried out with varied parameters like collector dosage, frother dosage, pulp density etc. on the flotation of siliceous limestone (Figure 5). Under optimum condition it was possible to get a product with 10.91% silica with CaO recovery of 87.9%.



[A] under Plane polarized light (PPL) [B] under Cross polarized light (XPL)

Figure 4 Typical grain showing quartz (Qz) and muscovite (Ms) interlocked in the matrix of fine-grained calcite as observed under optical petrological microscope.

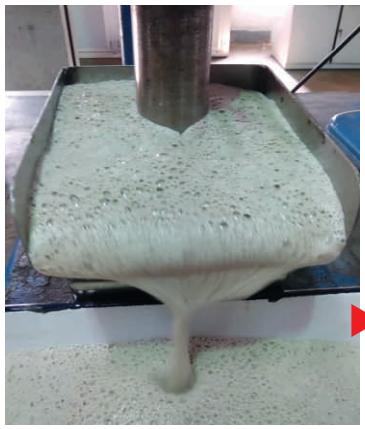


Figure 5: Bench scale flotation of limestone.

Outcome :

- Characterization study has established mineralogical and liberation characteristics of the limestone sample under investigation.
- Development of flotation based process for beneficiation of low grade limestone for cement making.

Impact on society / industry

India is endowed with vast deposits of siliceous limestone. Development of a process route for beneficiating these limestone deposits will be of great use for cement making industries.

Modelling and simulation analysis of de-sliming hydrocyclone at joda iron ore beneficiation plant

The sponsor is operating a Wet Iron Ore Beneficiation Plant of 1000TPH at Joda. The beneficiation process basically involves crushing, scrubbing / washing, classification followed by desliming to recover iron values at the accepted metallurgy. A significant quantity of iron values is reported to be lost during desliming operation. In this context, CSIR-NML conducted optimization study of desliming hydrocyclone. The study includes collection of plant data followed by mass balancing to identify the bottleneck in the existing circuit (Figure . 6). A steady-state model was developed with the help of the

balanced data to access various input scenario and optimum process parameters were predicted to minimise the losses.

Impact on society / industry

Improvement in plant productivity.

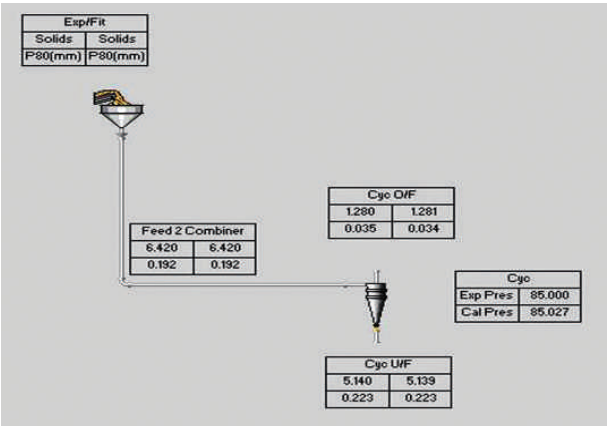


Figure 6: Schematic diagram of simulated desliming hydrocyclone circuit.

Pilot scale flotation studies of Iron Ore

The objective of the present study was to obtain an iron rich concentrate with alumina $\leq 3\%$with maximum yield and tailings with Fe <45% from inferior grade iron ore through froth flotation process. In northern parts of India, iron ore deposits comprise of hematite, goethite minerals with gangue of alumina and silica. Due to occurrence of these gangue minerals in fine size, generation of slimes of high alumina and silica during beneficiation process is inevitable. Though the iron values of these slimes are high, the lack of beneficiation technology forces their disposal in slime ponds. The practice of disposal is a threat to the environment and leads to huge land filling just to preserve the iron ore slimes. Beneficiation process involving froth flotation to recover iron values from slimes was undertaken in the present work. CSIR-NML is working on the development of novel reagents to treat the iron ore slimes through pilot scale studies. Bench scale trails were conducted at 0.5 kg scale. Further, these studies were scaled to pilot scale (20-25kg) to confirm the performance of the flotation reagents (Figure. 7). Results indicated high selectivity compared to conventional reagents and achieved a concentrate of 2.46% Al_2O_3 with 82% yield. The tailings with iron content <45% is being rejected during the reverse flotation of iron ore slimes. Effect of process parameters such as collector dosage and % solids in the feed were established. Batch pilot scale flotation studies have been conducted (20-25 Kg). Further validation of the batch pilot scale flotation results in a continuous mode (100-125 Kg) will be done before commercialisation.

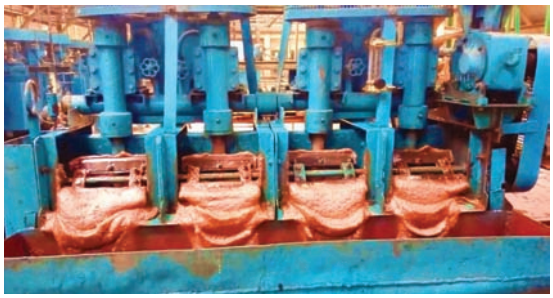


Fig.7: Pilot scale iron ore flotation study.

Impact on society / industry

Huge impact on industry in terms of revenue generation.

Study of particulate flow in centrifugal force field with continuous fluid current

Separation of particles in centrifugal concentrator depends upon the differential settling velocity of particles. Settling velocity of particle is dependent upon fluid profile inside the concentrator, operational parameter, physical properties of particles such as size, shape, density, and design parameter of concentrator. In order to understand the settling kinetics of particles inside the centrifugal concentrator, a mathematical model will be developed through first principle of force balance. Motion of particles will be modelled as a discrete phase, described by the Newton's laws of motion on an individual particle scale, while the flow of fluid (liquid) will be treated as a continuum phase, described by the analytical solution of Navier-Stokes equations. In the present investigation an attempt was made to study the fluid flow characteristics inside the

Falcon concentrator, as a first stage to obtain an understanding of particle segregation inside the concentrator. Tracer injection experimentation were carried out to identify the role of fluids which enters in the concentrator through gravity assisted feeding system, and through recoil hole on the concentrator wall. Based on the tracer based experimentation, it was established that fluid that enters through the gravity based feeding system is responsible for thin flowing film formation in the stratification zone. Momentum balance and continuity equation was simplified for high centrifugal force field, and the fluid velocity profile was estimated inside the thin flowing film (Figure 8). Estimated fluid flow profiles help to simulate the particle trajectories inside the Falcon concentrator. Influence of rotational speed, fluid flow rate and cone angle, on the fluid velocity profile are investigated. Fluid thickness over the concentrator wall is also estimated and it is typically in the order of ~150-200 micron. Future work will be undertaken on coupling of particle motion with fluid velocity profile.

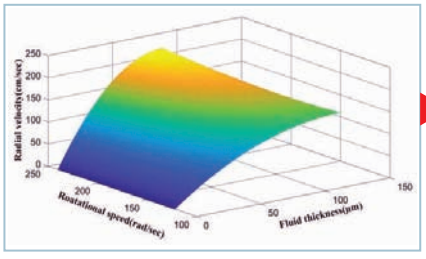


Figure 8(a): Estimated fluid velocity profile (Radial velocity)

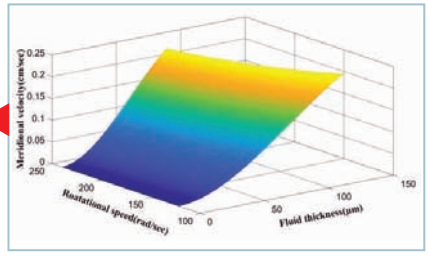


Figure 8(b): Estimated fluid velocity profile (Meridional velocity)

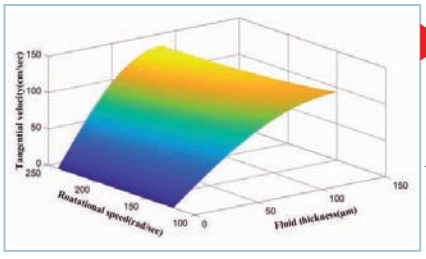


Figure 8 (c): Influence of rotational speed on fluid velocity profile (Tangential velocity) (Q=20 cc/sec and r=5.5 cm).

Design and optimization study of flotation process using modeling and simulation analysis

The objective of the project was to develop a suitable model for design and optimization of column flotation for coal/ore mineral. Any typical flowsheet of any mineral processing plant mainly consist of comminution (crushing, grinding, classification), separation (gravity, froth flotation, magnetic separation, electrostatic separation) and product handling (thickening, filtration). As the ore grade declines, the liberation size for beneficiation gets finer. So flotation may play a major role in the separation techniques in future. In this work, attempt will be made to develop suitable model, particularly for column flotation process, for optimization and scale-up purposes with major emphasis on the key factors, such as, rate constant, bubble size, superficial gas velocity, gas hold-up, particle residence time, mixing characteristics, etc. A wide range of mathematical models are available for both conventional and column flotation based on the first order kinetics. This work mainly comprises of a set of Laboratory/Pilot scale column flotation tests with coal samples to evaluate the first order kinetic rate constant in terms of ore characteristics (ore floatability) and machine characteristics in terms of bubble size, superficial gas velocity and gas holdup. The process of developing a model for the circuit and simulating it regularly will optimize the parameters affecting circuit performance and it will be useful in predicting the optimum operating condition of the circuit. The project is ongoing and future work will be undertaken on Pilot scale test and development of steady state model for simulation analysis.

Impact on society / industry

- Improve plant operating performance with significant improvements in grade and recovery
- Reduction in power consumption
- Reduction of operating and capital expenditure

Study of dewatering behaviour of fine particles in hydrocyclone

In mineral industries, most of the beneficiation processes involve large quantities of water as most of the separation takes place through wet beneficiation. Therefore, removal of water is required before proceeding for further processing. Thus dewatering in mineral processing plays a vital role. In the present work, the study was aimed at performance evaluation of a laboratory model 2" hydrocyclone for solid-liquid separation behavior, i.e. the dewatering performance. In this study, experiments were conducted in a 2" Mozley hydrocyclone using two mono density particles (silica and magnetite) having a specific size distribution (less than 150 micron). Experiments were planned according to design of experiments by varying the geometric (vortex finder diameter (VFD), spigot diameter (SPD)) and operating (inlet pressure) variables at three levels. The dewatering performance indicators are solid recovery to the underflow and water recovery to the overflow. Response surface methodology was employed to analyze the results. It was observed that VFD and SPD have more pronounced effect on dewatering behavior compared to inlet pressure. The interaction effect of pressure and SPD on solid recovery in the underflow (Rs) has been studied (Figure 9.). Solid recovery in the underflow (Rs) increases as SPD increases, irrespective of pressure. The results have been copyrighted as "NEURAL-HYDROCYCLONE"- a model based artificial neural network code to characterize solid-liquid separation behavior of a dewatering hydrocyclone. Future work will be the phenomenological modeling of the particle flow in a hydrocyclone in a turbulent condition. A battery of hydrocyclones can be used for large scale dewatering. The number of hydrocyclones and size of each hydrocyclone will be decided based on the throughput. There is always a possibility of partial or full replacement of thickeners by hydrocyclone.

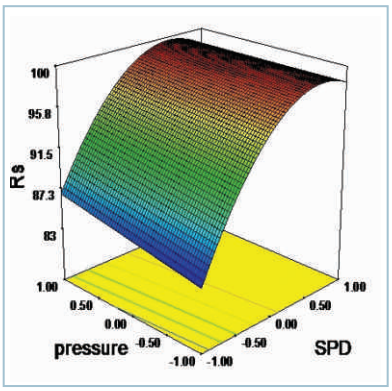


Figure 9 : Interaction effect of pressure and SPD on solid recovery in underflow

Impact on society / industry

Thickeners are extremely used for dewatering of slimes. Keeping the advantages of hydrocyclone, i.e. low space requirement, low installation cost, ease of operation, if it can replace thickener partly also, it can be a significant contribution to the mineral industries in terms of cost, space, time etc.

Major Technological & Scientific Targets Planned for 2019-2020

Technology for Dry Beneficiation of Non-coking coal for Application in Thermal power plant

- Conducting characterization, washability and dry beneficiation studies on coal sample from Ib Valley, Mahanadi Coal Ltd
- Development of technological process flow-sheet

Extraction of Tungsten from Hutti gold ore tailings

- Data analysis and development of technological process flow-sheet and computing material balance for beneficiation and hydro-metallurgical extraction of tungsten

Beneficiation of Low grade Limestone for Cement making

- Bench and pilot scale beneficiation studies on low grade limestone sample from Rajasthan.
- Development of flotation based process for reducing silica content to desired limit.

CSIR PROJECTS

Scale up and commercialization of indigenously developed hydrogen standard in steel

Hydrogen present in steel product is detrimental to its properties, as it causes hydrogen embrittlement, stress corrosion cracking, flake formation, etc. It can be well submitted that enormous amount of care is taken during all the stages of steel manufacturing to keep hydrogen to a bare minimum level (< few ppm). Measurement of this element in steel requires very careful manipulation during the sample preparation and testing. Contamination of hydrogen from any other sources during testing would lead to an erroneous value. Standards/reference materials used for calibration and hydrogen detection is costly and time consuming. The product is presently imported to India. CSIR-NML had executed a project under Fast Track Translational (FTT) program and successfully developed hydrogen standard in steel, indigenously. In continuation of this activity, to compete well and to offer better service to the Indian customers, the present program aims to scale up (No of bottles: 100 and No of pin/bottle: 100) and commercialize the indigenously developed product, hydrogen standard in steel, for hydrogen determination. However, certain issues observed during developmental program, such as identifying/producing reliable starting material for standard development, improving the standard deviation of the product, better surface appearance and hydrogen standard in different levels will be exclusively addressed in this project.

Control of hydrogen in steel pin samples, in a desired range, is challenging, as the stability of hydrogen in steel samples depends on various factors, like, steelmaking practice, steel composition, crystal structure and process parameters involved in diffusion annealing, and post cleaning processes. Equilibrium solubility of hydrogen in steels primarily depends upon the crystal structure of the matrix and it is found to have maximum solubility in the liquid steel. Therefore, one can find various types of steels with different crystal structures to have different levels of hydrogen in it. Identification of reliable steel as starting material for preparation of standard is one of the vital steps, followed by hydrogen diffusion annealing, introduction of defects and precipitates in the structure to keep the hydrogen at desired levels. Nevertheless, improving the surface appearance and standard deviation of the product at par with the market available standard material is essential.

Hydrogen standard is being extensively used in steel industry both for civil (primarily for railways maritime navigation, core sector for components of oil and gas) and also for strategic sector. Apart from steel plant it is also extensively used in power plants, aero industries, strategic units (AEC) dealing with steel components, national laboratories, institutes, BIS & other laboratories. One of the important aims of this project is to commercialize the indigenously developed hydrogen standard in steel. The current available hydrogen CRM in Steel has been supplied by foreign vendors at a cost of Rs 20,000/- to Rs 40, 000/- for 1 pack/bottle (100 nos. of pin sample). On an average, it can be assumed that consumption of hydrogen standard in steel (plant) industries would be at least 1 bottle (100 pins) per month. Therefore, it can be further assumed that 50 to 80% of the developed product will be served within one or two year. At present, the plan for commercialization is as follows:

No of bottles	:	100
No of pins per bottles	:	100 /bottle
Tentative cost	:	Rs 12,000 to 14,000 /bottle

The value added (w.r.t uncertainty, surface appearance etc.) hydrogen standard will be certified and listed in the regular CRM list of CSIR-NML for external usage. It is expected that the product will be commercially available to the Indian users from November - December 2019.

Socio-Economic Impact of Development of Hydrogen Standard in Steel	
a. Industry Impact	• Indigenous development of Certified Reference Material (CRM) standard for gases (Hydrogen) in steels • Import substitution (Make in India) • Cost effective than market available standard (40% reduced cost for Indian people) • Reduction in foreign exchange
b. Improvement in Quality of Life	• Improving the status of Indian Laboratories and industries
c. Others	• First synthetic gas based CRM developed by CSIR-NML (CRM No:501) • Prestigious service to our nation • Self-reliant CSIR

Synthesis of new 2D materials other than graphene for energy application

The main objectives of the project are

- To explore structure-property correlation of these new generation 2D materials based on metal chalcogenides and MXene through parallel theoretical calculations and experimental investigations.
- Efforts will be made to synthesize good quality 2D materials through easy technique for practical applications.
- Explore the use of MXene and metal chalcogenides material for supercapacitor fabrication.
- Understand the band gap of 2D metal chalcogenides with respect to layer thickness and their possible use in combination with MXene for energy conversion.

The development of two-dimensional (2D) high-performance electrode materials is the key to new advances in the fields of energy conversion and storage. The field of 2D materials has been dominated by graphene for over a decade now. Even though graphene has many exotic properties, it has drawback like absence of a band gap and difficult to functionalize. Experimental approaches originally developed for graphene are being extended to other layered materials and is fuelling the rapid growth of interest in 2D materials beyond graphene. New 2D materials include metal chalcogenide, phosphorene, boroene and MXenes. First fabrication of phosphorene by exfoliation of black phosphorus in 2014 with tunable band gap has been the focus of rapidly expanding research activities. MXenes, an intriguing family of 2D transition metal carbides, nitrides, and carbonitrides, have recently received considerable attention due to their unique combination of properties such as high electrical conductivity, hydrophilic nature, excellent thermal stability, large interlayer spacing, easily tunable structure and high surface area. These new 2D materials with high electron mobility and inherent band gap can be explored for energy storage through supercapacitor and clean hydrogen energy generation utilizing solar energy. In particular tunable band gap of metal chalcogenide can open a new avenue for hydrogen generation. Even new potential 2D materials can be projected from theoretical calculation.

Exfoliation of MoS_2 and WSe_2 were tried with different solvent followed by ultrasonic treatment. It was observed that the nitrogen containing molecules performs better than alcohols and glycols. Among the used solvents triethanol amine and n-methyl 2-pyrrolidone performs better. Possibly nitrogen containing molecules can easily bind with the surface of these two materials thus helping in reducing the van der Walls force between the layers. After sonication at different time period, the solution was centrifuged at 2000rpm for 20minutes so as to separate the heavier particles. Final obtained dispersed solution is stable even up to two months in the laboratory as shown in the Figure 1. Both the materials were examined under TEM so as to conform the exfoliation. TEM image as shown in Figure 2 confirms the exfoliation in the form of multilayered MoS_2 and WSe_2. In addition breaking of sheet structure to smaller one is noticed with the increasing sonication time. Detailed at characterizations are going on to establish the process. We have used molecular dynamics simulations to estimate mechanical properties of MoS_2-graphene nano-composite. To estimate mechanical properties, a multi-axial tensile deformation methodology has been implemented. A 12-6 Lennard Jones interaction potentials implemented for the interactions between MoS_2 and graphene sheets. After proper equilibrations, tensile deformations have been performed to extract stress-strain response for both pure MoS_2 sheets and MoS_2-graphene nano-composites. Synthesis of Ti_3C_2 MXene from the bulk Ti_3AlC_2 MAX phase by HF treatment was performed. Obtained MXene was characterized by SEM which indicates the removal of aluminium layer. Electrochemical performances of both Ti_3C_2 (MXene) and Ti_3AlC_2 MAX phase was carried out to ascertain the effect of 2D MXene over MAX phase. Complete characterization of the exfoliated WS_2 and WSe_2 in different solvent will be taken further. Evaluation of the band gap of these semiconductors in relation to layer thickness and subsequently synthesis and evaluation of TiO_2-2D composites for hydrogen evolution reaction will be done. Correlation of band gap, heterojunction formation and photocatalytic activity will also be done. Similarly, synthesis and evaluation of 2D-Ni.Co(LDH) composites towards capacitance and energy density, synthesis and characterization of P doped MXene for electrochemical capacitance monitoring, will be carried out and theoretical calculation of functionalized 2D materials and correlation with experimental results will be done as well. Above all the advantage of 2D material over the bulk material needs to be explored.

Figure 1: MoS_2 exfoliated in n-methyl 2-pyrrolidone

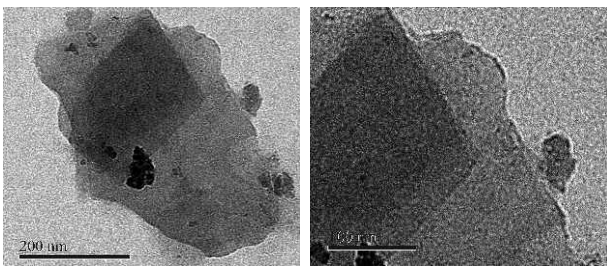


Figure 2: TEM image of exfoliated MoS_2

Smart sensing system for cold drawn high end wires

The presence of cracks/discontinuities such as seams, cracks, pits, slivers, weld-line defects and internal discontinuities in metallic wires and the failure to detect these during the wire drawing process often leads to long term production interruptions, significant economic losses and lower quality of final product. Undetected wire defects results in failure at the customer end during subsequent processing or while in use. It is desirable not only to detect the quality of the wires in terms of defects during the manufacturing stage itself with subsequent diversion of defective spools, but also to provide real-time feedback on

product quality during production - even at high speeds. Although a few sophisticated systems are available globally these are prohibitively expensive for large scale implementation. In fact, cost-effective, tailor-made systems are imperative for multiple line applications. CSIR-NML has already developed FlawGuard™, a low-cost device for sensing wire defects at high speed. Based on the principle of eddy-current (EC), this device has found ready acceptance with the biggest wire manufacturer in India and has been in regular operation since May 2017. Satisfaction with the performance of the device has resulted in the customer's request for up-gradation of the system beyond just defect detection and identification. Keeping this in view, this project aims to develop the next generation of FlawGuard™ incorporating a smart sensing system with remote monitoring and decision making capability on the quality of the wires. Additionally, the system would be capable of measuring the uniformity of the zinc coating, on-line. Such a facility is non-existent in galvanising wire lines and will address the long-standing issue of proper production of galvanised wire. Non availability of low cost inline GI coating thickness measurement, make the producer handicapped to assess the required thickness in all the production lines during drawing. Over-coating of Zinc leads to a huge economic loss whereas undercoating is not acceptable by the customer. Implementation of the developed system will address these issues too.

After completion of the electronics and sensor fabrication for inline coating thickness measurement of galvanised wire, one trial has been made at a Jamshedpur based Wire company, to study its suitability in the line. Figure 3 shows placement of sensor in one of the galvanising lines along with the sensor output voltage in the display. Calibration of sensor output voltage with coating thickness is being carried out using the Hot Dip Galvanising Process Simulator.

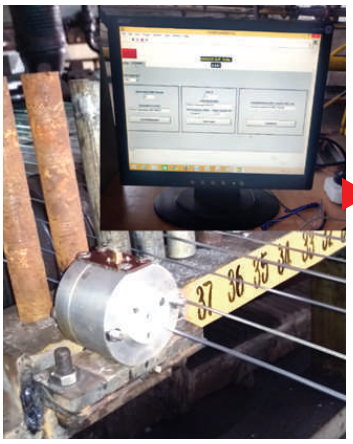


Figure 3: Placement of sensor in one of the Galvanising lines along with the sensor output voltage display

Piloting of the process for Production of Premium Grade Iron Oxide from Waste Ferrous Chloride Solution Generated from Steel Pickling and Ilmenite Processing Units

Ferrous chloride in high concentration range is a common effluent generated variety of processing units. Ilmenite processing units mostly follow chloride route to produce synthetic rutile. The highly acidic and concentrated ferrous chloride effluent generated from the process is usually pyrolysed/neutralised and the waste slurry is pumped to the designated slurry pond. Huge quantity of waste pickle liquor (WPL) is generated from galvanising units, generally to the tune of 30-60 L/MT of steel containing about 100-250 g/L of ferrous iron and 20-50 g/L of HCl. Similarly, during ilmenite processing, more than 1.5 times waste iron oxide/sludge to that of titania production is generated. The dumping of the above waste require huge area near the plant site. However, instead of dumping which involved huge cost, these wastes can be converted to a very high grade iron oxide

A complete flow-sheet is developed at CSIR-National Metallurgical laboratory for treatment of waste ferrous chloride pickle liquor for production of high end red oxide pigment was well as nano iron powder directly from waste chloride pickle liquor. The ferrous iron present in the liquor is first oxidized to ferric state using waste chlorine gas. From the oxidised solution ferric oxide is precipitated through an aging process by low temperature hydrothermal synthesis.

Very uniform size monodispersed particles of different shapes such as acicular, spherical, peanut, dumbbell, pseudocubic, and sizes ranging from 100 - 2000 nm were produced by this method. Both reduced tone and mass tone of the produced oxides were tested by M/s Tata Pigments Ltd. and the materials were found much superior in quality with respect to color. The process is demonstrated on kilogram scale and transferred to M/s Tata Pigments Ltd, Jamshedpur and M/s Rang Sarjan Chemicals, Gujrat.

However, it requires further up-scaling for generating data to engineer the process and also to build confidence among the interested entrepreneurs. It is proposed to up scale the process in two stages : (i) Production of iron oxide on 5 kg scale iron oxide and (ii) Production of iron oxide on 50 kg scale.

Waste acidic ferrous chloride solution, about 100 L each from waste steel pickling plants and ilmenite processing units have been collected. For carrying out iron oxide precipitation trials on 5 kg scale, a 3 stage chlorination unit is procured and overhauling job of 50 L autoclave is completed. A 500 L titanium lined autoclave is also procured for 50 kg scale trials and is under commissioning stage.

The list of CSIR-Projects also includes the below projects that have been detailed in various chapters of this report :

- Self-healing coating for corrosion protection of Steel and Aluminium alloys;
- Annealing simulator integrated with online process control sensors for run out table (ROT) process simulation;
- Pilot scale processes for recycling of metals/materials from E-waste
- Development of biodegradable eco-friendly flotation reagents for sillimanite, llmestone, iron ore fines and coal;
- Technology for Extraction of Tungsten (Yellow Tungsten Oxide or Ammonium Para-Tungstate or Metallic W-powder) from a Variety of Scraps.

CSIR-NML MADRAS CENTRE

Figure 1: Commemorative plank of NML Foundry Station at Madras (Chennai)

CSIR-National Metallurgical Laboratory Madras Centre had its roots in NML Foundry Station established in 1965 at Guindy Industrial Estate, Chennai (Figure 1). The idea of establishing Foundry Stations across the country was first proposed by Sir Jehangir Ghandy, the then Chairman, Executive Council of the National Metallurgical Laboratory with the intention of providing technical assistance and testing facilities to the foundry industry. The station had facilities to undertake the analysis of both ferrous and non-ferrous metals and chemical analysis of molding sands, etc. Later on, the idea of setting up of the CSIR Madras Complex, in close proximity to many other technological institutions, was conceived by Dr. S. Husain Zaheer and Dr. Atma Ram, former Director Generals of CSIR. The objectives were two-fold, (i) to provide Common Services in the interest of economy and (ii) to allow interplay of scientists working in different disciplines offering a unique opportunity for developing a multi-disciplinary culture. NML Foundry Station was shifted to the present campus of CSIR Madras Centre in 1973 and came to be known as NML Madras Centre. An Ore Dressing laboratory and a Refractory Unit were also added. Over the years, the Centre expanded its activities to include investigations on failure and root-cause analysis of metallurgical components, analysis of metallurgical and ore samples and value addition to metallurgical and mineral wastes. The beneficiaries include M/s Hinduja Foundries, Chennai, M/s Hindustan Zinc Limited, Udaipur, M/s The Ramco Cements Limited, Chennai, M/s Rajshree Sugars & Fertilizers, Tamil Nadu and M/s Tamil Nadu Electricity Board, Chennai.


Figure 2: Commercial scale flotation columns for barite (1000 tpd) at M/s Oren Hydrocarbons (P) Ltd., Chennai

The Centre made its mark at a national level for the indigenization of 'Column Flotation technology' for processing lean and fine-grained ores. The activities pertaining to it started in the middle of 1980s and have been continuing since then. Laboratory scale (74mm diameter) and Pilot plant scale (500mm diameter) flotation columns were designed, fabricated and field tested at various private and public sector mineral processing plants located across the country. The Column flotation technology has attained a Technology Readiness Level of 9. The USP of the NML Madras Centre is providing One-stop solution for installing commercial scale flotation columns by collaborating and partnering with an EPC company M/s McNally Sayaji Engineering Limited, Bengaluru and Reagents manufacturers and suppliers M/s Somu Organo-Chem Private Limited, Bengaluru and M/s Xanthate Technologies, Visakhapatnam. So far, 5 laboratory scale, 1 pilot scale and 6 commercial scale flotation columns have been commissioned (Figure 2). Presently, two commercial scale flotation columns are under installation, one at Belatinda Coal Preparation Plant of M/s Tata Steel Limited (200 tpd) and another at Mineral Separation Plant (MSP) of M/s Kerala Mineral and Metals Limited (KMML), Chavara, Kerala for sillimanite flotation

(100 tpd). Many awards including the Technology Award for the Most Significant CSIR Technology of the Five Year Plan Period (awarded in 2014) and 'National Mineral Award' from the Ministry of Mines, Government of India, were received in recognition of the Development of Column Flotation Technology.

Team - NML Madras Centre

The Centre also embarked on a programme for developing bio-degradable and eco-friendly flotation reagents for sillimanite, coal, graphite, limestone and iron ore fines in collaboration with CSIR-Central Leather Research Institute, Chennai under CSIR - Fast Track Translational (4M Theme) projects. The newly developed reagents for sillimanite and coal flotation proved to be more effective than the presently used ones in the plants. Another flagship programme currently being pursued is on 'Development of graphene-based membranes from graphite ore for desalination' in collaboration with CSIR-National Institute for Interdisciplinary Science and Technology, Thiruvanthapuram and sponsored by Ministry of Mines, Government of India.

Consultancy for design, erection, commissioning and process stabilization of flotation column for sillimanite beneficiation

Sillimanite was being recovered poorly by conventional flotation cells at the Mineral Separation Plant of sponsor. The sponsor approached CSIR - NML with a request to find ways to increase the recovery and grade of sillimanite. After the plant visit, it was observed that not only the present conventional flotation cells became defunct, the collector being used was non-selective for sillimanite flotaion resulting in poor recovery and grade. To obtain better grades and recoveries, the sponsor was suggested to adopt column flotation technology. Accordingly, a consultancy project for design, commissioning and process stabilization of flotation column for sillimanite flotation was awarded to CSIR - NML. It is being executed with the sponsor, and involves fabrication, supply, erection and commissioning of 100 tpd, 1.0m diameter flotation column. CSIR - NML Madras Centre would oversee the execution of the project and assist in process stabilization. Also, a new collector was developed for sillimanite flotation and was found to be superior to the one being used in the plant. The relative performance of the two reagents is shown in Figure 1. Figure 2 shows the on-going civil foundation work for flotation column and Figure 3 shows the flotation column shells delivered at the site for erection.

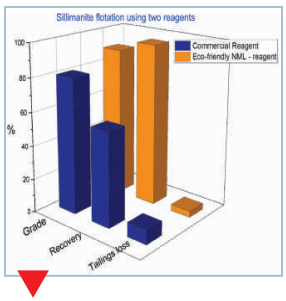


Figure 1: Relative performance of commercial reagent and NML - reagent for sillimanite flotation

Figure 2: Civil foundation work for flotation column in progress

Figure 3: Flotation column concentrate launder and shells delivered at the site for erection

Development of biodegradable eco-friendly flotation reagents for sillimanite, llmestone, iron ore fines and coal

Most of the reagents (collectors and frothers) used for flotation of minerals and coal in mineral processing industry are synthesized from organic/inorganic source materials and are classified as cationic, anionic and non-ionic. Majority of flotation reagents being used at present in the industry are not environmentally compatible and are non-biodegradable. The present investigation aims at developing eco-friendly and bio-degradable reagents for the flotation of various minerals such as sillimanite, limestone, iron ore fines and coal. Two different types of coking coal collected from two different seams differing in their inertinite, vitrinite, mineral matter and hence having varied washability characteristics were chosen. Four eco-friendly and biodegradable collectors were developed in collaboration with CSIR - Central Leather Research Institute, Chennai and the flotation performance of these was measured vis-à-vis the usual collector used in coal preparation plant on coal fines of both the coal samples. It was observed that at any given ash value, the yield of froth obtained using new reagents was higher than that of the plant collector in the case of both coal samples (see Figure 4).

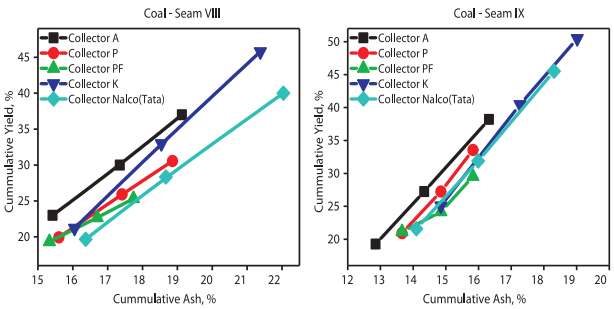


Figure 4 : Performance of flotation reagents

Similarly, a new flotation collector was developed for sillimanite which was found to be superior in selectivity to the one being used in the plant resulting in better grade and recovery. This collector, which is eco-friendly and biodegradable, would be utilized in the new flotation column to be commissioned at the sponsor's plant.

Impressions

…Apart from the above we would like to share some significant information with you and team NML. We already have accomplished the pilot plant studies as per our requirement leading for the detailing of commercial plant start up. These studies are based on the technology acquired from NML for Iron Oxide using Pickling Solution / Ferrous Chloride Solution. As of now we would be still continuing the pilot plant studies for further improvement and confidence building. Besides the pilot plant studies; we are already in progressive mode switching over to commercial production in parallel. In fact we already have started our project activity and at present are focusing the initial section of chlorination of Pickling Solution. Once Chlorination is established we would proceed to the final step of Iron Oxide manufacturing. We are quite sure about the commercial success of the project. In any case we would be continue keeping you informed regarding the commercial status of our project along with seeking all necessary help from you and your team.

Finally we need to thank you and team NML for the technical guidance provided to us along with cordial warmth whenever we came across by various means.

Rang Sarjan Chemicals
Gujarat
20 -11- 2018

…Thank you for sending to me a copy of the annual report.

It is a very well produced report, covering all aspects of your operation. I was reading the note on de-ashing of Indian coal, P82, and found the font size of the legends of Fig 2 too small to read.

One suggestion on this work, is that you present the yield of combustibles rather than coal yield. The figures may be more realistic and relevant.

Since I am involved in the coal to methanol project of CIMFR, this subject is of great interest to me. May I see the pilot plant, please?

Best wishes.

Tribidesh Mukherjee
25 - 06 - 2018

SERVICES & FACILITATION

Science & Technology in Ancient India

Fibbonacci Numbers

The Fibonacci numbers and their sequence first appear in Indian mathematics as matrameru, mentioned by Pingala. Later on, the methods for the formation of these numbers were given by Virahanka, Gopala and Hemacandra, much before the Italian mathematician Fibonacci

Science & Technology in Ancient India

Engineering

The division caters to and co-ordinates the engineering needs of the laboratory in matters of R&D and infrastructure, it also coordinates the maintenance of the residential complexes. The division has two groups, Works Services and Maintenance (WSM) and Project Planning and Engineering (PPE). Major activities of the division include: design and development of prototypes, project engineering, engineering consultancy, infrastructural development, R & D activities in the core areas of the laboratory, up-keep of premises, in-house maintenance, workshop facilities and support services.

Project Planning and Engineering (PPE) Group

The activities of PPE Group include prototype design and development, research and consultancy in the area of welding, setting up of critical R&D infrastructure, finite element and CFD modeling, maintenance of equipments, safety infrastructure to provide central workshop services, skill development, technology scale-ups and development of basic engineering packages (BEP), pilot plant operation and maintenance. During the reporting period the following high value equipment were serviced: Rolling Mill, Magnesium Plant automation system, AKA flow system and Servo Hydraulic Unit. The division also actively provides research and consultancy in the area of welding. In the reported period, the division has completed two consultancy projects and has been working on two major research projects. We are also developing state of the art welding research laboratory: The major achievements are as follows :

A. Research and Consultancy

1. Consultancy for repair of 500MW LP turbine rotor- the major work in this project was providing technical advice to the client for assessing and controlling the quality of the repair being done by third party using the welding process.
2. Research project on the effect of H_2 on fracture toughness of welds of API X 80 steel
3. Research project on toughness behavior of simulated heat affected zone (HAZ) of SA 508 and P 91 steels- A project on Heat Affected Zone (HAZ) Simulation of SA 508 and 9Cr1Mo steel. This project is targeted to understand effect of welding parameters on HAZ of the materials used in nuclear plants.
4. Consultancy to Metal Industry Development Institute (MIDI), Ethiopia, to set up welding research facility.
5. Weldability study for varying chromium composition in line pipe steel for ONGC.
6. Electrode evaluation study for sponsor.

B. Design and Development

In the reported period the division has also contributed to the requirements of several projects with respect to the prototype design and development. The major prototypes designed and developed were: design and specifications of material handling system for AKAFLOW equipment, design and specifications of inverse mold simulator, 50kg brass melting furnace, design and outsourcing of machining and shrink fitting for CIMFR canon, consultancy project on setting up of commercial plant for sodium production, design and development of air stratification origin, design and development of improved chamber for annealing simulator. In the reported period the division has been working on the following major jobs for critical infrastructure development:

1. Design, Supply, Installation, Commissioning & testing of 2 x 125 TR HVAC plants for creep building:
2. Setting up of infrastructural requirements for upcoming amorphous electrical steel pilot plant.

3. Facility development for 24×7 controlled atmosphere testing conditions for the Creep Laboratory. The division is actively leading modeling activities in amorphous electrical steel project. The division is in the process of modernization of the CFD laboratory for validation of modeling results.

C. Basic Engineering Packages

BEP for setting up a 100TPD commercial plant for flux preparation for phosphorus removal from steel produced in neutral lined induction furnace has been developed.

D. Pilot plant/ Large Scale operation and maintenance

1. Support in conducting campaign in Magnesium pilot plant facility: Electrical & Instrumentation systems, Signal flow SCADA systems for the Magnesium pilot plant facility has been revived and brought into operations.
2. Construction of energy efficient brass melting furnaces in various clusters of Bengal, Jharkhand and Odisha, and demonstration to artisans to be self sufficient.
3. Support in carrying out campaigns in annealing simulator facility.
4. Installation of facilities for welding research laboratory which include Welding Simulator, Twin wire submerged arc welding (SAW) machine, High Speed imaging system for study of metal transfer phenomena in welding and Stereo Microscope. CMM and Robotic MIG equipment are planned to be installed in the coming months.

E. Skill Development

Every year the division provides training to about 30 trade apprentices. Last year the division inducted graduate and technician apprentices. Training to about 40 apprentices were provided. In addition skill development training in the area of welding was imparted.

F. Central workshop

The central workshop receives jobs from various divisions, for specimen preparation of different materials, fitting, machining and fabrication of prototypes and repairing of miscellaneous jobs. Major facilities available in the workshop are: CNC Lathe, Universal Milling, Shaper, Radial drill, Pillar Drill, Double column band saw, Shearing, Pipe bending M/C, TIG / MIG welding, EDM wire cut machine.

Team - Engineering

Works Services and Maintenance (WSM) Group :

This group has diverse responsibility to upkeep infrastructure, create new infrastructure, and renovation of facilities in the seven campuses including laboratory, pilot plant and residential areas. The services include civil engineering, electrical engineering and refrigeration and air conditioning, lifts, water supply, etc. The work accomplished by the group can be categorized in 3 major categories namely new infrastructure, renovation jobs and routine maintenance jobs. The infrastructure management team has successfully completed new facilities creation jobs, like, new work station for sheet forming machine, new work centre for physical modeling and process simulation laboratory, civil foundation work for installation of vibratory cup mill. The infrastructure management team has successfully completed several renovation jobs as well: renovation, extension & construction for setting up work centers in NML, modernization of work spaces Directors floor, mezzanine floor, creep laboratory and auditorium, water tower at old pump house, making foundation and installation of cooling tower, water proof roof treatment, creation of open offices, and bio-mimetic laboratory.

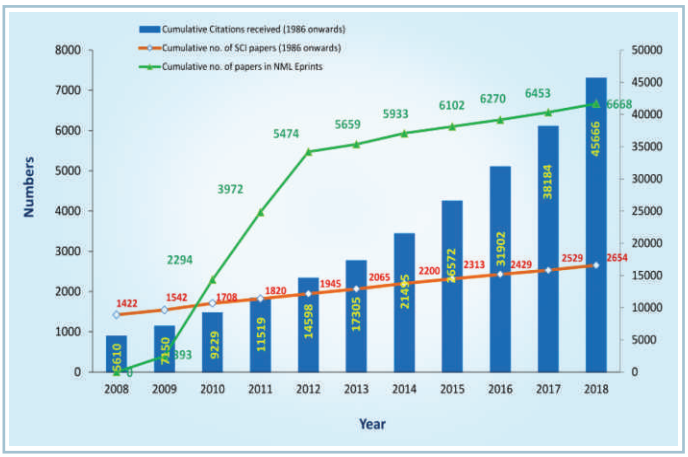
Engineering Targets Planned for 2019-2020

- In-house design and development of 5 Prototype models for R&D support and validations.
- DPR preparation for 2 In-house technologies for Technology transfer& Development.
- Competency development by training for 100 candidates in various trades under Skill development initiative
- Expansion of Welding laboratory by including cryolite bay area with it and its modernization by commissioning CMM, Robotic MIG, Abrasion cutter, Conventional Lathe, Material handling units, etc.
- Revival and modernizing of particle Image Velocimetry (PIV) equipment.
- Target of raising contract services for industries upto 10 Lakhs
- Target of doing in house job in central workshop upto 70Lakhs.
- Facility creation for Workshop to make "Single point contact" for catering all types of Mechanical support for catering Metallurgical research needs.

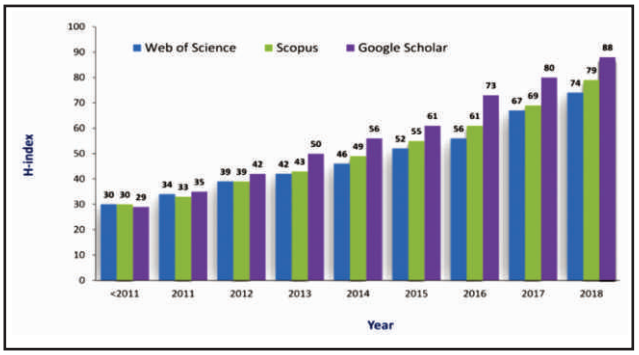
Knowledge Resources and Information Technology

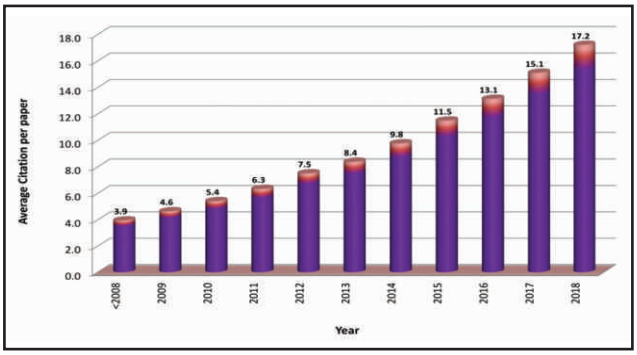
SCI Publications and Citations

177 research papers were published in SCI and NON-SCI journals from CSIR-NML during January-December, 2018. These papers are regularly uploaded in the Laboratory's Institutional Repository. The citation of the cumulative SCI publications (1986 onwards) from CSIR-NML has increased from 5610 (in 2008) to 45666 (till Dec 31, 2018) registering an increase of 8.14 fold in the citation growth. The average citation per paper is 17.21 against 15.10 in the last year. 134 articles received more than 75 citations/paper (source: Web of science / Google scholar) as on January 31, 2019.



Growth of Research Publications, Citation and NML IR (Eprints)

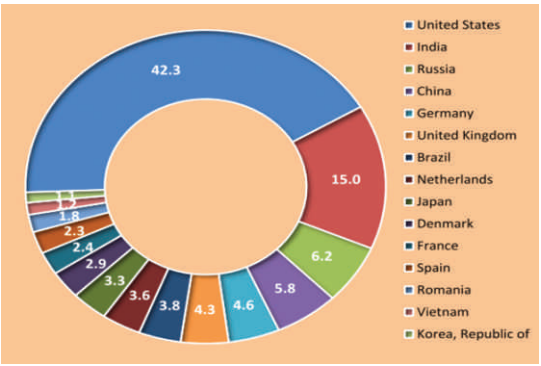




CSIR-NML H-index and Average Citation per paper

Institutional Repository

The CSIR-NML Institutional repository (http://eprints.nmlindia.org) has maintained its global visibility and achieved 17.3 fold increases in tariff, popularity with average hits of over 0.317 million per month and a cumulative over of 20.65 million hits since inception (2009). The researchers from 196 countries have accessed NML repository database. Among the global users, the top countries in decreasing order are United States, India, Russia, China, Germany, UK, Brazil, Netherlands, Japan, Denmark, Frances Spain, and so on.



NML Eprints in terms of No. of Countries & hits / downloads

Transparency Portal

The CSIR-NML Transparency portal (http://library.nmlindia.org/tp/index.htm) containing all information pertaining to staff pay & allowances, foreign and local travel, expenditure pattern, payment to the vendor, local purchase data, works and services, CAG report, etc. has been updated periodically. This cater to the information need of a citizen due to its global access. It can be mentioned here that CSIR-NML launched its transparency portal in May 2012.

Information under RTI Act

During the calendar year 2018, 93 applications were received and all of them were responded to within the time schedule. So far, no appeal was referred to Central Information Commissioner (CIC) for review. The data regarding RTI has also been uploaded in the laboratory's Transparency portal.

Information Products

- CSIR-NML Annual Report 2017-2018 (English & Hindi)
- CSIR-NML Brochures / Posters
- Director's Desk - November 2018
- CSIR-NML Record Book 2019
- Journal of Metallurgy & Materials Science (Diamond Jubilee Year 2018)

Team - KRIT

Research Planning and Business Development (RPBD)

The Division acts as an interface between the laboratory and the collaborators from Industry, Academia and Government. The Division is the first point of contact for the new clients who are seeking solutions for their R&D problems. Further, the Division serves as a gateway to reach the concerned technical area expert and helps the client to find appropriate solutions. The Division then suggests a feasible mode of collaboration and facilitates in completing all required formalities.

Figure 1 : RPBD as a Business Interface

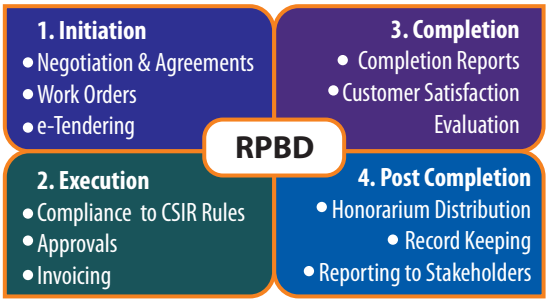


Figure 2: Role of RPBD during life cycle of aw R&D project

Technology Marketing

CSIR-NML has a bundle of Technologies and Products ready for commercialization, and a number of them are already in market. Second Edition of the "Technology Handbook" was published containing more than 60 technologies that CSIR-NML can presently offer. The Division strives to ensure that the Technological solutions on offer reach a suitable market place. Industrial /business meets and presentations are organized from time-to-time by the Division to create awareness amongst the industries of various sectors about the available technologies.

New Clients Added in 2018-19

1. Evergreen Recyclekaro (India) Pvt. Ltd. Mumbai
2. Jamshedpur Continuous Annealing & Processing Company Pvt. Ltd.
3. The Indo-French Centre for the Promotion of Advanced Research (IFCPAR, or CEFIPRA), France
4. LPSC, ISRO
5. Kanpur Metal Processors Pvt. Ltd., Kanpur
6. Kerala Minerals and Metals Limited
7. Proclaim Insurance and surveyors and loss Adjusters Pvt. Ltd., Kolkata
8. Shree Mahabir Refractory Works, Ranchi
9. The Singareni Collieries Co.Ltd, Telangana
10. Sree Rayalseema Hi-Strength Hypo Ltd., Andhra Pradesh

Technology Incubation

Aligning with the policy of central government to create a conducive entrepreneurial eco-system in India, CSIR-National Metallurgical Laboratory (CSIR-NML) established a section 8 company named CSIR-NML Technology Business Incubation Centre [NML-TBIC] at Jamshedpur.

IP Search and Analysis

Business Development group provides IP search and analysis services to its clients as well as in various projects undertaken by the Laboratory. The group comprises a dedicated team, having cutting edge tools and database resources to deliver such jobs to its clients on time. During 2018-19 the business Development group provided (i) IP search and Analysis, (ii) Evaluation of FTO Space, (iii) Patent Landscaping, (iv) Patent portfolio Analysis, (v) Patent Mapping, (vi) Patent Citation Analysis, (vi) White Space Mapping and (vii) Competitive Intelligence services in various technological domains in the area of Minerals, Materials and Metals.

The group has relevant expertise in providing competitive intelligence services by way of (i) Competitor Tracking/Profiling, (ii) Comparative Technology Evaluation, (iii) Market Assessment Studies, (iv) Strategic Grouping/Collaboration, (v) Patent SWOT Analysis, (vi) Patent Claim Analysis and Market Segmentation Analysis

Management Information Systems and Databases

A number of web based information systems and related databases continued to be developed and maintained in-house at CSIR-NML for the efficient overall functioning of the laboratory. These information systems and databases provide input for managerial decision making as well as support numerous key activities of the laboratory e.g. Project Information Management and Monitoring, Documents and Reports Management, Employee Profile Management, Human Resource (Competence and Man days Involvement) Management, Enabling Online Recruitment, Online In-house Projects Management. A number of databases are maintained in the division for smooth functioning and decision making of the management viz. Project, Invoice, Cash flow, Man-Days Involvement of Scientists, Project Completion Reports, Agreements, Equipment Utilization, Intellectual Property (Patents, Copyrights) and others.

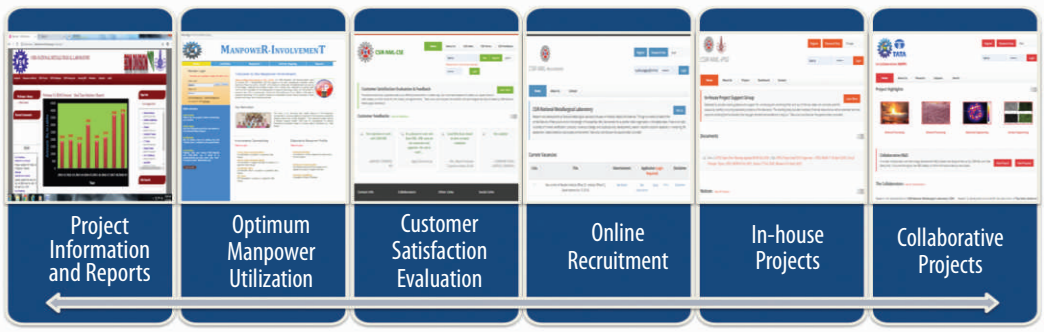
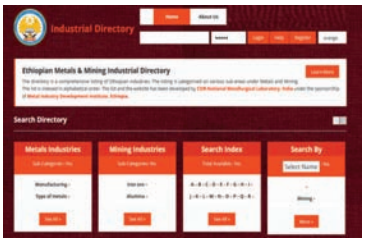


Figure3: E-Information Management in key functional areas of laboratory

Development of Web-based Information System for managing the National Databases pertaining to Ethiopian Industries, Equipments and Experts.

Under the Twinning Program between Council of Scientific & Industrial Research (CSIR), India and Metals Industry Development Institute (MIDI), Ethiopia, The Information Management Module is ongoing. The activities under the module include towards the development and implementation of three separate sub-modules to create web-based repositories and information management systems pertaining to the three national databases of Ethiopia. The work is ongoing and project team members from CSIR-NML have already visited MIDI for the work.



NABL Accreditation of Creep Laboratory

CSIR-NML, Jamshedpur is all set for NABL Accreditation of Creep laboratory in compliance with ISO/IEC 17025 Standard. A team comprising of scientists and officers of CSIR-NML have successfully coordinated the process. Lead Assessors (ISO 17025:2017) from M/s TUV SUD SOUTH ASIA PVT. LTD were instructors for the program. The complete process of Laboratory Accreditation of ISO 17025 was successfully conducted in four stages: (a) One Day Awareness Training Program on ISO 17025; (b) Internal auditor training and laboratory Quality Management System Training on Management Uncertainty and calibration; (c) Mock Audit & GAP Analysis against ISO/IEC 17025 and Understand Missing Requirements; (d) Document preparation: Quality manual, Quality Assurance Procedures, Laboratory Specific Forms, Instrument/Standard Operating Procedures. Certificates to the successful candidates were issued by M/s TUV SUD SOUTH ASIA PVT. LTD.

Training Programs

CSIR-NML organizes Corporate Training Programs (CTP) and Professional Training Programs (PTP) every year with dual perspectives. First is to enhance business prospects by collaboration with various industries and second is to enhance customer interaction. The CTPs focus on providing customized training packages to specific industry in the domain of CSIR-NML, whereas the PTPs are more generic in nature and intend to reach a number of participants from varied industries. Following trainings wereorganized at CSIR-NML during the reporting:

Corporate Training program (CTP)

Title of the Training	Industrial/Institution participation	Date of Training Programme	No. of Participants
Structural Integrity Assessment for Engineering Components (SIA 2018)	Indian Oil Ltd, Mathura Refinery and Oil India Ltd., Duliajan Assam.	August 6-10 2018	**11**
Mineral Characterisation and Beneficiation (MCB 2018)	Mining Mineral Resources (MMR), Democratic Republic of the Congo	October 3-5, 2018	**06**
Advanced Materials Characterization	Tata Steel	October & December 2018	**15**

Professional Training Program (PTP)

Sl. No.	Title of the Training	Industrial/Institution participation	Date of Training Programme	No. of Participants
1.	Laboratory Quality Management System as per NABL requirements (LQMS 2018)	TATA Steel, R S Safety & Calibration Consultancy, JAMIPOL, CSIR-NML	April 24-25, 2018	**23**
2.	Experimental Tools and Techniques for Materials Characterisation (ETMC-2018)	Usha Martin Limited, DRDO, Indian Oil Corporation Limited, Ramkrishna Forgings Limited, CSIR- Structural Engineering Research Centre	September 25-28 2018	**06**
3.	Metallurgical Failure Investigation of Engineering Components (MFIEC-2019)	RITES Limited, BPCL-Kochi, Tata Cummins, RDSO-Lucknow, Tata Power, ONGC, S. E. Railways	January 14-17, 2019	**13**

Skill Development programme:

Sl. No.	Title of the Training	Date of Training Programme	No. of Participants
1.	CSIR Integrated Skill Training Initiative Soft Skills for Quality Improvement (SSQi 2019)	February 27-28, 2019	**42**
2.	CSIR Integrated Skill Training Initiative Entrepreneurship Development On E-Waste Management (EDEM 2019)	March 12-15, 2019	**23**
3.	Advanced Training Program (on Manual Metal Arc Welding and Gas Cutting)	February 22- March 22 2019	**10**

Team-RPBD

Hindi Cell

The Hindi cell in the laboratory takes care of a number of activities during the year viz. translations of official letters and publications in Hindi and implementation of Official language in the organization. The cell also organizes a number of events around the year viz. Hindi Week Celebrations and Town Official Language Implementation Cell (TOLIC) meetings.

Activities for Hindi Implementation for TOLIC, Jamshedpur

CSIR-National Metallurgical Laboratory is the Secretariat of TOLIC, Jamshedpur. It has 58 Members from all the Central Govt. offices located at Jamshedpur and adjacent. Dr. Indranil Chattoraj, Director, CSIR-NML is Chairman of this committee. Under his Chairmanship this Committee is playing a vital role for enhancement of Official Language Hindi in these offices.

Official Language Implementation in the Laboratory

CSIR-National Metallurgical Laboratory, Jamshedpur has an active programme for the Implementation of Official Language, Rajbhasha Hindi. In addition to the regular official work and translations into Hindi, CSIR-NML proactively initiates a series of activities throughout the year which include: publications, conducting training, workshops, talks and annual competitions and divisional inspections for enhancement of Hindi use in the divisional activities.

Publications in Hindi

Annual Report, CSIR-NML Newsletter and Brochure are published in both Hindi and English languages and are circulated to CSIR units and various organizations of Govt. of India. Press releases are also being issued in Hindi and published in daily newspapers.

Promotional Activities for Hindi Implementation

- Four inspections are conducted by the cell covering all divisions and functionaries for identifying the probable areas of Hindi implementation / improvement as well as enhancing the use of Hindi in divisional activities.
- Incentive scheme for working in Hindi has been introduced and employees are actively participating in the scheme. Thirteen employees namely Shri Parmarth Suman, Shri Sanatan Naiya, Md. Nayeem Ansari, Shri Shekhar Sanga, Shri Rachit Ghosh, Shri Rabi Ranjan Kumar, Shri Amber Tirkey, Shri Jitendra Chaudhary, Shri Rohit Mudi, Shri Santosh Kumar Rai, Shri G. Dharma Rao, Shri Amit Prakash and Shri C.R. Chakraborty were awarded in the reporting period, under the scheme.

Hindi Workshop

- Four Table Workshops were conducted in Administration in the reporting year. The objective of the workshops were two folds, first was to address the issues encountered while preparing the Quarterly Hindi Progress Report, Hindi Noting and Drafting and second was to impart training of Unicode.

Hindi Week Celebrations

- On the occasion, Hindi competitions for NML Staff and Officers were organized from 17th to 24th September, 2018. The competitions included: Essay writing, Noting/Drafting, Hindi dictation and Self-written poetry recitation etc. On the Occasion of Self-written poetry recitation Dr. S.K. Narang, Retired Scientist, CSIR-NML, Jamshedpur judged the participants and delivered a lecture on the tradition of Hindi Poetry. On the occasion of the Valedictory function Shri Rajesh Kumar Ray, Prasar Bharati, All India Radio, Jamshedpur graced the function as the Chief Guest. All the winners were felicitated with prizes and certificates on the occasion of Hindi day celebration on 24th September, 2018.

Information Technology Group (ITG-KRIT)

The Information and Communication Technology Group caters and co-ordinates lab wide needs for IT resources and management in terms of creation of IT infrastructure and its maintenance. The unit is mainly looking after the development of IT facilities & infrastructure at CSIR-NML from basic to advanced level. It takes care of efficient management of IT resources within the laboratory,viz, timely up-gradation of existing IT systems with the latest technology, management and maintenance of the overall IT systems as well as the networks. The unit is well equipped with computational facilities in terms of hardware and software. The team ICT has scientists and officers who are actively involved to support the R&D activities performed in the lab by providing secure IT infrastructure and uninterrupted Internet facility. ICT Unit is taking care of the management and maintenance of LAN infrastructure of around 550 nodes at NML Main Campus with 100 Mbps (1:1), around 80 nodes at LSTF Area with 34 Mbps (1:1) Leased Line Internet Connectivity. Entire campus of CSIR-NML is covered by Wifi having more than 200 wireless equipments connected to it. ICT Unit is maintaining more than 15 servers to cater various infrastructure services. NML is making use of the IT infrastructure primarily for data transfer, communication, exchange of manuscripts and data with authors and referees, Email communication, ERP, conducting interviews, important meetings around the globe through video conferencing/ Skype,etc.

New activities 2018-19

Team- ITG

As a part of the e-procurement initiative by the CSIR HQ, New Delhi, CSIR-NML has also successfully implemented all its eligible procurement processes through the e-procurement portal developed and maintained by NIC. IT group takes care of the preparation the prerequisites including digital certificate specification. The installation of the same is being done by IT group for its internal users. In order to make the quarter allotment amongst its staff, IT group has developed web based system that computerized some of the processes. This would increase transparency of the said process. The portal can be accessed by CSIR-NML permanent staff from any part of the world. A variety of new scientific software have been procured by respective researchers and those have been put into the license server centrally configured and managed by IT group for CSIR-NML internal usage . These scientific software cater the need of R&D activities of CSIR-NML researchers.

In-House Research Project Support Group (*i*-PSG)

In-house Project Support Group (i-PSG) at CSIR-NML supports 'research projects' directed towards improvement in performance, relevance and impact of research undertaken. The in-house project support group aims to focus research areas at CSIR-NML confined to three research categories:

(A) **Thematic Research :** Themes which are generally virgin as far as CSIR-NML is concerned with the larger interest of the future of the laboratory in mind and are identified by the i-PSG along with HoD's and GL's. Each theme is nurtured by a Theme champion. There are six thematic research areas – (1) Fine Particles Processing (2) Advanced separation processes (3) Advanced Engineering Materials (4) Advanced Manufacturing Technologies (5) Environment, Energy and Resource Management and (6) Modelling & Simulation.

(B) **Technology development :** Technology development projects aim to yield a feasible technology at the end of the project.

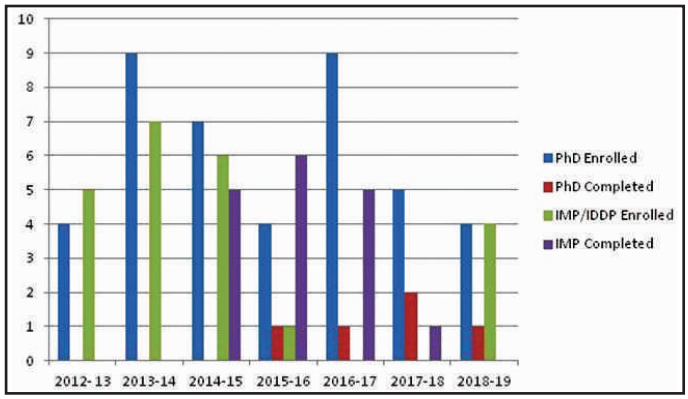
(C) **Scholastic Research :** Scholastic projects aim at supporting the research under AcSIR and scientist pursuing academic excellence at IIT's and other reputed institutes.

Fifty in-house projects were executed during the year 2018-19. In addition to the patents filed, the sponsored projects and the conference proceedings, there are also significant publications in SCI journals from the i-PSG projects. 'Shilowbhadra Banerjee Award-2018' for the Best In-house Research Project was conferred to Dr. D. Paswan, Dr. M. Malathi, Dr. D. Bandopadhyay, Mr. Manjit Singh and Mr. R.C. Mahato for their project (OLP-0283) on 'DRI production by Mill scale' (Figure1). The numbers of research projects supported by i-PSG during 2018-19 are **Thematic Research (11), Technology Development (10), Scholastic Research (4) and Others (25).**

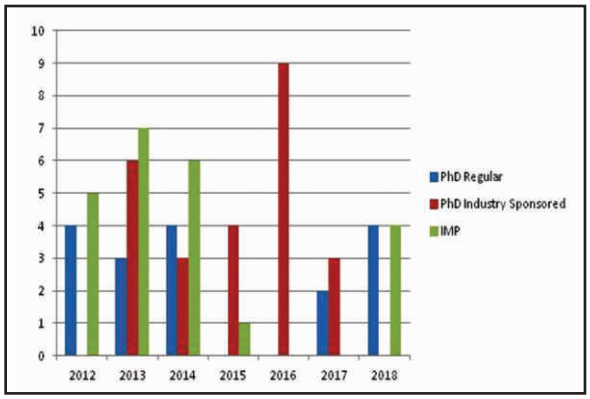
Figure 1: Dr. D. Paswan, Dr. M. Malathi, Dr. D. Bandopadhyay, Mr. Manjit Singh and Mr. R.C.Mahato received 'Shilowbhadra Banerjee Award-2018' for the Best In-house Research Project (OLP-0283) 'DRI production by Mill scale'.

Academy of Scientific and Innovative Research (AcSIR)

In 2018-19, 4 students have been admitted to the IDDP programme and 4 students in the Ph.D. programme. After enrollments in the current session, the total strength of Ph.D. students in AcSIR is 55. All the IDDP students have been awarded CSIR-GATE-JRF. PhD student Mr. Y. Rajshekhar was awarded the Ph.D. degree in December 2018.



Student Enrollment and Completion of Degree



Student Strength in different academic sessions at AcSIR-NML

AcSIR Faculties & Students

Administration

Administration provides a variety of support services for conducting R&D in the laboratory. The division has aligned itself to realize the vision of CSIR-NML and facilitates the overall system towards meeting the set goals and targets. The division has significant roles to play in every facet of career development of the staff as well as providing sustained care right from their recruitments to superannuation, and most of the times even after superannuation i.e. the pensioners. Administration connects all staff members from single nerve line and facilitates in fulfilling the various vital needs of staff viz. academic, career, housing and health in the following manner:

- Formulate and implement the policies concerning administrative procedure for smooth functioning of the laboratory.
- Provide advice to the functional bodies (committees / functional groups) within the organization.
- Maintain liaison with CSIR Headquarters on matters related to administration.
- Provide healthy working conditions and atmosphere to the laboratory by correct interpretation as well as implementation of governing rules and regulations.
- Assist authorities of the laboratory viz. Director, Advisor Management, Head Human Resource Group, for decisions on matters of administrative nature.
- Implement instructions of the Director on various matters.
- All the Scientific, Technical and Administrative Recruitment including Compassionate Appointment and their assessment / promotion are done in a time bond manner.

The division is headed by the COA, over all In-charge of the activities and supported by Administrative Officers, Section Officers, and a group of assistant section officers and other supporting staff. The division also includes a health care centre, security services and Hindi cell. The health care centre is run by two Medical Officers and supported by a group of staff assisting the officers in providing medical facilities for all staff. The security services for the laboratory are provided by the security department which is headed by the Senior Security Officer and supported by the Senior Technician-II. The Hindi cell is headed by the Senior Hindi Officer and supported by Junior Translators of Official Language Division ("Rajbhasha Vibhag").

In the recent past, Administration has undergone major shift in terms of work culture and towards implementing paperless processes. An improved work culture and decentralized leadership at all levels has been introduced to bring the desired changes. A trend of faster service delivery system has been inculcated in the staff to match with the expectations of CSIR-Enterprise Transformation initiative. The initiative was undertaken by CSIR to focus on building electronic workplaces and re-engineering processes for augmented service delivery by implementing the integrated ERP system through Internet Communication Technologies interventions.

Team - Administration

Stores & Purchase

The Stores & Purchase Division is mainly responsible for procurement of capital equipment, spares and consumable items. Different committees like Technical & Purchase Committee, Purchase Committee, Equipment Prioritization Committee and Standing Disposal Committee help the division in arriving at suitable decisions as per CSIR Purchase Rules of Goods & Services, 2008, and GFR 2017. Major procurements for which orders have been placed during 2018-2019 are:

1. Instrumented Universal Electro-Hydraulic Sheet Metal Forming Machine
2. 3-D Optical Microscopy Based Profilometer
3. TGA-QMS System for High Temperature Oxidation studies of Metals and Alloys
4. Magnetic Characterisation System for Amorphous Alloys in the form of Ribbons
5. Fixed Bed Coke Making Oven
6. Thermogravimetric Analyzer
7. Fully Automatic Isoperibol Calorimeter.

Apart from the above several other equipment, accessories and spares were ordered. The S&P Division also processes Annual Maintenance Contract for all the major equipment of the Institute.

The division has taken up a challenging task of implementation of the ERP, E-Procurement through CPP portal and procurement through Government E-Market (GeM) platform, with the objective of automation of processes and paper less office. It is coordinating with the CSIR Team and others in ensuring a speedy implementation towards ERP, E-Procurement and GeM. Apart from the normal task of procurement and maintenance of equipment and facilities, the division is sending bills through newly launched Accounting Software for timely and speedy payments.

The Stores & Purchase Division is headed by the Stores and Purchase Officer and respective Section Officers and supported by a number of Assistant Section Officers and Assistants. Stores and Purchase Section is a team of hardworking professionals working under the leadership of the Stores and Purchase Officer. The division strives to keep the system of R&D and other supporting services running in smooth condition by taking care of procurement activities related to materials / services in time and within the ambit of public procurement.

Team - Stores & Purchase

Finance & Accounts

The Finance & Accounts Division of CSIR-NML is actively engaged in planning, organizing, directing and controlling the financial activities of the Lab including accounting of all the financial transactions of the year as per GFR and CSIR guidelines. This division provides a central accounting and financial statement to Director, CSIR-NML and other stakeholders by employing a management information system. In the reporting year the new accounting software "Accounts Manager" has been implemented all across CSIR and its constituent Laboratories. This software enables all the stakeholders to get real-time financial information at their own desk.

Following are the major activities of the division

- Preparation of budget estimate and revised estimate for CSIR-NML and submitting the same to CSIR for allocation of funds.
- To ensure adequate funds availablity to acquire the resources needed to help the organization to achieve its objectives.
- To ensure cost control while facilitating adequate spending within laid down guidelines and procedures in the matter.
- To ensure adequate cash flow and proper management of funds through transfer of funds from CSIR as well as additional allocation, if any.
- Implementation of ERP system in Finance & Accounts Division to establish a procedurally correct and accurate system with cost effectiveness.
- To provide appropriate financial information relating to different heads of accounts and projects to the Director, Project leaders and other decision makers so that informed judgments and decisions are made. Posting of monthly progressive expenditure in CSIR-NML intranet to keep all employees informed about fund position.
- To prepare financial documents such as Receipts and Payments account and Balance Sheet of the organization on a given date for submission to CSIR and decision makers including submission to CAG (Audit) for certification of accounts.
- Preparation and submission of utilization certificate to sponsors of the projects as and when required.
- Pre Audit of all the bills before making final payment to avoid any irregularity or deviation from the financial rules.
- Promptly, accurately and efficiently recording all receipts and payments in the relevant ledgers and books of accounts.
- Closing of GPF/CPF accounts, remittance of funds to NSDL relating to New Pension Scheme and remittance of service tax, income tax, etc. within schedule date to appropriate authority.
- To provide progressive report returns on monthly expenditure, OB, Bank reconciliation, Audit Paras, etc,to maintain transparency.

Performance Highlights for the Financial Year 2018-19

1. Utilized Budget Grant allocated by CSIR- Rs. 6588.289 lakhs + Rs. 4075.259 lakhs (pension)
2. Utilization from Laboratory Reserve- Rs.130.273 lakhs
3. Successfully handled two CAG audits (Certification and Transaction) during the year. 8 out of 26 outstanding CAG Audit Paras have been settled during this period.
4. Generation of EBR by investment of surplus funds- Rs.503.319 lakhs
5. Settlement of 205 numbers of outstanding advances (O.B.) amounting to - Rs. 379.089 lakhs
6. Generation of Lab Reserve - Rs. 1511.549 lakhs.
7. Bank reconciliation of the Cash Book completed up to 31st March, 2019

Team - Finance and Accounts

NASI-NML Activities

The National Academy of Sciences, India, Jharkhand Chapter *envisions to empower the pupils of Jharkhand by developing scientific temper and a balanced rational approach towards life from a young age. In this connection a number of events are coordinated each year by the Chapter in association with CSIR-NML. In 2018-19 the significant events organized jointly by CSIR-NML and NASI are highlighted herein after:*

Prof. Meghnad Saha Memorial Inter-state Science Exhibition

In association with CSIR NML and Rajendra Vidyalya, Jharkhand State Chapter of The National Academy of Sciences, India (NASI) organized the first Professor Meghnad Saha Memorial Science Exhibition on September 15th, 2018 in the premises of Rajendra Vidyalya. This event was the first in a series of events planned to celebrate the life and teachings of the great Indian Physicist and the founder president of NASI, Professor Meghnad Saha, to commemorate his 125th birth anniversary. The exhibition included display of the scientific models, poster and power point presentations by the students of different schools of the city and nearby areas on one of the three topics, namely, health management, environment, and technologies for the future. 110 students and teachers from 22 schools belonging to Jamshedpur, Chaibasa, Deoghar, Ranchi and Chandil participated in the event. The prizes were given away to the winners respectively along with a citation during a NASI function at CSIR NML on Oct 5th, 2018. The ten best performing teams were also invited by CSIR-NML on Sept 28th to display their models and posters during an outreach program of Vigyan Bharati.

Figure 1: Inauguration of Professor Meghnad Saha Memorial Science Exhibition.
Students demonstrating Scientific Models & presenting new ideas

Prof. Meghnad Saha Memorial Lecture

NASI, Jharkhand chapter, in association with CSIR NML celebrated the life and teachings of Prof Saha by organizing the Prof Meghnad Saha memorial Lecture at CSIR NML on Oct 6th, 2018. Prof. Sankar Pal, former Director of ISI Kolkata, delivered the Prof Meghnad Saha Memorial lecture entitled "Evolution and challenges of Machine Intelligence to Data Science". The lecture deliberated on the anticipated role of machine learning in Big data technology revolution where India aims to strengthen its hold. More than 250 students from NTTF, Cooperative College, and Graduate College, attended the program and had a wonderful interactive time with Prof. Sankar Pal. The program concluded with prize distribution of the NASI's Interschool Science Exhibition Competition held at RV School, Jamshedpur. Chairman, NASI

Jharkhand Chapter, also felicitated Mrs Rakhi Banerjee, Principal of Rajendra Vidyalya, Jamshedpur for her support towards the chapter activities.

Figure 2: Professor Meghnad Saha Memorial lecture delivered by Prof. Sankar Pal

National Science Day & Best Science Teacher Award

The Jharkhand Chapter of NASI jointly with CSIR-NML celebrated the National Science Day on 28th February 2019 with great pomp and show. Dr D P Duari, Director, M P Birla Institute of Fundamental Sciences & M P Birla Planetarium, Kolkata was the Chief Guest of the function. In addition to CSIR-NML Scientific and technical staff, more than 200 students from Jamshedpur based institutions, like Jamshedpur Women's College, NIT Jamshedpur, ARKA Jain College and the Graduate College participated in the programme. The Chief Guest, Dr. D P Duari, delivered a popular science lecture on "Concepts and Challenges in Astronomy". In his lecture Dr. Duari, an associate of NASA, opened the secrets of universe, very systematically and elaborated on different cosmological phenomena. He talked in detail about Mars and Mars mission of India and its significance for human race at large. The Best Science Teacher Award(s) for Jharkhand state were also given away on this day by the Chapter. Dr. Tapas Ghosh, of DPS-Ranchi, and Ms Sushmita Sikdar, KPS-Mango, Jamshedpur were awarded for being the best science teachers in the reporting period.

Figure 3: National Science day celebrations at CSIR-NML jointly organized with NASI, Jharkhand Chapter

On Health- Hygiene & Nutrition

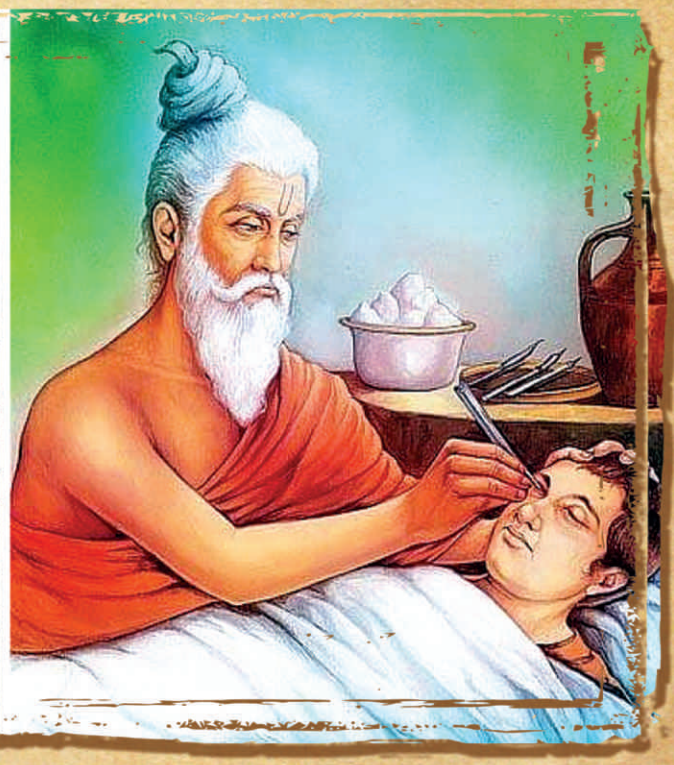
In keeping with the theme of NASI -"Science for the Society", Jharkhand state chapter has undertaken the responsibility of implementing a project entitled "Health, Hygiene & Nutrition Solutions for Scheduled Tribes of Jharkhand", as a joint initiative of Jharkhand State chapter of The National Academy of Sciences, India , CSIR-National Metallurgical Laboratory, Jamshedpur & FAITH in India (an NGO from Jamshedpur). The main objectives of the program include: education to mostly tribal villagers on healthy lifestyle, healthy food habits, prevention and cure of common diseases, proper sanitation, safe water, proper utilization of water, safe surroundings, personal & community hygiene. During 2018-19, the following programs have been organized:

1. Weekly nutrition awareness among the natives of Dhuan and Chirugora village through councilors. Emphasis was given on nutrition needs of children and house wives.
2. Awareness workshop on Health, hygiene and nutrition.
3. Health survey through medical camp at Chirugora.
4. Vigyan Choupal at Chirugora.
5. Survey of drinking water quality.
6. Health-hygiene and nutrition awareness camps at schools.
7. Joining FAITH in India towards constructing toilets in the village Chirugora

Figure 4: Medical camp, Health-Hygeine & Nutrition Workshop and Vigyan Choupal under tribal project.

RECOGNITIONS & ACHIEVEMENTS

Science & Technology in Ancient India



Cataract Surgery

First cataract surgery performed by the ancient Indian physician Sushruta, in 6th century BCE.

He used a curved needle Jabamukhi Salaka, to loosen the lens and push the cataract out of the field of vision.

Science & Technology in Ancient India

International and National Awards & Recognitions

Prestigious Fellowships

Dr. Abhilash
Sr. Scientist

CSIR Raman Research Fellowship 2018-19

Dr. Suman Kumari Mishra
Chief Scientist

Elected as Fellow National Academy of Sciences (NASI)India in the year 2018

Co-authored a book on "Superplasticity".

Dr. S. Ghosh Chowdhury
Chief Scientist

Outstanding Reviewer Awards

Dr. Trilochan Mishra
Sr. Principal Scientist

- Outstanding Contribution in Reviewing by Applied City Science ELSEVIER in June 2018

- Outstanding Contribution in Reviewing by Microporous and Mesoporous Materials in May 2018.

Dr. Manis Kumar Jha
Principal Scientist

- Outstanding Contribution in Reviewing by Journal of Rare Earths ELSEVIER in June 2018
- Outstanding Contribution in Reviewing by Separation and Purification Technology ELSEVIER in April 2018.

- Received the RCR 30 in 30 Award for the published paper entitled "Review of hydrometallurgical recovery of zinc from industrial wastes" in 2001 in Resources Conservation and Recycling ELSEVIER

- Misra Award: IIME Best Paper (Published) Award-2017 in Electro-Hydro and Bio-Processing category for paper entitled "Clean process for recovery of metals and recycling of acid from the leach liquor of PCBs"

Editorial Board/ National/International Committee Memberships

Dr. Trilochan Mishra
Sr. Principal Scientist

- Editorial Board Member of International Journal of Materials and Chemistry (SAP USA)
- Editorial Board Member of American Journal of Physical Chemistry (Science publisher USA)
- Editorial Board Member of Open Chemical Engineering Journal (Bentham Publisher)
- Member of Bureau of Indian Standards (BIS) for Inorganic Chemical Section Committee (CHD-1)

Dr. Manis Kumar Jha
Principal Scientist

- Editorial Board Member of an International E-Magazine Manthan ISSN no. 0974-6331 (Managed by NRI)

Dr. Abhilash
Sr. Scientist

- Editorial Board Member of an International Journal of Mineral Processing and Extractive Metallurgy Review-Taylor & Francis.

Best Paper/Poster Presentation Awards

Authors	Details	Conferred During or By
 **Ms. Charu Singh** CSIR-SRF  **Dr. SK Tiwari** Sr.Principal Scientist  **Dr. Raghuvir Singh** Sr.Principal Scientist	Best Paper Award for the paper "Effect of heat treatment of AZ91 magnesium alloy on the electroless Ni-P deposition"	International Conference "Advanced Material and Manufacturing Processes (ICAMMP)-2018" Jawaharlal Nehru Technological University KakinadaVizianagaram

Authors	Details	Conferred During or By
 **Dr. Saswati Chaklader** CSIR-N-PDF	Second Best Poster Award on the topic "Coal Water Slurry Fuel: Could Micronization of Indian Coal prove Beneficial under the theme" Sustainable Process Technologies" 	SEFCO 2018 CSIR-IIP Dehradun
 **Dr. Pratima Meshram** Sr. Scientist	Best oral presentation for the paper entitled "Spent Nickel Hydride Batteries- A Rich Secondary Resource of WEEE for Rare Earth Extraction"	International Conference on Science Technology and Applications of Rare Earths (ICSTAR-2018)
 **Dr. Sanjay Prasad** Principal Scientist	First prize in oral presentation for the paper entitled "Preparation of zinc powder from zinc dross" Authors: Sanjay Prasad Principal Scientist S K Maity Principal Scientist Aarti Kumari Scientist N S Randhawa Sr. Technical officer(1) and M Chandra Shekhar Sr. Technical officer(3)	32nd National convention of Institution of Engineers
 **Ms. Rekha Panda** CSIR-SRF  **Dr. Manis Kumar Jha** Principal Scientist	Best Poster Award for paper entitled "Process flow-sheet for the recovery of precious metals from e-waste"	International Seminar on Mineral Processing Technology (MPT 2018)Indian Institute of Technology (ISM) Dhanbad
	Best Poster Award for paper entitled "Recovery of gold from industrial effluent using adsorption technique"	International Conference on Environmental Challenges & Sustainability (ICECS 2018) Central University of Jharkhand (CUJ) Ranchi

Authors	Details	Conferred During or By
 **Ms. Archana Kumari** CSIR-SRF  **Dr. Manis Kumar Jha** Principal Scientist	Second Prize for poster presentation for the paper entitled "Sustainable environmental processes for rare earth metals (REMs) recovery from various resources: Indian context"	International Conference on Environmental Challenges & Sustainability (ICECS 2018) Central University of Jharkhand (CUJ) Ranchi
 **Ms. Rekha Panda** CSIR-SRF	• Young Scientist Award for paper entitled "Hydrometallurgical processing of E-waste to recover precious metals" • Young Scientist Award for paper entitled "Rare earth metals recovery from waste materials"	7th Bihar Science Conference 2018 College of Commerce Arts & Science Patna
 **Dr. Sanjay Prasad** Principal Scientist  **Dr. Shyamal Kr. Maity** Principal Scientist  **Ms. Aarti Kumari** Scientist  **Dr. M Chandra Shekhar** Sr. Technical Officer	Best Poster Award for paper entitled "Development of a process for the production of zinc powder from zinc dross" 	Micro symposium on recent developments in mineral processing and mechanical activation of solids CSIR-NML Jamshedpur
 **Preeti Karmakar** Project Assistant  **Ms. Suhani Kumari** Project Assistant  **Dr. Devabrata Mishra** Principal Scientist  **Dr. (Ms.) Archana Agarwal** Chief Scientist  **Dr. Kamala Kant Sahu** Sr. Principal Scientist	Best Paper Award for the paper "Selective Removal of Iron from Acidic Cobalt Chloride Solution by Solvent Extraction Using Alamine 336"	National conference on "WASTE TO WEALTH IN MINERAL AND METALLURGICAL INDUSTRIES (WWMMI)" during March 09-10 2018 organised by The Indian Institute of Metals, Bhubaneswar Chapter and CSIR-Institute of Minerals and Materials Technology Bhubaneswar in Collaboration with National Aluminium company Bhubaneswar.

Authors	Details	Conferred During or By
 **Dr. Saswati Chakladar** CSIR-N-PDF	 Best Paper Award	ICEE 2018 held at NIT Calicut Kerala during March 09- 10 2018

CSIR Foundation Day Awards

Essay Writing Competition

Winners (Hindi)

1st

Mr. Shashikant Chowdhury
Sr. Technical officer

2nd

Mr. Bhupeshwar Mahato
Sr. Technical officer

3rd

Mr. Krishna Kumar
Scientist

Winners (English)

1st

Ms. Sneha Mukherjee
Project Assitant

2nd

Dr. Sashwati Chakladar
CSIR-N-PDF

3rd

Mr. Robert Barla
Section Officer (F&A)

Meritorious Children Awards to the wards of Staff for Academic Excellence

i) One time lump sum cash award for securing 90% marks or above in each of minimum three science subjects in the Senior Secondary Examination (12th class) held in 2018. Mr. Hrishik Sagar S/o. Dr. Sarmishtha Palit Sagar Sr. Principal Scientist scored 96.33%.

ii) One time lump sum cash award for securing 100% marks in any science subject in 12th class held in year 2018. Mr. Hrishik Sagar S/o. Dr. Sarmishtha Palit Sagar, Sr. Principal Scientist scored 100% marks in Computer Science.

Mr. Hrishik Sagar
S/o. Dr. Sarmishtha Palit Sagar

CSIR-NML Foundation Day Awards

P. Ramachandra Rao award for Best employee (Technical)

Dr. Navneet Singh Randhawa
Sr. Technical officer

Mr. Manoj Kumar
Sr. Technnician

P. Ramachandra Rao award for Best employee (Non-Technical)

Smt. Prabha Srinivasan
Sr. Stenographer

Mr. Kumar Rahul
Section Officer

Altekar Award for Best Technology

For the paper "Quick repairing material from geopolymerisation from fly ash and granulated blast furnace slag".

Dr. Sanjay Kumar
Sr. Principal Scientist

Mr. Rohit Meshram
Scientist

Nijhawan award for the best technical paper published from CSIR-NML in the calendar year 2017

For the paper "Simultaneous twinning nucleation mechanisms in a Fe-Mn-Si-Al twinning induced plasticity steel"

Mr. Bhupeshwar Mahato
Sr. Technical officer

Shilowbhadra Banerjee Award

For the inhouse project "DRI production by Mill scale"

Dr. Dayanand Paswan
Sr. Scientist

Dr. M Malathi
Sr. Scientist

Mr. Manjit Singh
Sr. Technical officer

Dr. Debajyoti Bandopadhyay
Chief Scientist

Mr. Ram Chandra Mahato
Sr. Technician

S.P. Mehrotra Award

Dr. Dayanand Paswan
Sr. Scientist

For the best speaker in Colloquium series held at CSIR-NML in 2017-18

Special Appreciation Award for 2018

Md. SA Akhtar Ali
Laboratory Assistant

Mr. Bir Bahadur Sharma
Laboratory Assistant

Meritorious Children Award to the Staff Children

(for securing high marks in class Xth and/or XIIth exams)

S. Trisha
(Dr. J. Swaminathan)

Aditya Upadhyay
(Dr. AK Upadhyay)

Sayak Mandal
(Dr. SK Mandal)

Srikar Verma
(Dr. Ranu Verma)

Dibyaranjan Mishra
(Dr. Trilochan Mishra)

Ivan Jacob Thomas
(Dr. TC Alex)

Hrishik Sagar
(Dr. Sarmistha Sagar)

Utkarsh Lal
(Capt. Rajesh Lal)

Antara Sahoo
(Dr. KL Sahoo)

Vigilance Awareness- Slogan Competition

FIRST

Mr. Amit Prakash
Sr. Technical officer

SECOND

Mr. Abhilash Mishra
Project Assistant

Vigilance Awareness- Poster Competition

FIRST

Mr. Amit Prakash
Sr. Technical officer

SECOND

Md. Nayeem Ansari
Section Officer

THIRD

Ms. Roshani Singh

Hindi Week Competitions

Hindi "Shrut Lekhan"/ Dictation Writing Competition

Winners (Non-Hindi Mother Tongue)

FIRST

Mr. Sudip Kundu
Sr. Scientist

SECOND

Mr. Nimai Halder
Sr. Technical officer

THIRD

Mr. V. Rajnikant
Sr. Scientist

Hindi "Nibandh Lekhan"/ Essay Writing Competition

Winners (Non-Hindi Mother Tongue)

FIRST

Mr. Sudip Kundu
Sr. Scientist

SECOND

Ms. Suchitra Bhatta
Jr. Stenographer

Hindi "Nibandh Lekhan"/ Essay Writing Competition

Winners (Hindi Mother Tongue)

FIRST

Mr. Shashikant Chowdhary
Sr. Technical Officer

SECOND

Mr. Abhilash Mishra
Project Assistant

THIRD

Mr. Rohit Mudi
Junior Secretariat Assistant

CONSOLATION

Mr. Tipu Kumar
Sr. Technical Officer

Hindi "Kavya Path"/ Poetry Recitation / Writing Competition

Winners (Non-Hindi Mother Tongue)

FIRST

Ms. Pradipta Das
Project Assistant

SECOND

Ms. Suchitra Bhatta
Jr. Stenographer

THIRD

Mr. Anuj Mohan Pradhan
FAO

CONSOLATION

Mr. Sanatan Naiya
Sr. Technician

Winners (Hindi Mother Tongue)

FIRST

Dr. Arvind Kumar Arya
Sr. Medical Officer

SECOND

Dr. Pratima Meshram
Sr. Scientist

THIRD

Ms. Chanchala Kumari
Project Assistant

CONSOLATION

Mr. Abhilash Mishra
Project Assistant

"Prashansha Patra" Certificate for doing official work in Hindi Language

Mr. Parmarth Suman
Assistant Section Officer

Mr. Sanatan Naiya
Sr. Technician

Md. Nayeem Ansari
Assistant Section Officer

Prashansha Patra/ Certificate for doing official work in Hindi Language

Mr. Sekhar Sanga
Jr. Stenographer

Mr. Rachit Ghosh
Sr. Technical Officer

Mr. Ravi Ranjan Kumar
Junior Secretariat Assistant

Mr. Amber Tirkey
Section Officer

Mr. Jitendra Choudhary
Sr. Stenographer

Mr. Rohit Mudi
Junior Secretariat Assistant

Mr. Santosh Kumar Rai
Multi Tasking Staff

Mr. G. Dharma Rao
Multi Tasking Staff

Mr. Amit Prakash
Sr. Technical officer

Mr. C. R. Chakraborty
Multi Tasking Staff

CSIR-Foundation Day Essay Competitions

Winners of
"SWACHHTA PAKHWADA"
Essay Competition (Hindi)
Topic: "Clean India Healthy India"

FIRST

Mr. Amit Prakash
Sr. Technical officer

SECOND

Mr. Rohit Mudi
Junior Secretariat Assistant

THIRD

Mr. Piyush Ranjan
Junior Secretariat Assistant

Winners of
"SWACHHTA PAKHWADA"
Essay Competition (English)
Topic: "Clean India Healthy India"

FIRST

Mr. Rachit Ghosh
Sr. Technical Officer

SECOND

Mr. Raj Kumar Vishwakarma
Project Assistant

THIRD

Miss Snehlata Daizy Jojo
Project Assistant

Winners of
"SWACHHTA PAKHWADA"
Debate Competition
Topic: "Development is incomplete without Hygiene"

FIRST

Miss Priya M. Toppo
Junior Secretariat Assistant

SECOND

Dr. AK Arya
Sr. Medical Officer

THIRD

Mr. Rohit Mudi
Junior Secretariat Assistant

Horticulture Awards

3rd prize in the
GARDEN OF THE YEAR-2019
Competition in the
"Institution" Category

38 awards in different categories in **30th Annual Flower show** Jamshedpur

CSIR-NML Team awarded by Local Administration for organizing cultural events peacefully in the residential colony

Runners-up in Cricket in the inter CSIR 50th SSBMT Outdoor Tournament held at Dhanbad.

Invited Lectures Delivered

Dr. Amitava Mitra
Chief Scientist

- "Amorphous Electrical Steel", "INDIAN STEEL 2019"January 22-24, 2019 organised by Ministry of Steel and FICCI, Mumbai.
- Keynote address on "Evaluation of Residual Stress in Component using Electromagnetic Technique" at National conference on NDE-2018, December 19-21, 2018,Mumbai.
- "Advanced Electromagnetic Techniques for Residual Stress Evaluation of Components subjected to Fatigue Damage" at"All India Seminar on Residual Stress and Advanced NDE Techniques for Structural Intigrity Assessment- Key Challenges & Remedies, May 16-17, 2018, NIAS, Bangalore
- "Amorphous Steel- A New Generation Electrical Steel" at Indian Institute of Engineering Science & Technology, Shibpur, West Bengal on April 06, 2018

Dr. Ratnakar Singh
Chief Scientist

"Development of technology for beneficiation of low and lean grade iron ores for iron and steel making" International Seminar on Mineral Processing Technology (MPT - 2018) IIT (ISM) Dhanbad 10-12 October 2018

Dr. Trilochan Mishra
Sr. Principal Scientist

- "Recent Advances in Materials for Sustainable Energy" National conference IIT(ISM) Dhanbad 02-04 March 2018
- "Advanced Materials for Energy and Environmental Applications" National conference 12-14 December 2018
- "Green and Efficient Energy Technology and materials" International conference Central University of Jharkhand Ranchi 06-08 March 2019

Invited Lectures Delivered

Dr. Sarmishtha Sagar
Sr. Principal Scientist

- Invited speaker at NDE 2018 Mumbai December 2018
- Keynote speaker at AEMSD 2019 held at NML jointly by Inst of Engg Tata Steel & NML 18-19 January 2019

Dr. Manis Kumar Jha
Principal Scientist

- "Hydrometallurgical processing of titanium minerals especially related with new trends and prospect on the processing of the ilmenite in India" KIGAM South Korea 13th November 2018
- "Exploration of the utilization of E-waste for valuable metal recovery" 7th Bihar Science Conference 2018 College of Commerce Arts & Science Patna 04-06 December 2018
- "Commercial processes developed at CSIR-NML for electronic waste (e-waste) recycling" International Conference on Environmental Challenges and Sustainability Central University of Jharkhand Ranchi 31 October- 02 November 2018
- "E-waste recycling practices & prospects" Seminar of Special Lectures B.A. College of Engineering & Technology Jamshedpur 15th April 2018

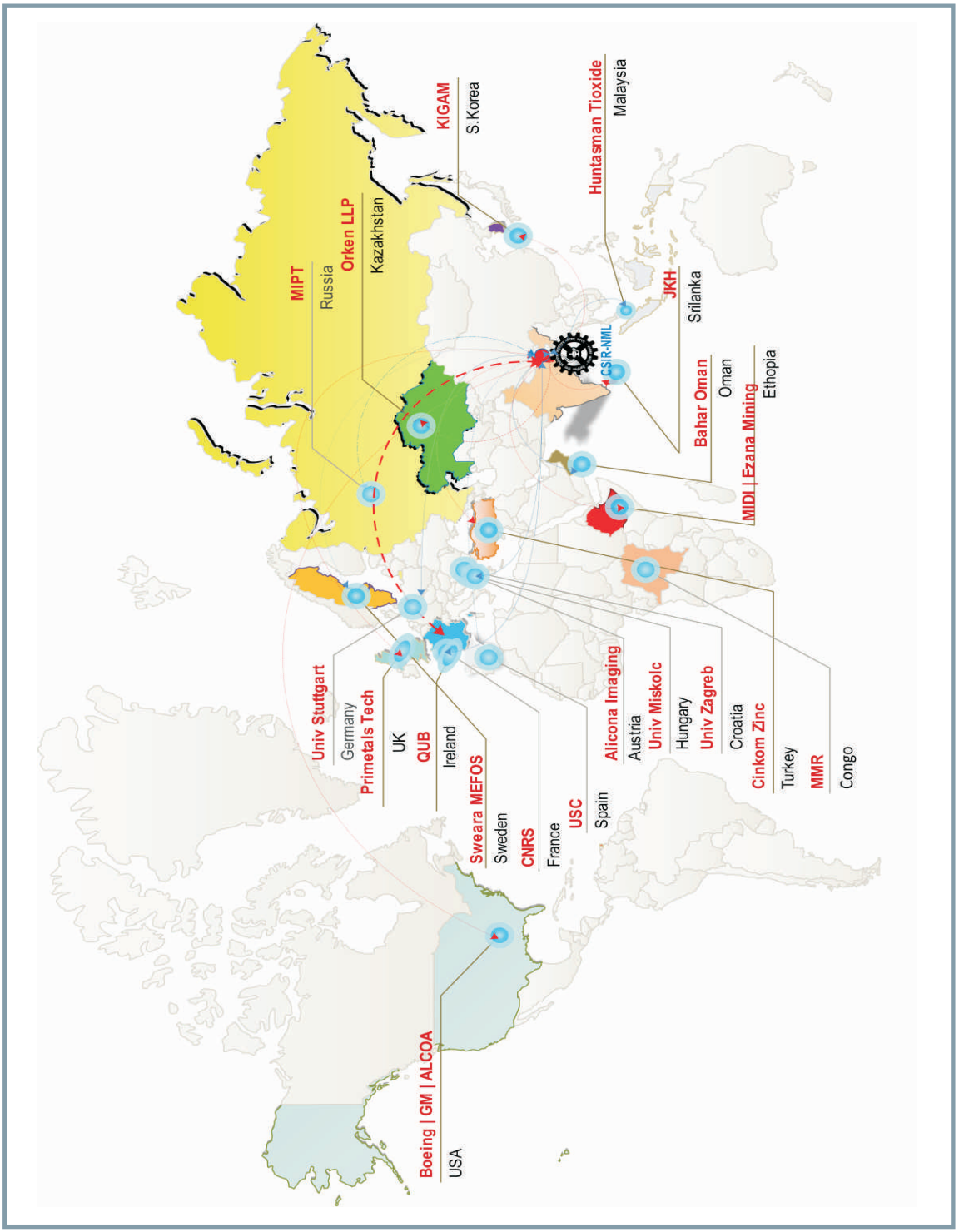
Dr. Abhilash
Sr. Scientist

"Sustainable Extraction of Critical and Strategic Elements from Secondary Resources" International Seminar on Mineral Processing Technology (MPT - 2018) IIT (ISM) Dhanbad 10-12 October 2018.

Dr. AK Arya
Sr. Medical Officer

Delivered a talk on management of Diabetes on 21 February 2019

International Collaborations



NEW FACILITIES

High Pressure Autoclave

A 500 L titanium lined autoclave has been procured from Nano-Mag Technologies Pvt. Ltd. to carry out scale-up experiments. SS316 reactor with titanium lining offers corrosion resistant environment to carry out a variety of dissolution and precipitation reaction at high temperature and pressure condition under oxidizing and reducing atmosphere. The designed temperature of the autoclave is 250 °C maximum and pressure up to 50 bar. The autoclave is equipped with sophisticated temperature and pressure controller along with stirring, gas inlet-outlet, sampling and cooling arrangement. The equipment will be useful for piloting of the ongoing iron oxide precipitation process.

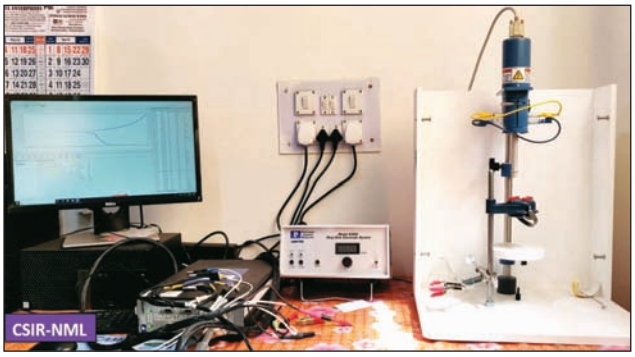
Skillveri Aura Lite Welding Simulator

The simulator is being used for virtual welding. This equipment can be used to train arc welding processes like manual metal arc welding (MMAW), gas metal arc welding (GMAW) and Tungsten inert gas welding (TIG). The equipment has a touch screen which acts like a welding work-piece and can be set in different positions like flat, horizontal, vertical etc. There are three types of torches which are similar to those used in MMAW, GMAW and TIG welding. On touching the screen with the welding torch, an image similar to a welding arc is produced and appears like an actual welding on work-piece. This equipment saves steel and welding consumables during the training of welders.

EDM Wire Cut Machine With Accessories and Wear parts and Consumables

The EDM wire cut machine (make S&T Model V400) can cut conductive hard materials with reasonable surface finish. Sharp notches upto radius of 0.1 mm can be cut on this equipment. The equipment is also used if some precious material is to be sliced, minimizing material wastage.

Hi-performance Bi-Potentiostat / Galvanostat with Ring Rotating Disk Electrode (RRDE) Set-up



This is a versatile electrochemistry research tool with access to a wide range of electrochemical techniques such as corrosion, electrochemical impedance spectroscopy, electrochemical noise, voltammetry, fuel cell, energy, etc. It includes a high end specification bi-potentiostat/Galvanostat system with both high voltage and high current channels, capable of controlling two different working electrodes independently in the same cell with separate or shared reference and counter electrodes. The RRDE system is a hydrodynamic technique and is capable of reaching a steady state quickly and will enable simulator of dynamic flow conditions in the Laboratory.

Applications : Corrosion evaluation, Electroplating/Metal deposition, Electropolishing, Electrochemical sensor development, Determination of reaction mechanisms, Electrocatalyst evaluation, etc.

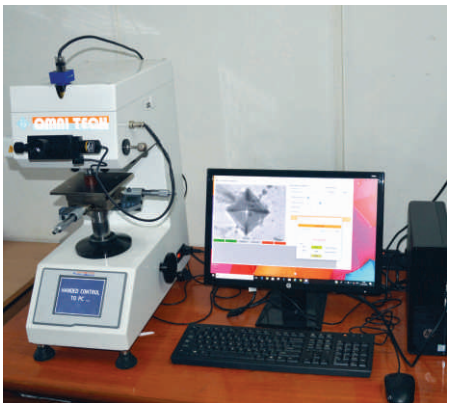
High Speed Imaging System

This is a high sped camera with illumination. The camera can capture images at 4000 frames per second with a resolution of 1024x1024 pixels. At reduced resolution the frame rate can go upto 5L frames per second. The system will be used for research in welding metal transfer, melt spinning process and other high speed metallurgical processes. The camera can be connected to a PC and its internal storage has a capacity of 32GB.

Instrumented Universal Sheet Metal Testing Machine

The instrumented universal electro-hydraulic sheet metal forming machine is used for evaluation of properties of sheet/strip of different materials. Basic features of the machine include electro-hydraulic drive, fully automatic test sequence and switch off at specimen failure with max. drawing force of 400 kN and for pre-setting the blank holder pressure up to 400 kN. This machine is capable of testing sheets and strips of metallic materials for the properties important for press working, stretch and deep drawing quality. The test system has provision for Erichsen Cupping Test, Deep Drawing Cup Test for testing drawing quality and ear forming tendency on sheet metal specimens, Hole Expansion Tests and Nakajima Tool for determination of Forming Limit Curves (FLC). This equipment is capable of providing a comprehensive solution to industrial issues pertaining to many aspects that are relevant to sheet metal forming.

Computerized Micro Hardness Tester



The micro hardness tester (**Make :** OMNITECH, **Model :** S AUTO) is equipped with operational features like motorized turret, manual stage (X, Y) with manual focus imaging (Z). The system is operable in fully computer controlled and manual modes. The system is capable of measuring both Vicker and Knoop hardness of materials as per ASTME384. It has test loads varying from 1gf to 2kgf with variable indentation approach velocity (5-60µm/s) and settable dwell time(5-999s). The sample stage is also equipped with digital micrometer heads for systematic microhardness measurements at desired intervals. The turret is equipped with 4 Objectives and 2 indents for Vicker and Knoop hardness measurements. The micro hardness tester is capable of measuring hardness (VICKER and KNOOP) of :(i) microstructural features such as particles/phases in ferrous metals and non-ferrous metal systems (ii) case/decarburization hardness along with case/decarburization depth measurement (iii) coating hardness including both soft metal and hard oxide coatings, etc.

Periodic Reverse Pulse Current Rectifier

Typical DC power source, which converts the signals from AC to DC and supplies the well-regulated current levels with the facility of ON and OFF (adjustable timing). Periodic Reverse Pulse Current Rectifier generates reversed polarity pulses along with the normal forward pulses, and the time frame for reversing the output is in milliseconds. This offers the flexibility of programming of the current waveform; two modes (1) unipolar, where all the pulses are in one direction (with no polarity) and (2) bipolar, where anodic and cathodic pulses are mixed. This power source has the capability to supply the current in precisely controlled square waveform upto 100 Amps peak value and 50 Amps average value along with the adjustable duty cycles. This can operate in both time and frequency modes separately.

Applications : Electroplating/Metal deposition, Electropolishing, Electroetching etc.

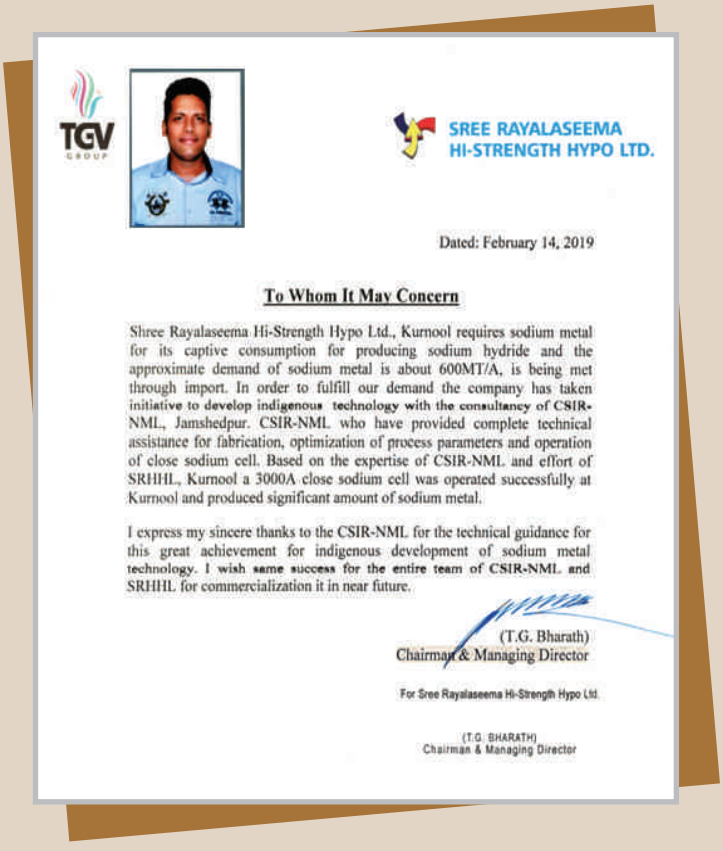
Fully Automatic Isoperibol Calorimeter

An isoperibol calorimeter is one where the surrounding jacket is maintained at a constant temperature while the temperature of the bomb and bucket rise as heat is released by the combustion. The Model 6400 Calorimeters are true isoperibol calorimeters. In these implementations, a water jacket, maintained at a fixed temperature, completely surrounds the combustion bomb and its 'bucket'. A microprocessor-based controller monitors both the temperature of the bucket and the jacket and performs the necessary heat leak corrections that result from differences in these two temperatures. These corrections are applied continuously throughout a test rather than as a final correction base on pre and post test measurements. A procedure determines the heat of combustion or calorific value of materials which are burnt as fuels.

Appreciation Letter from CMD M/s Sree Rayalseema Hi-Strength Hypo Ltd., Kurnool

…CSIR-NML provided complete technical assistance for fabrication, optimization of process parameters and operation of process parameters and operation of closed close sodium cell. Based on the expertise of CSIR-NML and effort of SRHHL, Kurnool a 3000A close sodium cell was operated successfully at Kurnool and produced significant amount of sodium metal. I express my sincere thanks to the CSIR-NML for the technical guidance for this great achievement for indigenous development of sodium metal technology.

T. G. Bharath
Chairman & Managing Director
M/s Sree Rayalseema Hi-Strength Hypo Ltd., Kurnool
14- 02 - 2019



TGV GROUP

SREE RAYALASEEMA HI-STRENGTH HYPO LTD.

Dated: February 14, 2019

To Whom It May Concern

Shree Rayalaseema Hi-Strength Hypo Ltd., Kurnool requires sodium metal for its captive consumption for producing sodium hydride and the approximate demand of sodium metal is about 600MT/A, is being met through import. In order to fulfill our demand the company has taken initiative to develop indigenous technology with the consultancy of CSIR-NML, Jamshedpur. CSIR-NML who have provided complete technical assistance for fabrication, optimization of process parameters and operation of close sodium cell. Based on the expertise of CSIR-NML and effort of SRHHL, Kurnool a 3000A close sodium cell was operated successfully at Kurnool and produced significant amount of sodium metal.

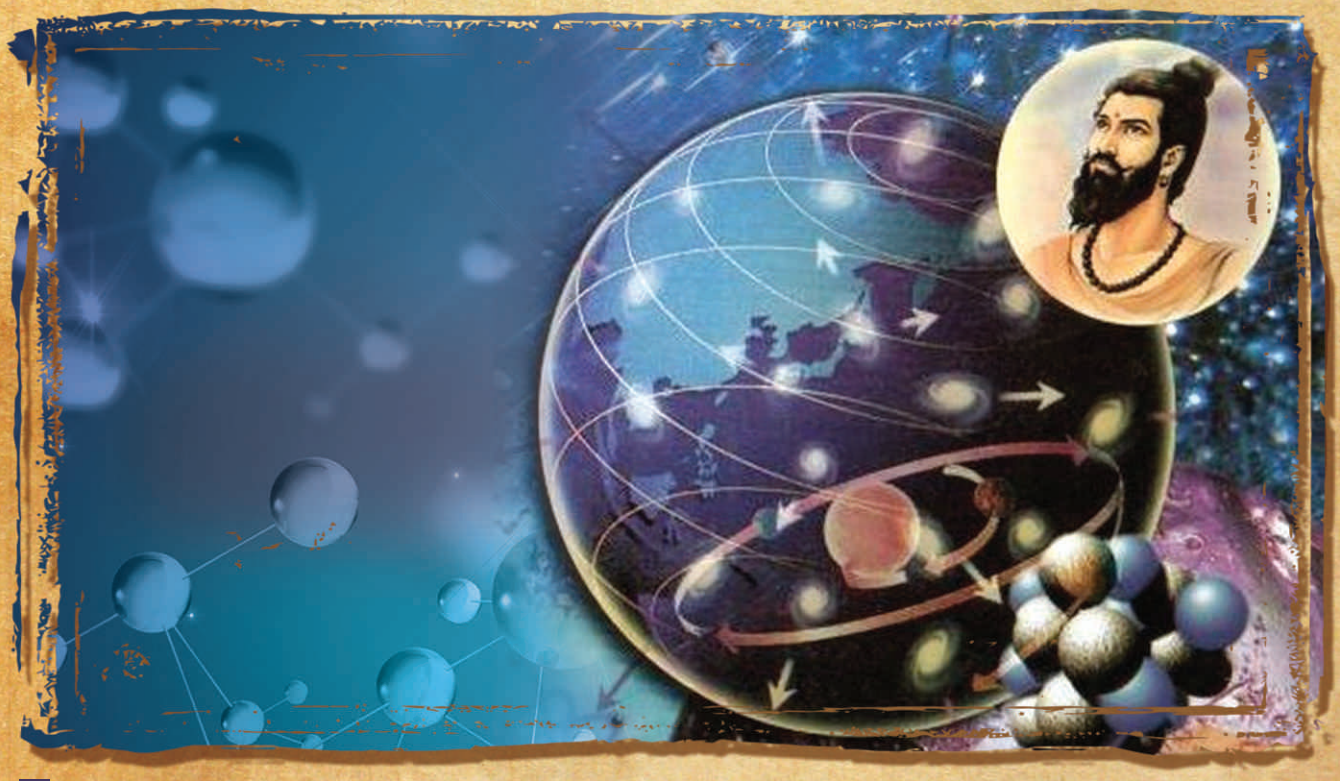
I express my sincere thanks to the CSIR-NML for the technical guidance for this great achievement for indigenous development of sodium metal technology. I wish same success for the entire team of CSIR-NML and SRHHL for commercialization it in near future.

(T.G. Bharath)
Chairman & Managing Director

For Sree Rayalaseema Hi-Strength Hypo Ltd.

(T.G. BHARATH)
Chairman & Managing Director

Science & Technology in Ancient India



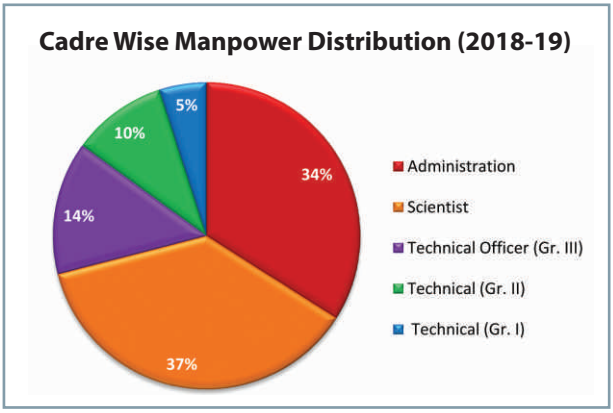
Atomic Theory

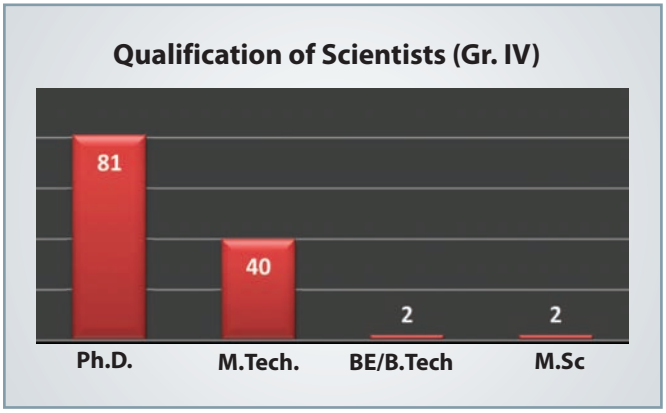
Kanad, is said to have devised the atomic theory. He speculated the existence of anu or a small indestructible particles, much like an atom. He further held that atoms of same substance combined with each other in a specific and synchronized manner to produce dvyanuka (diatomic molecules) and tryanuka(triatomic molecules).

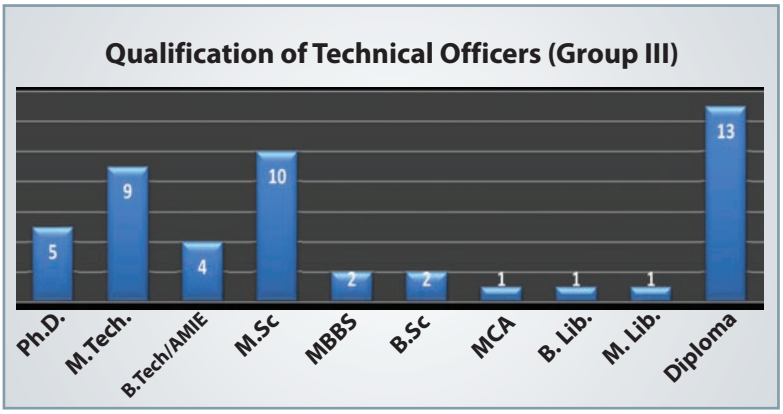
Science & Technology in Ancient India

HUMAN RESOURCE GROUP

Current Staff Profile







Recruitments

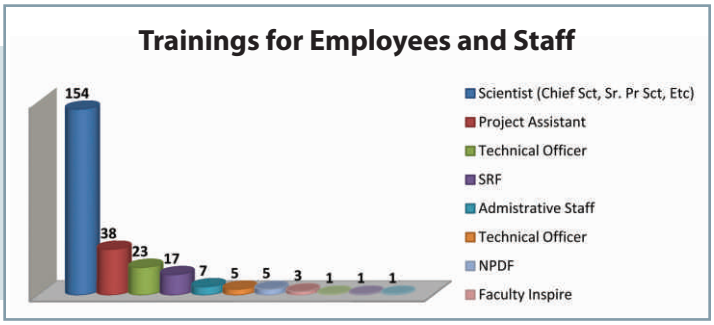
- 12 Scientist positions and 2 Technical Officer positions advertised and 3 Scientist positions re-advertised; Successful selection was carried out Final RAB approval is awaited.
- Around 55 candidates were selected as Project assistant / RA / SRF / JRF / PDF / Inspire

Internal Skill Building

All younger scientists are mandated to participate in institutional colloquium and the best presenters were awarded. This is an institutional initiative to motivate young scientists and provide them the first public forum to demonstrate their ideas, oratorical skills and techniques. In-house training on different subjects was provided catering to the skill development needs of different sections of employees. In this connection 22 nos. of lectures by many eminent people in different sectors of research and technology were organized.

Trainings for employees and staff

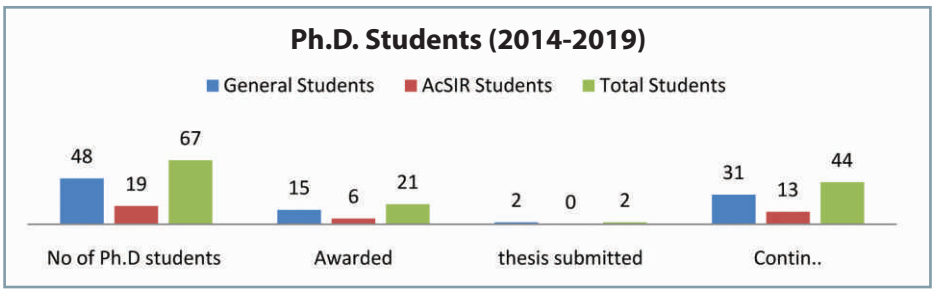
A total of 255 employees of all cadres were deputed in the reporting year for receiving trainings (33 nos.) and participating in conference, workshops and symposiums (222).



Supervision for the Master Degree and B. Tech. from other institutions during 2018-19

M. Tech. & M. Sc. Students ~ 1 year project work under the guidance of NML Scientists : 49 nos.

B. Tech. Students from various institutes ~ 1.5 months to 2.5 months project under the guidance of NML scientists : 80 nos. Summer Training : 48 nos., Winter Training : 32 nos.



Status of Ph. D. Students (2018-19)	General Students	AcSIR Students	Total Students
Newly Joined	9	2	11
Degree Awarded	2	2	4
Thesis Submitted	1	0	1
Continuing-----	31	13	44

Future Plans.....

In addition to the ongoing recruitments, CSIR-NML is planning recruitments of Technical Assistants as well as Group II personnel in the coming fiscal. CSIR-NML is also planning to recruit Project Assistants and Research Assistants as per project requirements. Well structured training for employees for their development and further knowledge enhancement as well image building through organizing conferences, workshops and training programmes.

Employee(s) Superannuated

Mr. T.K. Bhattacharjee
Sr. Technician (2)
30th June, 2018

Mr. Marsalan Kandulna
Sr. Technician (3)
30th June, 2018

Mr. Nimai Chandra Jana
Laboratory Assistant
30th June, 2018

Mr. Laxmi Narayan
Multi Tasking Staff
30th June, 2018

Dr. S. Subba Rao
Chief Scientist
31st July, 2018

Mr. Arvind
Multi Tasking Staff
31st July, 2018

Mr. Thushar Saha
Multi Tasking Staff
31st August, 2018

Mr. S.R. Hembram
Controller of Administration
30th September, 2018

Dr. S. Ranganathan
Chief Scientist
31st October, 2018

Mr. Keshav C. Gochhayat
Canteen Bearer
31st October, 2018

Mr. Subrat K. Mohanty
Laboratory Assistant
31st October, 2018

Mr. Gurdeep Singh
Laboratory Assistant
31st December, 2018

Mr. T.K. Paul
Sr. Stenographer
31st January, 2019

Mr. Veer Bahadur Sharma
Laboratory Assistant
31st January, 2019

Dr. Rakesh Kumar
Advisor Management
Chief Scientist
28th February, 2019

Mr. D.K. Sarkar
Sr. Security Officer
28th February, 2019

New Joinee (s)

Dr. Darukhshan Anjum
Resident Medical Officer
Sr. Technical Officer (1)
18th June, 2018

Mr. Kogapu Sudhakara Rao
Technical Officer
26th June, 2018

Staff Transferred

Transferred from CSIR-IMMT Bhubaneshwar

Dr. (Mrs.) Ranu Verma
Assistant Section Officer (G)
9th July, 2018

Transferred to CSIR-IICT Hyderabad

Mr. Ch. Srinivasa Rao
Sr. Technician (2)
20th July, 2018

Staff Resigned

Dr. Darukhshan Anjum
Resident Medical Officer
Sr. Technical Officer

Dr. Satadal Ghorai
Scientist

Sad Demise of Staff

Mrs. Sushma Minz
Section Officer (G)
15th April 2018

Dr. Subhadra Garai
Senior Scientist
4th August 2018

Trainings Organized

Professional Training Programs (PTP)

Professional Training Programme on Laboratory Quality Management System as per NABL requirements(LQMS 2018) (24th – 25th April 2018)

The training was attended by 23 executives from TATA Steel, R S Safety & Calibration Consultancy, JAMIPOL and CSIR-NML. The course was focused around the "General Requirements for the competence of Testing and Calibration" of laboratories.


दैनिक भास्कर

इंडस्ट्री, शैक्षणिक संस्था व आरएंडडी मिलकर काम करे तो बेहतर रिजल्ट- ए दासगुप्ता

Professional Training Program on Experimental Tools and Techniques for Materials Characterization (ETMC-2018)(25th - 28th September 2018)

The training program was organized by CSIR-NML for Industry experts, researchers and academicians. The objective of the program was to enhance knowledge of the participants in material characterization area by using novel experimental tools and techniques. The program was attended by 6 participants from Usha Martin Limited, DRDO, Indian Oil Corporation Limited, Ramkrishna Forgings Limited and CSIR- Structural Engineering Research Centre.

Professional Training Program on Metallurgical Failure Investigation of Engineering Components (MFIEC-2019) (14th -17th January, 2019)

A training program was organized with an objective to impart the knowledge on metallurgical failure analysis and characterization of engineering components to Indian metal industry community. The training was attended by 13 participants from RITES Limited, BPCL-Kochi, Tata Cummins, RDSO-Lucknow, Tata Power, ONGC and South Eastern Railways.

Corporate Training Program (CTP)

Corporate Training Program on Structural Integrity Assessment of Engineering Components (SIA-2018) (6th -10th August 2018)

A Corporate Training Programme on Structural Integrity Assessment of Engineering Components (SIA-2018) was organized by CSIR-NML. Various experts from the lab delivered talks and presented relevant case studies. The participants (11 nos.) were from Indian Oil Ltd, Mathura Refinery and Oil India Ltd., Duliajan Assam.



Mineral Characterization and Beneficiation (MCB-2018), (3rd -5th October 2018)

A three-day long corporate training program on Mineral Characterization and Beneficiation for six executives of Mining Mineral Resources, Democratic Republic of Congo was organized by CSIR-NML. The objective of the program was to uncover different aspects of characterization & beneficiation techniques, principles, and tools in the field of mineral processing. The training program included classroom lectures and hands on training in the laboratory and the pilot plant.


Training for Tata Steel Executives on Micro structural Characterization (4th January 2019)



Corporate Training Program on Micro-structural Characterization (20th -21st August 2018)

CSIR National Metallurgical Laboratory organized a training program for personnel from Scientific Services Division of Tata Steel Limited under the banner of "Metallurgical & Mechanical Characterization". The training program was divided into three modules viz. (i) Microstructural Characterization (ii) Advanced Mechanical Characterization & (iii) Corrosion & Tribological Characterization. The Module I was on Microstructural Characterization which was attended by 15 participants from Tata Steel Limited and the following were the contents of the course :

- Principles of Residual Stress Measurement using X – Ray Diffraction & Hands on training
- Principles of EDS, WDS, EBSD & Hands on training
- Principles & Analysis of Electron Diffraction and Microscopy & Hands on training
- Principles of X – Ray Photoelectron Spectroscopy & Hands on training

Soft Skills Training Program (STP)

Soft Skills for Quality Improvement (SSQi 2019) (27th -28th February 2019)

A two-day training program was conducted by CSIR-NML to tap the talent pool of young India and to ameliorate the noncognitive skills of an individual. The objective of the training program was to enable the trainees to face everyday challenges of life with confidence, dealing with people with ease and efficiency, doing better conflict management, developing leadership & teamwork skill and gaining effective communication skill. The program includes classroom lectures followed by some group activities. A total of 42 participants attended the program.

Training Programme on Entrepreneurship Development on E-waste Management (EDEM 2019) (12th -15th March,2019)

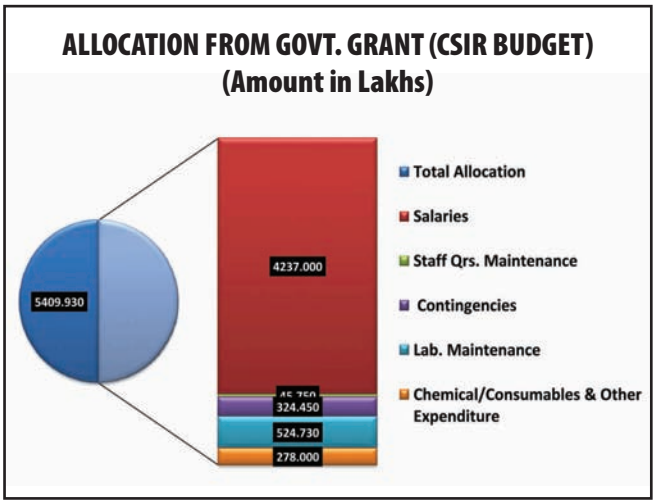
The program was attended by 23 participants from industry and academia.

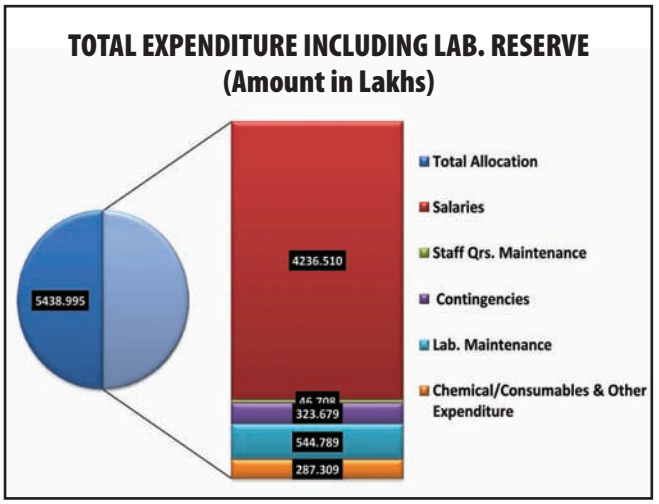
Star Clients

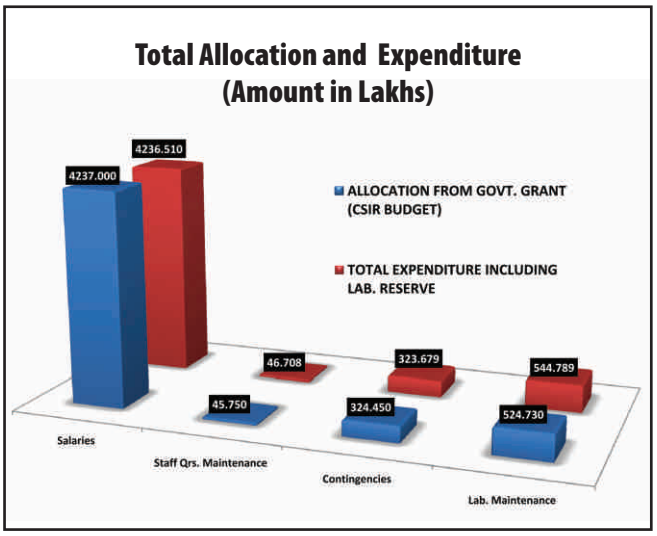
NML's Fortune 1000 Clients (2018-19)

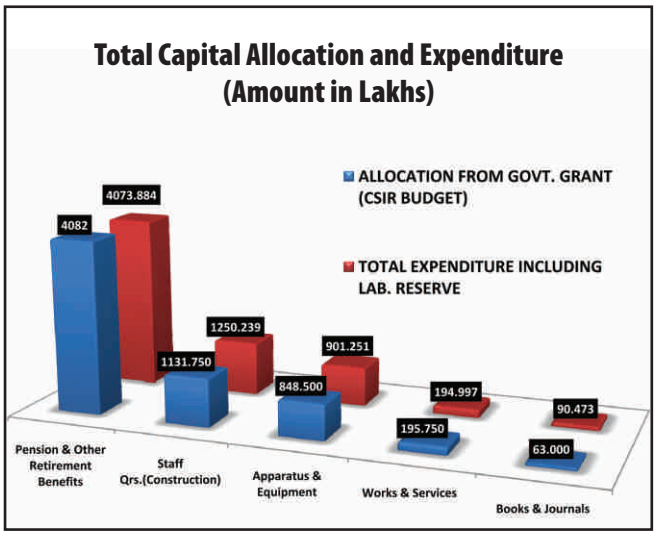
NML's ET 500 Clients (2018-2019)

Budget 2018-19









International Deputations

Sl. No.	Employee		Country (To Attend/ Participate)	Purpose/Event	Duration
1	Dr. Soumitra Tarafder, Chief Scientist		Korea Addis Ababa, Ethiopia	INAE-NEK Workshop Project Meeting	13 -16 May 2018 12 - 25 February 2019
2	Dr. Amitava Mitra, Chief Scientist		Addis Ababa, Ethiopia Addis Ababa, Ethiopia	Project Meeting Project Meeting	18 August 01 September 2018 12 -25 February 2019
3	Dr. Debajyoti Bandyopadhyay, Chief Scientist		Addis Ababa, Ethiopia	Project Meeting	18-26 August 2018
4	Dr. Swapan Kumar Das, Senior Principal Scientist		Addis Ababa, Ethiopia Addis Ababa, Ethiopia	Project Meeting Project Meeting	18 August - 01 September 2018 12 - 25 February 2019
5	Dr. Mita Tarafder, Chief Scientist		Addis Ababa, Ethiopia	Project Meeting	25 August - 02 September 2018
6	Dr. Sital Kumar Pal, Senior Principal Scientist		Addis Ababa, Ethiopia	Project Meeting	25 Aug.- 02 Sep. 2018

Sl. No.	Employee		Country (To Attend/ Participate)	Purpose/Event	Duration
7	Dr. Sarmishtha Sagar, Senior Principal Scientist		Addis Ababa, Ethiopia Addis Ababa, Ethiopia	Project Meeting Project Meeting	25 August - 02 September 2018 20 January - 02 February 2019
8	Dr. Rajneesh Kumar, Senior Scientist		Addis Ababa, Ethiopia	Project Meeting	20 January - 02 February 2019
9	Dr. B. Ravikumar, Senior Principal Scientist		Addis Ababa, Ethiopia	Project Meeting	20 January - 02 February 2019
10.	Dr. Sanchita Chakravarty, Senior Principal Scientist		Addis Ababa, Ethiopia Addis Ababa, Ethiopia	Project Meeting Project Meeting	29 September - 07 October 2018 20 January - 02 February 2019
11.	Mr. Nimai Halder, Technical officer		Addis Ababa, Ethiopia Addis Ababa, Ethiopia	Project Meeting Project Meeting	29 September - 07 October 2018 20 January - 02 February 2019
12	Ms. Minal Shah, Scientist		Stockholm, Sweden	Summer Colloquium	27 August- 07 September 2018

Sl. No.	Employee		Country (To Attend/ Participate)	Purpose/Event	Duration
13	Mr. Snehashish Tripathy, Scientist		Stockholm, Sweden	Summer Colloquium	27 August 07 September 2018
14	Mr. Biraj kr Sahoo, Scientist		Stockholm, Sweden	Summer Colloquium	27 August 07 September 2018
15	Ms. Sunati Mohanty, Senior Scientist		Stockholm, Sweden	Summer Colloquium	27 August 07 September 2018
16	Dr. Tarun Kumar Das, Senior Scientist		Saarbreuken, Germany Hungary	Symposium	02 - 10 October 2018
17	Dr. Sanjay Kumar, Senior Principal Scientist		Univ. of Miskolc,	Research Activities	30 October 30 November2 018
18	Dr. Beena Kumari, Senior Scientist		Addis Ababa, Ethiopia	Project Meeting	17 November - 25 November

Sl. No.	Employee		Country (To Attend/ Participate)	Purpose/Event	Duration
19	Mr. K. Sudhakar Rao, Technical Officer		Addis Ababa, Ethiopia	Project Meeting	17 November - 15 December 2018
20	Mr. Ashish Upadhyay , Senior Technical Officer		Addis Ababa, Ethiopia	Project Meeting	17 November - 15 December 2018
21	Dr. K. Gopalakrishna, Principal Scientist		Addis Ababa, Ethiopia	Project Meeting	17 November - 15 December 2018
22	Dr. AK Sahu, Senior Technical Officer		Addis Ababa, Ethiopia	Project Meeting	17 November - 15 December 2018
23	Mr. Sudip Kundu, Senior Scientist		Addis Ababa, Ethiopia	Project Meeting	17 November - 15 December 2018
24	Mr. Santosh Kumar Tiwary, Project Assistant		Addis Ababa, Ethiopia	Job on Assignment	17 November - 15 December 2018

National Deputations

Name and Designation	Purpose/Event (To Attend/Participate)	Place	Duration
Mr. Partha Pratim Pal, Senior Technical Officer Mr. Shailendra Kumar, Technical Officer	Training program on "Repair and Rehabilitation of Concrete Structures including Water Proofing Materials and Techniques" organized by National Council for Cement and Building Materials.	Delhi-Mathura Road, Ballabgarh	24-26 April 2018
Mr. Sanish Kumar Roy, Project Assistant	BRNS-AEACI Thirteenth School on Analytical Chemistry (SAC-13) organized by Board of Research in Nuclear Sciences, Department of Atomic Energy, India	New Delhi	23-30 April 2018
Dr. Sashwati Chakladar, National-Post Doctoral Fellow	Poster presentation under the section "Sustainable Process Technologies" at SEFCO-2018, a Symposium organized at CSIR-IIP Dehradun	Dehradun	11-12 May 2018
Mr. Chandra Veer Singh, Scientist	Workshop on "Structural Integrity Assessment of Nuclear Energy Assets" organized by Indian Structural Integrity Society, Mumbai	Bangalore	9-10 May 2018
Mr. Biraj Kumar Sahoo, Scientist Mr. Snehashish Tripathy, Scientist	National Conference on "Digital Trends in Metal Forming" and Training Program on "JMatPro Software"	Pune	22-24 June 2018
Ms. Y. Usha, Scientist Mr. Sunil Kumar, Scientist Dr. Krishnendu Mukherjee, Principal Scientist	Three days Workshop on "Modelling and Simulation" with emphasis on Engineering and Physical (including Earth & Environmental Sciences)	Bangalore	19-21 June 2018
Dr. Soumitro Tarafder, Chief Scientist Mr. Chandra Veer Singh, Scientist	Structural Integrity Conference & exhibition (SICE 2018), organized by DMRL, Hyderabad & Indian Structural Integrity Society (InSIS)	Hyderabad	25-27 July 2018
Dr. Jayanta Konar, Senior Technical Officer	National Seminar on emerging Trends in Analytical Sciences (ETAS-2018) organized by CSIR-Indian Institute of Chemical Technology Tarnaka, Hyderabad	Hyderabad	30-31 July 2018

Name and Designation	Purpose/Event (To Attend/Participate)	Place	Duration
Mr. Parikshit Munda, Senior Scientist	Technical course on "Stereology for Microstructural Qualification" by Prof. Sandeep Sangals, organized by Tata Steel, Jamshedpur	Jamshedpur	10-12 July 2018
Ms. Swapna Dey, Principal Investigator	Pre Conference Workshop on Structural Integrity Conference & exhibition (SICE 2018), organized by DMRL, Hyderabad & Indian Structural Integrity Society (InSIS)	Hyderabad	23-24 July 2018
Ms. Soni Jha, Project Assistant Ms. Vimla Kumari, Project Assistant M. Bhupinder Kour, Project Assistant Mr. Premchand Kumar Mahto, Project Assistant Mr. Durgesh Prasad, Project Assistant Mr. Ranjan Kumar, Project Assistant Ms. Noopour Deshmukh, Project Assistant, Ms. Tanushree Dutta, Project Assistant Ms. Suhani Kumari, Project Assistant Ms. Preeti Karmakar, Project Assistant	Students Seminar "Behind the Teachers Desk (BTTD 2018) " organized by Jamshedpur Chapter of Indian Institute of Metals , CSIR-NML Jamshedpur and Tata Steel	Jamshedpur	5-6 July 2018
Dr. Sanjay Prasad, Principal Scientist Dr. Pratima Meshram, Senior Scientist Dr. Abhilash, Senior Scientist Ms. Aarti Kumari, Scientist Mr. Shivendra Sinha, Scientist Mr. Sourabh Shekhar, Scientist Dr. Navneet Singh Randhawa, Senior Technical Officer Mr. Krishna Kumar, Scientist	22nd International Conference on Nonferrous Minerals and Metals (ICNFMM 2018) organized by Corporate Monitor in conjunction with Mecon Limited	Ranchi	6-7 July 2018
Dr. A. K. Sahu, Sr. Technical Officer Mr. Jyoti Kumar, Technician II	Rajbhasha Sangosthi Sah Karyashala and Quiz Competition organized by Hindustan Petroleum Corporation Ltd., Jamshedpur	Jamshedpur	28 August 2018
Dr. Sushant Kumar Nath, Senior Scientist Mr. Rohit B Meshram, Scientist	National Seminar on "Waste Management in Metallurgical Industries: Effective Industry Practices & Research Initiatives" organized by IIM, Kolkata Chapter & CGCRI, Kolkata & MIEEM	Kolkata	3-4 August 2018
Dr. Rajat Kumar Roy, Senior Scientist Dr. Ashish Kumar Panda, Principal Scientist	2nd International Conference & Exhibition on "Advanced Techniques & Practices of Inspection, NDT & Monitoring" organized by ISNT, New Delhi	New Delhi	10-11August 2018

Name and Designation	Purpose/Event (To Attend/Participate)	Place	Duration
Mr. Gaurav Kumar Bansal, Scientist Mr. Avanish Kumar Chandan, Scientist	National Conference on "Processing of Materials (NCOPM-2018)" organized by NIT Suratkal	Bangalore	19-21 September 2018
Dr. Pratima Meshram, Senior Scientist Ms. Aarti Kumari, Scientist Dr. Abhilash, Senior Scientist	International Conference on "Science, Technology and Applications of Rare Earths (ICSTAR-2018)" organized by REAI, IIME Tamil Nadu Chapter	Tamil Nadu	23-25 September 2018
Mr. A Ammasi, Scientist	Seminar entitled "Examination for Energy Managers and Energy Auditors" organized by The Institution of Engineers (India), Ranchi	Ranchi	22-23 September 2018
Dr. Sanjay Agarwal, Scientist Mr. Manoj Kumar, Senior Technical Officer	Engineering Quiz , organized by The Institution of Engineers (India), Jamshedpur	Jamshedpur	10 September 2018
Dr. Paras Nath Mishra, Principal Scientist Mr. Krishna Kumar, Scientist	India International Science Festival organized by Indira Gandhi Pratisthan	Lucknow	3-8 October 2018
Dr. Thomas C Alex, Senior Principal Scientist	First Hindalco Alumina Conference organized by Utkal Alumina, Doraguda	Odisha	4-6 October 2018
Mr. E Malliah, Technical Assistant	Orientation Training Program organized by CSIR-HRDC	Ghaziabad	8-12 October 2018
Mr. V Rajni Kanth, Senior Scientist Mr. Tipu Kumar, Technical Officer	Gleeble Users Workshop of India 2018 and National Conference on "Physical Simulation on Thermo-Mechanical Processing of Materials" organized by IIT	Roorkee	12-13 October 2018
Mr. MG Walunj, Scientist	Short Course on "Powder Metallurgy" and Demonstration of 3D Printing Additive Manufacturing (PMSE-18) organized by College of Engineering	Pune	12-15 October 2018
Mr. Anuj Mohan Pradhan, Finance & Accounts Officer	National Conference on "Indirect Taxes (GST)"	Nagpur	26-27 October 2018
Mr. Rajeev Ranjan Srivastava, Senior Technical Officer Mr. Rachit Ghosh, Senior Technical Officer	Program entitled "Capacity Building for Engineers and Architects" organized by CSIR-IICB, Kolkata	Kolkata	29-31 October 2018
Ms. Rekha Panda, Senior Research Fellow Ms. Archana Kumari, Project Assistant	International Conference on "Environmental Challenges and Sustainability" organized by Central University of Jharkhand	Ranchi	31 Oct.-2 Nov. 2018

Name and Designation	Purpose/Event (To Attend/Participate)	Place	Duration
Dr. Sanjay Agarwal, Senior Scientist Dr. Sanjay Prasad, Principal Scientist Ms. Aarti Kumari, Scientist Dr. Abhilash, Senior Scientist Dr. Pratima Mesharam, Senior Scientist Dr. Sushant Nath, Senior Scientist Mr. Sourabh Shekhar, Scientist Mr. Ammasi A, Scientist Mr. Shivnedra Sinha, Scientist Dr. Deepak Chandra Sau, Scientist Mr. Ranjit Kumar Singh, Senior Scientist Mr. JN Patel, Technical Officer Dr. Navneet Singh Randhawa, Senior Technical Officer Mr. Rachit Ghosh, Senior Technical Officer Mr. Rajnikanth Choudary, Technical Assistant Ms. Archana Kumari, Project Assistant Dr. Ratnakar Singh, Chief Scientist Dr. Manoj Kumar Mohanta, Senior Principal Scientist Dr. Sanchita Chakraborty, Senior Principal Scientist Dr. Shobana Dey, Principal Scientist Dr. Rajesh Kumar Rath, Principal Scientist	17th International Seminar on "Mineral Processing Technology (MPT 2018)" organized by ISM, Dhanbad	Dhanbad	10-12 October 2018
Dr. Kamala Kant Sahu, Senior Principal Scientist	14th National Seminar on "Waste to Wealth for Healthy Environment" at Malanjkhand Copper Project	Balaghat, Madhya Pradesh	30 November - 3 December 2018
Mr. Gulshan Kumar, Junior Steno Mr. Dhanajay Chaudhary, JSA	Training Program on "Taxation Law a : Direct and Indirect Taxes" organized by CSIR-HRDC	Ghaziabad	26-27 November 2018
Mr. Ashok K, Scientist	Workshop on "Steel Cleanliness and Slag Practices" organized by IIM and RINL, Vishakhapatnam	Visakhapatnam	23 November 2018
Mr. Laxmi Narayan Singh, Section Officer Mr. Nalin Kumar Singh, Stores & Purchase Officer	Knowledge & Skill Upgradation Programme on "Latest Trends in Public Procedures" organized by CSIR- HRDC, Lucknow	Lucknow	14-16 November 2018

Science & Technology in Ancient India

Smelting of Zinc

Evidence suggests that zinc was first produced in quantity in India and China. At Zawar in Rajasthan, India, the remains of a smelting industry dating from the 14th century have been found.

Science & Technology in Ancient India

INTERACTIONS & CELEBRATIONS

Science & Technology in Ancient India

Seamless Metal Globe

The first seamless celestial globe was made in Kashmir by Ali Kashmiri ibn Luqman through lost-wax casting. Before these globes were rediscovered in the 1980s, modern metallurgists believed that it was technically impossible to produce metal globes without any seams, even with modern technology.

Science & Technology in Ancient India

Distinguished Visitors

Speaker	Topic	Date	
Dr. Sudip Dasgupta (PhD, WSU,USA), Assistant Professor, Department of Ceramic Engineering, National Institute of Technology, Rourkela	***"Gelatin, Chitosan and Bioactive Nanoceramic Based Composite Scaffold for Orthopedic Applications"***	13th April 2018	
Mr. Parminder Singh, ROSHNI Jamshedpur	***"Awareness of Eye donation"***	04th June 2018	
Dr. Benjamin Tordoff, Carl Zeiss	***"Advances in Automated Mineralogy"***	07th June 2018	
Mr. Ankan Guria, Application Manager for High Temp Furnace & Materials	**"Latest Development of Heating systems application"**	07th June 2018	
Prof. K. Mondal, Material Science & Engineering Department, Indian Institute of Technology Kanpur	***"Nanoporous Materials by Dealloying"***	08th June 2018	
Dr. Abir Bhattacharyya, Post Doctoral Research Associate, Department of Mechanical & Aerospace Engineering University of Florida, USA	***"Evolution of Cyclic Plasticity during Rolling Contact Fatigue of a Case-Hardened Bearing Steel"***	08th June 2018	

Speaker	Topic	Date	
Prof. Dr. Sharmila M. Mukhopadhyay, Wright University, USA	***"Next Generation Nanomaterials: Hierarchical Hybrid Architectures"***	08th June 2018	
Mr. Tim Hoefft, Global Materials Manager, Caterpillar Inc	***"Materials Technology at Caterpillar Inc"***	13th June 2018	
Dr. Pralay Pal, Deputy General Manger, TATA Technologies	***"Application of emerging technologies in digital product development in the automotive industry"***	28th June 2018	
Dr. Tanmoy Bose, Faculty, NIT Shillong	***"Detection of local defect resonance frequencies in metallic and composite specimen using bicoherence"***	02nd July 2018	
Dr. Giuseppe Carlo ABBRUZZESE, CSM Italy	***"Metallurgical model of grain oriented high temperature coil annealing"***	11th July 2018	
Dr. R. Sunder, BISS (P) Ltd, Bangalore	***"Modelling Sequence Effects in Fatigue Crack Growth under Near-Threshold Flight-Spectrum Loading"***	30th July 2018	

Speaker	Topic	Date	
Mr. Kaushik Kalita, DHIO Research & Engineering Pvt Ltd., Bengaluru	***"3D fracture mechanics simulation"***	29th August 2018	
Prof. Sirshendu De, Department of Chemical Engineering, IIT Kharagpur	***"Ultra low-cost innovative spinning of polymeric hollow fibers and their various applications"***	14th August 2018	
Ms. Echo Gao, Senior Product Specialist, Thermo Fisher Scientific MSD	***"Recent developments in mineral liberation analysis"***	07th August 2018	
Mr. Ravi Kumar, Cyber Cell, Jamshedpur	***"Cyber Crime Awareness"***	19th September 2018	
Mr. Rajesh Kumar Rai, Akashvani	***Hindi Week Lecture***	24th September 2018	
Dr. Stephane Pellet Rostaing, Director, Marcoule Institute of Separation Chemistry (ICSM), France	***"Molecular systems for Metal Extraction/Separation: Processes and Associated Mechanisms"***	27th September 2018	
Prof. Sankar K Pal, Distinguished Scientist and Former Director, Indian Statistical Institute, Kolkata	***Professor Meghnad Saha memorial lecture on "Pattern Recognition, Machine Intelligence to Data Science: Evolution and Challenges"***	05th October 2018	

Speaker	Topic	Date	
Prof. Takeshi Iwamoto, Associate Professor, Hiroshima University, Japan	***"Recent progress on an estimation of rate sensitivity in the metallic materials with mechanically-induced phase transition and its related topics"***	29th October 2018	
Prof. Navneet Arora, Professor, Mechanical and Industrial Engineering, I.I.T. Roorkee, Uttrakhand	***"Balance between stress and excellence in life"***	29th November 2018	
Mr. Arpit Dwivedi, CEO, METNMET Research, A start-up venture of students of IIT, KGP	***"Make in India: Technology development and technology transfer of high temperature ceramics, MMCs and high strength high electrical conductivity alloys"***	27th November 2018	
Mr. Vikas Kumar (IRTS), Area Manager, Tata Nagar	***"Vigilance & Awareness"***	02nd November 2018	
Dr. Gordana Medunić, Faculty of Science, Department of Geology, University of Zagreb, Croatia	***"Coal-related environmental pollution has been affecting our lives"***	03rd December 2018	
Prof. Pinaki Bhattacharjee, Indian Institute of Technology, Hyderabad	***"Bulk Heterostructured High Entropy Alloys: A New Frontier in Microstructural Design"***	09th January 2019	
Prof. Ashok Saxena, University of Arkansas	***"Creep and Fatigue Crack-Growth in Structures and Materials"***	17th January 2019	

Speaker	Topic	Date	
Padam Shri Dr. Kota Harinarayna, Raja Rammana Fellow at NAL, Ex. Program Director and Chief Designer of India's Light Combat Aircraft & Distinguished Scientist, DRDO	***"From manned fighters to unmanned combat aircraft- India's journey"***	09th January 2019	
Dr Samita Bhattachraya, Leadership Transformation & Whole brain engagement Expert at Tata Steel	**"Leading with the Brain in Mind"**	07th March 2019	
Dr. DP Durai, Director, MP Birla Institute of fundamental science and MP Birla Planetarium, Kolkata	**"Concepts and Challenges in Astronomy"**	28th February 2019	

SPECIAL EVENTS

Swachhata Pakhwada (1st- 15th April 2018)

The event was observed at CSIR-NML and numbers of events were organized to mark the event at office places and residential complexes of CSIR-NML. Lecture, Essay writing and Debate competition were also organized during the week.

Activity NML Flats, Agrico
(5th May 2018)
Residents join hands to clean the campus.

Activity at LSTF Pilot Plant
(7th May 2018)
Staff of the laboratory participated in the events related to the cleaning of the Laboratory Pilot Plant area.

Celebration of
'Swachh Ghar Pariwaar'
at CSIR-NML Colony, Golmuri
(12th May 2018)
Residents of the colony joined hands to clean the surroundings.

Town Official Language Implementation Committee Meeting (24th April 2018)
Officials from various government offices attended meeting organized at CSIR-NML.

National Technology Day Celebrations (11th May 2018)

Mr. HM Bangur, Managing Director, Shree Cement Pvt. Ltd., Kolkata graced the occasion as the chief guest. Mr. Bangur highlighted upon the expectations of industry from the R&D laboratories and academic institutions. He also suggested the ways to bridge gaps between the two. Dr. Amitava Mitra, Head-Research Planning and Business Development presented the technologies developed and transferred during the year 2017-18 as well as the scientific services delivered by CSIR-NML. CSIR-NML Annual Report 2017-18 was released by the chief guest on the occasion. Around 250 students from the technical institutes from in and around Jamshedpur also participated in the program.


दैनिक भास्कर

वैज्ञानिकों ने देश को प्रौद्योगिकी में सशक्त बनाया : डॉ चट्टोराज

एनएमएल में राष्ट्रीय प्रौद्योगिकी दिवस मनाया गया

एनएमएल में निरीक्षण करते अतिथि व अन्य।

छात्रों ने एनएमएल का किया भ्रमण

72nd Meeting of CSIR-NML's Research Council (1st June 2018)

The development of the laboratory in terms of R&D projects & outputs was reported to the research council members.

World Environment Day (5th June 2018)

On the occasion of World Environment Day, a short programme was organized at CSIR-NML which included tree plantation by Prof. Rajesh Prasad (IIT Delhi) and followed by interview streaming of Hon'ble Minister of Science and Technology from Rajya Sabha TV.

Blood Donation Camp (7th June 2018)

Blood Donation Camp was organized at CSIR-NML. In this event 105 units of blood was collected.

Short Term Course on Advanced Thermodynamics (26th-28th June 2018)

Behind the Teachers Desk (BTTD) (5th -6th July 2018)

A students Seminar on Metallurgy & Materials Engineering was jointly organized by IIM Jamshedpur Chapter, CSIR-NML and Tata Steel Ltd. at CSIR-NML Jamshedpur. Mr. Debashish Mazumdar, President-, Works, Head- Steel Business, Usha Martin Ltd. graced the inaugural function as the Chief Guest. More than 250 students from all over the country participated in the program.

A technology transfer Agreement was executed with M/s. Recycle Karo, Mumbai for "Extraction of precious metals" (30th July 2018).

An agreement was executed for Development of Briquetting technique for utilization of Steel plant solid waste with Ferro Scrap Nigam Ltd. (10th August 2018).

A technology transfer agreement was signed with M/s Shree Mahabir Refractory Works, Ranchi for a process for Production of Highly Metallized DRI from Mill Scale & Lean Grade Non-Coking coal in Tunnel Kiln (10th August 2018).


Independence Day Celebrations (15th August 2018)

The national flag was hoisted by Dr. Indranil Chattoraj, Director CSIR-NML and the function was attended by staff and families of staff. A number of events were organized to mark the event at both laboratory and residential complexes viz. Quiz, Sit & Draw, Essay, Hindi Poem Competition, Cultural Program and Friendly Football Tournament.







Prof. SN Sinha Memorial Materials and Metallurgy Quiz (SNSM3Q-2018) (24th August 2018)

CSIR-NML in association with the Indian Institute of Metals, Jamshedpur Chapter organized the 6th Prof. SN Sinha Memorial Materials and Metallurgy Quiz (SNSM3Q-2018) for Standard XI and XII students. 29 schools in and around Jamshedpur participated in the quiz and Loyola School, Jamshedpur bagged the first prize.

Hindi Week Celebrations (17th-24th September 2018)

Hindi week was observed in the laboratory, and a number of events viz. Essay Writing and Poetry Recitation were organized in this connection. The program was concluded with the lecture of Mr. Rajesh Kumar Rai, Akashvai.

Cyber Security (19thSeptember 2018)

A Workshop on Cyber Security was held at CSIR-NML. Officers from Jamshedpur, Cyber Cell addressed the staff for creating awareness on the topic.

Town Official Language Implementation Committee Meeting (27th September 2018)

Members from various government officials met at CSIR-NML to discuss the implementation of the official language "Hindi" in the offices of the district.

76th CSIR Foundation Day Celebrations (26th September 2018)

Prof. TC Rao former Director of Regional Research Laboratory of CSIR, Bhopal graced the occasion as chief guest. The event started with the documentary film showing the legacy of CSIR and its contributions over the last 76 years. On this event, the CSIR-NML employees who completed their 25 years of service were felicitated by the chief guest, Director-NML and the COA. Meritorious wards of staff who could secure very high scores in their Xth or XIIth exams or could ensure admissions in the premier institutes of India viz. IITs, NITs were also awarded by the dignitaries on the occasion.






Outreach program of IISF & E (28th September 2018)

An outreach program of India International Science Festival & Expo (IISF & E) 2018 was held at CSIR-NML, Jamshedpur. Prof. KK Shukla, Director, National Institute of Technology, Jamshedpur graced the occasion as a chief guest and Mr. Arun Kumar, Director, DST, Government of Jharkhand was present as the guest of honor in the event. A large number of participants & visitors from in and around Jamshedpur came to witness the event.



Vigilance Awareness Week (29th September - 2nd October 2018)

The vigilance awareness week was observed at CSIR-NML. A number of programs were also organizedto mark the event.



Vigilance Awareness Lecture

(2nd November 2018)

A lecture was given by Mr. Vikas Kumar (IRTS), Area Manager, Tata Nagar for increasing the awareness on the topic. Mr. Vikas Kumar (IRTS), Area Manager, Tata Nagar for increasing the awareness on the topic. Mr. Vikas Kumar (IRTS), Area Manager, Tata Nagar for increasing awareness on the topic.


Thermo-Cale Software Workshop (3rd October 2018)

A workshop was organized for the researchers of the laboratory to upkeep their expertise on the software.



Prof. Meghnad Saha Memorial Lecture (5th October 2018)

On 125th birth anniversary of Prof Meghnad Saha, founder President of NASI, the Jharkhand chapter in association with CSIR NML celebrated the life and teachings of Prof Saha by organizing Prof Meghnad Saha memorial Lecture at CSIR NML on Oct 6th, 2018. Prof. Sankar Pal, former Director of ISI Kolkata was the chief guest of the function. Dr I Chattoraj, Director, CSIR NML, briefed about the life and contributions of Prof Saha in the different fields of Physics in general and astro-physics in particular. Dr Sinha, Chairman of the chapter remembered Prof Saha for his contribution in establishing the first science academy in India and its mandate towards welfare of society. Prof Sankar Pal delivered the Prof Meghnad Saha Memorial lecture entitled "Evolution and challenges of Machine Intelligence to Data Science". The lecture deliberated on the anticipated role of machine learning in Big data technology revolution where India aims to strengthen its hold. He also cautioned the students to choose areas relevant to their education streams and not falter around the big hype names. More than 250 students attended the program from NTTF, Jamshedpur, Cooperative College, and Graduate College, also interacted with Prof. Sankar Pal during the one-hour lecture. The program concluded with prize distribution of the NASI's Interschool Science Exhibition Competition held at RV School, Jamshedpur. Little Flower School, Jamshedpur bagged the first position, whereas Carmel Junior College, Jamshedpur and St. Xaviers School, Chaibasa bagged second and third sport. Chairman NASI Jharkhand Chapter also felicitated Mrs Rakhi Banerjee, Principal Rajendra Vidyalya Jamshedpur for her support towards the activities of Chapter.


69th CSIR-NML Foundation Day Celebrations (26th November 2018)

The occasion was celebrated at a large scale in the laboratory and a number of awards were presented to the CSIR-NML staff and wards of staff in the main function. Dr. Indranil Chattoraj, Director-NML talked about the contributions of the laboratory in the upliftment of science & technology in the country as well as in abroad. Meritorious staff children were also awarded on the event for securing high marks in class Xth and/or XIIth exams.


Training on MICRESS software (28th November 2018)

A training was organized for the researchers of the laboratory to upkeep their expertise on the software.

Agreement Signing with National Institute of Technology (NIT), Jamshedpur for R&D and Academic Collaboration (11th December 2018)

Visit of Air Marshal Kuldeep Sharma, Indian Air Force (IAF) (27th December 2018)

The purpose of the visit was to examine the existing infrastructural facilities of CSIR-NML for the asset management of the IAF, specifically aircrafts. The prospects of collaborative R&D work on mutually interesting research areas were also explored.

Safety Training (28th December 2018)

In-house fire safety training was organized in CSIR-NML. This training was arranged with an intent to impart knowledge along with hands-on training to the staff on fire safety and how to handle fire safety devices in decisive situations. More than 20 staff got trained and witnessed the fire safety demonstrations.

"Vishwa Hindi Diwas" Celebrations
(10th January 2019)


दैनिक जागरण

22 वर्ष पूर्व बनी नगर राजभाषा कार्यान्वयन समिति

एनएमएल के निदेशक को बनाया गया समिति का अध्यक्ष, वर्षभर कराए जाते हैं कार्यक्रम

National Seminar on "Advances in Engineering Materials for Sustainable Development (AEMSD 2019)" (18th-19th January 2019)

32nd National Convention of Metallurgical and Materials Engineers (The Institution of Engineers) and National Seminar on "Advances in Engineering Materials for Sustainable Development (AEMSD 2019)" was organized at CSIR-National Metallurgical Laboratory. The seminar received tremendous attention from various industries, academia, and reputed research organizations across the nation. More than 100 delegates participated in the seminar.


THE AVENUE MAIL
Jamshedpur, Friday, January 18, 2019
City to host 32nd National Convention
Mail News Service

Staff Picnic 2019 (20th January 2019)

CSIR-Staff Club organized picnic for the NML staff at Galudih Resort, Mahulia, Jharkhand

Visit of Honourable Member of the NCSC (21st January 2019)

Dr. Yogendra Paswan, Honourable Member of the NCSC visited CSIR-NML and interacted with staff of the laboratory.

70th Republic Day Celebrations (26th January 2019)

Republic day was celebrated at CSIR-NML and its residential complexes. The staff members along with their families participated in the celebrations. On the occasion, Badminton Tournament (Single and Doubles) was also organized by the CSIR-NML Staff Club.




Visit of National General Secretary of Vigyan Bharati (4th February 2019)

Sri Jayant Sahashrabuddhe visited CSIR-NML and interacted with technical and non-technical staff. The eminent personality talked about the importance of Vedic science & experts and their contribution to modern science and technology and spreading positive awareness in the field of biotechnology, mathematics, and engineering etc.


Indo-German Bilateral Workshop on Additive Manufacturing of Metals (AMM-2019), (4th - 6th February 2019)

Inaugural function at CSIR-National Metallurgical Laboratory, Jamshedpur


State and Neighbour

THE AVENUE MAIL

Jamshedpur, Tuesday, February 05,

NML collaborates with Germany for metal research

An Indo-German bilateral workshop on "Additive Manufacturing of Metals: Current issues and way forward" was organized by CSIR-National Metallurgical Laboratory (CSIR-NML), Jamshedpur, jointly with Leibniz-Institut für Werkstofforientierte Technologien (Leibniz-IWT), Bremen, Germany. The workshop was supported by Indo-German Science and Technology Centre (IGSTC) under its 'Open Call for Indo-German Bilateral Workshops' fostering interaction between Scientists/researchers from industry and academia. The coordinators of the workshop were Dr. Volker Uhlenwinkel, Leibniz-IWT (Bremen) and Dr. V. C. Srivastava, CSIR-NML (Jamshedpur). Professor Indranil Manna, AJC Bose Fellow and Institute Chair Professor, Indian Institute of Technology, Kharagpur, inaugurated the workshop as Chief Guest. Dr. Debashish Bhattacharjee, Vice President, Technology and New Materials Business, Tata Steel, was the Guest of Honor and Dr. G. Padmanabhan, Director, ARCI-Hyderabad, was the Guest Mentor during the inaugural function. Dr. I. Chattoraj, Director, CSIR-National Metallurgical Laboratory, Dr. Roshan Paul, Director IGSTC were also present amongst the dignitaries. This bilateral workshop brought together Indo-German scientific, educational and industrial fraternity, working on different aspects of additive manufacturing, on a common platform and provided an opportunity for the dissemination of knowledge and learning in the still emerging additive manufacturing technologies. The workshop consisted of 25 expert talks as well as a poster session for young researchers; culminating into cross-fertilization of ideas, networking for cooperation and discussion on important current issues on additive manufacturing of metals and alloys. The contributions of young researchers were recognized and two best

Director (CSIR-NML) and Director (IGSTC) with Indian and German coordinators of the workshop

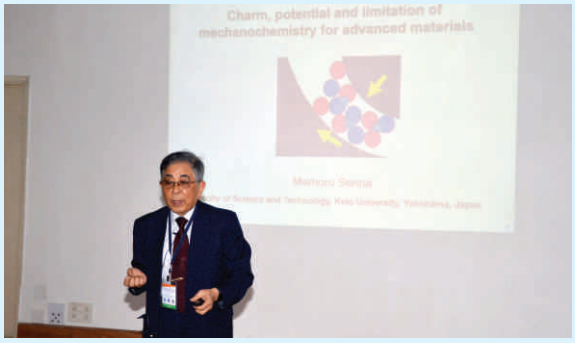
posters were awarded. The participation of over 100 participants from academia, industry, national laboratories and the research students from major institutions, actively involved in additive manufacturing, from Germany (Leibniz-Institut für Werkstofforientierte Technologien, Bremen; Helmholtz-Zentrum Geesthacht, Geesthacht; Fraunhofer Institute for Mechanics of Materials IWM, Freiburg; Fraunhofer Institut für Fertigungstechnik und Angewandte Materialforschung (IFAM), Bremen; Lehrstuhl für Photonische Technologien der Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen; Bremer Institut für angewandte Strahltechnik BIAS, Bremen; Heraeus Additive Manufacturing GmbH, Hanau; Aconity3D GmbH, Herzogenrath; Indutherm Erwärmungsanlagen GmbH, Walzbachtal; Additive Works GmbH, Bremen) and India (Indian Institute of Technology, Kharagpur; Indian Institute of Technology, Chennai; CSIR-CMERI, Durgapur; NIFFT, Ranchi; GE Global Research, Bengaluru; Indian Institute of Technology, Hyderabad; RRCAT, Indore; ARCI, Hyderabad; CSIR-IMMT, Bhubaneswar; INTECH-DMLS, Bengaluru; Tata Steel Limited, Jamshedpur; Wipro3D, Bengaluru; Bharat Forge Limited, Pune; CSIR-AMPRI, Bhopal; CSIR-CGCRI, Kolkata; Indian Institute of Technology-BHU, Varanasi; MNNIT-Allahabad, Prayagraj) ensured fruitful knowledge networking and active interactions.

Participants of Indo-German Bilateral Workshop

Agreement Signed with General Electrics (GE), Bengaluru, India
(5th February 2019)

Visit of Director, Oil and Natural Gas Corporation(ONGC) (18th February 2019)

Microsymposium on 'Recent Developments in Mineral Processing and Mechanical Activation of Solids (22nd February 2019)



Material Research Society of India (MRSI) Jamshedpur Chapter organized the event; Indian Institute of Mineral Engineers (IIME) Jamshedpur Chapter and CSIR-National Metallurgical Laboratory (CSIR-NML) were the co-organizers. Recent advances in the area of minerals and materials processing was the broad theme area of the symposium. In detail, the topics included: (a) characterization of minerals, ores and secondary resources, (b) mechanical activation of solids in mineral processing, (c) mechanochemistry - fundamentals and applications, (e) bioprocesses in minerals processing, (f) innovative approaches in solid waste utilization, and (g) modelling and simulation. The micro-symposium consisted of lectures by experts in the field from India and abroad; the distinguished speakers who enriched the symposium through lectures were Prof. Indranil Manna (AJC Bose Fellow & Institute Chair Professor, Indian Institute of Technology, Kharagpur), Prof. Mamoru Senna (Keio University, Japan), Prof. S. Subramanian (Indian Institute of Science, Bangalore), Dr. S. Srikanth (Former Director, CSIR-NML, Jamshedpur), Prof. C. Sasikumar (Maulana Azad National Institute of Technology, Bhopal), Mr. Santhosh Daware (Tata Research Development & Design Centre, Pune), Dr. Sanjay Kumar (CSIR-NML, Jamshedpur). Besides the invited lectures, a poster session focused on the symposium theme was also organized for contributory papers from academia and research & development institutions. The inaugural ceremony was graced by the dignitaries Dr. Indranil Chattoraj, Director, CSIR-NML, Jamshedpur, Dr. A.K. Mukherjee, Vice-President, IIME

Jamshedpur Chapter & Head Raw Materials Research, Tata Steel, Jamshedpur. Prof. I. Manna, Prof. M. Senna, Prof. S. Subramanian, Dr. S. Srikanth, Prof. C. Sasikumar, Mr. Santhosh Daware, Dr. Sanjay Kumar and Dr. T. C. Alex (Convener of the programme). To mark the occasion, a Souvenir of Microsymposium was also released. Around 50 delegates from different parts of the country participated; the delegates belonged to institutions like IIT Kharagpur, CSIR-IMMT Bhubaneswar, Tata Steel Jamshedpur, Ashapura Group of Companies Mumbai, Govt. College of Engineering & Ceramic Technology, Kolkata, MNIT, Bhopal, CSIR-NML, TRDDC Pune, CIMFR Dhanbad, ISM (IIT) Dhanbad. There were three technical sessions and a poster session in the symposium, besides the valedictory function. In the valedictory function, Prof. Senna gave away the prizes to the award winners of the poster session. Thereafter, Dr. Rakesh Kumar (Chief Scientist and Advisor, Management) was felicitated for his contributions to the theme area of the microsymposium. The symposium came to a close with the vote of thanks.

CSIR-NML Tennis Ball Cricket Tournament (23rd February 2019)

The tournament was held for the NML staff.

CSIR-NML Annual Sports Day (24th February 2019)

A number of sports activities were organized to mark the event.

The Staff and staff- families participated in the activities.

In-house Fire Safety Training (26th February 2019)

A fire safety training program was organized at NML. The program included classroom lectures followed by hands-on training and live demonstrations. The objective of the training was to impart knowledge of basic fire fighting, use of fire extinguishers, preventing burn injuries and usage of fire devices.

National Science Day Celebrations (28th February 2019)

Dr. DP Durai, Director, MP Birla Institute of fundamental science and MP Birla Planetarium, Kolkata was the chief guest of the function. The chief guest delivered a popular lecture on "Concepts and Challenges in Astronomy". Best teacher awards were also presented to the teachers of Kerala Public school, Jamshedpur and Delhi Public school, Ranchi.

International Women's Day Celebrations (7th March 2019)

A panel discussion followed by a fun fair for the CSIR- NML staff & staff families was organized on the event.




73rd Meeting of CSIR-NML Research Council (8th March 2019)


CSIR-NML Publications and News

Science & Technology in Ancient India

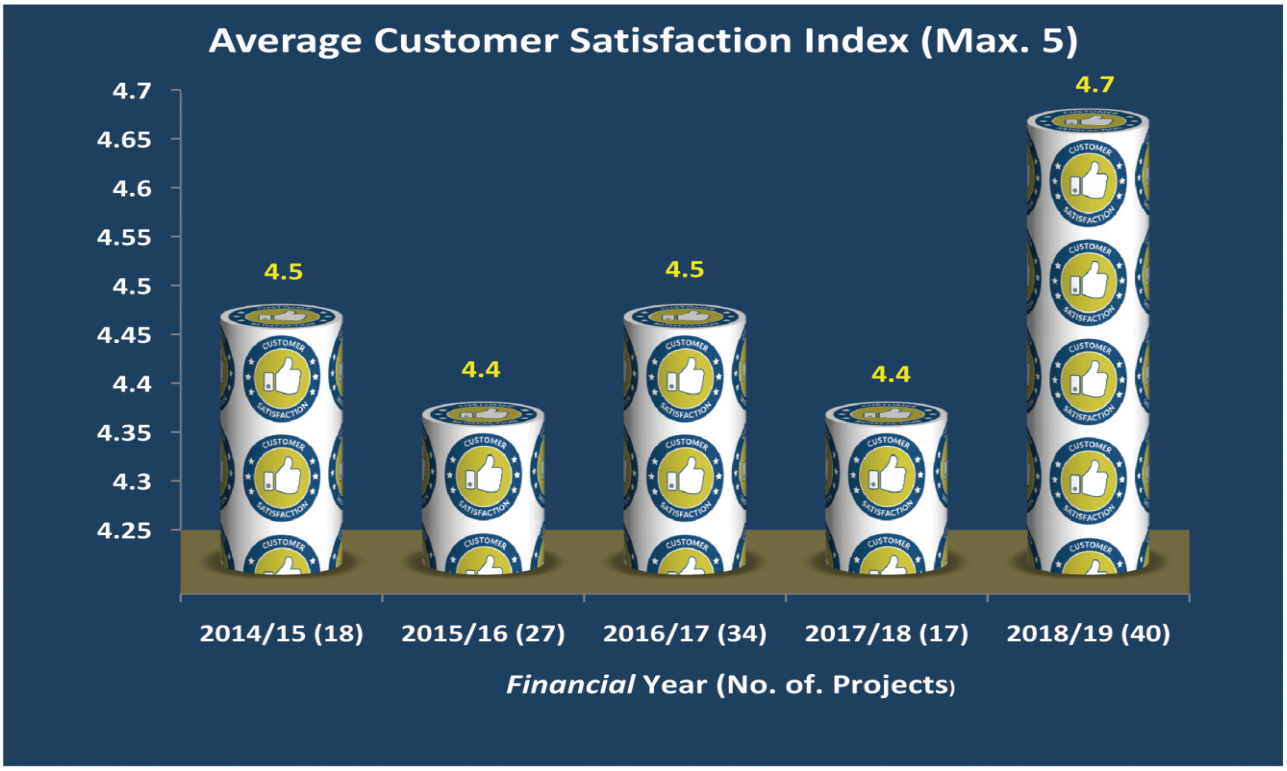
Wootz Steel

A pioneering steel alloy matrix developed in India. This steel was used to make the famed Damascus swords. Produced by the Tamils of the Chera Dynasty, the finest steel of the ancient world was made by heating black magnetite ore in the presence of carbon in a sealed clay crucible kept inside a charcoal furnace.

Science & Technology in Ancient India

Customer Satisfaction Evaluation Index and Feedback

100% of our customers recommended us for providing R&D Services



"First time applied USIMPAC software in Tata Steel to understand the performance of crushing plant. Lot of simulations lead to selection of optimum condition which was recommended for the plant trial. Plant trials showed reduction in recirculation by 35-40% and hence energy and other operating cost savings were also realised. Concerned scientists commitment in the project was encouraging. Overall experience in the project was excellent. ***(SSP 1065)***

- Tata steel Pvt. Ltd., Jamshedpur

"Its a pleasure to work with Team NML. NML team is too cooperative and supportive. We wish to work in future with NML. ***(SSP 1133)***

- Bajaj Electricals Ltd., Mumbai

"Very good experience. ***(CLP 0179)***

"Project was not commissioned to realize financial benefits. It was for R&D. ***(CLP 0148)***

"Good work done. ***(CLP 0171)***

"It was good project and good experience to work with NML experts, very good. ***(CLP 0182)***

"Very good. ***(CLP 0146)***

"Very good experience working with CSIR-NML. ***(CLP 0178)***

"Nice work. ***(CLP 0136, CLP 0137, CLP 0162)***

"It was different kind of project with NML and Dr. Beena understood the requirements well and conceptualized the system nicely. The system can be further improved. ***(CLP 0186)***

- Tata steel Pvt. Ltd. Jamshedpur

"Good. More focus should be there on timely completion. (SSP 1121)

- ***Bharat Petroleum Corportion limited, Kochi***

"Very satisfied". ***(SSP 1062)***

- ***Starwire India Limited, Haryana***

"The team worked efficiently to complete all the project tasks initially envisioned. The analysis provided was very useful. The laboratory has expertise in the field. ***(CLP 0177)***

- ***Tata Steel Head Rolling Technology, Jamshedpur***

"Satisfied with the work done. (SSP 1128)

- ***Tata Steel R&D Division***

"I am super excited to work with Dr. Sahu and the team. State of the art machinery exists, but unless there is a cost effective model, there will be poor utilization of the same by startups and MSMEs, which in a way form the backbone of innovation. The commitment towards customer satisfaction of the group makes me wonder at times, why did I not come here earlier. Technology is very good, but the market is not accepting the product as yet. We are trying to figure out a way to market the product. Please have incubation facility, so that we can set up in the same facility and more importantly, the state of the art testing facilities can be made available to us for virtually free of cost, so that there is a win-win situation for both the lab and the startups. ***(SSP 1048)***

– ***Teyasi Innovations, Jamshedpur***

"Nice experience to work with CSIR-NML. ***(SSP 1038)***

- ***Boeing Company, WA***

"Collaboration with NML enabled the joint UK-India funded research to progress. Whilst no additional financial benefit accrued from the research to our industrial partners, new knowledge was developed. ***(SSP 0971)***

- ***Primetals Technologies Limited, UK***

"Overall satisfied with the service provided. ***(SSP 1064)***

- ***Mangalore Refinery & Petrochemical Ltd.***

"Good experience to work with CSIR-NML. Looking forward to more technology transfers. ***(SSP 0915)***

- ***Mahashrya chemicals Pvt. Ltd., Odisha***

"Limitation of accelerated creep approach for condition monitoring was observed in the project. For some realistic data, the time need to be increased, otherwise the evolution of microstructure would be quite different from the real condition in field. This aspect to be taken care of in future otherwise results would not be realistic. ***(CLP 0117)***

- ***NTPC Ltd.***

"Excellent job done. ***(SSP 1110)***

- ***Wonder Cement Ltd.***

"Excellent ! Enjoyed working with the personnel of the projects involved. ***(SSP 0811)***

- ***Indian Oil Corporation Ltd., Faridabad***

Patent Applications Filed: 2018-19

SN	NML Ref No	Title	Inventors	Assignee
1	PAT-0529/2018/IN	A process for the production of higly metallized DRI from mill scale & lean grade non-coking coal in tunnel kiln	D.Paswan, M.Malathi, D.Bandyopadhyay, M.Madan, A.Ammasi and S.Thatoi	CSIR
2	PAT-0530/2018/IN	A process for the production of ferric sulphate and silica powder from copper slag	K. K. Sahu, D. Mishra, S. Agarwal and Archana Agrawal	CSIR
3	PAT-0531/2018/IN	Hot-dip Al-Si-Mg-Cu-Sc coating on steel sheet with excellent in corrosion resistance as well as hot forming application and process for the production thereof	Mahesh Gulab Walunj, Gopi Kishor Mandal, Suman Kumari Mishra, Vikas C Srivastava, Lokesh Chandra Pathak, Rajesh Pais	Tata Steel & CSIR
4	PAT-0533/2018/IN	A cost effective, on-line smart sensing system for defect detection and identification in high end wires drawn at high speed	Tarun Kumar Das, Chandan Dutta*, Alok Kumar*, Arpita Ghosh, Sushil Kumar Mandal and Sarmishtha Palit Sagar	CSIR
5	PAT-0534/2018/IN	Electro deposited ceramic coating for hardware submerged in hot dip galvanizing bath and process of electrodeposition	Mahesh Gulab Walunj, Lokesh Chandra Pathak, Himanshu Bapari	CSIR
6	PAT-0535/2018/IN	A process for recovering zinc as zinc phosphate and other valuable products from zinc dross	R. Choudhari, S. Sinha, D. Mishra, S. Shekhar, K. K. Sahu, A. Agrawal	CSIR
7	PAT-0536/2018/IN	A process for the production of gadolinium metal from gadolinium chloride by electrolysis	Shyamal Kumar Maity, Mallarouth Chandra Shekhar, Parvesh Kumar Dhawan, Jayant Konar, Bandi Prabhakara Reddy, Suddhasattwa Ghosh	CSIR & IGCAR
8	PAT-0537/2018/IN	A environment friendly nickel electroplating process on magnesium alloy in non-aqueous bath	Charu Singh, Raghuvir Singh and Shashi Kant Tiwari	CSIR
9	PAT-0538/2018/IN	A process for direct production of low and medium carbon ferromanganese in electric arc furnace	Navneet Singh Randhawa, Rajesh Kanyut Minj, Satadal Ghorai, Sandip Ghosh Chowdhery, Krishna Kumar, Deo Prakash Singh, Manoj Humane, Jay Narayan Patel	CSIR
10	PAT-0539/2018/IN	A process for the recovery of high pure terbium oxide from phosphor powder of waste fluorescent lamps	S.K. Sahu, Aarti Kumari and Swati Pramanik	CSIR
11	PAT-0541/2018/IN	A process for quality enhancement of heat altered coal using micronization and oil agglomeration	Saswati Chakladar, Sanchita Chakravarty, Sanjay Kumar, T C Alex, Ashok K Mohanty	CSIR

SN	NML Ref No	Title	Inventors	Assignee
12	PAT-0542/2018/IN	A process for the recovery of potash and high pure iron oxide from iron rich glauconitic clay	Saurabh Shekhar, Shivendra Sinha, Devabrata Mishra, Kamala Kanta Sahu, Archana Agrawal	CSIR
13	PAT-0543/2018/IN	An electrolytic process for the production of zinc powder from zinc dross	Sanjay Prasad, Shyamal Kumar Maity, Aarti Kumari And M. Chandra Shekhar	CSIR
14	PAT-0544/2018/IN	Universal hot dip galvanizing process for steels using prior sol-gel dip coating	Mahesh Gulab Walunj, Shashi Kant Tiwari, Lokesh Chandra Pathak	CSIR
15	PAT-0545/2018/IN	Heating Assembly (I)	Ranjan Kumar Sahu, M Madan, V Rajinikanth, Nimai Haldar, Himanshu Bapari	Bajaj Electricals Ltd & CSIR
16	PAT-0546/2018/IN	Heating Assembly (II)	Ranjan Kumar Sahu, M Madan, V Rajinikanth, Nimai Haldar, Himanshu Bapari	Bajaj Electricals Ltd & CSIR
17	PAT-0547/2018/IN	A process for the preparation of high induction Fe-based amorphous and nanocomposite alloy strip	Premkumar Murugaiyan, Rajat Kumar Roy, Ashis Kumar Panda, Amitava Mitra	CSIR
18	PAT-0551/2018/IN	An advanced auxiliary cold chamber for an annealing simulator	B. Ravi Kumar and Nimai Halder	Tata Steel Ltd & CSIR
19	PAT-0552/2019/IN	An Air Generating System For Improved Performance Of Column Flotation Cell	Shobhana Dey and Ratnakar Singh	CSIR

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Reference Number	Title (Authors)	Year
C108	An Informational Management System for managing research support group activities (Authors: Beena Kumari, A.Upadhyay, S.K.Pal, A.Mitra and S.K.Mandal)	2018
C107	A web-based information system to manage customer satisfaction evaluation & feedbacks (Authors: Beena Kumari, S.K.Pal, A.Upadhyay and A.Mitra)	2018
C106	NEURAL_HYDROCYCLONE-A model based artificial neural network code to characterize solid-liquid separation behaviour of a dewatering hydrocyclone (Authors: Suchandan K Das and Sunati Mohanty)	2018
C105	Microstructure Atlas of P91 Steel (Authors: Rajat Kumar Roy, Avijit Kumar Metya, Ashis Kumar Panda, Mainak Ghosh, Sarmishtha Palit Sagar, Swapan Kumar Das, Jaganathan Swaminathan, and Amitava Mitra)	2018
C104	Microstructure Atlas of P22 Steel (Authors: Rajat Kumar Roy, Avijit Kumar Metya, Ashis Kumar Panda, Mainak Ghosh, Sarmishtha Palit Sagar, Swapan Kumar Das, Jaganathan Swaminathan, and Amitava Mitra)	2018
C103	NEURAL_NANOBAINITE_MECH - A model based multi-input-multi-output (MIMO) artificial neural network code to predict mechanical properties of nanobainitic steel. (Minal Shah and Suchandan K Das)	2018
C101	NEURAL-NANO-BAINITE LATH - an artifical nerual network code to estimate the bainite lath thickness in silicon rich steels (Minal Shah and Suchandan K Das)	2018

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