वार्षिक प्रतिवेदन 2017-18

Annual Report 2017-18

CSIR-National Metallurgical Laboratory

Jamshedpur - 831007, India

CSIR India

The Council of Scientific & Industrial Research (CSIR), established in 1942, is an international benchmarked contemporary R&D organization with a dynamic network of 38 national laboratories, 39 outreach centres, 3 Innovation Complexes and 5 units (http://www.csir.res.in/). CSIR focuses on diverse areas encompassing: Aerospace Science and Engineering; Agro, Food Processing & Nutrition; Biology and Biotechnology; Chemicals and Petrochemicals; Earth Sciences; Ecology and Environments; Electronics and Instrumentation; Fuels and Energy; Geotechnics, Housing and Road Construction, Healthcare, Drugs and Pharmaceuticals; Leather; Mining, Minerals, Metals and Materials; Metrology; Ocean Science and Engineering; Water; and, more. The spectrum of activities covers all facets of research (basic science to industry to society driven), human resource development, intellectual property and, protection of traditional Indian knowledge. CSIR's expertise and experience is exemplified in about 4600 active scientists supported by about 8000 scientific and technical personnel. The mission of CSIR is to create a "New CSIR for New India" and its vision is to "Pursue science which strives for global impact, technology that enables innovation-driven industry and nurture trans-disciplinary leadership thereby catalysing inclusive economic development for the people of India". Through its wide science and technology base, CSIR strives to make a difference in the lives of Indian people, particularly the Common Man, and help solve day to day problems. CSIR is ranked 84th among 4851 institutions worldwide and is the only Indian organization among the top 100 global institutions, according to the Scimago Institutions Ranking World Report 2014. CSIR holds the 17th rank in Asia and leads the country at the first position. The scientific staff of CSIR constitute only about 3-4% of India's scientific manpower but contribute to 9.6% of India's scientific outputs. In 2015, CSIR published 5797 papers in SCI journals with an average impact factor per paper of 3.02.

CURRENT LEADERSHIP

Shri Narendra Modi
Prime Minister
President CSIR

Dr. Harsh Vardhan
Cabinet Minister
S & T and Earth Sciences
Vice President CSIR

Dr. Girish Sahni
Director General, CSIR
Secretary DSIR

CSIR is serving the society through a large number of R&D programmes with broad focus on : Affordable and Healthy Food – Agri-food technologies; Medicines for the Common Man – Affordable healthcare; Sustainable and Green Energy; Chemistry and Environment; Smart and Functional Materials; Multi-purpose Solutions exploiting Smarter Engineering Structures/Design and Electronics; Improving Connectivity for Economic Development through Civil Aviation; Climate Change and Earth System Sciences; Technology for the masses – 'CSIR 800'; Digital India – Data Intensive Scientific Discovery; Economic Vigour through Scientific entrepreneurship. The R&D efforts are aligned with Government initiatives, such as Make in India; Swachch Bharat; Clean Ganga; Swasthya Bharat; Smart Cities; Smart Villages; Clean, efficient, affordable and renewable energy technology solutions; Innovate in India; etc. in a significant way.

CSIR-National Metallurgical Laboratory

CSIR-National Metallurgical Laboratory (CSIR-NML), established in 1950 is a premier Indian research organisation dedicated to various facets of Minerals, Metals and Materials – science, technology, industrial services and human resource development. Since its inception, the Laboratory has made notable contributions in the areas of mineral beneficiation and agglomeration, ferrous and non ferrous metallurgy, alloy development and processing, materials science & engineering and resource conservation & environment. Specific examples include: adoption of laboratory developed flowsheets in mineral industries; technologies for bulk and speciality ferroalloys, magnesium, manganese (electrolytic manganese metal/di-oxide), etc; substitute alloys; services rendered through the largest creep laboratory, failure analysis and remaining life assessment; and, contributions towards conservation of Indian heritage. A historical accounts of past achievements (1950-2010) of CSIR-NML Jamshedpur is painted in the Diamond Jubilee commemorative volume *'la vintage metallurgie : 60 years of marriage of science to industry'* (http://eprints.nmlindia.org/4360). 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, automotive, energy, railways, strategic, societal, and others. Glimpses of recent/ongoing activities of the Laboratory is presented here for the benefit of our stakeholders and, seeking their partnerships for further advancements.

In India, nearly thirty percent of steel is produced by secondary steel producers using induction furnace route. High phosphorous content makes the steel substandard and unsuitable for structural applications. CSIR-NML in association with All India Induction Furnace Association (AIIFA) and Ministry of Steel has developed a flux to reduce the phosphorus level from 0.07-0.09% to BIS prescribed limits of < 0.05%. The flux which is tested under industrial conditions has potential to benefit large number of secondary steel producers. Efforts are on to fine tune the flux chemistry and its usage with high lining life.

CSIR-NML is diversely associated with activities connected with energy sector. Significant efforts are directed on coal and the activities ranging from prospecting using 'coal core analysis' to beneficiation for ash removal, and value added products from fly ash. Innovative flowsheets involving dry beneficiation are developed to reduce ash in the coals of different origins.

CSIR-NML column technology which was earlier exploited in commercial operations for beach sand minerals, limestone and barite, is now successfully tested for coal in the columns set-up at mine sites. Technologies for the production of geopolymer paving blocks using fly ash with/without iron and steel making slags/red mud have been developed and successfully tested under field conditions. Research pursuits of CSIR-NML are also aligned with the material needs of the sector. A wear resistant steel was developed by the Laboratory to address the silt erosion problem during hydel power generation in Himalayan region. Newer initiatives from the Lab include development of advanced electrical steels and evaluation of materials for the futuristic ultra-supercritical plants.

Magnesium holds the key for the success of the national programmes for titanium and zirconium extraction, and, next generation Mg-alloys for the automotive sector. CSIR-NML's contribution to Mg technology development goes back to 1971, when a 250 tonnes per annum pilot plant based on the Pigeon process was commissioned. The plant and technology were subsequently transferred to an industry, M/s Southern Magnesium Ltd who was the only commercial producer of Mg in India until 2002 when the plant closed due to Chinese dumping. CSIR-NML, under the 12th Five Year Plan has developed a novel magnesium extraction technology (Magnatherm process) which employs moderate vacuum and involves direct heating. The technology was developed on 300 kg pilot scale using an indigenously fabricated reactor. Based on large number of pilot plant trials, design and operational data have been generated for further scale up to ~ 1000 kg reactor.

In the strategic sector, specific focus of the Laboratory is on extraction and processing metals, namely tungsten, sodium and gadolinium. Tungsten is a strategic metals with applications in space and defence programs. Efforts are directed towards exploitation of low grade indigenous resources and recovery from scraps generated during processing and post usages of components. To address immediate needs, CSIR-NML has developed and commercialised a technology for the recovery of tungsten from a large variety of W-bearing scraps. The developed technology is superior in terms of tungsten recovery (> 90%), co-recovery of associated metals (e.g. Co, Ni), process economics and environmental considerations. Indigenous technologies for sodium and gadolinium, essential for atomic energy programme were successfully developed. Sodium is produced using electrolysis cells from 50 kVA to 500 kVA capacity, and further scale up of the process by industry is in progress. Similarly, high purity gadolinium was produced by fused salt electrolysis.

Almost the entire requirement of potash for our country is imported since resources of traditionally used chloride ores are scarce. Technically and economically attractive processes to recover potash from indigenously available non-traditional silicate resources, notably feldspar and glauconite are being developed. An innovative process, possibly the first of its kind, has been developed at CSIR-NML under an industry sponsored programme. The process, which permits high recovery of potash along with all other constituents present in feldspar (e.g. Si as Fe-Si) has the potential to radically change the technology scenario. Encouraged by the success of the process at 10 kg scale, it is now being considered for further scale up and commercial exploitation. Process flowsheets based on pyro-/hydrometallurgy were developed and evaluated for the recovery of potash from glauconite sand. In yet another innovative development, mechanical activation of glauconite was used to alter its cation-exchange capacity and develop a greener option which would permit its direct usage as a source of potash.

Solid wastes and effluents are of major concern in metallurgical industries from the point of view of resource conservation and environmental considerations. For example, large quantities of solid wastes (e.g. slimes and fines during iron ore mining, slags, mill scale) and effluents (e.g. pickle liquor) are generated during iron and steel making operations. NML has developed a number of processing options and value added products to address the problem. Some of these have been tested in real plant conditions and include: DRI from slimes/mill scale using tunnel kiln; mill scale briquettes as coolant in LD converter steel making; pig iron from the smelting of self-reducing briquettes (slime and Jhama coal) in a Low shaft furnace; and, magnetite for heavy media separation using high pure hematite produced during pickling operation as raw material. Strategies for the recycling and reuse of LD slag have been developed using smelting in a 175 kVA furnace and the processes are available for further probing on industrial or semi-industrial scale. By smelting, phosphorus is removed and the resulting slag is suitable as a source of lime and cementitious material. In yet another significant development, technologies have been

developed and tested for the production of a wide spectrum of value added iron oxide pigments.

In recent times, the Laboratory has paid increasing attention to the design and development of equipment which are tailor-made for specific metallurgical research and tests. The objective is also to minimise dependence on imported equipment which are often priced exorbitantly. Under one such initiative, an annealing simulator was developed which offers exciting possibilities to simulate batch and continuous annealing processes commonly practiced in steel industry (e.g. IF steel with desirable dew point setting, ultra-fast cooling for dual phase or complex phase steel annealing cycles, etc.). Similarly, several devices were developed for on and off site NDT of industrial components and materials. One of these, MagStar, a portable magnetic sensing device for Non-destructive Evaluation of Steel Structures/ Components measures Magnetic Hysteresis Loop (MHL) and Magnetic Barkhausen Emissions (MBE). MagSys, a Giant Magneto Impedance (GMI) based magnetic sensing device is also ready for commercialization as a structural health measuring tool. The device is capable of detecting very low magnetic field and magnetic phases. An NDT device for detecting defects in wire during fabrication has been developed and installed at the sponsors site. In collaboration with our sister laboratory, CSIR-CGCRI, various applications of FBG sensors including temperature profiling of continuous casting moulds, have been perfected.

Several new alloys and materials have been developed based on the specific needs of our clients and collaborators. A collagen-graphene composite was developed for super capacitive applications for a Sri Lanka based multinational. Several advanced coatings have been developed at the behest of aerospace multinationals with green protocols and materials in mind. Advanced steels development and their qualifications have been carried out successfully, in collaboration with various steel producers.

Brassware artisans across the country are at a crisis because of stiff competition from China. Further, there is the risk of the age-old practices becoming extinct with loss of livelihood. The home based traditional pit furnaces used by the artisans are fuel inefficient and polluting. As part of a National Innovation Council initiative, NML has developed a cost effective, fuel efficient and eco-friendly coke based brass melting furnace for the metal artisans utilizing waste heat recuperating system and arresting suspended particulate matter (SPM) inside the pit. A few such furnaces were installed in Moradabad, Uttar Pradesh and in Balasore, Odisha. Simultaneous efforts are on to enhance awareness and training of artisans. CSIR-NML has also developed an efficient, low cost anti-tarnishing lacquer to prevent tarnishing and to maintain the metallic cluster of brass handicrafts. The developed lacquer is technically and cost-wise superior to the lacquers available in market. The technology has been transferred to a private entrepreneur for its commercial production.

CSIR-NML pays special attention to human resource development. Under the banner of Academy of Scientific and Innovative Research (AcSIR), the Laboratory initiated (in 2012) post-graduate and doctoral degree program in Materials and Metallurgical Engineering. The programme especially encourages enrolment of industry sponsored candidates. Besides regular courses, large number of need based short term training and skill development program are organised by CSIR-NML to meet specific industry requirement or fulfil requirement of societal missions.

In line with the CSIR Platinum Jubilee speech by Honourable Prime Minister, CSIR-NML took a number of initiatives to connect with stakeholders, including the public at large. 'NML Technology Handbook' is an updated (2016) compilation of potential technologies available from the Lab. The Handbook is available in soft copy format (http://eprints.nmlindia.org/2176).

NML has been sharing its arsenal of facilities with industry, academia and research organisations. In order to further augment the utilisation of equipment and pilot scale facilities beyond its own use, an equipment booklet 'Equipment Facilities @ CSIR-NML' is published as hard copy and on-line (www.eprints.nmlindia.org/7245).

Organizational Structure

Shri Narendra Modi
President, CSIR
Hon'ble Prime Minister of India

Dr. Harsh Vardhan
Vice-President, CSIR
Hon'ble S&T Minister of India

Dr. Girish Sahni
Secretary, DSIR
Director General, CSIR

Dr. Indranil Chattoraj
Director CSIR-NML

Dr. Rakesh Kumar
Adviser-Management

Dr. S.K. Das
Adviser-NKN &ICT

Dr. S.K. Mishra
Head-HRG

Dr. Amitava Mitra
Head-RPBD

Dr. S.K. Mandal
Head-KRIT

Dr. S. Tarafder
Head-MTE

Dr. D. Bandopadhyay
Head-MER

Dr. Ratnakar Singh
Head-MNP

Dr. Arvind Sinha
Head-AMP

Dr. S. Subba Rao
Head-NML-MC

Mr. I.B. Mishra
Head-ENG
(upto 31-12-18)

Mr. Prarvesh Kumar
Head-ENG

Mr. S.R. Hembram
COA-ADMIN

Mr. N.K. Singh
Officer-S&P

Mr. A.M. Pradhan
Officer-F&A

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)

Contents

Research Council (RC)

Prof. Amol A Gokhale (Chairman)
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-Director, 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. Anjan Ray (DG's nominee)
Head, RPPBD CSIR, New Delhi

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

Impressions

It is always a pleasure to visit NML. This is always a place for metallurgists like me to get recharged. I have seen new faces and an eagerness to do things. I wish them the very best. I am looking forward to seeing NML reach even greater height.

Prof. K. C. Chattopadhyay, IISC, Bangalore
15th June 2017

It is a privilege for me to visit CSIR-NML and have a historic cooperation to work as Director General MIDI. Hope your laboratory which is the most prominent in the area of Metal & Engineering sector development. I am glad to have collaboration in capacity Development.

Worknehdelelegn Shumete
Director General, Ethiopian Metals Industry Development Institutes, Addis Abase
17th June 2017

I am deeply honored to be invited to deliver the platinum jubilee lecture at NML, one of the earliest laboratories in India in material engineering domain.

Prof. Indranil Manna, Director, IIT Kanpur and Kharagpur
26th Sep 2017

The excellence of National Metallurgical Laboratory is a voyage and journey of immense value to the country. Successes of India in Metals Alloys and Minerals are attributed to S&T contributions of NML. Leadership is of high quantity and many a specialist proving NML has contributed in a big measure to the achievement of National significance and importance. The Lab. shall do ever better, in the coming years with more effective and ecosystem. My best wishes and all the support from a friend of NML.

Baldev Raj, Chancellor ACSIR Director
19th Nov 2017

This historic institute really through all its activities teaching us, and giving us confidence that the twining agreement with Ethiopia and MIDI will enable to top the potential and utilize it to develop Ethiopian Metal and Engineering industries.

Hon' Jeshame Lemma Wodojo
Ababa State Ministry of education, Ethiopia
17th June 2017

…I just express my sincere thanks to you and Mishraji for the coordination and confidence you provided, for the process. Now my conviction is very high to materialize that. I must say, process was very tricky and just the optimum way to happen…

Biplob Das,
Vedanta Ltd., Thoothukudi, Tamil Nadu, India
27th Mar 2017

I thank CSIR-NML for inviting me as chief guest on the foundation day. I am impressed by the faculties and researches going on at NML and I am sure the lab. will live up to its expectation

Prof. Sourav Pal
IISER Kolkata & IIT Bombay
27th Nov 2017

FOREWORD

In the current fiscal, there were a number of significant advances in different domains that we can be justifiably proud of. CSIR-NML has initiated work on two projects of national importance. The first is the setting up of a pilot plant for production of *electrical amorphous steels*, a first of its kind, in the country. There has been an increasing use of amorphous materials for a variety of transformers; with the entire material being imported. This initiative by CSIR-NML will catalyse indigenous amorphous steels development. The second project of national importance is with regards to the development of Advanced Ultra-Supercritical (AUSC) Powerplants in India. The project, co-ordinated by NTPC, BHEL and IGCAR aims at improving the efficiencies of thermal power plants by increasing the temperatures of operations. This necessitates new temperature resistant alloys as compared to those in vogue in conventional power plants. Our laboratory has been entrusted with the evaluation of a suite of mechanical and corrosion properties of candidate materials, as well as understanding material damage mechanisms.

In a Ministry of Steel sponsored project, highly metalized DRI was produced in a commercial tunnel kiln, using mill scale, iron ore fines and non-coking coal. The scale of operation was 3.0 to 5.0 Tons of input per batch. The process is being pursued by several DRI manufacturers for transfer of technology. In addition to the latter, a number of projects have been carried out and processes developed in the matters of valorization of wastes. These include briquetting of bottom ash and pond ash of thermal power plants, development of light weight porous materials, tiles and grout from LD slag, and geopolymer cement, ferric sulphate and silica powder from copper slag. In the same domain, CSIR-NML has recovered vanadium from spent catalysts and Bayer's sludge, and rare earth elements from Nd-Fe-B magnets retrieved from electronic wastes. Tellurium has been recovered from copper refinery anode slime, and a number of valuable metals have been recovered from Lithium ion batteries.

CSIR-NML has continued its synergistic association with Railways through RDSO and other organizations. In collaboration with RDSO, a standard, WD-70-BD-10, was developed for indigenization of Grade E castings used for manufacturing of Center Buffer Couplers (CBC) and for safety in rail transport. As a direct outcome of these investigations, six manufactures in India have started manufacturing and supplying CBC to Indian Railways. No service failures were reported in the last six years. Our laboratory is also involved in the evaluation of certain properties for a rail steel being developed by SAIL. Evolution of surface cracks in long steel products, made via continuous casting route, is one of the critical problems in steel making industries. CSIR-NML analysed the operational data at various stages of product development of an integrated steel plant and was able to indicate process as well as material deficiencies. CSIR-NML developed materials with enhanced wear resistance property for use as grinding balls by a major cement industry. Using a neuro-fuzzy approach, it has been able to develop selection criteria for corrosion resistant pipeline materials for ONGC. A low alloy steel was developed using the quenched and partitioning route, in collaboration with Tata Steel, which shows much better properties than conventional steels. A collaborative project, in association with SAIL/RDCIS has been initiated on the development of advanced high strength steel grades. Using the laboratory developed annealing simulator, a number of process optimizations were carried out which were validated with industrial trials or data.

A number of advanced materials, processes and techniques were developed. A super-capacitance material was developed for a Sri Lankan multinational. A new series of 18 karat gold alloys, were designed and developed for TITAN through arc melting and suction casting. For the same client, cyanide free electrolyte was developed for electrolytic cleaning of rust

from plain carbon steel components of wrist watches. A chrome free polymeric coating, having corrosion inhibitor groups chemically bonded to the polymer backbone, was developed for an Aerospace Multinational. A complete cost effective on-line defect detection system developed by CSIR-NML has been commissioned at Tarapur wire mill, of Tata steel. For a project from ONGC, CSIR-NML successfully designed, fabricated and installed a closed loop corrosion test rig for corrosion studies in flow simulated sea water with different controlled O_2 levels. CSIR-NML in collaboration with CSIR-CGCRI has established the feasibility of using Fibre Bragg Grating (FBG) for real-time temperature monitoring of billet mould at Tata Steel and has successfully captured the real-time temperature data for the lifetime of a mould in the caster

CSIR-NML continued its activities in the strategic sectors. The laboratory initiated a Defence Research and Development Organization (DRDO) sponsored project on Tungsten recovery from low grade tailings in the previous fiscal. This entailed beneficiation of ores having very low W followed by extraction of the metal. A full-fledged pilot plant is now operational and initiatives in this project have met the approval of DRDO. The laboratory kept its promise of supplying IGCAR with Gadolinium of certain purity and quantity. This was produced for the first time in the country using electrolytic route.

The outputs and outcome during the year were very satisfying. The external cash flow (ECF) generated was the highest in the history of the laboratory. Against a target of Rs. 25 Crores, the ECF crossed 40 crores, of which industrial ECF was in excess of 30 crores. This was possible due to diligence, dedication and industrial savvy of our scientists of the R&D Divisions as well as R&D support divisions. 20 patents and 5 copyrights were applied for, 5 new technologies were developed and 3 available technologies were transferred. The knowledge generation through publications was, however, on the lower side, with only 99 SCI publications in 2017. While, increased industrial research involvements were partly responsible for this decline, the lowering is a matter of concern. To address this issue, the in-house projects group has devised new incentives and encouragement for novel and out of the box investigations through a system of thematic research.

The Director General of CSIR, has spearheaded the creation of inter-laboratory research theme, a horizontal knowledge networking, which has not been tried out in CSIR before. CSIR-NML is participating in some of these themes, with its core theme being “Mining, Minerals, Metals and Materials (*4M*)”. As and when the thematic programmes and projects evolve and take shape, CSIR-NML is ready to be a part of those of relevance to the core mandates of the laboratory. The laboratory has participated in various Niti-Ayog meetings on mission research, on Rare Earths extraction, on Manufacturing Processes and on e-wastes. As and when a national mission on any of these areas evolve, CSIR-NML would be ready and eager to be part of it.

In addition to the mission projects as well as various industrial projects initiated earlier, or in this fiscal, we look forward to increased interactions with industrial as well as governmental research sponsors. An inter-laboratory international programme, Twinning with Metals Industry Development Institute, Ethiopia, is all set to take off. This project will see scientists of five CSIR Laboratories (CEERI, Pilani; CMERI, Durgapur; CLRI, Chennai; CSIO, Chandigarh; and, NML, Jamshedpur) working together and in tandem to provide technical expertise to Ethiopian counterparts. A similar international programme, fully funded by the beneficiaries, is rare, even in CSIR. The programme will definitely enhance the prestige and renown of CSIR. Our laboratory is the nodal laboratory in this initiative.

I am happy to report significant reinforcement of our Human Resources during the fiscal, in different specializations and cadres. 23 new personnel joined our rolls, in administrative as well as scientific positions. We intend to follow continuous and highly selective replenishment of our human resources to ensure a leadership and mentorship hierarchy.

I extend our gratitude and appreciation to our esteemed sponsors, members of our Research Council, and numerous other friends and mentors, for reposing their faith in us and for providing continuous support and advice. I will reiterate the sense of honour and privilege I feel to be a part of this laboratory and to be able to facilitate, advice and mentor a group of talented and dedicated individuals.

(Dr. Indranil Chattoraj)
Director, CSIR-NML

Sir Shanti Swaroop Bhatnagar | 1942-1954

Sir Shanti Swaroop Bhatnagar (1894 - 1955) was the Founder Director and first Director General of the Council of Scientific & Industrial Research (CSIR). He is credited with establishing twelve national laboratories. Dr. Bhatnagar played a significant role in building of post independent S&T infrastructure and in the formulation of India's S&T policies. His research contribution in the areas of magneto chemistry and physical chemistry of emulsions were widely recognized. In 1936, Dr. Bhatnagar was conferred with Order of British Empire (OBE). He was Knighted in 1941 and was elected as Fellow of Royal Society, London in 1943. He was awarded the Padma Vibhushan in 1954 by the President of India.

On the basis of evaluation reports of NML, RDSO has registered three (03 Nos.) vendors for Upgraded High Tensile Coupiers for freight stock and six (06 Nos.) vendors are under development stage. Couplers manufactured and evaluated at NML have been reported from field. Train parting cases have also reduced due to Coupler/Knuckle failure. Although revenue saving has not been calculated but it has definitely prevented the revenue losses.....

.....Appreciation letter from Indian Railways

LPSC, ISRO in co-ordination with NML Jamshedpur have developed ultrasonic flaw meter for spacecraft propellant gauging applications. NML through their innovative concepts and implementation have been successful in developing the electronics and signals processing techniques in order to assess the flaw meters as low as 0.11/min. LPSC, ISRO congratulate the NML Team for this work and look forward for further co-operation in this prestigious programme.

.....Appreciation from ISRO

Based on the technical/scientific advice of Dr. Dayanand Paswan and Dr. M. Malathi, Scientist, CSIR-NML, Jamshepdur, we have made certain modification in our Tunnel Kiln. Thereafter, more than 70 tons of DRI has been produced with an average metallization of 86% and 0.033% Sulphur. The pilot plant trials are still going on since 5th March 2018.

We are fully satisfied, confident and happy to inform you that we will be commercially producing 18 tons/day DRI in the present capacity of our furnace.....

.....Shree Mahabir Refractories Works

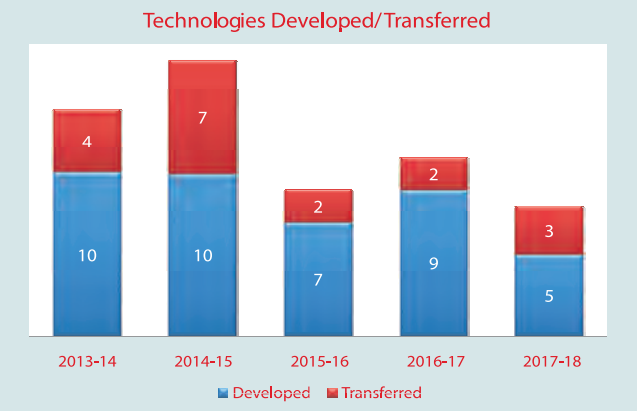
Subject : Performance report Trials of eddy current surface flaw detector(Flaw Guard) developed by NML for 1.6mm MTB wire

Inference & way forward:

- *The Flaw-Guard successfully detected pre-identified gross surface defects in wire during normal drawing operation*
- *The defect data capturing and report generation system to be improved for effective utilization of system.*
- *Need to improve the sensitivity of detector to capture fine surface defects.*
- *It is proposed to take trials with improved version of Flaw-guard to test its actual operational performance. Once the usability is proved the equipment shall be useful for strengthening internal quality control of wire during drawing.....*

.....Performance report of FlawGuard implemented at Tarapur Wire Mill

R & D Outputs


Technologies Developed/Transferred
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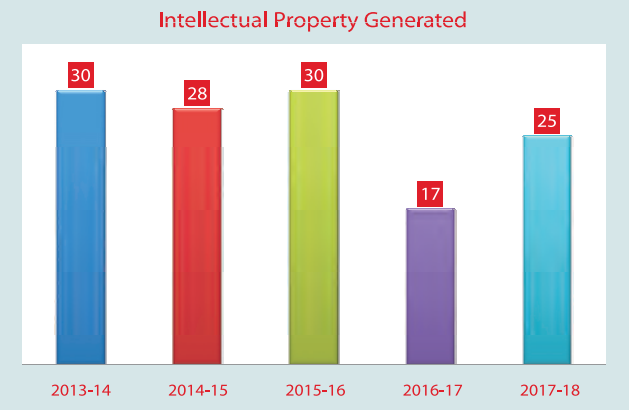
Developed
Transferred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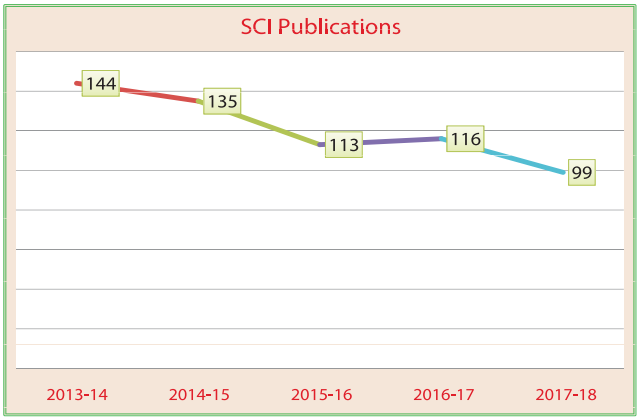
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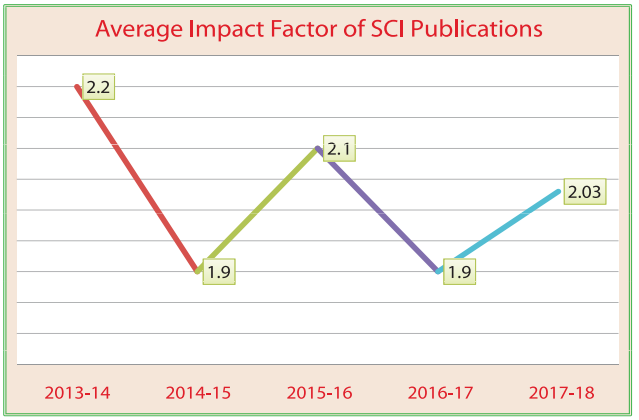
Average Impact Factor of SCI Publications
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1.9
2.1
1.9
2.03
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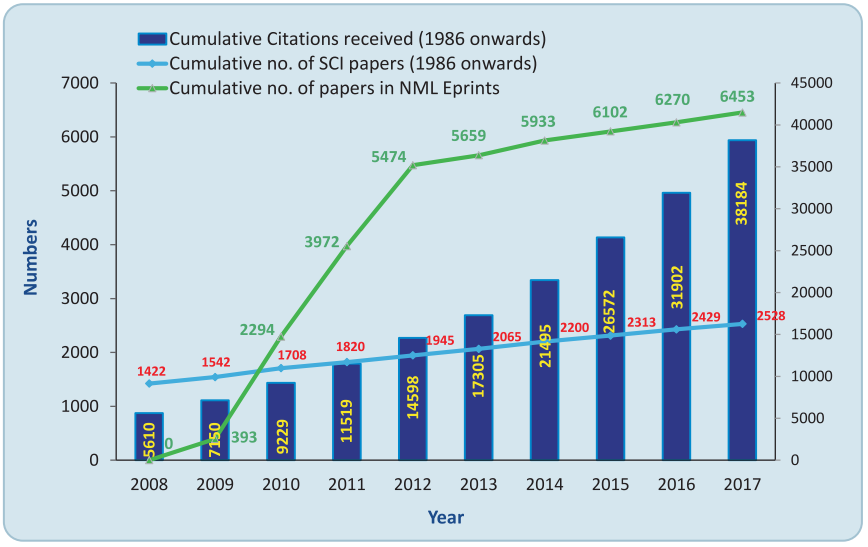
Cumulative Citations received (1986 onwards)
Cumulative no. of SCI papers (1986 onwards)
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Numbers
Year
2008
2009
2010
2011
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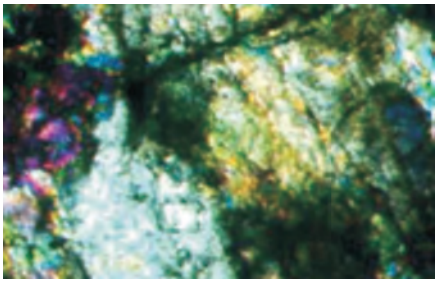
NML Technologies and Processes

Mineral Processing

Beneficiation of low grade Baryte Ores

The technology developed is for beneficiation of rejected low and lean grade baryte ores and the concentrate so produced which is useful for oil drilling, barite chemical and other applications. The technology is based on concentration of low-grade barite ore (sp. gr. 3.9) by gravity and flotation methods. The low-grade ore is upgraded to marketable grade product with sp. Gr. 4.1 .The process also enables processing of off-grade mine waste dumps for suitable industrial applications.

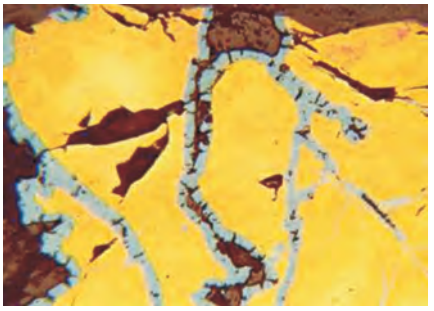


Beneficiation of Low-grade Iron Ores

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.

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 by gravity and magnetic separation techniques followed by hydrometallurgical extraction of tungsten as ammonium para-tungstate.



Copper Concentrate from Copper Ores

The process produces copper concentrate from copper ores by froth floatation and pyro - metallurgical route. The technique is based on froth flotation of copper bearing minerals from ore after milling. In which the concentrate is dewatered and used for extraction of metal by pyro-metallurgical route. The process has been commercialized to (i) 1000 tpd plant at Rakha Copper Project and (ii) 6000 tpd Malanjkhand copper project.

De-ashing of High-ash Thermal Coal

This technology involves treating high-ash thermal coal for reducing the ash level by adopting gravity concentration and flotation techniques by which the ash level can be reduced to 10-15% from a feed of 30-35% ash depending on the coal characteristics. The clean coal fines thus produced is utilized for injection in blast furnace.

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.

Column Flotation Technology

The column flotation technology is used 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. 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.

Metals, Materials and Alloys

Wide Metallic Glass Ribbon Processing Unit

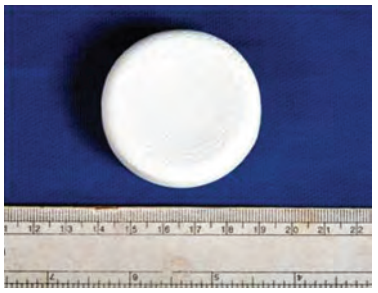
The device is used for the production of different types of alloy using melt spinning system. It has a wide application in rapidly solidified material processing unit for magnetic alloys that can be used in transformer core, magnetic sensor applications, saturable reactors, choke coils, core materials for circuit breaker, etc. and also processing unit for brazing alloys that can be used in joining materials as heat-exchanger for automobile and aircraft industries. The liquid metal is poured on 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) No hazardous gas emitted; (d)Ferromagnetic shape memory alloy: Ni-Mn-Ga, Co-Ni-Al. Licensed for manufacturing to M/s Vacuum Techniques Pvt. Ltd., Bangalore.

Biomimetic Hydroxyapatite nanopowders

The hydroxyapatite particles are developed through single-step biomimetic process at ambient conditions in narrow size range of 80nm – 100nm and having uniform morphology. The product is used as a bone grafting material for orthodontics. The technology has been licensed to M/s Eucare Pharmaceuticals, Pvt. Ltd. Chennai and M/S Surgiwear Ltd, Shahjahanpur.

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 Surgiwear Ltd, Shajahanpur.



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 as bone healing & 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 Surgiwear Ltd, Shajahanpur.

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 lesser defects. Spinning of graphene-collagen with PVA polymer to form fibres with varied applications. Yield varies from 0.03-0.05% as compared to the reported best of 0.3%.


After 90 days at the power plant

Erosion resistant steel for underwater components of turbine hydrogenerators

This alloy is multiphase and developed based on TRIP effect; hence can be used at room temperature as well as lower temperatures. The steel was 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.

Coatings and Lacquers

Anti-Tarnishing Lacquer for Silver and Copper-based Alloys

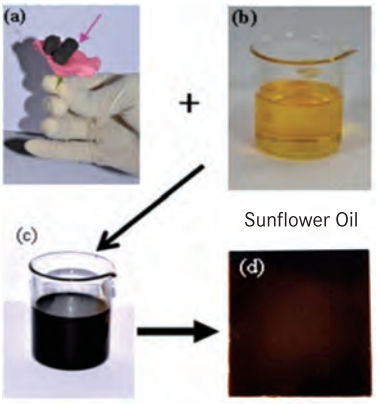
Anti-tarnishing lacquer is a one component fast drying interior lacquer for use on brass, copper, bronze and silver surfaces. It prevents tarnishing (blackening) and provides a durable finish resistant to water, acid and alkali environments. The formula contains active corrosion inhibitors chemically 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.

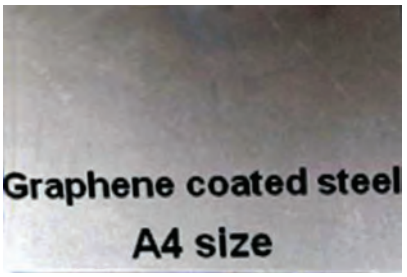
Dip Cleaner cum Brightener for Gold and Diamond

The product can be used to clean, brighten and enhance glitter of used gold & diamond jewelleries at home. The advanced formulations is free from harmful mineral acids and other harsh chemicals making it safe for domestic use. Cleaning is performed by dipping the jewellery in cleaning solution for 30 minutes followed by washing in water. Metal loss during cleaning is negligible even if gold items remain in solution for several hours. Gold jewelry with embedded precious stones can be safely cleaned using the dip cleaner. Rubbing is not required for cleaning and hence difficult to access areas in jewelry can be cleaned quickly and efficiently by simply dipping it into the solution. The cleaning solution can be used as the medium in ultrasonic cleaning bath to clean bulk quantity of gold jewelry in short time without affecting the embedded precious stones. Same cleaning solution can be used several times and can be safely disposed off without any environment pollution. Product has been commercialized by M/s. Mahashraya Chemicals (P) Ltd., Balasore, Odisha.

Anti-Corrosive Chemical for Steel Sheet, Rebar and Wire

An anti-corrosive chemical has been developed for the corrosion prevention of steel sheet, rebar and wire. The developed chemical has the following silent features: (a) Synthesis protocol consists of mixing of chemicals, (b) Improves anti-corrosion properties of metals; (c) can be applied on a surface by dip coating followed by drying at room temperature for 1 h or by curing at 150°C for 5 min, (d) cured coated products at 250°C gives golden and brown colours with 5 mins curing time, (e) cured products give good luster, (f) Coating forms a good adhesion on a surface and (g) can also be applied on a surface using brush and spray. The process has been licensed to Teyasi Innovations, Jamshedpur.





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 substrate 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 transparent conductor.

Iron and Steel making

Low sulphur Directly Reduced Iron from waste iron ore slime including rejected coal containing more than 50% ash

Developed product can be used as feed/substitute of scrap material for the electric furnace, BOF furnace and induction furnace for steel making. The process utilises ~100% waste materials to yield a value added product. This invention is useful for converting steel plant wastes fines / mining waste fines 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 suitable for induction furnace, electric arc furnace and blast furnace for iron and 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 suitable for induction furnace, electric arc furnace and basic oxygen furnace steelmaking.

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 in to 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 (-20%) and flux consumption.

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. This is a cold bonding process, so it is energy efficient. Curing time is very short (5-10 min). It utilizes iron ore micro-fines and coal fines or coke fines or carbon containing waste fines in iron making or sintering. 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). Since it is a composite pellet, it can be reduced faster than normal pellets and $C0_2$ in steel plant's waste gas is utilized in strengthening of pellet.

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) and able to withstand cold handling. Sintering is possible without using any external heat or any coke breeze; the waste material itself is the heat source. The produced sinter is suitable for use in both iron and steel making.

Pelletization of iron ore fines/slimes

The technology is developed for pelletisation of iron ore fines using suitable binder/s. The Pellets formed can be used for iron and steel making after induration. The process is environment friendly.

Briquetting of ore fines

This technology produces briquettes of ore fines with suitable binder through briquetting press. Ore fines and industrial wastes 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 ones are not generated through this technology.

Flux and a Process for de-phosphorization of steel in induction furnace

The phosphorus level in steel produced through induction furnace route varies from 0.07-0.09%, which makes the steel of poor grade. Using CSIR-NML flux and process methodology phosphorus level can be brought down from 0.09-07% to 0.03 to 0.04%, which is well within prescribed limit of BIS.

Devices and Process Intermediations

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

This 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. It is suitable to use on-site to assess the extent of damage accumulation in components after extended period of service at high temperatures. The 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. It 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 can detect the presence of magnetic phase in non magnetic materials. The technology has been licensed for manufacturing to M/s Technofour, Pune.

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 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 (transverse cracks, weld joint, craw feet, etc.) 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 the 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).

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 minerals 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 time-consuming and cumbersome conventional chemical analysis methods. From the developed calibration curve, the alumina content in the ores can be determined within 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 leading to resource optimization in a safe and environmental friendly manner. Real time analysis of feed grade to the plant operators allows optimization for achieving targeted production and grade.

Ultrasound Pulser-Receiver for Onboard Propellant Gauging of spacecraft

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 device will be used for GEOSAT class spacecrafts and interplanetary missions. The developed ultrasonic flow meter can be integrated in the spacecraft for onboard propellant gauging and can also be used as a gas and liquid flowmeter.

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 a 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.

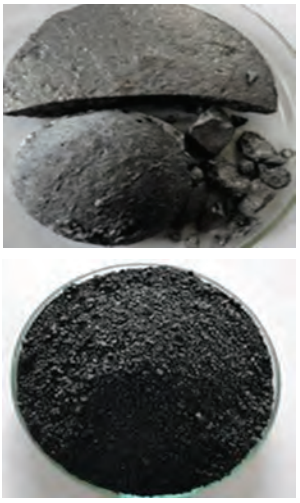
Annealing Simulator Device for annealing of steel specimens under desired environmental conditions for testing and characterization

An integrated annealing simulator device for annealing under desired environmental 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 rate 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 for temperature recording for entire cycle of annealing simulation and (viii) precision environmental control on annealing simulation.

Value Additions to Industrial Wastes & Lean Sources

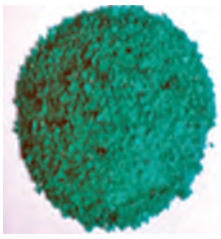
Production of Ferronickel from Spent Nickel Catalyst

It is a simple smelting process for recovery of nickel as ferronickel of various grades from different nickel catalysts containing nickel in the range, 8 -18%. By controlling the parameters and the process techniques, ferronickel of 20 - 75% Ni grade have been produced with > 90% Ni recovery. The process consists of mixing the spent catalyst with additives, heating and reducing the mixture to get ferro-nickel.



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

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.



Simple and cost-effective production of Nickel Sulpahte

The technology is related to the production of nickel sulpahte from spent Ni-catalyst waste. Nickel sulphate is used extensively in electroplating, organic chemical synthesis, metal coloring, dye mordant, manufacturing other nickel salts, Ni-Cd battery. The process consists of direct acid leaching in presence of a promoter followed by impurity removal to produce nickel salt/metal. The 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 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 very low temperature and low acid concentration, 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 is much easier and involves lesser number of steps.

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.

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 etc., 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).

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 of utilising the dump slag generated in the copper plants. The Technology has been licensed to M/s Sterlite Copper, Tuticorin.

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 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 MI 5 - M35 grade concrete. It uses ambient temperature synthesis and generates 30% less $C0_2$, 35% low embodied energy than conventional equivalent product. The product meets USEPA 1311 specification for toxicity. Also due to low $C0_2$ emission and less embodied energy, it falls in the category of green technology. 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 considered alternative to Portland cement which is produced from two major industrial waste, fly ash and granulated blast furnace slag. During synthesis, the alumino-silicates present in feedstock undergoes polymerization and poly condensation 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 up to 900°C and (iii) uses ambient temperature synthesis and generates 70% less $C0_2$ than Portland cement.

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

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

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

A process is 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.

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

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.

Energy efficient brass and bell metal melting furnace

The technology focuses on new fuel efficient brass melting furnace. These have advantages over conventional furnaces like a) ~ 20% reduction in coke consumption; b) ~ 80% less suspended particulate matter (SPM) and toxic Zn vapour in flue; c) Reduction in melting cycle which attributes for ~25% increase in productivity; d) Minimum alteration of existing operating practices of traditional brass melting furnace; e) Construction by using locally available materials.

Technologies Transferred

Transfer of Technology for Production of Ferric Sulphate and Silica Powder from Copper Slag,
Transferred to Sterlite Copper, Tuticorin

Slags produced during pyrometallurgical processing have been traditionally considered as a waste. In the case of copper extraction processes, it has been estimated that 2.2 ton of slag is generated for every tonne of copper produced. Currently, this has been considered as a material for road construction or abrasive material for cleaning metallic surfaces. Copper slag is an impure iron silicate glass (fayalite) with very little inclusion copper/copper matte and other minor impurities. Therefore iron oxide and silica constitute >95%. Most reported research targeted minor metal recovery and very few attempted to recover iron. None of the researchers reported complete value realization by targeting both iron and silica in usable form.

The recycling processes reported in literature leave behind substantial amount of residues to be disposed of or otherwise used. Therefore most of the slag is usually land filled after processing. CSIR-National Metallurgical Laboratory developed a very unique process 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.

Processing conditions for each unit operations were optimised for Sterlite copper slag containing 51.1% Fe and 27.4% SiO_2. Under optimised condition, more than 35% ferric sulphate solution and very fine white silica powder containing more than 95% SiO_2 were produced. One matric ton of copper slag generate about 5 kL of ferric sulphate solution containing more than 100 g/L ferric iron and about 300 kg of silica powder. The process was demonstrated and transferred to M/s Sterlite Copper, Tuticorin.

Sterlite copper is planning for a 1000 kg copper slag processing pilot plant at their site to scale-up the process for setting-up a commercial ferric sulphate production plant. Silica produced from the process will be useful for phosphoric acid production. Implementation of the process will not only take care of environmental norms but will also make them independent on the matter of availability of chemicals for critical operations of treating effluents.

During demonstration of the process to M/s Sterlite Copper, Tuticorin.

Transfer of Technology for Production of Pigment Grade Iron Oxide from Waste Chloride Pickle Liquor, Transferred to M/s Rang Sarjan Chemicals, Varuch Gujarat

Red iron oxide pigment lead the global pigment industries. Its application and production become increasingly important due to its pure hue, consistent properties, and tinting strength. At CSIR-National Metallurgical Laboratory, a simple process was developed for production of highly dispersed iron oxide of uniform size and shape from variety of waste resources including chloride pickle liquor. The processing steps consist of oxidation of ferrous iron followed by conversion to desired grade iron oxide. The process is so tuned that a particular size and shape could be engineered with required magnetic properties. The developed process takes care of the impurity present in the starting material and can produce high purity iron oxide suitable for other high end applications in making soft ferrites, catalysts, sensors etc. 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 oxide gives very high color purity and matches that of different standard grade high end iron oxide available in the market.

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 at a temperature of about 100-160 °C from its hydroxide precursor.

M/s Rang Sarjan Chemicals, who is an established pigment manufacturer, had shown interest to commercialise the NML's process for production of high end iron oxide from ferrous chloride solution generated from the pickling process of steel. The process was tested for the waste chloride pickle liquor available to M/s Rang Sarjan Chemicals and was successfully demonstrated to them before transfer. Highly monodispersed iron oxide particles of different sizes ranging from 100 nm to 600 nm were produced under different condition of precipitation. Both reduced tone and mass tone of the produced oxides were tested and found to be of much superior quality with respect to pigmenting properties.

The process can also convert various high iron containing effluent generated from galvanising and ilmenite processing units in to different high value products. High concentration of iron chloride solution is generated in pure form during direct dissolution of laterite, and can also be converted to produce such high value products. Thus an integrated treatment plant to produce high grade iron oxide / iron powder will not only generate revenue but also avoid the problem of disposal.

Signing of ToT agreement

Demonstration of the process

Iron oxide produced during demonstration

Quick Repairing Material by Geopolymerisation of Fly Ash & Granulated Blast Furnace Slag
to VENSPRA LABS, Vijaywada

CSIR-NML has transferred the technology for quick repairing material by geopolymerisation of fly ash and granulated blast furnace slag to M/s Venspra Labs, Vijaywada. The product developed by this technology will be used for quick repairing of infrastructures such as road and buildings. The uniqueness of this technology is it requires low capital investment, have good return on investment, require small space and can be handled by unskilled and semi-skilled workers and operates at ambient temperatures. The product falls under green category as it has very low CO_2 emission compared to Portland cement and is eco-friendly.

Indian road network consists of 33 Lakhs km However, due to excessive use, heavy loads and with time, this road infrastructure is becoming aged. Some of the common defects occurring in roads are pot holes, cracks and uneven patches. These deterioration spread across a road system very quickly resulting in soaring costs and major financial impacts on the economy and citizens. This creates the necessity of a quick repairing material, which can be applied to restore the road in a short time.

Through the present technology, quick repairing material will be produced using Industrial wastes and by-products, namely fly ash and granulated blast furnace slag, which will be applicable for roads as well as other infrastructures. The important properties for quick repairing material is quick setting and fast strength development. This product will be available in two parts, a powdery solid and a liquid activator. The product manufactured by this technology will have the following physical properties :

- Initial setting time will be ~30 minutes and final setting time will be less than 120 minutes.
- The average drying shrinkage of mortar bars prepared and tested in accordance with IS 4031 Part 10, shall not be more than 0.15%.
- The average compressive strength, when tested as per IS-4031-Part 6, shall be as follows.

Time	Compressive strength (Mpa)
24 ± 1 hour	Not less than 20 Mpa
168 ± 2 hour	Not less than 35 Mpa
672 ± 4 hour	Not less than 45 Mpa

Societal Projects

Technical need assessment study for the Zn/Ni plating clusters in Howrah, West Bengal

A technical need assessment study was conducted in July 2017 at Howrah Sewing Machine Clusters to understand the current practices of the Zn and Ni plating activities for small machine parts and the possible R&D intervention as well as training needs. The project is sponsored by the Foundation for MSME clusters. A report, highlighting the current practices, state of the art knowledge of Zn and Ni plating and the recommendations for possible technology interventions, was submitted. CSIR-NML conducted a training program on electroplating which was held during 11-12th September 2017. The training modules addressed (1) Principles, Methods and Application of Electro Chemical Deposition, (2) Enhancement of plating quality using buffering agent (3) Various plating methods, (4) Pickling Process, (5) Chemicals to be used and not to be used in products to prevent corrosion (6) Chemicals for oil removal, (7) Chemicals for increasing brightness of coating, and, (8) Environment friendly chemicals. On 12th September 2017, an industry tour was arranged. The participants and organizers visited Gilard Metals and Sinha Electro Chemical Plant in Adityapur and were highly benefitted by observing the semi automatic and manual practices followed for electroplating. The stakeholders observed Acid Zinc, Electro less Nickel Plating, Hard Chrome Plating, Zinc Nickel plating and uniform plating processes.

Figures below show the industrial visits and interactions of the participants with scientists of CSIR-NML.

Interactions with brass artisans of Bali village in West Bengal

India is the largest Brass making country in the world. This art has been practiced in India for over thousands of years. Brass metal casting is one of the oldest traditional practices in vogue in many states of India. West Bengal brass artisans produce utensils, artifacts, and jewelry. Bali village, in Goghat Block of Hooghly district in West Bengal, is known for traditional vessels made out of Brass, for more than 500 years. Some Brass metal utensils like bowl, kolshi, glass, etc. are produced by rural artisans of this village by clay moulding process. The age old process of metal casting is time tested and the products are of excellent quality. However, the artisans, who are making these products manually, face many economic as well as technological challenges. Inadequate infrastructure of home based manufacturing units, labour intensive manufacturing processes, energy inefficient clay furnaces, and, zinc vapour contaminated work environment, are some of the issues that require attention for remediation. Those factors are responsible for the demise of this age old craft/products, and buyers are gradually accepting Chinese products.

On receiving an invitation from the Foundation for MSME clusters, scientists of CSIR-National Metallurgical Laboratory visited Bali village to carry out need assessment for technological interventions. Various recommendations through exposure training, technology integration and process automation were communicated for collaboration.

Customized long scissor tong

Upper mould of a Pitcher (Kalshi)

School-NML Interactive programme

SNIP programme has been designed to give the students, teachers and professional an exposure to modern laboratory environment and to develop a science temperament in them for their career development. This programme has been carried out at CSIR-NML since June 2011 and till date, a total 16,700 students from 191 School along with teachers have participated in this programme and derived the benefits. During 2017-18, a total of 699 students and 38 teachers from 13 schools has visited the laboratory under INDSS-NIP, CSIR-NML, TECNIP & JIGYASA.

A school interaction programme designed specifically for Kendriya Vidyalayas named "JIGYASA", under the collaboration with the Ministry of Human Resources Development, is a CSIR programme for connecting school students and scientists to extend the classroom learning of students with experimental education in research laboratory environment. "JIGYASA" aims to inculcate the culture of inquisitiveness on the one hand and scientific temper on the other, amongst the school students and their teachers. CSIR-NML has selected the Kendriya Vidyalayas in the Ranchi zone and had invited students and teachers of such schools. Around 180 students and 10 teachers of Kendriya Vidyalaya, Chakradharpur, and Atomic Energy Central School, Turamdih have already visited CSIR-NML and further interactions with other schools are planned.

Targets Achieved

Performance Targets Achieved in 2017 - 2018

	Objectives	Planned	Achieved
1.	External Cash Flow (ECF)	25 Crores	40.80 Crores
2.	Industrial ECF (a part of ECF)	17 Crores	31.12 Crores
3.	Customer Satisfaction Index	4.5	4.4
4.	SCI Publications	120	99
5.	Patents	20	20
6.	Copyrights	5	5
7.	Technologies to be Developed	8	5
8.	Technologies to be Transferred	3	3

Technologies Developed :

1. Development of synthetic flux and a process for de-phosphorization of steel in induction furnace
2. Cyanide free process for leaching and recovery of gold.
3. Cyanide free alkaline electrolyte and electrochemical process for rust removal from plain carbon steel components
4. Improved version of metal oxides nanomaterial based anti-corrosive chemical
5. Ultrasound Pulser-Receiver for Onboard Propellant Gauging of spacecraft

Technologies Transferred :

1. Production of Ferric Sulphate and Silica Powder from Copper Slag, Transferred to Sterlite Copper, Tuticorin
2. Transfer Technology for Production of Pigment Grade Iron Oxide from Waste Chloride Pickle Liquor, Transferred to M/s Rang Sarjan Chemicals, Varuch, Gujrat
3. Quick Repairing Material by Geopolymerisation of Fly Ash & Granulated Blast Furnace Slag to VENSPRA LABS, Vijaywada

Major Technological & Scientific targets Planned and Achieved in 2017-2018

Advanced Materials and Processes

Targets Planned	Targets Achieved
Collagen-Graphene nanocomposites for energy devices	Two patents, [Indian and Taiwanese] on Supercapacitors have been filed. Attempts are on with the Sponsor for the development of a prototype.
Process for developing 18K Gold alloy for Jewellery applications	New composition and process has been developed for 18K Gold alloy with lower melting point. Patent has been filed.
Development of Al-Si coatings on High Boron steels, and Zn-Al-Mg coatings on AHSS	A new Al-Si-Mg-Cu-Sc alloy has been made for high temperature applications. Development of Zn-Al-Mg coating on AHSS is under progress
Graphene Oxide based anti-corrosive paint for steel	Graphene oxide based paint was developed. Commercialization of the product is under progress.

Materials Evaluations and Monitoring

Targets Planned	Targets Achieved
Evaluation of steel for Advanced Ultrasupercritical Thermal Power Plant	Under mission mode programme "Advanced ultra supercritical Technology", four projects with total financial outlay of Rs. 853.98 Lakhs sanctioned for advanced alloys evaluations
Technology for breakout detection in the Continuously cast Billet Caster	FBG based sensor Technology developed and demonstrated at the billet caster of Tata Steel by mapping the real time temperature of mould till its full life.
Implementation of Flaw Guard for continuous defect detection in two wire drawing lines at Tarapur Wire Mills	One Flaw Guard system has been installed, and is operating successfully, at line 212 of Tarapur Wire Mill, since May 2017.
Study of benefits of Cr microalloying/ modification of microstructure for enhancing corrosion resistance of carbon steel for water injection pipeline	Continuous flow closed loop corrosion test rig has been indigenously fabricated and performing as per our requirement. Design of the equipment is patented.

Steels and Related Developments

Targets Planned	Targets Achieved
Amorphous Electrical Steel (AES) : Plant drawing and specification of equipment	Pre-Indent conference for Expression of Interest (EOI) held with prospective vendors. Preparation of draft specifications underway.
Development of Galvannealing processes for DP 590 & DP 780 grades of AHS steels.	Galvannealing process for DP 590 developed. Galvanizing process for DP-780 grades developed.
Development of steel for grinding media for Cement industry	A process developed which shows 20 % improved wear resistance of virgin material. A new alloy composition also developed which shows 25% improved wear resistance. Two patents filed.
Development of steel used in cannon for mining application	Steel with the existing composition of cannon materials prepared at lab scale, and heat-treatment optimized. Fabrication of 2 cannon inner membrane in progress.
Production of low phosphorus steel in industrial Induction Furnace using CSIR-NML developed flux and process under identified suitable lining • Industrial trial in 10 ton Induction furnace • Critical analysis of neutral lining performance under oxidizing and basic slag • Techno economical feasibility of Flux, lining and process • Standard Operating Procedure for De-phosphorisation in Induction furnace • Patent and Commercialization of Flux and Process • The technology has to be disseminated through movie, series of Work shop and lecture to the plant people	• Industrial trials in 10 ton induction furnace conducted. Phosphorus reduced from 0.07 % to 0.02%. • Minor erosion in neutral lining observed under basic and oxidizing slag. • Techno economics of the flux and the process evaluated. Performance of neutral lining needs prolonged trials. • SOP for basic slag and neutral lining finalized. • Patent submitted and is under process. • The technology uploaded in youtube, knowledge has been disseminated to AIIFA, SEMA, AIRMA and secondary steel making sector through a series of presentations in national seminars organized by MoS.

Mineral Processing & Metals Extraction

Targets Planned	Targets Achieved
Recovery of tungsten values from Hutti gold ore tailings	Bench scale beneficiation study involving gravity, enhanced gravity, magnetic separation and flotation completed and flowsheet developed for recovering tungsten values from the tailing sample. Pilot scale validation of the beneficiation process completed.

Targets Planned	Targets Achieved
Development of process flow-sheet for extraction of tungsten (W) metal from Hutti gold mine tailings & recycling of tungsten base heavy alloy scraps. • Process flow-sheet freezing in bench scale (100 – 1000 g product). ❍ 1kg scale process development for production of high pure W-powder from tungsten base heavy alloy scraps ❍ 50–100 g scale process development for production of high pure ammonium para-tungstate (APT)/W-powder from a suitable grade concentrate generated from Hutti gold mine residue/tailing	• Process flow sheet developed at 500 g - 1 kg scale for production of high pure W-powder (purity >99.92%) of desired specification (conforming to the specs for various defense applications) from tungsten heavy alloy turnings, along with recovery of other valuable metals such as Co and Ni as salable mixed hydroxide(s). • Process developed at 100 g scale for production of high pure ammonium para-tungstate (APT) from a scheelite concentrate containing 1.9% WO_3 comprising of alkali leaching - precipitation - solvent extraction -crystallization route. Tungsten recovery efficiency of more than 90% achieved during processing of the concentrate.
Coal beneficiation for use in thermal power plant and metallurgical industries.	• Projects initiated for dry beneficiation of non-coking coal for application in thermal power plant. • Initiated collaborative project with industry towards deshaling and reduction of water consumption in de-ashing of coking coal by dry beneficiation.
Coal Core Analysis • 10000 samples to be analyzed • Facility Creation: [7 Kg scale of coke oven, Proximate analyzer, Bomb Calorimeters]	• More than 10000 samples have been analyzed • Equipment order placed for facility creation
Flotation studies on iron ore	High selectivity achieved through pilot scale flotation studies with novel reagents, compared to conventional reagents resulting in concentrate with 2.46% Al_2O_3 with 82% yield, and Fe(T) <45%.
Agglomeration of chromite ore concentrates	Briquetting of chromium concentrate carried out with different binders and briquettes produced with suitable breaking load and drop number.
Agglomeration of iron ore fines	Jointly, with Tata Steel, designed and developed Stationary Bed Pellet Induration Machine with down draft facility. It simulates firing zone of straight grate induration strand for pellets.
Pilot scale study on recovery of chromite values from tailings	Project on development and pilot scale validation of process for recovery of chromite values from slimes/plant tailings initiated.

Business and Human Resources Targets: Planned & Achieved in 2017-2018

Business Targets Planned	Targets Achieved
• Professional Training Courses to be organized in 7 areas/subjects	• Four Professional Training Programmes and three Corporate Training Programmes carried out
• Registration of CSIR-NML Technology Business Innovation Center as Section 8 Company	• CSIR-NML Technology Business Innovation Centre (NML-TBiC) registered as a section-8 company.
• Creation of On-line customer satisfaction feedback gathering and evaluation system	• On-line customer feedback gathering and evaluation system is under progress
• Entrepreneurship development on e-waste	• Workshop on e-waste deconstruction and various other activities completed
• Generating new business clients including international collaboration	• 7 new Indian clients generated
• Organize CSIR integrated Skill development programme	• Various activities and workshops, including for artisans, conducted

Human Resources Development Targets	Targets Achieved
• Recruitments of Scientists, Technical Officers and Technical Staff	• 5 scientists recruited
• Recruitment of Clerks and Stenographers	• 18 Stenos, LDCs and UDCs recruited
• Recruitment of Gr. II Technical Assistants	• Gr-II Technical Assistants recruitment under process
• Organizing CSIR Platinum Jubilee lectures	• Platinum Jubilee lectures delivered by Seven internationally eminent Scientists and Leaders
• Organizing Colloquium series for young scientists	• Colloquium lectures delivered by 17 young scientists
• Organizing Internal trainings and skill building activities	• Various lectures, workshops and trainings conducted
• Deputing employees for trainings, knowledge dissemination, etc.	• 155 personnel deputed for different trainings, workshops, conferences, etc.

Targets Planned

Performance Targets planned in 2018 – 2019

	Objectives	Planned
1.	External Cash Flow (ECF)	**40 Crores**
2.	Industrial ECF (a part of ECF)	**25 Crores**
3.	ECF from Private organization including testing activity (a part of Industrial ECF)	**10 Crores**
4.	Customer Satisfaction Index	**4.5**
5.	SCI Publications	**120**
6.	Patents	**25**
7.	Copyrights	**5**
8.	Technologies to be Developed	**8**
9.	Technologies to be Transferred	**5**

Business Targets Planned for 2018-2019

- Professional Training Courses to be organized in area of
  - Laboratory Quality Management system as per NABL requirement
  - Metallurgical Analysis of Failures in Materials
  - Mineral characterization, beneficiation and agglomeration
  - Metallurgical Analysis for quality assurance
- Organizing Industry-R&D meet
- Initiation of activity under CSIR-NML Technology Business Innovation Center (NML-TBiC)
- Implementation of on-line customer satisfaction system
- Up gradation of on-line equipment booking software
- Creation of information system for industries in the areas of Metals, Materials, Minerals and Mining
- Generating new business clients including international collaboration

Major Technological & Scientific targets Planned for 2018-2019

Amorphous Electrical Steel

- Preparation of Tender specifications for plant equipment and infrastructural facilities.
- Start of procurement process.
- Laboratory activities on Amorphous Electrical Steel preparation and characterization.

Hot Dip galvanizing simulation

- Development of Galvanizing and Galvannealing process for 980 MPa grade AHSS.
- Development of Zn-Al-Mg coatings on AHSS using HDPS.

Extraction of Tungsten from Hutti gold ore tailings and Scrap

From ore tailings :

- Bulk generation of concentrate for large scale hydrometallurgical extraction studies.
- Development of pilot scale process for hydrometallurgical extraction of tungsten from pre-concentrates.

From Scrap :

- Process validation in kg scale for recycling of tungsten heavy alloy turnings.
- Erection and commissioning of pilot plant for production of 100 kg/day scale high pure W-powder from recycling of tungsten heavy alloy turnings.
- Product evaluation, process flow-sheeting in pilot scale with generation of engineering data.
- Supply of about 200 kg high pure W-powder to sponsor.

Technology for dry beneficiation of non-coking coal for application in thermal power plant

- Collection of bulk coal samples from coal mines.
- Characterization, washability study and development of process flow-sheet for one coal sample.

Technology development for production of sodium metal

- Design and drawings of pilot scale 3000A close sodium plant.
- Development of flow chart, details of raw material, plant layout, specification of equipment, etc for setup of pilot scale plant.
- Technical assistance during installation and commissioning of equipments, electrolytic cell, chlorine plant, etc.
- Study of process parameters and further scale up to commercial plant.

Special Steel Development and Characterisation

- Wear/Abrasion resistant steel through quench & partitioned process during hot strip rolling.
- Improvement in operational life of Mn steel Blow bar used for lime crusher.
- Creep data on Alloy 617 forge for Advanced Ultrasupercritical Technology.
- Fracture Master curve on 20MnMoNi$_{55}$ for nuclear pressure vessel.

Prof. M. S. Thacker | 1955 - 1962

Prof. Maneklal Sankalchand Thacker (1904–1979) was an Indian power engineer, academician and the director general of the Council of Scientific and Industrial Research. He served as a secretary at the Ministry of Scientific Research and Cultural Affairs (present-day Ministry of Culture) (1957–62) and sat in the Planning Commission of India as a member from 1962 to 1967. He was an elected fellow of the Indian Academy of Sciences and the Indian National Science Academy. The Government of India awarded him the third highest civilian honour of the Padma Bhushan, in 1955, for his contributions to literature and science education.

Flagship Projects

Advanced Ultrasupercritical Power Plant - Material Evaluation at CSIR-NML

Energy demands in India largely rely on the ample coal deposit available in the country. However, to be abreast with the environmental demands it is essential to adopt a clean coal based power generation technology. Various technologies such as supercritical, ultrasupercritical, advanced ultrasupercritical, integrated gasification combined cycle, are being attempted worldwide and are in different stages of development and commercialisation. The overall objective in all these technological advancements is to reduce the carbon emission in order to avoid adverse environmental impact. This can be achieved in two ways: (i) by developing a technology for carbon dioxide capturing and storing, a process called CCS or (ii) enhance the power plant efficiency by increasing the steam parameters such as temperature and pressure. The first option, apart from developing an appropriate technology for carbon capturing, involves additional transportation and storage cost. The second option, by enhancing steam cycle parameter, will not only improve the plant efficiency but is also expected to consume less coal per unit power generation and thus reduce less carbon emission per MWe. Enhancement of steam cycle parameter thus becomes a preferred option.

In India, to meet the energy demands and to address the climate change issues, it has been decided to set-up clean coal technology based Advanced Ultra Super Critical (AUSC) power plants through a National Mission Programme. The project is envisaged in two phases. The first phase would focus on research and development on all aspects of AUSC technology and in the second phase an 800 MWe demonstration AUSC power plant will be established. Once the demonstration is successfully proved, it will not be difficult to establish large number of power plants with AUSC technology.

Indigenous AUSC Technology

Though acquiring technology is easier and expeditious to implement, there is always a perpetual dependence on foreign suppliers. This in a long run will be more expensive due to increased dependency on key materials and technologies. Indigenous development of technology, including the indigenisation of materials is thus inevitable. Additionally, in-house development of such technology also has the potential to significantly improve the spin-off benefits in the related industries. In the present scenario of availability of coal as the major source of energy up to about 2050, developing AUSC on our own would be the wiser choice. Realising that the country already has a plan in place to set up a number of 800 MWe capacity supercritical power plants, it should not be difficult to select a 800 MWe plant for AUSC demonstration purposes. The challenges are, however, many fold

- there are no matured AUSC technologies available in the world so that the lessons learned can be quickly adopted
- materials to be employed needs to identified or developed
- large scale fabrication needs to be established
- the R&D outcomes from the rest of world, especially on materials, cannot be directly applied due to variations in the coal chemistry
- a complete understanding of the coal resources needs to be documented

To overcome the challenges, the Indian AUSC will largely depend upon its experience with the matured sub-critical

power plants in the country. For the proposed AUSC plant, the materials for some of the components will be similar to those mature sub critical plants in the country. Only in some critical components, (eg., boiler, super heater zones) the materials will be optimised to suit the enhanced steam temperature and pressure. Advanced materials will be developed only for top end of super heater and reheater boiler tubing, main steam and hot reheat piping, high pressure and intermediate control valves, HP/IP turbines and turbine integral piping. The choice of high temperature material has to be in line with the ASME codes and they have to qualify various high temperature properties to meet the requirement.

Materials for Indigenous AUSC Technology

Following materials are proposed to be used in the Indian AUSC programme

- Grade-23 steel (2.25Cr-1.6W-V-Nb-B, as per ASME code case 2199) for water walls;
- Grade-91 steel (9Cr-1Mo-V-Nb-N, as per ASME SA-213) for superheater and reheater tubing.
- 304HCu austenitic stainless steel (18Cr-9Ni-3Cu-Nb-N, as per ASME code case 2328) for the final stage of superheater tubing, in which the finely dispersed spherical copper precipitates (of 32 nm size) are highly stable in the austenite matrix even after long-term ageing up to 10,000h
- Nickel-base Alloy 617 (52Ni-22Cr-13Co-9Mo, as per ASME SB-167 specification), with controlled composition (Alloy 617M) for the final stage of superheater and reheater tubing at the hottest zone, with the higher requirements of A617M including notably stringent limitations on elements such as C, B, Cr, Ti, Fe, Si and Mn, and a solution annealing temperature higher than 1160°C.

Through a 2 year pre-R&D programme with the initiative and funding from Office of the Principle Scientific Advisor, some of these materials have already been developed in the product form.

Role of CSIR-NML in Material Evaluation for Indian AUSC programme

Materials being the back bone for the success of this ambitious program, evaluating them for the fitness for purpose and for long term life assessment is of paramount importance. The material evaluation program thus has been envisaged to develop (i) design data and (ii) damage assessment data for asset management. The design data evaluation has been planned in an Inter Laboratory Round Robin mode. CSIR-NML will be a part of this round robin programme along with other Indian R&D organisations, universities and institutes. Considering the skills/ expertise and facilities available in CSIR-NML, the following design data will be evaluated at the laboratory

- Generation of creep data of Alloy 617M forge and Alloy 625 cast for AUSC rotor application.
- Creep crack growth behaviour of 10Cr-Alloy 617Mbi-metallic weld joint and 304HCumaterials
- Fracture and fatigue crack growth behaviour of 10Cr-Alloy 617M bi-metallic weld joint and 304H materials
- Fireside corrosion and oxidation behaviour of Alloy 617M and 304 Hcu

Many of the components of AUSC power plants will be subjected to service conditions that lead to high levels of stresses, creep, fatigue and creep-fatigue interaction, and varied extent of fire-side corrosion and steam oxidation. Therefore, special attention would have to be given for 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. For this purpose, capability exists in the country but significant developmental efforts are needed. Some of the areas which need attention include design and development of high-temperature sensors, techniques and procedures for early-damage detection, online monitoring and continuous life-prediction methods, non-contact and global area monitoring, NDE modelling, signal analyses and image-processing techniques for enhanced sensitivity and quantitative NDE. CSIR-NML will be looking into some of these aspects in an attempt to develop sensors/sensor devices for long term assessment of components. Financial sanctions for all the activities have been received and some of the activities have already been started. It is expected that all the design data plans will be completed in two years time and the long term activities will span over a period of five years.

Amorphous Electrical Steel (AES) for Energy Applications

The Ministry of Steel, Government of India, has recently granted a project to CSIR-NML with an outlay of around Rupees Thirty Six Crores for the Pilot scale development of amorphous electrical steel for energy applications. The project will span over four years which would include activities pertaining to processing of amorphous electrical steel in a pilot scale level, so that it could reach a technology readiness level and be accepted by Indian industrial units for indigenous production of AES. The project is also targeted to develop a prototype transformer in collaboration with Indian transformer manufacturers, using the developed materials from the pilot plant. The validation of the transformer through indigenous development of amorphous electrical steel is expected to strengthen the Indian transformer industries in terms of saving foreign exchange, besides providing self-sufficiency in transformer material supply and lessening the dominance of international price on the cost of transformer manufacturing. The project is an indigenous effort towards amorphous electrical steel production in India on a substantial scale which is expected to lead to the adoption of the same by industries and establishment of commercial plants for production of the same. In addition to technical advantages, amorphous alloy transformers also ameliorate environmental concerns to a significant extent. Hitachi, Japan, have reported that the impact of amorphous transformers on reducing CO_2 emissions is as high as 1,20,000 tonnes/year and Japan has adopted amorphous distribution transfer technologies fairly long time back. In US, this technology has led to a drastic decrease in use of oil for transformer application thereby reducing the volume of CO_2 emissions.

CSIR-National Metallurgical laboratory (NML), which has been involved for more than two decades in the development of a series of amorphous and nanostructured magnetic alloys wanted to indigenize the technology of producing amorphous electrical steel. The development of rapidly solidified amorphous and nanocrystalline materials are carried out through several routes out of which melt spinning is a technique to get the product in the form of sheets from which transformers are produced. In this technique the liquid metal is directly poured on a rapidly rotating Cu-based wheel to get continuous strip of about 30 m thick without any rolling process. The typical cooling rate for production of amorphous alloy or Metallic Glass is 106 K per second. The technique has been previously used by CSIR-NML in the development of a laboratory prototype melt spinner for production of 30mm wide ribbon under the CSIR network project on *"Advanced manufacturing Technology"* (AMT). Using the developed equipment, a range of Fe-, Co-, FeCo-, FeNi-based metallic glasses and nanostructured metallic ribbons have been prepared at laboratory scale.

The proposed pilot plant will be established in the pilot plant premises of CSIR-NML. The pilot scale project has two fold objectives (i) to establish a 100kg pilot scale melt spinning facility and establishing process parameters for the production of FeSiB based continuous amorphous electrical steel (Metallic Glass) having dimension 100mm wide & 20-30mm thick and (ii) a prototype transformer development using the manufactured amorphous electrical steel. The technology envisaged under the program is an energy efficient process towards a product for electrical application wherein the liquid metal will be directly quenched into continuous thin sheet (~25 μm) without any forging and rolling operation which is usually required in other electrical steels. This leads to direct energy saving and associated reduction in greenhouse emissions. For the preparation of transformer material alloy, low carbon iron, ferroalloys like ferrosilicon and ferroboron will be used. The ferroalloys are commercially cheaper compared to pure elements. Moreover, as the proposed technology will enable processing in ambient environment, expensive inert gases will not be required. Emphasis will be given on the development of pilot scale instrumentation comprising of melting furnaces and melt spinning systems, heat treatment schedule, which can be up scaled to the level of industrial production. In India, the indigenous development of amorphous materials as in the present project of CSIR-NML, is expected to boost the environment friendly amorphous transformer technology, a step towards clean environment.

Subsequent to the onset of the project, macro and micro-planning has been done to identify different activities and the project team comprising of members with relevant experience / expertise. The activities of the project have been identified as (i) Intellectual property analytics

and management (ii) Infrastructure development (iii) equipment design & development (iv) alloy design & preparation (v) process modeling (vi) magnetic annealing & characterization (vii) procurement & pilot plant campaign (viii) prototype transformer development & (ix) business opportunities. The intellectual property related issues will be dealt in terms of white space analysis. The analysis would look into CSIR-NML's stake with respect to process, product and technology. Infrastructure development is aimed to establish a pilot scale facility to house the state of art amorphous electrical steel production unit, annealing facility and magnetic characterization facility. The industrial shed for the project is expected to be around thousand square meters. The project team responsible for equipment design and development will look into the preparation of detailed specifications of production unit with emphasis on ease of handling and product consistency. The scope of novelty features in the production unit is to be guarded through appropriate intellectual property claims. Besides the equipment features, the novelty in alloy design and properties will also be looked into. The project team involved in alloy design and development would look into potential amorphous electrical steel alloys for transformer applications. This team will work synergistically with the characterization group of the project team to enhance the property of amorphous electrical steel ribbons in terms of quality and property. The magnetic characterization of the prepared amorphous ribbons will be carried out in accordance with available standards pertinent to transformer applications. In this four year project, the focus of the activity in the final year will be on application of the developed ribbon for transformer application. Efforts will be made to tie-up with transformer manufacturing companies for the evaluation of ribbons prepared at CSIR-NML amorphous electrical steel pilot plant. This activity is expected to go hand-in-hand with the scope of seeking business opportunities with such companies and translation of process into a marketable technology.

CSIR-NML is cruising towards freezing of specifications and identification of vendors in India who can supply the pilot scale production unit based on project requirements and NML's specification inputs.

Strategic Projects

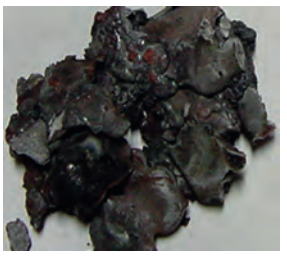
Development of a Process for Production of Gadolinium Metal by Fused Salt Electrolysis of Gadolinium Chloride

Gadolinium (Gd) is a rare earth metal (REM). The exceptionally high neutron absorption capacity of Gd makes it a strong candidate for shielding and lining material in nuclear reactors. Presently the total demand of the metal is met through imports only. CSIR-NML has fulfilled the requirement of gadolinium metal of the sponsor for their captive applications as surrogate of plutonium (Pu) for electro-refining studies. In collaboration with IGCAR, Kalpakkam, CSIR-NML has developed an indigenous technology first time in India for production of gadolinium metal by fused salt electrolysis of gadolinium chloride. During the production process, the experimental parameters were optimized and scale-up of 100A cells were designed indigenously and operated successfully. About 500 gms of elemental gadolinium metal powder was produced, which was subsequently pelletized and melted into cast metal in a vacuum arc melting furnace (Fig.1). The purity of the metal was found to be 98.7 to 99.7%. The experiences of the study enables CSIR-NML to produce gadolinium indigenously to meet the future demand of gadolinium metal in India.

100A electrolytic cell

As-produced Gd Metal lump

As-produced Gd metal powder



ARC melted Gd Metal

Fig. 1 : Steps in Gd production

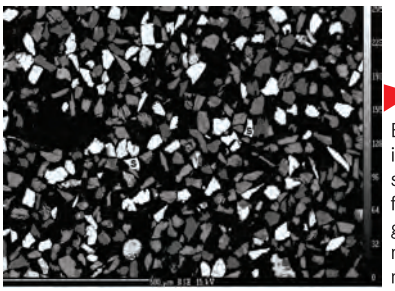
Development of Process Flow sheet for Beneficiation and Extraction of Tungsten Metal from Mines Waste

Tungsten is an elastic, ductile metal with high tensile strength, low thermal expansion and the highest melting point (3422±15°C) and boiling point (5700°C) of all metals. It is used in lamp filaments, electrical contacts, cutting tools and armours. As tungsten carbide, it is used for cutting tools, in high temperature steels used for construction, in mining equipments, turbines, and as structural material in nuclear, defence and space technology. The world reserve of tungsten in terms of metal content are 3.2 million tonnes, distributed broadly amongst China (64 per cent), Russia (9 per cent), Canada (4 per cent) and the US (5 per cent). India's reserve of tungsten is 224 million tonnes assaying over 0.1% WO_3, 44 million tonnes of lean grade ore assaying 0.01-0.08% WO_3. Thus, tenor of the ore is much less than the discards of milling plants in other countries (Fig. 2). Presently, there is no tungsten production in India and the domestic demand is met through imports. Thus, tungsten is a strategic metal. The domestic tungsten demand is increasing steadily, and at present it is about 150 MT/month. Due to the increasing global demand of tungsten and export restrictions from the major producers, indigenous production to meet a part of the domestic demand is inevitable. CSIR-National Metallurgical Laboratory is working on development of indigenous technologies for production of tungsten metal from domestically available resources. The objective of the research is to develop a process flow-sheet for beneficiation and extraction of Tungsten metal from mine wastes.

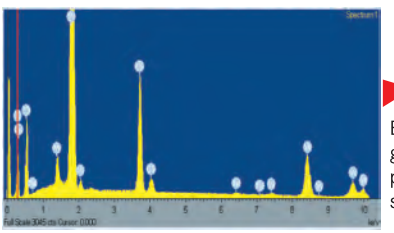
The scope of the work involves characterisation, process mineralogical study, beneficiation and hydrometallurgical extraction from a mines tailing with 0.02% WO_3. The work has been carried out in two major modules- (i) Mineral processing to generate a concentrate and (ii) hydrometallurgical extraction of tungsten from the concentrate. The mines tailing has been observed to contain particles of size 25 micron 75% passing through with scheelite as the tungsten bearing mineral. The gangue minerals include silicates like quartz, plagioclase,

perthite, biotite, amphibole, oxides such a spinel, rutile, chromite, and magnetite and sulphides like arsenopyrite, pyrite, chalcopyrite, pyrrhotite. The mines waste was subjected to gravity separation followed by magnetic separation and a scheelite concentrate with about hundred times enrichment was obtained.

The tungsten concentrate was further processed by hydrometallurgical routes for production of high pure APT. The concentrate was subjected to alkali leaching under ambient condition followed by solvent extraction of tungsten from the leach solution. The tungsten loaded organic was stripped by NH_4OH followed by evaporation of ammonium tungstate to crystallize high pure ammonium para-tungstate crystals (purity >99.6%). The overall tungsten recovery achieved was higher than 90%. The pilot scale study is under progress.



Back Scattered Electron image of only two scheelite grains in the field of view. Rest all the grains are gangue minerals present in the mines waste sample.



EDX spectra of scheelite grain confirming the presence of stoichiometric Ca and W.

Fig. 2 : Low amounts of W available in Indian ores

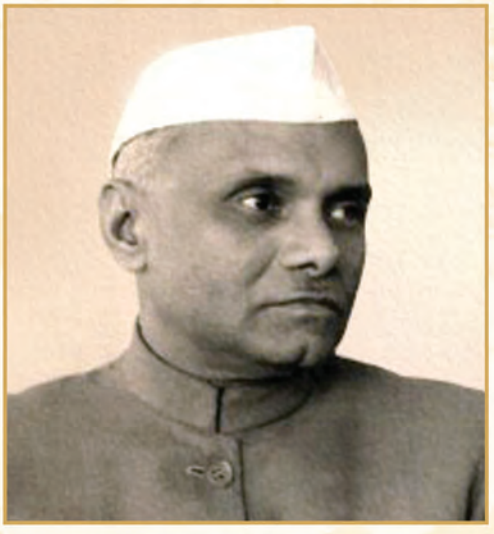
Recycling of Tungsten Base Heavy Alloy Scraps for Production of High Pure Tungsten Powder

In order to lessen the import burdens and become partly self reliant with respect to domestic tungsten demand, it is important to develop indigenous technologies for recycling of available scraps. Therefore, the main objective of this project is to develop process flow-sheet in pilot scale (100 kg/day scale tungsten powder production) and do a detailed techno-economic evaluation for commercial production of tungsten from tungsten base heavy alloy scraps/turnings generated from various defence establishments of our country. The process flow-sheet developed so far in bench scale is superior to contemporary technologies in several aspects, 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 95%) and higher ROI. The produced W-powder meets the desired spec with respect to purity >99.94%. Based on the bench scale process optimization and flow-sheeting, a pilot plant with 100 kg/day scale W-powder production capacity has been installed and commissioned at CSIR-NML recently. The pilot plant was inaugurated by Dr. S.V. Kamat, Director, DMRL, Hyderabad on 25th May-2016 (Fig.3).

Fig.3 : Glimpses of 100 kg/day W-extraction pilot plant

Dr. S. Husain Zaheer | 1962 - 1966

Dr. Syed Husain Zaheer (1887-1971) was an Indian chemist. Prior to taking up the directorship of CSIR, he served as the director of the Indian Institute of Chemical Technology, a division of CSIR, where he established the department of Biochemistry. After his superannuation from CSIR, he chaired the Board of Governors of the Indian Institute of Technology, Kanpur. The Government of India awarded him the third highest civilian honour, Padma Bhushan, in 1972, for his contributions to science.



Dr. Atma Ram | 1966 -1971

Dr. Atma Ram (1908-1983) started his career as a member of the research team (1942-1944), directed by the late Dr. S.S. Bhatnagar, in the Industrial Research Bureau and subsequently joined the Council of Scientific & Industrial Research (CSIR). In 1945, the Governing Body of CSIR entrusted to him the responsibility of organizing the newly started Central Glass & Ceramic Research Institute. He was appointed Director of the Institute in 1952. Dr. Atma Ram was appointed Director-General, Council of Scientific & Industrial Research (CSIR) on August 22, 1966. He served as the Chairman, National College of Science and Technology (NCST), 1977; Principal Advisor, Prime Minister and Union Cabinet on Science and Technology, 1977-83. He was awarded the Shanti Swarup Bhatnagar Prize, 1959; Padma Shri, 1959; Plaque of Honour, All India Glass Manufacturers Federation, 1964; Doctorate (Hon. Cau.), Lenin Soviet Technology Institute, Leningrad, 1959.

Advanced Materials

Advanced Materials and Processes (AMP) Division was constituted on the 1st of April 2017 to address research and development in advanced materials and advanced processes and techniques covering a broad spectrum of scientific and technological issues, addressing demands in energy, space, oil & gas, iron & steel, biomedical and infrastructure sectors. The division comprises of 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 matters of materials, methods and devices beyond the current state-of-the-art. 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 their evaluations. The important projects that the division handled in the reporting year are categorized into two areas: Advanced Materials and NDE.

Advanced Materials

A project from Surgiwear mandated development of Mg-based biocompatible and biodegradable alloys suitable as bio-implants. A series of Mg-Y, Mg-Gd, Mg-Zn-Mn, Mg-Gd-Y-Zr-Zn alloys were made and investigated structurally. The mechanical properties of a few alloys in the as-cast condition was exceptionally good; yield strength of 360 - 420 MPa and ultimate tensile strength of 440 - 445 MPa were observed. These alloys are potential materials for lightweight structural applications. Most of the as-cast Mg alloys prepared under this project are found to possess strength values above 200 MPa. Post processing of a few selected alloys are also being planned to enhance the mechanical properties. Corrosion investigation of these alloys in simulated body fluid are also being conducted.

The objective of a project on collagen-graphene composites for energy devices, from John Keells Research, a multinational from Sri Lanka, was to synthesize collagen-graphene composites doped with iron oxides, calcium hydroxy phosphates and silver nanoparticles, and to electrospin them with polymers to make nanofibres (*Fig.1*). These nanofibres were then heat treated and directly used as electrodes and the capacitance measured. A specific capacitance of 570 F/gm, was observed.

A collaborative project between CSIR-NML, Jamshedpur and National University of Science and Technology (NUST), Moscow, Russia, funded by DST aimed to develop nanocomposite ribbons and wires with enhanced functional magnetic properties and ferromagnetic stability. In this activity, so far, at CSIR-NML, an alloy with nominal composition of $(Co_{94}Fe_6)_{72.5}Si_{12.5}B_{13}Cr_2$ was prepared by arc melting in an argon atmosphere using pure elements. For the preparation of the wires, an in-water quenching apparatus with induction melting facility was used (*Fig.2*). Wires with typical diameter of 109 microns were obtained. The Giant magneto-impedance property of the wires was measured using the

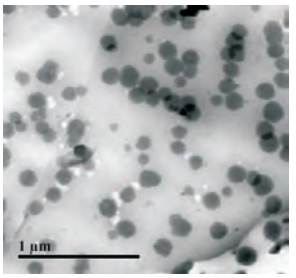


Fig.1: Nanofibres

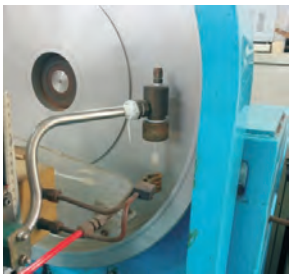


Fig.2 : In-water quenching

four probe technique at an applied current of 2mA for different driving frequencies ranging from 200kHz to 10MHz. The as-quenched wires displayed a GMI_{max} value of 291% at 4MHz. The wires showed single peak at low frequencies while a dual peak behavior was observed at higher frequency as in the case of 4MHz (*Fig.3*). The wires also displayed soft magnetic character with a coercivity of 180 mOe. Further activities would include modification of the alloy composition with the replacement of metalloids Si or B by other elements and evaluation of GMI, soft magnetic and structural behaviour.

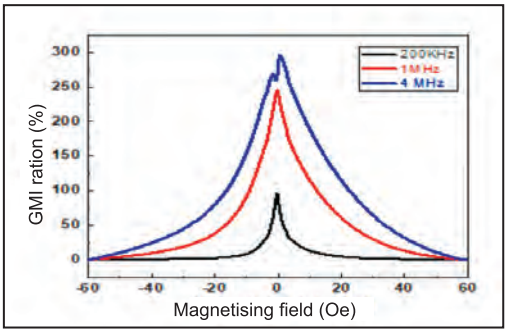


Fig.3 : Demonstration of GMI by developed wires

A collaborative project on development of Iron-based rapidly solidified alloys from high phosphorous pig iron (HPPI) is aimed at the development of multi-component rapidly solidified alloys utilizing the HPPI, a steel industry byproduct. A series of multi-component alloys have been designed to have enhanced glass forming ability and prepared utilizing industrial grade ferro-alloys through induction melting route. The HPPI and modified alloys were re-melted and rapidly solidified in Chill block melt spinning process (CBMS) at various surface linear velocities (v) of 22, 26, 33, and 42m/s in an ambient atmosphere. The increasing linear velocities correspond to higher cooling rate and decreased cross section of the obtained ribbons. The ribbons were processed in ambient atmosphere and were of good quality with minimal surface defects. The obtained ribbons were evaluated for their structural, thermal and soft-magnetic properties. The XRD and DSC result confirms the vitrified nature of the As-Quenched ribbons. The under-cooled amorphous ribbons exhibit excellent soft magnetic characteristics (Hc<10 A/m) (*Fig.-4*)

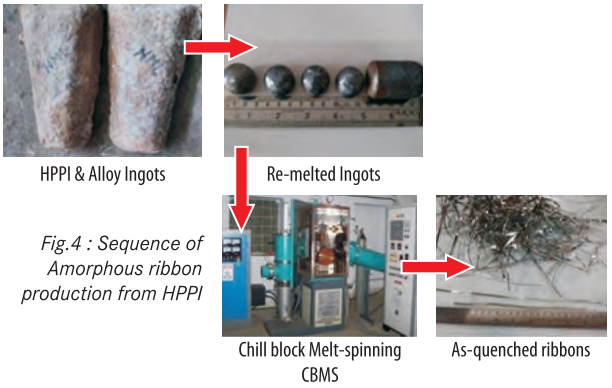


Fig.4 : Sequence of Amorphous ribbon production from HPPI

A new series of 18 karat gold alloys, sponsored by TITAN, were designed and developed through arc melting and casting in the form of rods by suction casting, which showed melting point in the range of 350 -470°C, and hardness within 210-310 Hv. In European countries, 18 carat gold alloys are conventionally used for jewelry purposes unlike India where 22 carat is used. 18 carat gold alloy is usually processed through cold working and subsequent heat treatment, with hardness in the range of 150-290 Hv. Some applications, like in the watch industry, need higher hardness. A new series of Au-Ag-Cu-Si alloys were designed and developed through arc melting and casting in the form of rods of 3, 4 and 6mm diameter by suction casting. The minimal gold content was maintained at 75wt% for fulfilling the 18 karat category grade. The alloys with more than 1wt% Si result in melting temperatures of 350 - 470°C, and the hardness was within 210-310 Hv. Low melting point with higher gold alloys will be suitable for special jewelry applications. After several attempts, one alloy was successfully cast as a ring without any damage of the rubber mould. More trials are going on to prepare rings for commercial purpose.

In another project sponsored by the Watch Division, TITAN, cyanide free electrolyte was developed for electrolytic cleaning of rust from plain carbon steel components of wrist watches, like small screws (dimension: 1-2 mm), before assembly. The rust removal process is very fast (1-2 minutes) and employs alkaline solution to prevent any damage like hydrogen pick up and surface activation. The developed process is currently being used at TITAN in commercial production. Cyanide free chemical solution was also developed to leach out gold from the electroplated watch straps and cases for gold recovery (*Fig.5*). The developed gold leaching process is very fast (2-5 minutes) without affecting the base metal. Gold can be recovered from the leach solution with zero discharge and the solution can be regenerated for further gold leaching. Therefore, the developed process is economical and environment friendly. Plant trials at TITAN for recovery of gold from market return cases and straps were successful. Using the above two processes, TITAN watch division will be able to comply with the Tamil Nadu Pollution Control Board directive to eliminate the use of cyanide in its factory.

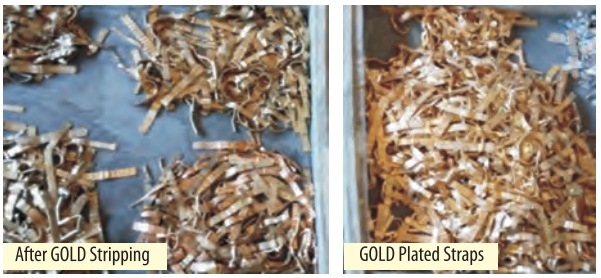


Fig. 5 : Gold stripped products

Tata Steel sponsored a project to develop corrosion resistant amorphous coatings of $Fe_{63}Cr_8Mo_2B_{17}C_5Si_1Al_4$ and $Fe_{56}Cr_{13}Mo_2B_{16}C_4Si_2P_7$ on steel substrate. As cast metallic glass ribbons of $Fe_{63}Cr_8Mo_2B_{17}C_5Si_1Al_4$ were fully amorphous while $Fe_{56}Cr_{13}Mo_2B_{16}C_4Si_2P_7$ alloys were only partly amorphous. The glass forming ability of $Fe_{63}Cr_8Mo_2B_{17}C_5Si_1Al_4$ is better than that of $Fe_{56}Cr_{13}Mo_2B_{16}C_4Si_2P_7$. The XRD patterns of $Fe_{56}Cr_{13}Mo_2B_{16}C_4Si_2P_7$ ribbons, powders and the coated sample exhibited small diffraction peaks superimposed on the amorphous hump which indicate the formation of intermetallic phases within the amorphous matrix. These intermetallic phases are identified as (i) Fe-Si, (ii) Fe_2B, (iii) Cr-Fe-Si, (iv) Mo-Fe-Si and (v) Cr-Si. XRD Pattern of samples coated with $Fe_{63}Cr_8Mo_2B_{17}C_5Si_1Al_4$ was completely amorphous. Moreover, the DSC scan of these ribbons revealed wide super cooled liquid region indicating good glass forming ability of this alloy. Though the coated samples exhibited some un-molten particles, coating was adherent and continuous. Thickness of the coating increased with increasing layers of coating. Both the coatings exhibited corrosion resistance, the corrosion rate of the sample coated with the $Fe_{56}Cr_{13}Mo_2B_{16}C_4Si_2P_7$ alloy with three passes was the least. Both the investigated compositions have potential for developing corrosion resistant coating on steel substrates.

In a project sponsored by an Aerospace Multinational, CSIR-NML has developed a chrome free polymeric coating using suitable polymeric corrosion inhibitors. The polymeric corrosion inhibitors have corrosion inhibitor groups chemically bonded to the polymer backbone. The corrosion inhibitor groups chemisorb to Aluminium surface providing corrosion protection and the polymer chain provides adhesion to the paints. A new polymeric corrosion inhibitor was synthesized and conversion coating on Aluminium alloy AA2014 was done successfully, using the new polymer. A top coat of acrylic polymers was used to test the paint adhesion, and the corrosion resistance performance of the coating system was evaluated in a salt spray chamber. The coating passed the scratch tape test for paint adhesion and passed 336 hours of salt spray test (*Fig.6*).

Fig. 6 : After 336 hours of Salt Spray Test

For a project from ONGC, CSIR-NML successfully designed, fabricated and installed a "Closed loop corrosion test rig" for corrosion studies in flow simulated sea water with different controlled O_2 levels (*Fig.7*). This was designed by CSIR-NML. The equipment is attached with two types of test rigs for coupon exposure as well as for electrochemical studies using online potentiostat under flow condition. Two different Cr alloys were prepared having 0.5% and 1.0% Cr, in addition to the base alloy, and laboratory scale corrosion evaluations were carried out to monitor the effect of chromium addition on the corrosion rate of the material.

Fig. 7 : Closed loop corrosion test rig designed by CSIR - NML

Non-destructive Evaluations (NDE)

NDE activities at CSIR-NML can be broadly categorized under two heads: [I] Development of methodologies for damage assessment of engineering components and [II] sensors & devices for structural health monitoring.

Development of methodologies for damage assessment of engineering components

In a collaborative project between CSIR-NML and NTPC, creep damage assessment of high temperature headers and pipelines was carried out using multi parameter Non-Destructive examinations. The headers and pipelines of power plants operating at high temperatures and pressures undergo creep deterioration for long time exposure, which requires a remaining life optimization for avoiding catastrophic failure and estimating the critical components beyond their design life. The traditional techniques for remaining life assessment of boiler tubes/pipes are generally extrapolation of statistics of past failures on the basis of historical database upon thermal and mechanical factors and accelerated creep rupture test of post-service samples. These techniques have some difficulties in terms of availability of long term data base and maintaining of same creep environment at laboratory scale. Hence the alternative approach is continuous monitoring and periodic inspection of components through NDE techniques. Under this project, the creep damage assessment through magnetic and non-linear ultrasonic (NLU) techniques has been carried out on two types of boiler pipes made of ASTM A335 P22 (2.25Cr-1Mo) and ASTM A335 P91 (9Cr-1Mo) steel. The as-received microstructure of P22 steel pipe comprises of discrete pearlite phase and Cr- rich carbide precipitates in the ferrite matrix, while Cr and Mo rich carbides are in homogeneously distributed in martensitic matrix of P91 steel pipe. The samples of P22 and P91 are creep exposed at the creep conditions of 550°C/115MPa, 575°C/115MPa, 600°C/100MPa and 550°C/200MPa, 600°C/140MPa, 650°C/100MPa, respectively. The creep interrupted samples show a complex precipitation behavior as a function of creep strain and time. A rapid increase of magnetic hardening is noticed prior to failure for both the pipes. Moreover, an abrupt increase in the NLU parameter at 4-5% strain was observed in all test conditions (prior to transition from secondary to tertiary creep). The project outcome was a multi NDE parameter based technique to predict creep damage in P22 and P91 materials. Two microstructure atlases for P22 and P91 steels have also been published under this research program (*Fig.-8*).

A project sponsored by a Multinational mandated investigation of electromagnetic properties of shot peened 4340M steel with fatigue cycles with an emphasis on the evaluation of residual stresses using Magnetic Barkhausen Emissions (MBE) techniques. The 4340M plates were cut as per ASTM standards for fatigue testing. Then, the samples were normalised at 870°C for 1 hour. Interrupted fatigue study was carried out at two stress levels (36% and 60% of yield stress) for the heat treated sample. The fatigue cycles were interrupted at intervals of 5000 cycles and 10000 cycles for test carried out at 60%YS and 36%YS respectively till failure. X-ray residual stress study and MBE study were carried out on heat treated samples subjected to interrupted fatigue. The data for interrupted fatigue at 36% of yield stress is shown in *(Fig. 9)*. The MBE signal output for the sample has been calibrated and converted to stress values through tensile test studies. It was observed that variation of residual

Fig. 8: Mircrostructural Atlas

stress measured using XRD and MBE with fatigue cycles follow similar trend and indicate different stages of fatigue mechanism. The normalised samples were shot peened using 0.5mm steel shots of hardness 55–60 HRC for required peening intensity of 0.0101 Almen. The MBE signals plots before and after shot peening are shown in *(Fig.10)*. It was observed that post shot peening, the MBE signal for 4340M steel reduced from 0.072mV (pre-shot value) to 0.060mV. This reduction in the MBE signal output is attributed to shot peening induced compressive stresses.

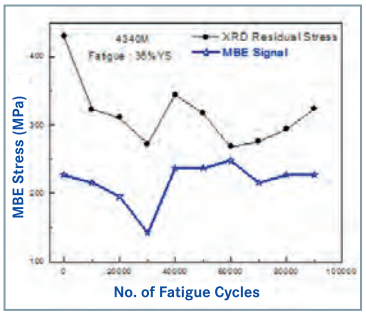


Fig. 9 : Stress determination correlation

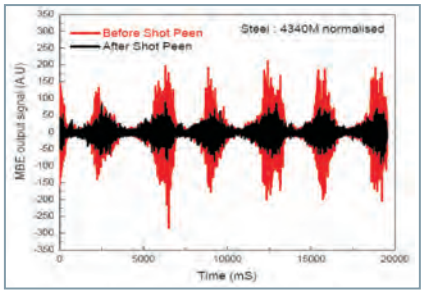


Fig. 10 : Effect of shot peening on residual stress

ASAP, the acronym of the project Advanced Electromagnetic Sensors for Assessing Property scatter in high value steel is sponsored by Primetals, UK. Interstitial free (IF) steel sheets are processed through the sequences of slab reheating, hot rolling, coiling, cold rolling, intermediate annealing and final coiling, prior to being used in the automobile industries. The resultant properties are predicted through the precise characterization of the deformation microstructure and sub-grain growth during recovery followed by formation of recrystallized strain free grains during annealing. Due to the ferromagnetic nature, non-destructive electromagnetic techniques are the most suitable for the evaluation of microstructural parameters and mechanical properties. The recovery and recrystallization behaviors of cold rolled IF steel have been investigated by destructive (optical microscopy and hardness) and non-destructive electromagnetic sensor, (which allows direct measurement of strip samples with no surface preparation). The onset and completion of recrystallization are clearly monitored through destructive techniques of optical microscopy and hardness measurements. The nucleation of new recrystallised grains was observed in the sample annealed at 600°C/15min, while completion of recrystallization occurred at 700°C/15min. The destructive techniques are not very accurate in monitoring recovery; for example, changes in hardness of <20% are seen. In contrast, the magnetic properties of annealed steel show the onsets of both recovery and recrystallization, with recovery accounting for $\approx$ 60% change in the coercivity value. Therefore, the measurement of magnetic softening through an electromagnetic sensor can play a crucial role for understanding recovery and recrystallization behavior of steels during industrial processing.

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 is very critical which form cube-on-edge Goss texture towards the rolling direction to enhance the magnetic property. However, the material property deteriorates in course of service. Generally, samples of specific size are needed to evaluate the magnetic properties like core loss, flux density, and permeability. NTPC has felt the need to develop on-site non-invasive measurement techniques to find the damages in CRGO steel sheet. With an aim to establish non-invasive electromagnetic measurement technique for evaluation of damage in CRGO steel, NTPC has sponsored a project to CSIR-NML. The as-received CRGO sheet of 0.27mm thickness were heat treated at different temperatures, and magnetic properties were evaluated using an electromagnetic sensor (MagStar), and Epstein set. Magnetic property by MagStar was evaluated at different angular directions with respect to the rolling direction. It was found that the coercivity was higher in the transverse direction due to hindrance of magnetic domain movement. Further studies are going on to establish the technique for onsite application.

The segregation of carbon in high carbon steel grades resulted in wire breakage while drawing. To evaluate the segregation along the length of a billet is a painful exercise. Objective of this Tata Steel sponsored project is to develop a correlation between macrotructure and extent of carbon segregation, so that by the evaluation of transverse macrostructure of a single slice of billet, the extent of segregation along the length of the billet can be known. In a previous work carried out by CSIR-NML, it was observed that the extent of segregation varied along the length of the billet and had a relationship with the equi-axed zone size. In this project our attempt was to arrive at a correlation between equi-axed zone size and segregation index of continuously cast high carbon billets. 3m long longitudinally sectioned billets at different casting conditions were used to evaluate the

macrostructure along the whole length using ultrasonic imaging. Sectioning of the billets down to the centre line was made to take sulphur prints and to measure carbon segregation values along the 3m length at the centre line. Ultrasonic imaging proved as a reliable and environment friendly technique for measuring and quantifying equiaxed zone size in billets. The results from ultrasonic imaging also showed that macrostructure of a single slice could be used as a reliable method for estimating carbon segregation in the billets. Under this project an image processing software has been developed to quantify the equi-axed zone size, central porosity and to separate segregation and pores. Macrostructure of 1m long billet as revealed by ultrasonic imaging is shown in *Fig.11.*

Ultrasound is a widely used technique in non-destructive testing of materials. It also finds applications in refining

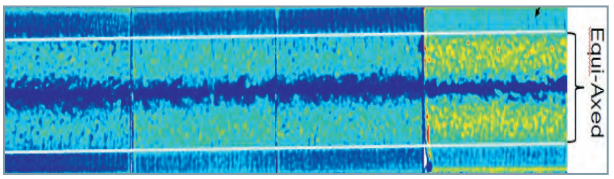


Fig. 11 Billet Macrostructure by ultrasonic imaging

the cast structure of various metals, especially steels. Exposure of steel components to ultrasound waves causes lattice vibrations, thereby increasing the population of defects or imperfections, such as dislocations. It also results in phase changes in steels and is known to greatly influence the kinetics of solid state transformations such as spheroidization etc. In a previous work, CSIR-NML had studied briefly the effect of ultrasound treatment on low carbon (LC) steel samples of varied compositions with mostly ferritic or dual phase microstructure, processed into 3-4 mm thick hot-rolled plates. The hardness of the softer grade materials namely IF and Mild Steel (MS) was found to decrease and increase respectively due to the treatment. In this work ultrasonic treatment of IF and LC, as cold rolled, and, cold rolled and annealed, have been proposed. It was observed that ultrasound treatment of cold rolled and annealed IF steel caused an increase of 20% in hardness after 20 mins of ultrasound treatment. Details of microstructural analysis will be done to understand the cause. This project is sponsored by Tata Steel.

The mineral industry consumes vast amounts of energy and almost half of that is consumed during comminution. Only about 5% of such energy of comminution is expended to generate new surfaces; the remainder is lost in frictional losses and heat. Comminution is an important unit operation at various processing units of Tata Steel for size reduction of coal, coke, iron, manganese, chromite, sinter and fluxes. A project was taken up to explore a new idea of ultrasonic wave treatment of materials to minimize the energy consumption. This concept is already used in medical industry to break kidney stones. Kidney stone is relatively soft and friable, and is relatively easy to break by high energy ultrasonic waves. Application of the idea for mineral processing operations requires idea validation and identifying a commercially implementable solution at a bigger scale. For validation of the idea, three different materials, coal, Mn ore and Banded Hematite Jasper (BHJ) Iron ore, were taken. It was observed that ultrasonic treatment erodes the particle surfaces which ultimately increases liberation and fracture but it takes more than 30 minutes which makes the process energy inefficient. Figure below represents the pictures of the untreated and treated coal samples (*Fig.12*). Studies reveal that coarser particles of coal, Mn and Iron ores took 0.1 to 1hrs, 0.5-2 hrs and >2 hrs to break, respectively. It is required to

Fig.-12 : Comminution using ultrasonics

reduce the comminution time by increasing the intensity of ultrasound waves by designing a different horn or by using grinding media such as steel balls to make the process techno-economically viable.

Development of need-based Sensors & devices for Industrial applications

A complete cost effective on-line defect detection system developed by CSIR-NML has been commissioned at Tarapur wire Mill, of Tata steel, and the system is operational from May 2017. The system is low cost and equipped with features not available in the high cost imported systems. Features embedded in the developed system are graphical representation as well as data logging, post processing, defect location identification,

defect characterization (severity of defects; low, medium & high), Report generation, Comprehensive report of graphs as well as logged data of each run in a tabular format as per the occurrence of events (low or severe defects) and listing of the number of defects corresponding to each event, ASCII data for further understanding of the root cause of defects and for decision making, Remote sensing through internet of things (IOT), customized software for smart monitoring and control, SMS and email alert to the operator. Picture below shows the location of the installed system at Tarapur wire mill (*Fig.13*).

Coke fed into the Blast Furnace contains moisture, which

Fig.13 : Wire defect detection on-site.

normally varies from 0.5% to 5%. The content of moisture mainly depends on method of quenching adopted, i.e. dry or wet. The high moisture content in coke affects BF performance adversely in terms of Coke rate and production rate. Therefore moisture determination of coke is done on a regular basis – thrice in a day – once per shift. This conventional method of moisture determination is time taking and fully dependent on resource and infrastructure availability. In the first phase of a sponsored project by Tata Steel, lab-scale experiments have been carried out to study the feasibility of microwave assisted IR thermography (MAIRT) for estimation of moisture in blast furnace coke. The said technique has been found to be suitable for estimation of moisture in BF coke, Nut coke, Gross coke samples collected from coke plants 1 & 2 and from H & I blast furnaces. Validation has been done on site at CRMT Lab, Tata Steel on 64 gross coke samples collected from CP1, CP2, IBF and HBF at different shifts for 12 days. The moisture wt.% estimated by microwave-assisted IR imaging is found to have a good correlation (R2=0.956) with the moisture wt% obtained by conventional technique in CRMT Lab. In the present project, implementation of microwave-assisted IR Thermography technique will be attempted for fast, online estimation of moisture in blast furnace coke samples. The online estimation of moisture of blast furnace coke will enable operators to take quick action in case of any deviation in moisture content of coke, thus ensuring stability in BF operation.

Fibre Bragg Grating (FBG) sensors can accurately measure strain with high resolution which can be utilized, through proper calibration, for determination of weight of moving as well as static stock. Existing arrangement for weighing of rail wagons suffers from reliability and robustness issues. Under this Tata Steel sponsored project FBG strain sensors were used to measure the wheel/rail vertical force in terms of measuring the shear strain developed around the neutral axis of the rail due to wheel load. In an FBG sensor, the direct measure and is the shift of wavelength which is a function of strain. The aim was to correlate the strain measured by the FBG sensors with known loads and to draw a calibration curve which subsequently would be used to determine unknown loads. FBG sensors were deployed in the web and on the foot of the rail for measurement of strain induced by the wheel load. Arrangements of sensors used during the experiment are shown (*Fig.14*). Four FBG sensors 'a', 'b', 'c' and 'd' were deployed in the rail web around the neutral axis (NA) and using this configuration the vertical wheel

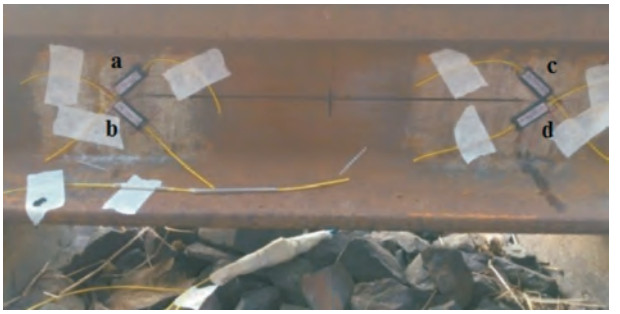


Fig.14: FBG sensor arrangement for strain measurement

load was computed. For a particular rail section if the wheel loads are known, then a calibration curve may be drawn where the measured strain is expressed as a function of the wheel load. To estimate the loads from the measured strain data, two locomotives, one test wagon and two empty wagons were used in different combinations. Subsequently, the average total strain for each carriage was computed and the corresponding loads were obtained from the

calibration curve. It was observed that unknown weight of a moving stock can be measured with FBG sensors with desirable accuracy. Weight of moving wagon with a resolution of 0.019T/με was established.

In another project, the objective is to record live mould wall, cold face temperatures, of a billet casting mould, across the face and on all four faces. The activity consists of sensor fabrication, packaging and temperature calibration, array of FBG sensor insertion in the four faces of billet, installation in the caster and real time data capturing, data compilation and modelling. 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. Rhomboidity (off squareness/obliquity) and cracks are two billet defects noticed in this grade which accounts for most of the rejections. Previous studies have identified that the solidification pattern in the mould to be the sole cause for the cracks and one of the primary causes for rhomboidity.

In order to understand the defects and the casting mechanism, data of the heat flux is essential. Due to the constraint of space, difficulty in instrumenting and low returns, thermocouples are never used in billet casting moulds commercially. Researchers instrument a few sample moulds to generate the data required. Traditionally two wire thermocouples are used (*Fig.15*). This leads to a number of wires coming out of the mould which makes it difficult to handle. CSIR-NML in collaboration with CSIR-CGCRI has already established the feasibility of using FBG for real time temperature monitoring of billet mould at Tata Steel and successfully captured the realtime temperature data for the lifetime of a mould in the caster (*Fig.16*). In this project it is planned to use FBG sensors to generate the temperature readings of all the four faces to understand the root cause of cracks and Rhomboidity in the billet. These optical fiber based temperature sensors have an advantage in that with one single fiber, multiple temperatures can be read.

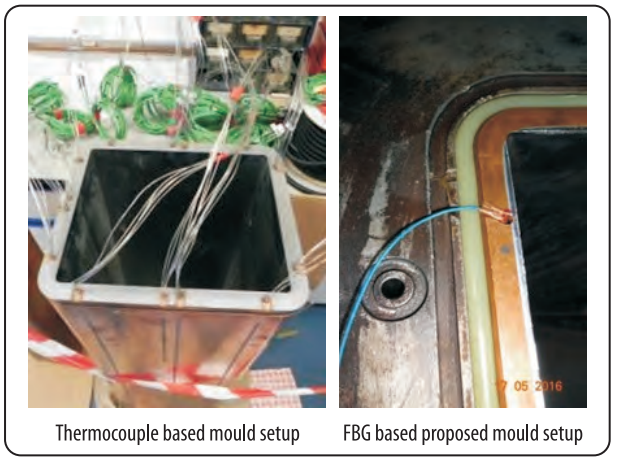


Fig.15: Temperature measurement conventionally, and using FBG

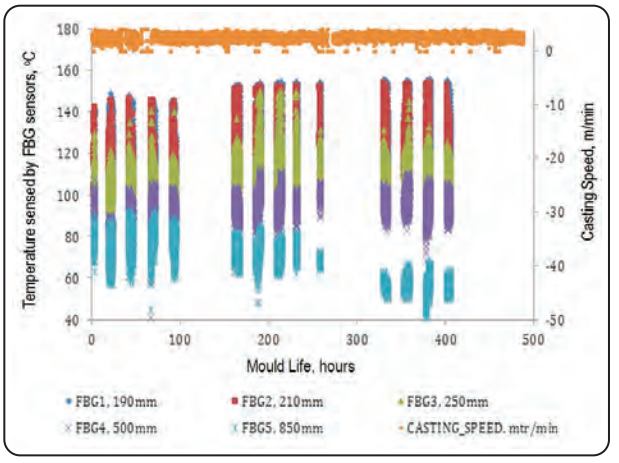


Fig.16: Real-Time Temperature monitoring using FBG

Metal Extraction and Recycling

Metal Extraction and Recycling (MER) Division primarily deals with different facades of ferrous and non ferrous metals, value addition to various industrial wastes and chemical characterization of raw materials and products. Towards effective execution of the laid down mandate, the division has been divided into four major groups, namely, Ferrous Process, Non-ferrous Process, Waste and Resource 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 direct reduced iron 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, and extraction of rare earth metals from industrial wastes. The Waste and Resource 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, chemical characterization of raw materials and products for both internal and external clients, chemical and structural characterization of coal from all major coal fields in India and production of Certified Reference Materials.

Through a series of brain storming sessions, the division has identified a few items for future research stress which includes value addition to LD slag, improvement in utility of non coking/low grade coal, energy auditing of metallurgical processes and waste heat recovery from low energy sources. A brief description on a few important research initiatives during the last financial year and their outcome thereof has been presented in subsequent sections.

Additionally the division had organized the following major programmes :

- **Interactive Programme on Coal for Metallurgical & Thermal Application** (*An Appraisal of its Characterization and Utility*) was organised at CSIR-NML, Jamshedpur from January 22-25, 2018.
- The proficiency testing programme on **Elemental concentrations in Manganese ore (PT-Mn-Ore/2015-16)** in collaboration with CSIR-National Physical laboratory, New Delhi.
- Training Program on **Experimental Techniques in Iron and Steelmaking**, during Dec 6 -9, 2017

The division has executed a large number of research projects in the period of this report. The activities have been classified into four major categories and a brief description of each is presented below :

Process and Technology development

Production of Highly Metalized Directly Reduced Iron from mill scale & Lean Grade Coal in Tunnel Kiln

Mill scale containing approximately 72 % Fe is generated during processing of steel towards production of various long and flat products. More than 1.4 million tons of mill scale is generated annually in India. Although, integrated steel plant consumes about 85% of the mill scale generated through sintering, no suitable process exists for the secondary sector.

In India, approximately 13% of total coal reserve is coking coal and the remaining is low grade coal or non-coking coal. The conventional coal based processes available for production of Direct Reduced Iron (DRI) production require high grade ferruginous materials in the form of lump or high temperature indurated pellets and good quality coal. These commercial technologies suffer from low thermal and low chemical efficiency. Till date no process has been developed to utilize mill scale and low grade coal for production of DRI without pre-induration. CSIR-NML has been actively involved in developing a process for production of highly metalized Directly Reduced Iron (DRI) from mill scale and lean grade non-coking coal in Tunnel Kiln, with funding made available by the Ministry of steel, India.

Green composite pellets were prepared from crushed and ground mill scale, iron ore fines and non coking coal. Various pelletizing parameters were optimized to yield optimum green strength of the pellets. Reduction study of these pellets, containing different percentage of iron ore fines were carried out at different temperatures (1000 to 1250°C) and times (10 to 100 minutes). Through laboratory scale experiments, the process parameters were optimized to achieve highly metalized DRI at 0.5 kg to 5.0 kg scales.

Based on the findings of the laboratory investigations, plant trials were carried out using an existing tunnel kiln using 3.0 to 5.0 Tons input per batch. Fine tuning of the process parameters have been carried out to yield highly metalized DRI in the commercial tunnel kiln. After optimization, approximately 35 tons of highly metalized (>89% metallization) DRI has been produced in the commercial tunnel kiln. Subsequently, a series of preliminary melting tests have been carried out in a commercially operating induction furnace. The melting behaviour and slag characteristics of these DRI pellets indicate their suitability as a feed for EAF, IF and in BOF as a substitute of scrap.

Reduction of energy consumption in iron ore sintering by modified coke breeze distribution

In normal sintering of iron ore, there exists a wide difference in temperature between the top and bottom of the sinter bed. The temperature of sinter bed gradually increases towards the bottom. This may result in differential sinter quality arising out of insufficient fusion at the top and excessive fusion at the bottom. Thus, the coke breeze requirement becomes higher than the actual thermal requirement. Through engineered coke breeze distribution, i.e. higher amount of coke at the top and lower amount of coke at the bottom, heat could be homogeneously distributed and actual coke requirement is likely to be lower compared to the existing requirements. The present study aimed at studying the sinter characteristic by varying the coke proportion from top to bottom in sintering of iron ore, thereby explore the possibility of reduction in coke consumption without sacrificing the sinter quality. In a laboratory scale investigation, it has been observed that for a bed of 5.5% uniform coke mixture, the temperatures at the top and bottom were 1111°C and 1421°C respectively. The temperature gradient between top and bottom could be significantly reduced by adding coke in two layers, 5.5% at the top and 5% at the bottom. When it was divided into three layers, coke proportion gradually decreasing towards the bottom, the temperature difference between top and bottom was further reduced. Differential addition of coke breeze resulted in improved sinter quality (shatter, tumbler and abrasion indices) and decrease in the overall coke rate by 10-12%. This innovative methodology of coke breeze distribution thus results in homogenized sintering bed temperature, improved the sinter quality and considerably reduced energy consumption.

Production of fine iron powder from pickle liquor iron oxide using hydrogen gas

To reduce the carbon dioxide (CO_2) emission during iron making and to make the process more environment friendly, the possibility of using hydrogen as an alternate reducing agent to carbon for the production of iron powder is being actively pursued.

In the present investigation, the reduction of iron oxides fines by hydrogen has been studied in a laboratory scale high temperature tubular furnace and a fluidized bed reactor under a wide range of process parameters. The raw materials and the products were characterized through Chemical analysis, Particle Size Analysis, X-Ray Diffraction (XRD) and Scanning Electron Microscopy (SEM). Reduction studies have been carried out using two schemes, namely isothermal reduction and two stage reductions: conversion to magnetite at low temperature, followed by reduction at higher temperature. While some fused particles have been observed in the temperature between 600°C to 650°C in the isothermal reduction process, the same was absent in the two stage reduction process.

In isothermal heating scheme, as high as 90% metallization could be obtained at 700°C and 120 minutes of reduction time. Similar degree of metallization was observed in the two stage heating scheme, but at much lower times, indicating lower energy consumption. The results indicated that this process depends mainly on the heating process, heating time and temperature. The SEM micro graph and the X-Ray diffraction peaks of the product have been presented in *Fig.1*. The current investigation demonstrates the potential of using hydrogen for the treatment of iron oxide fines in an environment friendly manner.

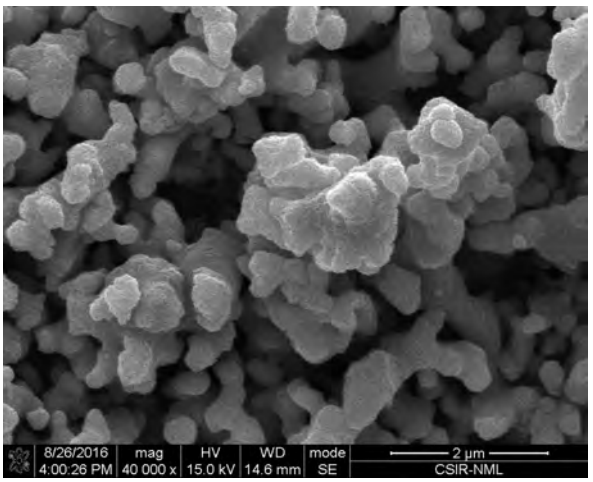


Fig. 1 : SEM of iron powder after reduction

Development of Magnesium Metal Production Technology

Magnesium is widely used in automotive sector, steel, defense, aerospace, and others. Presently, China, using the Pidgeon process supplies more than 85% of the worldwide magnesium requirement. The present study was aimed at developing a magnesium producing technology at a competitive cost by an Electrothermal Route. Electrothermal process consists of the reduction of calcined dolomite with ferro-silicon in the liquid state at temperatures of 1500-1600°C under a vacuum of around 10–20 millibar. The process has been successfully demonstrated in a state-of-the-art designed pilot plant of 300-450 kg Raw Material (R.M.)/40 kg Mg per batch scale. The process has been found to be environment friendly. Prior to the pilot scale campaigns, detailed thermodynamic modeling and fluid dynamic modeling have been conducted to correlate the slag chemistry, operation temperature, vacuum levels and for identification of an optimum temperature and pressure combination. Nineteen campaigns have been carried out towards optimization and fine tuning of all the process parameters. The pilot plant operation has been standardized to achieve an yield of up to 85% with the purity of magnesium of approximately 93%. The produced sponge magnesium has been refined by flux refining to produce the magnesium of more than 99.7% purity at a scale of 500g. The pilot plant set-up along with the sample of sponge magnesium and the refined magnesium is shown in *Fig.2*

Fig. 2 : Pilot plant set-up along with the sample of sponge magnesium and the refined magnesium.

Technology Development for Commercial Production of Sodium Metal

Sodium is an alkali metal which never occurs in free state in nature due to its high reactivity. It has low melting point (98°C) and low density (0.97g.cm^{-3}) and has extensive applications in drugs and pharmaceuticals, petroleum and atomic reactors. Sodium is not produced commercially in India and the total demand of the country is met by importing from other countries like China, France, Japan, etc.

CSIR-NML, Jamshedpur has already developed a technology for production of sodium metal at a bench scale (500A capacity) by molten salt electrolysis of commercial sodium chloride *(Fig.3)*. This technology is being scaled up for large scale production of sodium for strategic applications. In order to meet increasing demand of the metal in pharmaceutical applications, M/s Shree Rayalseema, Hi-Strength Hypo Ltd., Kurnool, Andhra Pradesh has sought technical assistance from CSIR – NML in setting up a commercial sodium production plant near Kurnool, Andhra Pradesh. In the first phase of the activity, CSIR- NML has undertaken the responsibility

Fig.3 : **a.** *CSIR-NML 500A Sodium Closed Cell* **b.** *Sodium Metal Collection* **c.** *Sodium Metal*

of providing know-how for design of a 3000A cell and setting up a plant for pilot scale operation. The test cell is in advanced stage of fabrication and would be commissioned soon. CSIR-NML will participate during the operation of the cell and will provide necessary technical feedback for improvement of the cell efficiency and provide help in optimizing the parameters for further scale up. After successful commissioning of the 3000A cell, the commercial scale activity will be initiated. CSIR-NML will provide technical assistance and consultancy during construction of commercial scale sodium cell.

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

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 without affecting output, or any increase in output at the same energy rate has important commercial implication. It has been estimated that 3% increase in production rate could mean a reduction of specific energy consumption of around 1.2kWh/t and thus good saving in energy costs. The two major issues related to the grinding and fineness of cement are (a) Grinding of clinker into fine cement often results in agglomeration, coating on the ball and inner surface, which results in more energy consumption and loss of productivity, and (b) Cements, both OPC and PPC, shows high water demand for consistent mixture, which during hydration results in porous structure causing difficulty in desired strength attainment. The current investigation aims at developing a customized grinding aid towards increasing productivity of cement grinding mill and to develop a customized performance enhancer suitable for the cement clinker of SCL by which the water demand (w/c ratio) of cement is reduced and consequently, the compressive strength of cement is increased.

Various grinding aids have been tested on the cement clinker. The rationale for selecting grinding aids are as follows: (a) cheap and easy availability (b) should have different functional group, so as to understand which group gives better compatibility with cement, and (c) performance reported in literatures. In all the grinding studies, the clinker without aid has first been milled for a specific duration of time and used as reference material. Then the effect of various grinding aid on the particle size distribution for the same milling time has been studied. An improvement in grinding efficiency was observed for the synthetic high molecular weight polymers. Further studies are in progress.

Valorisation of Wastes

Valorisation of wastes includes the process of reusing, recycling or converting wastes into value added products. Brief descriptions of a few of the industrially important activities being pursued are presented below.

Briquetting of bottom ash and pond ash for easy & environmental friendly transportation

In India, the major part of electricity is generated through thermal power route. Coal used in thermal power station is generally high in ash content (35–40 %). Approximately 80% of the incombustible component of the coal transforms to fine fly ash under high temperature and reducing atmosphere prevailing in the boilers and the remaining (~20%) is collected at the water impounded hopper below the boilers, as the bottom ash. Typical generation of fly ash from 1000 MW plant is about 250 tph. Significant portion of the fly ash which does not find utility is dumped into ponds in the form of slurry to avoid air pollution during its transport. Usage of such large amount of water, together with associated cost implications, is a non-sustainable option. The current activity aims at developing suitable process for agglomeration of fly ash so as to avoid environmental pollution during transport with minimal water requirement.

The techniques adopted for agglomeration of fly ash, and fly ash-bottom ash mix included pelletization, roller press briquetting and extrusion. Feasibility study on extrusion of fly ash/ fly ash-bottom ash mix (1:1) had been done on a fabricated batch facility *(Fig. 4)*. It was found that a minimum 15% clay addition was essential to have the extrusion of fly ash/ fly ash-bottom ash mix and water requirement for this mix was around 36%. Use of large

amount of clay and water did not comply with the purpose of the project in terms of cost and resource conservation.

Briquetting of fly ash or fly ash + bottom ash was done in continuous roller press, available at CSIR-NML, with different binders at different dosages. Binders used

Fig. 4 : **a.** *Extruding of fly ash-bottom ash mix in the ratio 1:1, with clay*

b. *Extrusion*

included natural organic and inorganic materials used in mineral agglomeration. Each batch consisted of 15 kg charge material. The process involves feeding of the powder soaked with water and binder to the feeder of the briquette press. The feeder then supply the material to the pockets of the two wheels in opposite directions and the material gets pressed into pillow shape *(Fig. 5)*. In general, the yield has been found to be in the range of 30-40% only. Compacting pressure attainable in the press was not sufficient to produce strong enough briquettes to withstand the impact of fall from the roller pocket.

Pelletization of fly ash (1-2 kg batch) had been carried out in a continuous disc pelletizer (Fig. 6). Various inorganic (natural and synthetic) and organic binders, alone and in

Fig. 5 : Green briquette from roller press

combination, were used for pelletization. Depending upon the type and amount of binders, cold compressive strength of pellet was found to vary between 2 to 10 kgf per pellets and the pellets would withstand up to 3 drops after a few days of curing. Presence of fly ash particles, larger than those generally used in pelletization, resulted in relative unsmooth surface of the spherical pellets. However, this was of little consequence as the purpose of the investigation was to reduce the usage of scarce water and avoid air pollution during dumping. Among all the three agglomeration techniques tried, pelletization was found to be most suitable in terms of strength, yield and ease of operation.

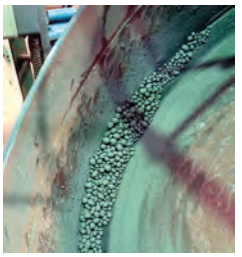


Fig. 6 : **a.** *Pellet Preparation*

b. *Prepared pellet*

Development of alternative products from various derivatives of LD slag

The slag generated in the LD vessel during primary steel making process contains high amount of phosphorous and lime. Presence of high phosphorous makes it unsuitable for recycling in sinter making where lime and iron value of the slag could have been recovered. As a result, most of the LD slag is dumped, causing substantial loss of natural resources and serious environmental problem. An effort has been initiated in collaboration with Tata Steel to pre-process LD slag and subsequently engineer it for developing products for a series of alternate applications including (a) porous material for heat and sound insulation panels, (b) fiber reinforced composite material (c) white cement component.

As received LD slag derivative, called HPPI slag, was characterized by chemical analysis as well as using X-ray for phase identification. HPPI slag contains CaO, SiO_2, Al_2O_3 as major and MgO and Fe_2O_3 as minor phases. HPPI slag could be easily ground to less than 20 µm particle size by 1 h ball milling. This slag contains mostly glassy phases.

The following products have been developed with HPPI slag :

Light weight porous material

HPPI slag has been used as main raw material for the development of porous structure using geopolymerization route at ambient conditions. The porous block produced using HPPI slag is shown in *Fig. 7*. Properties of the porous samples can be tailor made by control of synthesis parameters.

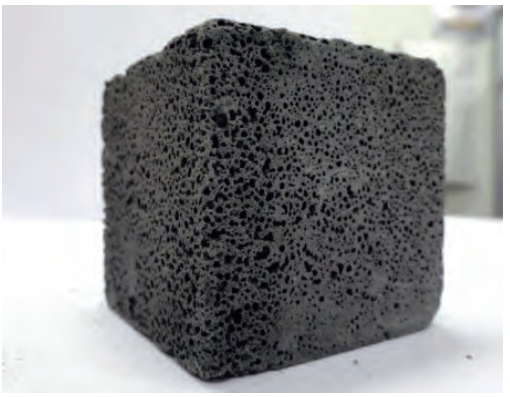


Fig. 7 : Developed porous sample using HPPI slag through geopolymerization

Development of tiles

Tiles were prepared through geopolymer route using HPPI slag and 8M NaOH and sodium silicate solution (1:1 volume ratio). Very high strength was developed. Around 30 MPa and 70 MPa compressive strength was achieved after 7 and 28 days of curing, respectively.

Development of grout

Grout material was developed through geopolymerization of HPPI slag. Very high compressive strength [1 day- 32.5 MPa and 3 days-50.6 MPa] was achieved. Strength matched with or was better than the required ASTM standard (1 day -31.0 MPa; 3 days -41.0 MPa).

Development of paint

Milled HPPI slag has been used as filler/extender to develop paint. The developed paint, after application is shown in Fig. 8. Good adhesiveness of the paint, no change in color, no change in gloss and no cracking were observed.

Fig. 8 : Developed paint using HPPI slag

Technology Demonstration for Geopolymer Cement

Use of fly ash as geopolymer cement has shown potential for its value addition. Recently, Tata Power has sought technical assistance from CSIR-NML to prepare a detailed project report (DPR) for 50 tons/day capacity pilot plant for making geopolymer cement from fly ash. Prior to embarking upon large scale production, it was desired by the sponsor to demonstrate the suitability of fly ash based geopolymer cement for civil construction. In the first stage of the project, CSIR – NML was entrusted with the responsibility of producing 20 tons geopolymer cement and participate in making of a concrete road using this cement, at a site designated by the sponsor. Required quantity of geopolymer cement was prepared as follows:

Production of dry powder : The dry cement powder has been produced by milling suitable proportion of the fly ash, OPC and metakaolin together in a continuous type ball mill of 1 ton capacity. The material to ball ratio was kept at 1:10. Around 30 min ball milling produced uniformly mixed homogeneous powder of dry geopolymer cement. 20 tons of dry powder has been produced and kept in packed condition avoiding direct contact with atmosphere.

Production of alkali activator : The alkali activator solution was prepared by mixing NaOH solution of suitable strength with commercial grade alkali silicate solution prior to use. 4000 litres of sodium hydroxide solution has been prepared and 40000 litres of alkali silicate solution has been procured for use in the cement.

The road was prepared as follows:

1. Preparation of sodium hydroxide solution 24 hours before mixing with fly ash
2. Preparation of alkaline activator by mixing sodium hydroxide solution with alkali silicate
3. Use of cement: sand: aggregate in the ratio of 2:2:4 as suggested by Tata Power
4. Casting of road and curing under covered condition for a minimum of 7 days

The prepared road developed a strength of 30 MPa in 7 days time and showed a compact structure. The progress of casting of the road has been presented in *Fig.9*. The road is now operational.

Fig. 9 : Casting of road

Mission on Coal

In spite of rapid growth in the areas of renewable energy, use of coal for power generation will continue to rise in India. With a growing fleet of coal power plants running at less than 60% of their capacity and robust power demand growth, thermal power route is forecast to increase at nearly 4% per year through 2022. With respect to coking coal, the consumption of coal is rising in steel industries. The Coal Laboratory at CSIR-NML has been developed with the goal of providing state-of the-art facilities and utilities that are flexible and reliable. The laboratory provides detailed coal characterization and assists in sustainable growth of Indian coal sector.

Advance coal characterization

The quality of coke production largely depends on coal type, coal rank, maceral composition, blending of the coals and to a lesser extent on operational parameters and coal preparation. The situation is more compelling in the Indian context because Indian coals show far greater variability in maceral composition than coals from Western countries. The organic and inorganic materials are mainly composed of macerals and minerals which can be broadly considered as reactive (binders) and inerts (fillers) depending on their behaviour during carbonisation. The ash content and its composition in coke affect productivity of blast furnace. Detailed study on inorganic components in coal is of prime importance to enhance the performance of coke in blast furnace operation. EPMA back-scattered photomicrograph reveals three compositional siderites in coal (Fig. 10). Carbonate minerals are known to be important in relation to their influence during coal conversions and are transformed into a number of phases during coking process. Depending on reaction environment, sulphides

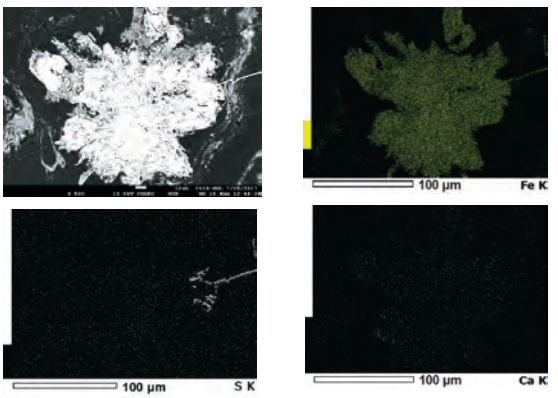


Fig. 10 : Back-scattered photomicrograph showing dendritic calcium siderite within the coal. Photographs represent the X-ray elemental mapping/distribution for Fe, S and Ca respectively

and carbonates of iron and calcium will form a wide range of phases such as hematite, magnetite, wustite, anorthite etc. Coke minerals can be classified on the basis of the potential resistance to thermal and reacting environments as refractory, semi-refractory, and reactive while their distribution pattern can be described as

discrete, disseminated and pore inclusion. Part of the minerals, (like quartz, meta-kaolinite and periclase), appear to be very large in size and can be attributed as excluded minerals of the parent coal. XRD diffractogram of coke ash shows the presence of lime, wustite, aluminosilicate, quartz, pericles, rutile, anorthite, leucite, hematite, magnetite and iron-sulphide.

Elucidation of Chemical Structure of Coal

The chemical structure of coal can be critically analyzed by advanced techniques like solid state NMR, TEM, XRD, Raman spectroscopy and FT-IR. Though, consensually, coal structure consists of fused aromatic systems linked with aliphatic components, a detailed structural elucidation of the coking coal and the coking component in particular, is not yet known. The series of physical changes which occurs in caking coals during the heating process are softening, melting, fusing and re-solidifying. The chemical structure of the specific component in coking coals which is responsible for such caking behaviour is not known yet. Importantly, this component is absent in non-coking coal.

Research initiatives have been undertaken at CSIR-NML to isolate and characterize the coking component from a high-coking coal of Indian origin. Instead of using whole coal, density gradient separation of raw coal into various fractions has been carried out to isolate the organic part from the inorganic impurities present in coal. The isolation of coking component has been optimized using organic extraction solvents like dimethyl sulfoxide (DMSO), N-methyl-2-pyrrolidone (NMP), methanol, dimethyl formamide (DMF) or solvent mixture (CS_2/NMP). Upon isolation of the coking component, a detailed chemical structural analysis has been carried out using analytical tools like solid state NMR, XRD, HRMS, Raman spectroscopy and FT-IR. Effort has been made to synthesize the isolated component in-house, so as to incorporate the same in non-coking coal in order to improve on their coking property.

Production of coke using non coking coal and semi coking coal

India has the fifth largest coal reserves in the world. Of the total reserves, nearly 88% are non-coking coal reserves, while tertiary coal reserves account for a meagre 0.5 % and the balance is coking coal. The Indian coal is characterised by its high ash content (approx. 45%) and low sulphur content.

- In order to utilize the non-coking coals for metallurgical purposes, a thorough understanding of coal constituents is of prime importance. The coking process and the physical and chemical properties of coke are largely influenced by the petrographic properties of coal: their maceral composition and rank.
- High non-coking coal deposits in India demands thorough insight into the key chemical, structural and physical properties of low rank coals. Three different coals- high coking, semi coking and non-coking were chosen for a proposed comparative study to develop possible relation between the structural parameters of coal of different ranks with those of physical properties so as to identify underlying reasons leading to differences in coking potentials of coal.

In the current research initiative, a process for preparation of coke using non-coking and semi-coking coals is being attempted. The first stage of the process is about isolating the active coking components present in semi-coking and coking coals, using density gradient separation technique or using organic solvent like dimethyl sulfoxide (DMSO), N-methyl pyrrolidone (NMP), and N,N-Dimethyl formamide (DMF). These active coking components, responsible for the swelling property, should be present above a threshold level to make the coal suitable for coke making. In the current process, isolated active coking components from coking or semi-coking coal were blended with washed non-coking (thermal) coal having ash content below 20% in ratios varying from 10:90 to 99:01 and the stamped sample was carbonized in a laboratory scale coke oven to prepare coke. Free Swelling Indices (FSI) of a few of the blends investigated have been presented below :

Blend	Blend 11 (90:10)	Blend 12 (80:20)	Blend 13 (70:30)	Blend 14 (60:40)	Blend 15 (50:50)
FSI	6.0	5.5	4.5	4.0	3.5

A patent has been filed on the above findings.

Influence of Micronization on Mineral Content and Chemical Structure of Indian Coal

Micronization of coal is a process for reduction of particle size to approximately 20 microns which greatly assists in producing clean coal with ash <3%, sulfur <0.5%. The small particle size of micronized coal allows more effective

separation of mineral inclusions from the coal matrix, resulting in greater demineralization efficiency. Further,

- Any chemical process dependent on the diffusion of small molecules through coal will be enhanced by micronization since diffusional barriers will be reduced to a few microns. Thus micronization greatly enhances combustion characteristics of coal.
- Micronized coal burning is one of the most effective de-NO_x /SO_x technologies for its high NO_x /SO_x reduction efficiency and low operating cost.

Development of Certified Reference Materials (CRMs)

Analytical Chemistry (ANC) Group of CSIR-NML is engaged in preparing Metallurgical Certified Reference Materials (CRMs) for the last three decades and presently markets 29 CRMs and has a client base of more than 300 organizations. CSIR-NML is also associated with CSIR-NPL, New Delhi for about two decades in the matters of Bharatiya Nirdeshak Drabya (BND) and has participated in the round robin testing and proficiency testing programmes. Presently, out of 29 metallurgical CRMs, 16 are Metals & Alloys, 7 are Raw Materials, 1 is Allied material and 5 are Spectrographic Standards. 3 new CRMs, namely, CRM No.: 220 Stainless Steel (Turning form), CRM No.: 166.3 Manganese Ore (low Grade) (powder Form) and CRM No.: 166.4 Manganese Ore (High Grade) (Powder form) have been developed. *Fig. 11* presents a few of the metallurgical CRMs developed at NML for ores, Ferro-alloys and spectro standards.

Fig.11: CRMs developed at NML

Analytical activities of ANC group

ANC has established a state of the art wet chemical as well as instrumental analysis laboratory. The Laboratory is fully equipped to handle analysis of trace and ultra-trace elements in various kinds of metallurgical samples. The main thrust of this group is to develop analytical methods for different processed samples used in or emanating from metallurgical applications. Additionally, the group provides analytical supports for various on-going in house R&D projects as well as for external clients. The chemical analysis support service is NABL accredited under ISO/IEC 17025-2005 from 2011 and has successfully maintained the accreditation status till date. The group frequently conducts training programmes for internal as well as external participants as well as various skill development programmes on chemical analysis, for students.

Harnessing of Secondary Sources

Production of Ferric Sulphate and Silica Powder from Copper Slag

Slags produced during pyrometallurgical processing have been traditionally considered as a waste. In the case of copper extraction processes, it has been estimated that 2.2 ton of slag is generated for every tonne of copper produced. Currently, this has been considered as material for road construction or abrasive material for cleaning metallic surfaces. Copper slag is an impure iron silicate glass (fayalite) with very little inclusion of copper/copper matte and other minor impurities. Therefore iron oxide and silica constitute >95% of the slag. However, most of the investigations reported in literature, targeted minor metal recovery, and very few attempted to recover iron. None of the researchers had reported complete value realization by targeting both iron and silica in usable form.

The recycling processes reported so far, leave behind substantial amount of residues to be disposed of or otherwise used. Therefore, most of the slag is usually land filled after processing. CSIR-National Metallurgical Laboratory developed a very unique process 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 has a 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 effluents/wastes. The process is useful for partly solving the ecological and environmental issues with an added economic advantage of utilizing the dump slag generated in the copper plants.

Processing conditions for each unit operations were optimized for Sterlite copper slag containing 51.1% Fe and 27.4% SiO_2. Under optimized conditions, more than 35% ferric sulphate solution and very fine white silica powder containing more than 95% SiO_2 were produced. One metric ton of copper slag generate about 5 kL of ferric sulphate solution containing more than 100 g/L ferric iron and about 300 kg of silica powder. The process was demonstrated and transferred to M/s Sterlite Copper, Tuticorin.

Sterlite copper is planning for a 1000 kg copper slag processing pilot plant at their site to fine tune the process for setting-up of a commercial ferric sulphate production plant. Silica produced from the process will be useful for phosphoric acid production. Implementation of the process will not only take care of environmental norms but will also make them independent on the matters of availability of chemicals for critical operation of treating effluents.The technology has been demonstrated Fig.12.

Copper Slag from Sterlite Copper

Produced Ferric Sulphate and Silica Powder

Fig.12 : Demonstration of process to M/s Sterlite Copper, Tuticorin

Production of Pigment Grade Iron Oxide from Waste Chloride Pickle Liquor

Red iron oxide pigment dominate the global pigment industries. Its application and production become increasingly important due to their pure hue, consistent properties, and tinting strength. At CSIR-National Metallurgical Laboratory, a simple process was developed for production of highly dispersed iron oxide of uniform size and shape from variety of waste resources including chloride pickle liquor. The major processing steps consist of oxidation of ferrous iron followed by conversion to desired grade iron oxide. The process is so tuned that a particular size and shape could be engineered with required magnetic properties. The developed process takes care of the impurity present in the starting material and can produce high purity iron oxide suitable for other high end application in making soft ferrites, catalysts, sensors etc.

The process produces very uniform size iron oxide in the range 100-2000 nm of different shapes and color. Due to the highly dispersed and very uniform nature of the particles, the produced oxide gives very high color purity and matches the color of different standard grade high end iron oxide available in the market.

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 at a temperature around 100-160°C from its hydroxide precursor. M/s Rang Sarjan Chemicals, who are an established pigment manufacturer, had shown interest to commercialise the NML's process for production of high end iron oxide from ferrous chloride solution generated from the pickling process of steel. They have signed an MoU with CSIR-NML for transfer of the technology for production of iron oxide from pickle liquor.

The process was tested for the waste chloride pickle liquor available to M/s Rang Sarjan Chemicals and was successfully demonstrated to them before transfer. Highly monodispersed iron oxide particles of different sizes ranging from 100 nm to 600 nm were produced under different condition of precipitation. Both reduced tone and mass tone of the produced oxides were tested and found to be much superior in quality with respect to pigmenting properties.

The process can also convert various high iron containing effluent generated from galvanising and ilmenite processing units into different high value products. High concentration of iron chloride solution, which is generated in pure form during direct dissolution of laterite, can also be converted to produce such high value products. Thus an integrated treatment plant to produce high grade iron oxide / iron powder will not only generate revenue but also avoid the problem of disposal.

The technology has been demonstrated (*Fig.13*) and transferred to M/s Rang Sarjan Chemicals.

Fig. 13: : Iron oxide produced during demonstration of the process for production of red oxide pigment from chloride pickle liquor

Recovery of Vanadium from Spent Catalyst and Bayer's Sludge

In India, there are no primary resources of vanadium and there is no indigenous commercial production. However, the country is abundantly rich in secondary resources like Bayer's sludge, red mud, and others, which are presently being explored to develop techno-economically viable routes for the extraction of vanadium. These processes can eliminate the accumulation of this hazardous waste.

CSIR-NML, in a sponsored project from Hindustan Zinc Limited, is attempting extraction of vanadium from spent catalysts (4-6% V_2O_5) of sulfuric acid plant. At present, HZL generates spent catalysts to the tune of approx. 30 MT/year, which is disposed in secured land-fill area. Spent catalysts are classified as hazardous waste in Category 4.2 of schedule-I of HWM Rules, 2016 (CPCB). Apart from vanadium, the spent catalyst is rich in silica with alumina, iron and nickel. The project is aimed to produce ammonium metavanadate and vanadium pentaoxide hydrometallurgically. Vanadium has been extracted from spent catalysts *(Fig.14)* and the process is currently being optimised for devising an economic flowsheet to extract and separate vanadium as vanadium pentaoxide (>99% V_2O_5) from sized raw material by acid leaching and sequential precipitation.

The vanadium value present in the Bayer's liquor does not precipitate initially along with $Al(OH)_3$, however its concentration gradually builds up due to recycling of the caustic liquor that hinders growth of the hydrated alumina seeds and affects the process efficiency. Thus, the liquor

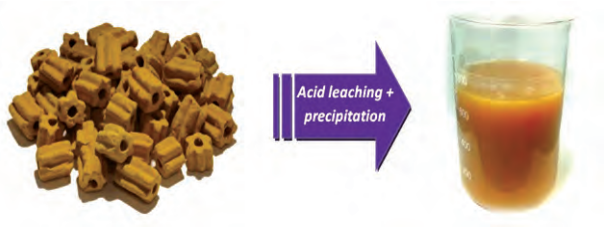


Fig.14 : Process En-route for vanadium extraction from spent catalysts

is cooled to precipitate sodium salt of vanadium. Bayer's sludge is a complex salt with 10-20 % V_2O_5 besides free alkali, phosphate, silica, alumina and fluoride and it is generally produced at a rate of 1000-2000 tpy. Vanadium sludge is classified as hazardous waste in Category 11.7 of schedule-I of HWM Rules, 2016 (CPCB). Conventionally, the vanadium values can be recovered from the sludge by water washing; however it leads to a vanadium-bearing alkaline solution that carries sodium phosphate as an undesirable impurity. It is thus desirous to develop a low acid, zero-waste process with production of high pure vanadium products and maximum reagent regeneration.

Processing of Electronic Wastes

Close loop process for the recycling of Li-ion batteries (LIBs)

A close loop process for the recycling of LIB's to recover Co, Cu, Mn, Fe and Li as value- added products fulfilling zero waste concepts has been developed. LIB's are crushed and subjected to beneficiation to separate cathodic material, plastic and metallic fractions. Li, Co. Mn and Fe are recovered from the cathodic material. Leaching followed by solvent extraction, electro-winning and precipitation are employed for separation of high purity metals. Co, Cu, Mn, Fe and Li could be recovered more than 98% *(Fig. 15)*.

Fig. 15: Marketable Products

Recovery of valuables from the scrap Nd-Fe-B magnets of computer hard disk

Neodymium-iron-boron (Nd-Fe-B) permanent magnets containing ~31-32 wt% REEs are widely used in wind turbines, household appliances, computer hard disk drives, etc. A hydrometallurgical process was developed to recover Rare Earth elements from the scrap magnets. The magnets are initially demagnetized, crushed and leached in acid at ambient temperature. The leach liquor obtained is further processed using solvent extraction to recover the acid. This is followed by precipitation to separate rare earths from iron. Pigments are prepared from the complex of iron so obtained. Thus, salts of rare earths, iron pigments and acids were the valuable products obtained from these magnet scraps *(Fig. 16)*

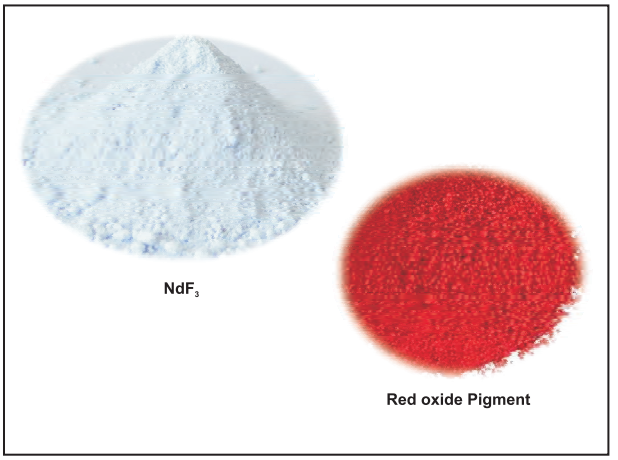


Fig. 16: Rare Earth Salt and Pigment

Extraction of Tellurium from copper refinery anode slime

A process has been developed for the recovery of tellurium from copper telluride sludge and deselenized slime produced during processing of copper refinery anode slime. The process flow involves leaching followed by electrowinning. More than 90% of the tellurium present in copper telluride sludge and deselenized anode slime could be recovered. The leach liquor generated by leaching was then subjected to electrowinning for producing >99% pure tellurium as metal powder. The process has been patented and is scheduled to be commercialized by the sponsoring industry.

Production of electrolytic zinc metal from zinc dross

This process produces electrolytic grade zinc powder from zinc dross generated in galvanizing plant, which is suitable for paint/pigment, chemical and non-ferrous industries. The process can treat dross of different grades (80-95% Zn). The present process overcomes the limitations of distillation and condensation process for production of Zn powder which usually contains impurities. A purity level of 99.5% in the zinc powder has been achieved. This makes the powder suitable for several high end applications.

Materials Engineering

The Materials Engineering division functions through four groups, namely, **a.** Corrosion Engineering, **b.** Materials Mechanics, **c.** Materials Processing, and **d.** Microstructural Engineering. The important research activities, group-wise, are presented below :

a. Corrosion Engineering

Corrosion audit

CSIR-NML carried out corrosion auditing of Tata Steel, Kalinganagar (TSK) plant using atmospheric corrosion exposure tests. This required assessment of the performance of mild steel through accelerated laboratory tests (exposure to CO_2 & SO_2) and actual exposure at 21 different locations with varying environmental conditions of TSK Plant. Every 3-month period, marked samples were removed for observations. The corrosion rates over time and for different locations are indicated in *Fig.1*. Rust formed on the specimens was carefully collected for further characterization and corrosion rate determination using standard procedure (ASTM G1). The constituent phases of the oxide scale were identified using X-ray

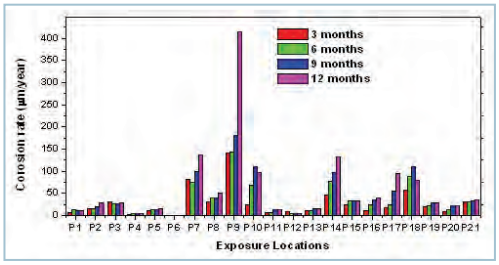


Fig.1: Corrosion rate plots of mild steel exposed for 3, 6, 9 &12 months at 21 locations of Tata Steel, Kalinganagar Plant

diffraction and Raman spectroscopy. Specimens after collection of the rust were de-scaled with suitable solution made as per the ASTM standard G1. The morphology of the oxide scales was examined using scanning electron microscope. The chemical compositions of the different phases in oxide scales were also determined using Wavelength Dispersive Spectroscopy (WDS). The corrosion categorization/ auditing of steel plant for developing corrosion protection strategy was probably tried out for the first time in an Indian Plant. Existence of lepidocrocite phase (α-FeOOH), an unstable and non-protective oxide of iron and Fe_3O_4 were associated with locations which revealed large corrosion rates. Increased corrosion rate corresponded to an oxide containing higher surface roughness and deep rooted or wide longitudinal cracks. This investigation guided the client to strategize remedial actions to prevent the infrastructure of different sites of the plant from corrosion /damage.

Performance Evaluation of Coated steel

In a project sponsored by Tata Bluescope, 24 different protective coatings, which included metallic, polymeric and combination coatings on steel substrates, were assessed for a period of 5 years. Samples were exposed at three different locations of the country: Jamshedpur, New Delhi and Ratnagiri which were representative of industrial, urban and marine atmosphere *(Fig.2)*. The exposed specimens were retrieved every year for comparing the corrosion performance. The specimens were evaluated for corrosion rate, fading, blistering, rusting and creepage. Location specific comparison of these parameters were carried out. These findings will be used by the client, for selecting the appropriate corrosion protection scheme for their structural sheets and other components

Fig.2 : Photographs of the top surface of samples exposed for three years at (a) Jamshedpur, (b) New Delhi and (c) Ratnagiri

Corrosion failure Investigation

The premature failure of Agitated Nutsche Filter Drier (ANFD) filter mesh (*Fig.3*) used for manufacturing of Active Pharma Ingredient (API) by M/s Hospira (Pfizer India), which is a multi-layered filter mesh made of SS316L, was investigated. The microscopic failures *(Fig.4)* in the filter mesh caused significant losses in yield & product quality. The multi layered filter mesh samples were observed under stereo microscope followed by,

Fig.3: View of filter mesh installed on ANFD drier (coutrtsey M/s Hospira Pvt. Ltd. Chennai)

Scanning Electron Microscope (SEM). Compositional analysis of corrosion products /entrapped particles, was performed by Energy Dispersive Spectroscopy (EDS). The filter samples were subjected to corrosion tests: (i) weight loss during short and long time immersion in standard & Pfizer solutions and (ii) electrochemical tests. Crevice corrosion was identified as the primary mode of mesh (SS 316L) failure. As the crevice corrosion is caused by entrapped liquid/wet substances between the shielded/occluded regions of the mesh layers, it is important to clean the entrapped substance and ensure filter mesh is completely dry during the rest period between the cycles of filtration. The client has implemented the recommendations and taken preventive measures to avoid such failures.

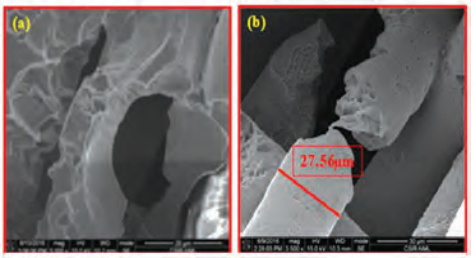


Fig.4:Localized corrosion under the joint and filler layer of stainless steel 316L of as-received failed mesh

Improved corrosion performance of aluminum alloy bracket

The IFB Ltd., Goa, is a leading manufacturer of front door household washing machines in India. The washing machines have Al-Si (*Fig.5*) brackets below the washer drum to support and rotate the drum with the help of steel axles. The Al-Si bracket often corrodes and fails before the warranty period (~4 years). A project supported by IFB, aims to analyze the failure and develop preventive

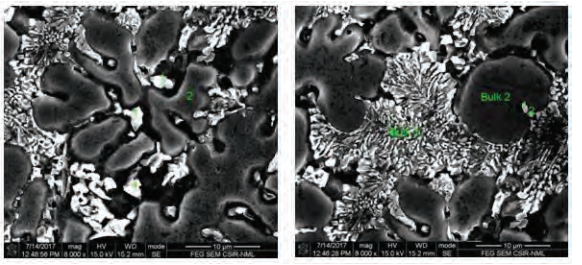


Fig.5: Microstructure of the Al-Si bracket containing eutectic Al-Si and alpha Al

solutions. It was observed that the depth of corrosion attack was as high as 87 µm/month on a ~2mm thick bracket (*Fig.6*). An Epoxy based coating was developed with two different surface pre-treatment methods, which passed 1000hours of salt spray exposure. Descalers for cleaning stainless steel washer drums were developed and are ready for plant/IFB trials.

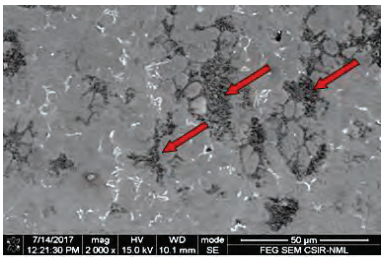


Fig.6: Corrosion attack along the interdendritic regions in as polished failed bracket

b. Materials Mechanics

High temperature deformation behaviour of nickel based superalloys used for aero engines

A bouquet of projects were carried out to study high temperature deformation behavior of nickel-based superalloys used for manufacturing blades/discs/liners of aero engines. CM 247 LC DS/EA, Nimonic 263, IN718, Udimet 720 etc. are candidate alloys for manufacturing blades/liners/discs and are critical engine materials. It is important to generate the strain range-life relationships (LCF properties) for these alloys. However, the operating load patterns on these components are best represented by hold-time fatigue testing which are known as creep-fatigue interaction tests. The ultimate failure of these discs results from creep-fatigue interaction. Therefore, it is imperative for the designers to have the creep-fatigue interaction behavior of these alloys used for gas turbine engine components thoroughly assessed.

LCF, creep-fatigue interactions, mean stress and hot corrosion effect on LCF, microstructure evolution during LCF/CF/creep exploitation were studied for nickel-based superalloys CM 247 LC DS/EA, IN 718, Udimet 720. This involved microstructural characterization of the as-received cast and forged alloys, study of tensile and cyclic deformation behavior, establishment of strain-life relationship at different temperatures, creep characterization of as-received alloys, determination of creep-fatigue damage diagrams, and, detailed microstructural studies (SEM/TEM) during LCF/CF/creep exploitations.

Mechanism of serrated plastic flow in a cast nickel-based superalloys was investigated in the temperature range of 25-850°C by conducting tensile tests employing strain rates of $1x10^{-3}$, $1x10^{-4}$ and $1x10^{-5}$ s^{-1} *(Fig.7)* and subsequent TEM studies. Shearing of γ′ precipitates by super partials {a/2[110]} bounded by anti-phase boundaries were found to be responsible for the serrated yielding as shown in *(Fig.8)*.

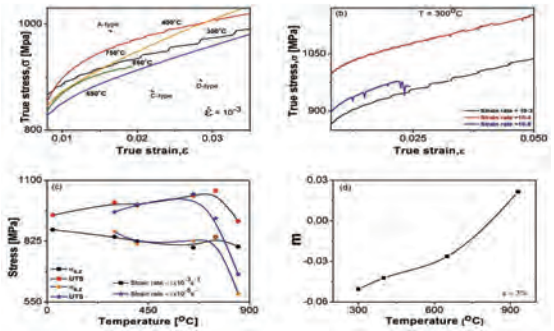


Fig.7 : (a) typical true stress-strain curves; (b) variation of $\sigma_{0.2}$ and UTS with temperatures; (c) variation of strain rate sensitivity, m, with temperature at a true plastic strain of 3%; and (d) true stress-strain curves at 300°C and at strain rates of $1x10^{-3}$, $1x10^{-4}$ and $1x10^{-5}s^{-1}$.

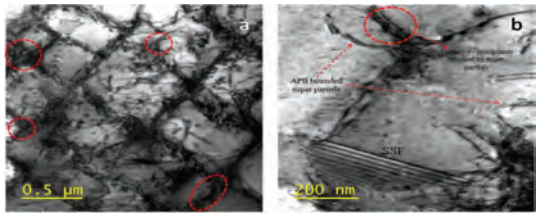


Fig.8 : (a) Low magnification TEM bight field image showing shearing of secondary and tertiary (shown in circle) γ'- precipitates by superlattice intrinsic stacking faults (SISFS) and superpartials bounded by APB in the specimen and (b) high magnification TEM bright field image showing superlattice stacking fault (SSF) and APB bounded superpartials inside secondary and tertiary γ'- precipitate in the specimen tensile tested at 300°C.

In contrast to other structural alloys, yield strength of nickel-based superalloys either remained constant or increased with temperature up to 700–800°C making them more suitable for high temperature structural applications. However, the increase in yield strength is usually accompanied by a decrease in ductility. CSIR-NML investigated the substructural evolution in a directionally solidified nickel base superalloy CM 247 DS LC during tensile deformation, where ductility is not impaired even when yield strength is at its highest (at 750°C). Extensive TEM studies offer plausible dislocation based mechanisms for retention of high ductility at 750°C *(Fig.9)*. The highest yield strength is attributed to the presence of intersecting faults along with partials bounded by anti-phase boundary. However, high ductility is due to the formation of SISF inside c0 precipitates. These mechanisms provide necessary impetus for further alloy development. The experimental data generated in these projects are being used by the aero engine designers.

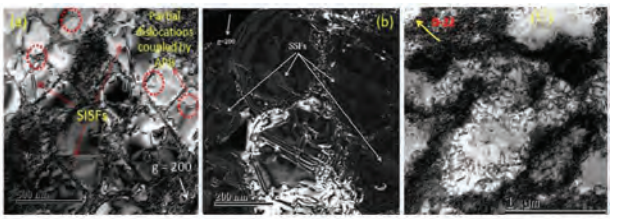


Fig.9: (a) TEM bight field image showing intense dislocation activities inside γ'-precipitates, superlattice intrinsic stacking faults (SISFS) and superpartial dislocations bounded by APB in the specimen and (b) TEM dark field image showing various superlattice stacking faults (SSFS) intersecting each other inside γ'-precipitate in the specimen tensile tested at 750°C, and (c) TEM image of the specimen tensile tested at 850°C

Indigenization of Center Buffer Coupler manufacturing

In collaboration with RDSO a standard WD-70-BD-10 was developed for (i) indigenization of Grade E castings used for manufacturing of Center Buffer Couplers (CBC); and (ii) safety in rail transport. This involved visual and microstructural inspection for casting defects, microstructural and mechanical characterization, and, health assessment. As a direct outcome of these investigations, Six manufactures in India have started manufacturing and supplying CBC to Indian Railway. No service failure were reported in the last six years. The

impact of these projects of last 8 years can be realized from the letter of appreciation received from the Ministry of Railways (*shown in "Impressions"*).

Fatigue and Fracture behavior of rail steels

Steel Authority of India, is developing rail steel of a specific grade according to the requirements of an Iranian agency. The mechanical properties of these indigenous developed steel need to be evaluated. CSIR-NML is involved in some of the evaluations. These include fatigue and fracture toughness tests at -20°C for qualification as per EN-13674-12011standard, and, assessment of fatigue crack growth rate as per EN-13674-12011.

Fatigue and Fracture characterization of modified 403 martensitic stainless steel

The deformation, fracture and fatigue behavior of modified 403 martensitic stainless steel will be evaluated from sub-zero to reactor operation temperature (-60°C to 300°C). The actual material grade data and a better understanding of the toughness, fracture and fatigue behavior of the MSS-403 will help in assessing the safety margins of coolant channel end-fitting of AHWR/PHWR under pressurized thermal shock loading during refueling operation. In addition to this, tensile, and metallurgical investigations such as micro-structural characterization and fractographic examination (of failed specimens) will also be carried out. Some initial results are shown in *Fig 10*.

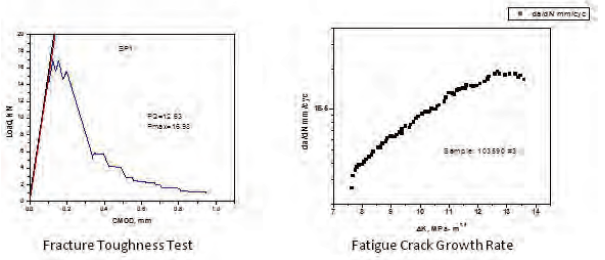


Fig.10: (a) Fatigue life determination; and, (b) Fatigue crack growth tests carried out on 403 martensitic stainless steels

Materials Processing

Identifying the Causes for Crack Development in Billets and Rounds during Hot Rolling

Evolution of surface cracks in long steel products is one of the critical problems in steel making industries. The long products (hot rolled billets, bars and rods) are made through continuous casting route, with subsequent thermo-mechanical processing. The surface cracks were mainly revealed during inspection after the final stage of hot rolling at steel producers end or before forging at customers' site. Moreover, subsurface cracks which are present in steel billets may evolve after forging at customer's site. This leads to subsequent rejection of steel billets. The surface cracks in billets mostly followed the longitudinal direction of rolling and the depth of penetration of these defects is observed to be within 2mm. However, in some cases, extensive penetrations of cracks were also observed *(Fig.11)*.

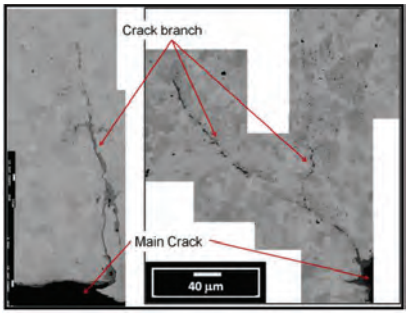


Fig.11: Cracking and crack branching in steel billets

CSIR-NML analyzed the operational data at various stages of product development. Non-destructive evaluation of the samples, structural and compositional analysis (iv) mechanical property evaluation (v) forging and rolling simulation, were carried out followed by (vi) data driven parametric analysis and thermodynamic study. Cracked billets showed the presence of Al_2O_3 and FeO inclusions indicating improper secondary steel making practices as well as inefficient removal of scales during descaling processes. The presence of clusters of alumina in bloom and alumina inclusions in billets indicates excess addition of Al in the steel bath, improper oxide flotation and improper removal of oxides from liquid steel. The excessive amount of inclusions, may also have been due to the high turbulence in the mould that may lead to mould powder entrapment as well as re-oxidation of liquid steel. The presence of Si, Ca and Na traces in most of the alumina dominating oxide inclusions can be attributed to excess addition of mould powder during casting. Ultrasonic C-scan revealed casting defects. Data analysis showed that the mould powder consumption rate was considerably higher than the stipulated literature information. Oscillation mark depth exceeds the recommended value of 0.6 mm for several heats.

Identifying the cause of deformation of high Cr grinding balls used in cement production and devising remedial measures to obtain less wear

The main objective of this investigation was to improve the wear resistance property of the high Cr (~12% Cr) Cast Iron Grinding balls. This involved finding the cause of deformation/ de-shaping/ breakage of high Cr grinding balls, and, provide remedial measure to prevent the same to ensure lesser wear per metric tonnes of cement production. Non-uniform microstructure and hardness properties were found be the main cause for low wear resistance of grinding media. Pearlite phase was identified in various grinding balls which were due to flaws in controlling heat-treatment and quenching procedures. Porosity was found to be present in various grinding media which were responsible for fragmentation of the grinding media.

Abrasion mechanisms such as micro-cutting and micro-fatigue were found to be prominent mechanisms involved in de-shaping of grinding media. A process has been developed to achieve cast iron grinding media with microstructure containing martensite, retained austenite, M_7C_3 and M_3C *(Fig.12)*, to achieve hardness of 65-67HRC. The process was developed to achieve fine martensite with lower residual stress. The developed material shows 20% improved wear resistance. Another alloy has also been developed which shows 25% improved wear resistance of virgin material. Two Joint Patents have been filed based on these developments.

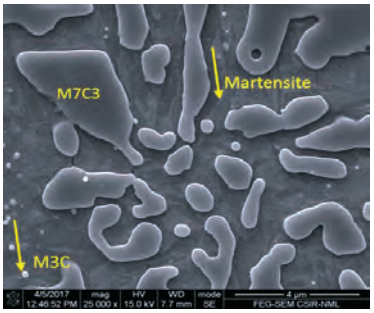


Fig.12: TEM image of cast iron having fine martensite (~3 nm), M_7C_3 and M_3C phases

Failure analysis of front axle beam

Failure investigation of a failed front axle beam was carried out through (1) visual inspection (2) residual stress analysis (3) NDT analysis to locate cracks/defects followed by sample preparation for investigation (4) reconfirmation of alloy composition (5) optical and SEM studies to reveal the microstructural features and inclusion characteristic (6) analysis of fracture surface to understand crack initiation and propagation phenomena and (7) hardness and tensile testing for comparison of the mechanical properties with the required specifications for this grade of steel.

Based on the experiments and the results obtained thereof, it was concluded that the front axle beam was broken due of fatigue failure. It seems that the segregated sulphide/oxide inclusion, both at the surface and subsurface regions, detach at the inclusion/ matrix interface during grinding forming microcracks *(Fig.13)*. The failure seems to be due to hand grinding of flash and presence of inclusions at the surface and sub-surface regions, particularly the breaking of high aspect ratio MnS inclusions present in the sub-surface regions. Subsequent crack growth takes place under the cyclic loading conditions. Crack propagation in the matrix was enhanced due to the localized segregation of complex oxy-sulphide inclusions.

Based on the results and analysis, recommendations to the customer for quality improvement were provided in order to avoid the failure of the component in near future. Suggested recommendations were accepted by the customer. Further instances of failure have not been reported by the customer.

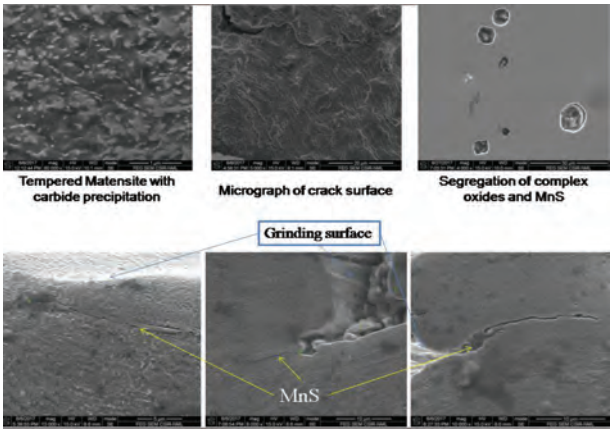


Fig.13: Micrographs revealing the summary of the failure investigation on front axle beam.

Microstructural Engineering

Effects of Inclusions on Pitting Corrosion on Line Pipe Steel

The variations in the microstructure of line pipe steel (Grade X60) lead to significant changes in its corrosion behavior. Use of any particular steel for a given environment needs a robust data bank through which life predictions of components can be made confidently to avoid catastrophic failure. In this project qualitative and quantitative estimation of various non-metallic inclusions in API 5LX52 and X60 grade line pipe steels were carried out, along with assessment of the corrosion damage with the purpose of developing a damage potential index. It was envisaged to identify the most susceptible inclusions and develop a ranking system, and thereby provide a material selection benchmark. The work involved collection of API 5L X 52-60 grade steel from different sources followed by qualitative and quantitative estimation of various non-metallic inclusions, identifying their morphology, determining their class and their distribution. Corrosion damage was indexed using pitting corrosion studies *(Fig.14)*. An adaptive neuro fuzzy based model was used to study the effect of microstructural variation on the performance of the candidate steel (*Fig. 15*).

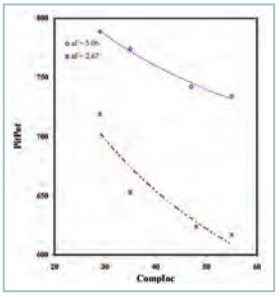


Fig.14: Variation in pitting potential with complex inclusion at various area fraction of cementite for a API grade steel

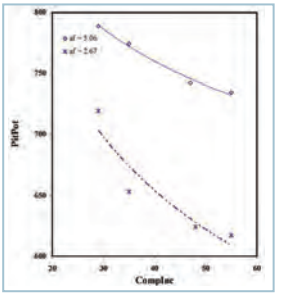


Fig.15: Prediction of Pitting Potential using Fuzzy based model with higher (HCI) and lower (LCI) 99% confidence interval for a API grade steel

Microstructure of Fusion Boundary of Ferrite-Nickel Based Alloy in Dissimilar Metal Weld (DMW)

In an effort to identify the role of heterogeneities on the mechanical behavior of DMW, a project was undertaken with the objectives of structural characterization of dissimilar materials welded joints, fabricated with different buttering materials and weld metal, and evaluation of their mechanical properties.

In this ongoing investigation nine dissimilar welded joints have been so far investigated and three more are in progress. Different microstructural features like HAZ, type-II boundary, type-I boundary and martensitic region that are developed owing to different filler alloy, electrode, and method used in welding, were identified and characterized *(Fig.16)*. A detailed study of buttering alloy - weld (fusion boundary), carbon steel-butter alloy interface is planned. Ni-based super alloys were found preferable buttering material for reducing heterogeneities across weld and improving joint efficiency. The buttering material was the weakest link within the assembly, as crack initiation and propagation was through them during uni-axial deformation tests.

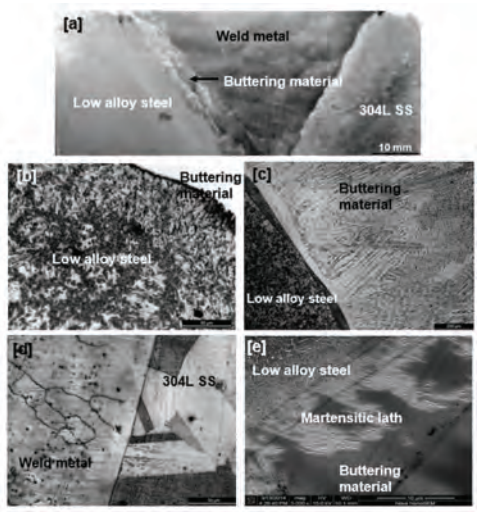


Fig.16: Dissimilar metal welded joint (a) macro image, (b) and (c) interface between LAS and buttering material, (d) interface between weld metal and 304L SS and (e) lath martensite near fusion boundary

Development of Quenched & Partitioned (Q&P) steel through Hot Strip Mill Route

A project was undertaken to develop Q&P steels through HSM route using Gleeble simulation. The targets were UTS of 1200MPa with 15% Elongation and a minimum hardness of 450 BHN. The present project envisaged retained austenite stabilization during hot rolled coil cooling (non-isothermal) after quenching to a temperature between M_s and M_f *(Fig.17)*. The carbon

partitioning from martensite to austenite will result in retained austenite between martensite laths, thus improving mechanical properties. This would eliminate the need for isothermal heat treatment facility after hot strip mill. However, this process critically requires the

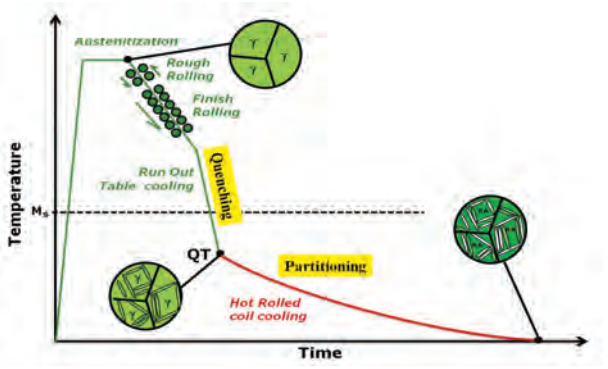


Fig.17: Schematic of quenching and non-isothermal partitioning process

design of suitable alloy composition and an optimum quenching/coiling temperature which decides the austenite phase fraction and partitioning kinetics. In view of the above, the present work focused on designing of a suitable alloy composition. A low alloy steel which can stabilize austenite during non-isothermal partitioning process *(Fig.18)* was developed and two Patents were filed jointly with Tata Steel. The developed alloys can achieve UTS in the range of 950-1550 MPa with 11-15 % elongation and 300-450 BHN hardness. Simulations were performed on developed alloys using different quench temperatures

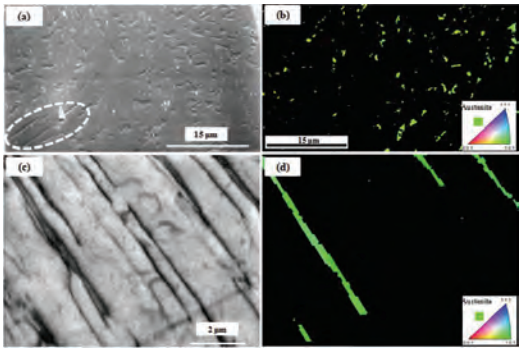


Fig.18 : EBSD analysis (a) secondary electron image; (b) corresponding inverse pole figure (IPF) of austenite phase; (c) image quality (IQ) map of high magnification scan and (d) corresponding IPF of austenite phase (green and black colors represent austenite and martensite phases, respectively)

and the resulting microstructure was then correlated with mechanical properties. The stabilization of retained austenite during hot rolled coil cooling simulation was demonstrated which negate isothermal partitioning or tempering treatment. The increased impact toughness and abrasive wear resistance of developed alloys will improve the service life of component used in locomotive and earth moving industries.

On-site residual stress distribution profiling of hot rolled sheets

A project sponsored by Tata Steel, required evaluation of residual stress pattern and distribution, in six selected grades of hot rolled steel sheets, and its correlation with sheet distortion problems which are encountered at the customer end during slitting. Distortion of the hot rolled cut to length sheets during slitting at the customer end is due to the presence of residual stresses. Residual stress pattern measurements have been carried out at the plant site on the hot rolled cut to length sheets using strain gauges *(Fig.19)*. If found applicable, this technique would be highly beneficial for the purpose of minimizing rejections at customer end owing to distortion in steel sheets.

Fig.19: Strain Gauge fixation on the HR sheets

Effect of Continuous Annealing process parameters on Ferrite+ martensite phase formation in DP steels

Dual-phase steels derive their perfect blend of properties via hard second phase, martensite or bainite, in a softer ferrite matrix. The key to refine the mechanical properties of DP steels rests on optimizing and tailoring the hard second phase distribution and size in the ferrite matrix. There could be several combinations of processing routes depending on governing mechanisms such as

recrystallisation, phase transformation and pearlite dissolution, which can affect the morphology and distribution of the martensite phase. All these mechanisms are invoked at various stages of annealing process cycle. In the present study experimental simulation of various annealing parameters were carried out on a cold rolled steel using a custom designed annealing simulator.

The evolution of microstructure was studied by field emission scanning electron microscope. The evolving microstructures were correlated with governing mechanisms of recrystallisation, pearlite dissolution and phase transformation. Through these simulations, it was possible to tailor the microstructure and consequently improve the tensile properties of dual phase steel. Heating rate and annealing below inter-critical annealing temperature (Ac_1) up to upper critical-annealing temperature (Ac_3) seems to greatly influence the final microstructure of dual phase steel. Ferrite recrystallisation before austenite nucleation promoted ferrite "in-grain" martensite formation. Further, the effect of high heating rates causing grain boundary martensite formation could be minimized by ferrite recrystallisation and pearlite dispersion. Continuous heating to peak temperature without isothermal annealing resulted in "in-grain" martensite formation with serrated interfaces. This type of martensite was observed to improve the tensile properties of dual phase microstructure. The modified annealing process resulted in predominant formation of martensite within the ferrite grains with serrated lath martensite interfaces *(Fig.20)*. This type of martensite was considered

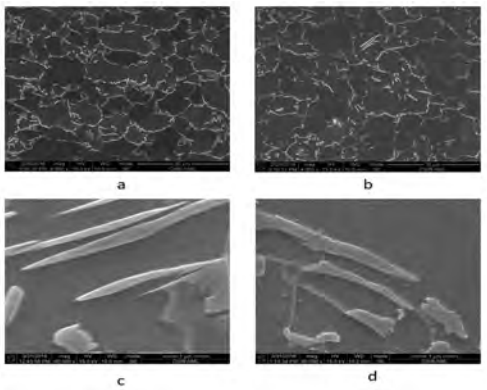


Fig.20: (a) and (b) show microstructure modification between the conventional DP590 and modified DP590 microstructure. Corresponding high magnifications images are shown in (c) and (d)

responsible for the observed improvement in the tensile properties and bake-hardening response. Furthermore, along with improved bake-hardening response, negligible loss in tensile ductility was also noted. This behaviour was correlated with delayed micro-crack initiation at martensite interface due to serrated nature *(Fig.21)*.

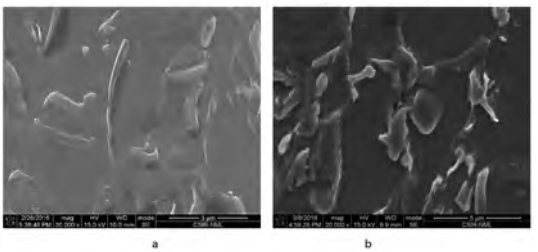


Fig.21: (a) Micro crack at the martensite-ferrite interface in conventional DP steel; (b) microvoids coalescence at the interface of modified DP steel

Study of microstructure and texture evolution in low carbon formable steels

The scope of the work was to examine and analyse developed microstructure and texture of hot and/or cold rolled annealed steel of following three grades of steels :

a) Grade A : Low Carbon (0.06 % max) Aluminium killed Steel;

b) Grade B : High Strength Low Carbon Micro-Alloyed Aluminium killed Steel;

c) Grade C : Dual Phase steel, and thereby establish correlation between texture and formability of low carbon formable steels. A concurrent objective was to develop expertise of RDCIS (SAIL) on EBSD/texture studies.

The steel samples were subjected to annealing simulation, batch annealing and continuous annealing cycles. Evaluation of microstructure and texture using Transmission Electron Microscope (TEM), X-Ray Diffraction (XRD) and Electron Back Scattered Diffraction (EBSD) of hot and cold rolled un-annealed and annealed (simulated, batch and continuous) samples of identified grades, were carried out. A correlation was established between mechanical properties, microstructure and texture of identified grades of steel under hot rolled and cold rolled batch and continuous annealed condition. Grade A steel processed through optimized Batch Annealing cycle, resulted into strong gamma fibre*(Fig. 22)* and thereby very high plastic anisotropy (r_m =2.45) by

optimization of annealing cycle; the process has been patented with SAIL. This is being reported for the first time in EDD steel and the anisotropyis comparable to that of IF/IF-HS steels. An insight and understanding on the

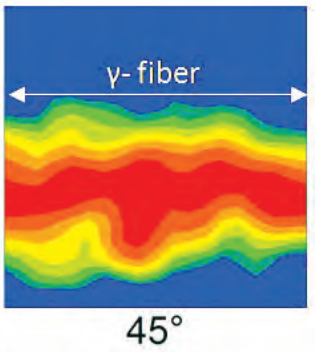


Fig.22: showing ODF section at $\varphi_2 = 45^\circ$ on the RD-TD plane, of the optimized annealed cycle sample from GRADE A (B/N=0) illustrating fully developed γ-fibre beneficial for deep drawing

synergistic effect of Nb and Si addition on microstructure texture and mechanical properties of high strength formable grade steel have been developed. A good combination of strength and ductility was achieved in Grade B steel with ((Nb+Si wt. %)=0.304) *(Fig. 23)*. A dual phase(DP) ferrite-martensite microstructure *(Fig.24)* has been obtained in Grade C steel having UTS of 864 MPa and total elongation of 11%.

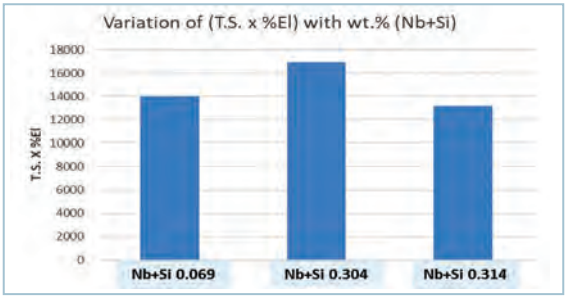


Fig.23 : Good combination of strength and ductility achieved in Grade B steel with (Nb+Si wt. %)=0.304

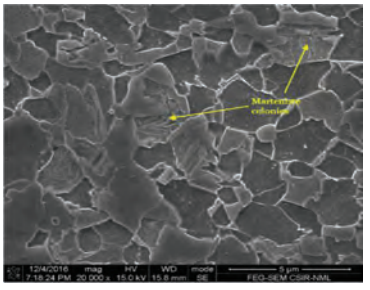


Fig.24 : Dual phase(DP) ferrite-martensite microstructure obtained in Grade C steel

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

Automobiles are the second largest source of greenhouse gas emissions in the world. This calls for weight saving in the body-in-white (BIW) and other automotive parts to maximize the fuel efficiency.

Quenched and partitioned (Q&P) advanced high strength steel will enable the end user to use thinner gauges, which would reduce the overall weight of the vehicle leading to lower fuel consumption and greenhouse gas emissions. RDCIS/SAIL and CSIR-NML has undertaken a collaborative assignment for development of the third generation of advanced high strength steel through quenching and partitioning process having high strength with enhanced ductility and good formability. The objective is to develop third generation AHSS with excellent strength-ductility combinations (T.S. X %El. ⩾ 25 GPa % with 800-1200 MPa TS). This will involve alloy designing and studies of the kinetics of Q&P process to produce AHSS sheet. In this ongoing project, Alloy design, thermodynamics studies *(Fig.25)* and kinetics studies *(Fig.26)* have been done followed by heat making and hot rolling to 4.5 mm thickness sheet.

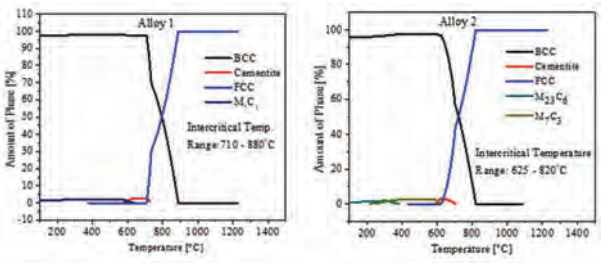


Fig.25:Thermodynamic property diagram showing the variation of phase fraction with temperature in Alloy 1 and Alloy 2

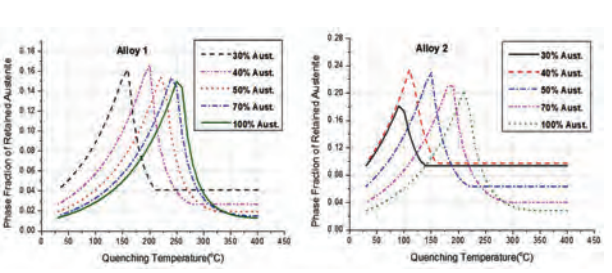


Fig.26:Kinetics study showing a variation of final retained austenite fraction with quenching temperature in quenching and partitioning process of alloy 1 and alloy 2

Optimisation of Continuous Annealing Line (CAL) parameters for achieving r-bar greater than 2

The present research aims to address the effect of chemical composition, in particular, effects of stabilizing interstitial elements, on industrial manufacturing processes of interstitial free high strength (IFHS) steel. Four different interstitial free high strength steels stabilized with elements; a) Ti, b) Ti-Nb stabilized, and c) Al addition to Ti-Nb stabilized, were used in this study. These steels were manufactured in the steel industry to a finished cold rolled thickness of 0.8mm. Cold rolled steels were subjected to annealing simulations using a custom designed annealing simulator. Annealing simulation parameters used were similar to industrial batch (BAF) and continuous annealing line (CAL) processes. Processed steels were evaluated for formation of Lüders bands, which is critical for surface finish for automobile panel manufacturing, during tensile deformation. The results of the present work show that chemical composition of stabilizing elements (Ti, Nb) imposes a restriction on selection of batch or continuous annealing line manufacturing process. This is because formation/absence of Lüders bands strongly depends on the precipitation characteristics of steel during the annealing process *(Fig.27)*. The deficiency in the concentration of stabilizing elements was considered mainly responsible for the Lüders elongation. This has been verified with the data of industrially produced IF and IFHS steel, through BAF, CAL and Continuous Galvanizing Line (CGL). This study could be a very useful guide for the selection of appropriate annealing process and chemical composition for industrial manufacturing of IF and IFHS steels.

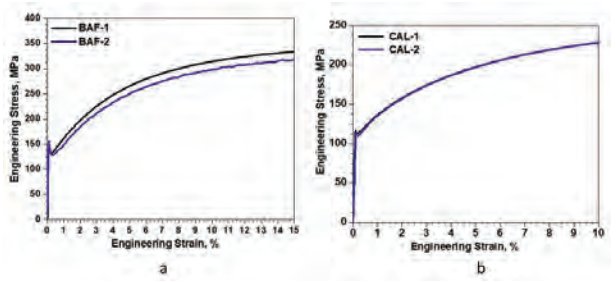


Fig.27: Stress-strain curves for Ti-Nb stabilized IFHS steel annealed after (a) batch annealing (BAF) and (b) continuous annealing (CAL) process showing the absence of Lüders elongation

Determination of stacking fault energy of cold rolled medium manganese steel by X-ray diffraction

Over the last decade, research in the field of Advanced High Strength Steel (AHSS) for automotive applications has undergone a paradigm shift from low Mn 1st-Gen AHSS grades such as TRIP steels and high Mn 2nd-Gen AHSS such as TWIP steels to medium Mn (3-10 wt.% Mn) TRIP and/or TWIP aided steels. This is primarily due to the unique combination of strength and ductility obtained in medium Mn steels. Furthermore, there are few inherent problems associated with the first and second generation AHSS like safety standards (for first generations), processing difficulties, weldability and cost (for second generations). To overcome these, medium Mn steels have evolved in which enhancement of properties is achieved through post-processing treatments to engineer the composition and volume fraction of the austenite phase. These medium Mn steels are new whose deformation behaviours are not yet fully understood. Since the deformation behaviour of austenite is highly dependent on the SFE, it requires precise measurement of SFE by some suitable technique. The objectives of the present project were to determine the stacking fault energy (SFE) of the austenite phase in cold-rolled medium Mn steel by x-ray diffraction technique, which were inter critically heat-treated for austenite stabilization *(Fig.28),* to investigate the deformation behaviour of the austenite phase and to find out the correlation between the SFE and

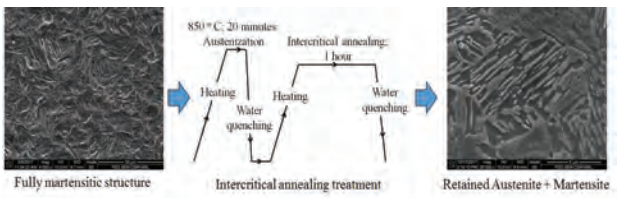


Fig.28: Schematic of heat treatment schedule showing the evolution of microstructure before and after the intercritical annealing.

deformation behaviour of austenite. Till date, the investigations have revealed information on the inter critical temperatures : 670°C is the inter critical temperature for complete dissolution of carbides in the microstructure, and, 640°C is the intercritical temperature for obtaining austenite phase with optimum stability such that it yields highest UTS*TE value (~ 26.8 Gpa%) *(Fig. 29).*

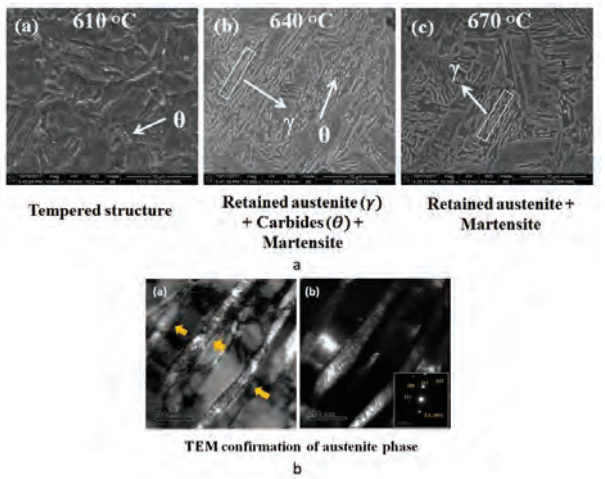


Fig.29: (a) SEM micrograph of the specimens annealed at different intercritical temperatures for 1 hour. (b) Bright field TEM micrograph showing retained austenite films (Left picture) indicated by arrows; Dark field TEM micrograph corresponding to the austenite diffraction spot (Right picture).

Maximisation of Goss Texture in Fe-3.2Si Electrical Steel

This project aimed to develop indigenous processing route for the production of CRGO, keeping in mind the crowded patent space for this genre. Trials were made upto the maximum possible limits within the laboratory scale to obtain the required microstructure of CRGO steels. Laboratory scale experiments have been done to produce hot-band for CRGO steels. Laboratory scale cold-rolling and annealing have been done to produce large Goss grains. Several compositions were cast at NML. Hot-rolling was done through novel processing routes to make 2 mm thick strips. The rolling passes and temperatures were modulated to obtain the proper final microstructure. The strips were annealed and prepared for cold rolling. After cold rolling, the thin sheets were annealed in several steps to obtain large Goss grains *(Fig. 30)*. Decarburization of the cold rolled sheets was done in a controlled atmosphere. The formation of grain size inhibitor was studied in details. An efficient method was established to produce an acquired inhibitor. By controlling the chemistry of the steel and hot-rolling at a lower temperature a new direction for hot-rolling of this steel is proposed which is generally prescribed to be rolled in austenite+ferrite region in the literature. Four patents were filed from this project.

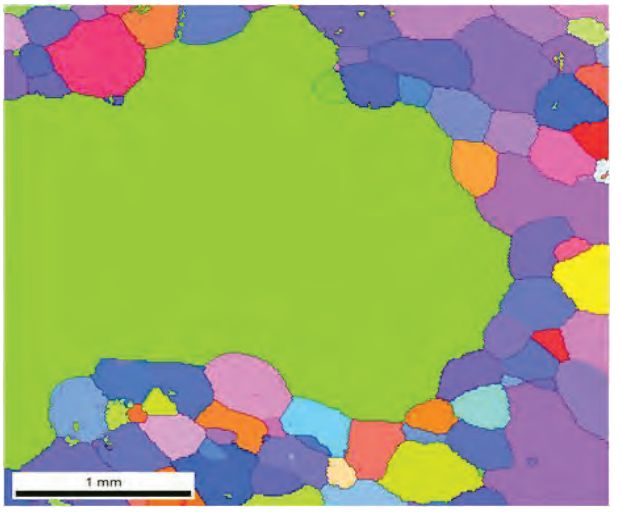


Fig.30 : Secondary recrystallized Goss grain obtained from a selection of suitable processing parameters

Mineral Processing

Mineral Processing is a core area of research in CSIR- National Metallurgical Laboratory. The division is engaged in R&D in mineral characterization, beneficiation and agglomeration. A brief description of the major R&D projects carried out in 2017-18 is given below :

De-ashing of High ash Indian Non coking coal by Dry Beneficiation

Out of the Indian coal reserves of around 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 problem, difficulty in pulverization and excessive generation of 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% for use in power plants as per the governmental regulations. 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 involves huge infrastructural and maintenance costs, requires huge amount of water & media, and there are environmental issues related to effluents discharge. Wet washing also adds moisture to clean coal which is undesirable.

Recently CSIR-NML has developed expertise and facility for dry beneficiation of non-coking coal (*Fig.1*). Process flowsheet was developed for reducing ash in non-coking coal for application in thermal power plants and in DRI making, 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. The scope of the present study includes characterization, washability study and deshaling/dry beneficiation of non-coking coal for application in thermal power plant followed by techno-economic feasibility study of the process. Basically, air fluidization techniques will be applied for dry beneficiation.

Typical result on earlier samples showing the effect of longitudinal angle of deck on ash and yield of clean coal product is depicted in (*Fig.2*) . The study is in progress.

Fig.1: Pilot scale facility for dry beneficiation of coal.

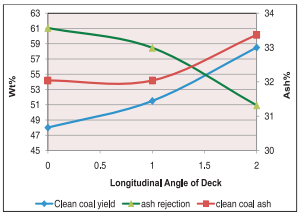


Fig.2 : Effect of longitudinal angle of deck on ash-content and yield of clean coal.

Briquetting of Chrome Concentrate Micro-fines for Ferroalloy Production

The beneficiation of chromite used for ferro-alloy production results in significant amount of fine grained concentrate. The chromite fines need to be agglomerated for charging to submerged arc furnace. The flue dust generated in metallurgical processing is recirculated through agglomeration. In an industrial scale, agglomeration of chromites ores is carried out by sintering, pelletisation or briquetting, but, the latter is preferred because the other two are high energy intensive with high infrastructural cost and addition of gangue components as binders. So an attempt was made in this project to convert the chrome micro-fines to briquette for use as raw material in ferroalloy making. The objective of the present study is to find a suitable binder to produce briquettes from chrome concentrate micro-fines. Different binders such as bentonite, lime, ladle furnace slag, molasses, cement, maize starch, etc. were tried for the briquetting of chrome concentrate. Different dosages with combination of two or more binders were studied and optimized in briquetting of chrome concentrate micro fines. Under optimised conditions, the briquettes with

126kgf CCS and 25 drop number were produced for production of ferro-alloy (*Fig.3 & 4*).

Fig.3 : Briquetting facility.

Fig. 4 : Chromite ore briquettes.

Development of Stationary Bed Pellet Induration Furnace

In a pelletisation plant, generally the induration is carried out in straight travelling grate and grate-kiln, which occupies large space. A travelling grate facilitates with both up draft and down draft facilities. To simulate the firing zone of pellet induration, CSIR-NML in collaboration with Tata Steel designed and developed a gas based stationary grate induration strand with down draft facility. The developed equipment and temperature profile inside the induration chamber is shown in *Fig.5 and Fig.6* respectively. In the latter figure R1, R2, R3 and R4 are four different regions of induration chamber, namely, the top layer, the middle layer of pellets, the grate bar and the wind box, respectively. Successful trial runs have been carried out using the new facility developed.

Fig. 5: Indigenously develope Stationary Bed Induration unit.

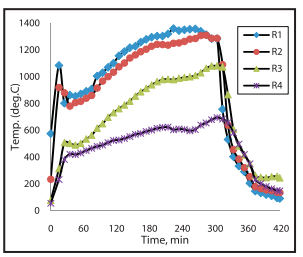


Fig. -6: Temperature profile at four regions of induration chamber.

Beneficiation Study on Recovery of Iron Values from Iron ore Slimes

The proper utilisation of wastes creates a balance between natural resource management and sustainable growth. The management of tailings from iron ore mines is an important issue not only from the point of view of pollution control but also regarding the conservation of resources. After the beneficiation of iron ore, the tailings which are disposed to tailings ponds, have iron content of 50% or more. However, as per the guidelines of the Indian Bureau of Mines (IBM) the iron content in the tailing should be below 45%. In view of this, CSIR-NML had undertaken a study on characterization and beneficiation of iron ore slime from the eastern parts of India to develop a process technology for recovering of iron values from slimes. The benchmarks of the process were concentrates with $Al_2O_3 \leqslant 3.2\%$ and Fe> 60%, with the reject containing less than 45% Fe. The beneficiation process developed based on the bench scale study involved desliming, wet high intensity magnetic separation followed by dewatering of products. The process developed through bench scale study was validated by pilot scale operation. The product generated *(Fig.7)* is acceptable with respect to grade with reasonable high yield.

Fig.7: Iron ore concentrate and reject from iron ore slime.

Deshaling and Reduction of Water Consumption in Wet Beneficiation of Coking Coal

Beneficiation of coking coal in India is carried out by gravity and flotation techniques so as to lower the ash content. In gravity separation process, coarse grained coal is beneficiated using heavy media bath and jig. The medium sized coal is beneficiated by heavy media cyclone and the fines are processed by water-only cyclone and froth flotation. Presently Indian industries are carrying out wet beneficiation process which requires large volume of water, generates slime water as effluents causing environmental problems, at the same time produces a clean coal with relatively low calorific value due to the moisture. Presently, quality of the coking coal is depleting due to deeper mining. The coal found at greater depths has high ash and has difficult washability. Beneficiation of this type of coal needs to be addressed based on their properties.

CSIR-National Metallurgical Laboratory has been involved in dry beneficiation of coal. Dry beneficiation of coking coal (-1mm) by air table had shown encouraging results. The objective of the present research is to beneficiate coking coal by twin dry and wet beneficiation thereby lowering the net water consumption. In the present project, characterisation, washability study, deshaling and beneficiation will be carried out. The combination of dry and wet methods can improve the metallurgical performance and lead to water conservation. A conceptual process flowsheet for beneficiation of coking coal with reduced water consumption, will be developed.

Studies on Recovery of Chromite Values from Tailings of Chromite ore Beneficiation Plant

With fast depletion of high grade chromite ores there is a need to exploit low and lean grade chromite ores as resources (*Fig.8*). In addition to exploiting the new resources, it is also important to maximize recovery of chromite values in the existing beneficiation plants. The process route for chromite ore beneficiation involves comminution, classification, followed by gravity separation. It produces chromite concentrate with more than 40% Cr_2O_3. The tailings from chromite beneficiation contain 18 to 20% Cr_2O_3. However, as per the new guidelines of IBM the chromite content in the tailing should contain <10% Cr_2O_3. In view of the above, CSIR-NML had undertaken a study on characterization and bench scale beneficiation of chromite tailing from eastern part of India had and developed process technology for recovering of chromite values from tailings. In Phase-I, a process flowsheet was developed at a bench scale involving desliming followed by gravity/enhanced gravity separation. The validation of the bench scale results through a pilot scale study is under progress in Phase-II of the project.

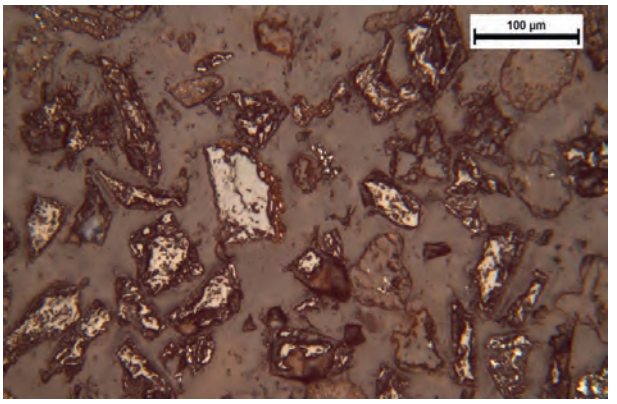


Fig.8 : Photomicrograph showing locking of chromite with goethite, quartz and ferruginous clay.

Pilot Scale Flotation Studies of Iron Ore

In the northern parts of India, iron ore deposits comprise of hematite, goethite minerals with gangue of alumina and silica. Due to the occurrence of these gangue minerals in fine sizes, generation of slimes of high alumina and silica during beneficiation process, is inevitable. Though iron values of these slimes are high, the lack of beneficiation technology requires their disposal in slime ponds. The practice of disposal is a threat to the environment and leads to huge land fillings. Consequently, a beneficiation process involving froth flotation to recover iron values from slimes was undertaken. 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. Those studies were scaled to pilot scale (20-25kg) to confirm the performance of the flotation reagents (*Fig.9*). Results indicated high selectivity compared to conventional reagents and a concentrate having 2.46% Al_2O_3 with 82% yield was achieved. The tailings with iron content <45% were rejected in the reverse flotation of iron ore slimes. Effect of process parameters such as collector dosage and % solids in the feed were established.

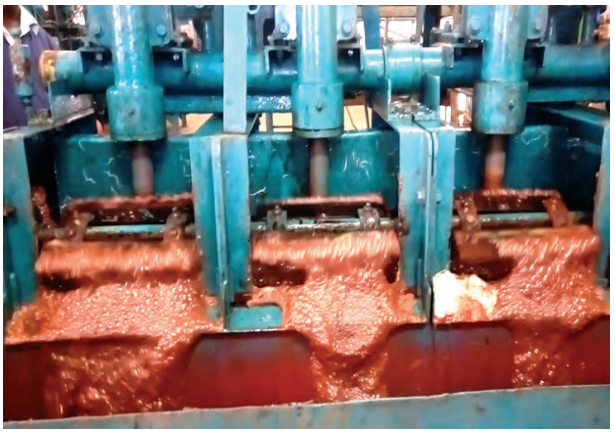


Fig.9: Pilot scale iron ore flotation study.

Desliming Hydrocyclone Simulation Studies

Desliming is very common operation in iron ore beneficiation, in which very fine particles separation is required. Typically, low diameter hydrocyclones [50mm (2")] are preferred for this kind of operation. But due to lower capacity and small orifice in these very small hydrocyclones, the operational problems are significant with average amount of tramp over size. The objective of the present study was to achieve a cut size between 5-10 micron with a 4" hydrocyclone. The work includes conducting pilot scale test with different parameter combinations of vortex finder, apex followed by development of steady state model and conducting simulation analysis to achieve the required cut size. Optimum parameters were predicted to achieve 5 micron cut size. Particle size distribution and efficiency curve were also estimated for the optimum condition, as shown in *Fig.10 & Fig.11* respectively. Under optimum condition sufficient quantity of products were generated.

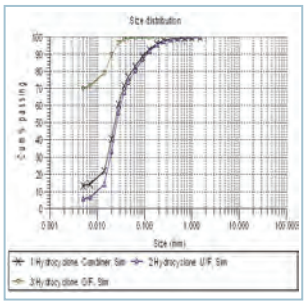


Fig.10: Simulated particle size distribution.

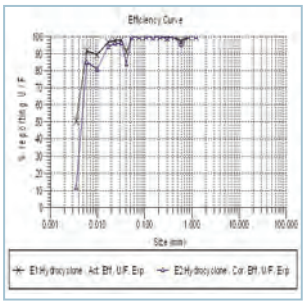


Fig.11: Simulated efficiency curve.

Modelling and Simulation Analysis of Comminution Circuit

Size reduction operation in mineral beneficiation circuit is an extremely energy intensive operation. The process of developing a model for crushing circuit and simulating it regularly will optimize the parameters affecting the circuit performance. Simulation studies will be useful in predicting the optimum operating conditions of the circuit and therefore retrofitting the circuit. The objective of the present study was to predict the maximum throughput of the crushing circuit (*Fig.12*) along with the optimum parameter to achieve that throughput. The study includes a steady state model development using actual plant data followed by validation and prediction of the process effects through off-line simulation. *Fig.13* shows the simulated particle size distribution of different streams. Simulation analysis indicates a 20% (700tph to 840tph) improvement in the circuit throughput with change in crusher closed side setting (CSS). The work is in progress.

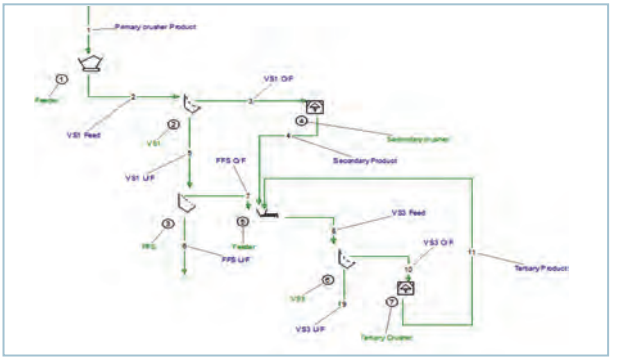


Fig.12 : Crushing circuit under study.

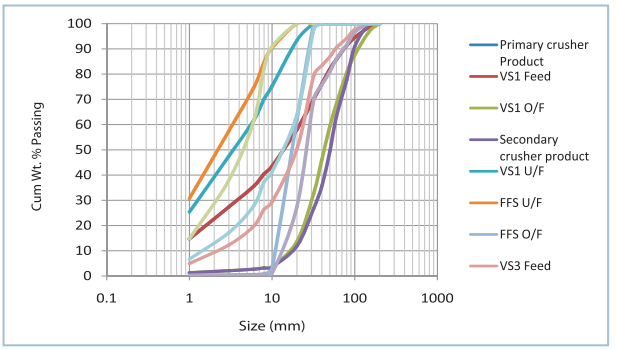


Fig.13 : Simulated particle size distribution of different streams.

Beneficiation of Siliceous Limestone for Cement Industries

Limestone of various grades are extensively used in cement, metallurgical, glass industries, food processing, paper making, leather, wastewater treatment, as well as adhesives. Cement industries are the leading consumer (about 69%) followed by Steel (12%) and Chemicals (3%). The chemistry of limestone required by Cement Industry is 42% (min.) CaO, 11-14% SiO_2, 1-1.5% (max.) Fe (T)

CSIR-NML has taken up a research project on the beneficiation of argillaceous limestone containing 39% CaO,19% SiO_2, 23% total insolubles, and 0.8% Fe(T).The objective of the work is to develop flotation based process for reducing silica content for its effective utilization in cement making industry. Mineralogical studies including optical microscopy (*Fig.14*) & XRD (*Fig.15*) reveal that feed sample consists of calcite (C) as the major ore mineral, with minor amount of gangue minerals such as quartz (Q), muscovite (M), kaolinite (K), and palgioclase. Flotation study is being carried out under varying process condition for reducing silica content in limestone sample. The initial flotation results are encouraging.

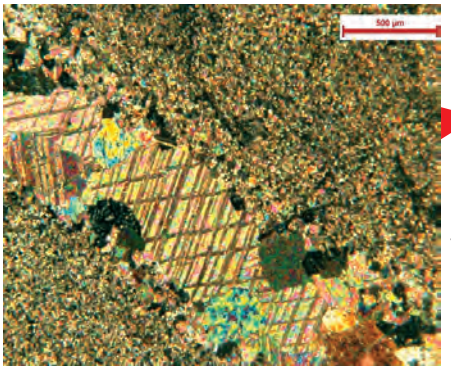


Fig.14 : Photomicrograph showing very fine grained calcite intruded by a coarse grained calcite vein in argillaceous limestone.

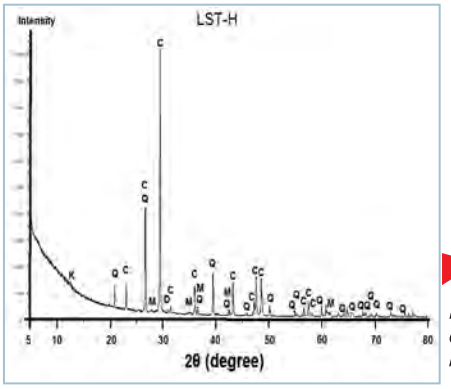


Fig.15: X-Ray diffractogram of limestone sample.

Dr. Y. Nayudamma | 1971 -1977

Dr. Yelavarthy Nayudamma (1922-1985) was a chemical engineer and a scientist. He was awarded many national and international awards and honours, including Padma Shri in 1971. Dr. Nayudamma was conferred with the prestigious Raja-Lakshmi Award in 1983 from Sri Raja-Lakshmi Foundation, Chennai. He served as the Director General of CSIR, New Delhi and also as the 4th Vice-Chancellor of the prestigious Jawaharlal Nehru University in New Delhi from 12th June 1981 to 27th October 1982. He also served on many prestigious national and international committees.

Prof. M.G.K. Menon | 1978 - 1981

Prof. Mambillikalathil Govind Kumar Menon (1928-2016) was a physicist and policy maker. He had a prominent role in the development of science and technology in India over four decades. One of his most important contributions was nurturing the Tata Institute of Fundamental Research, Mumbai, which his mentor Homi J. Bhabha founded in 1945. He undertook experiments with cosmic rays to explore the properties of fundamental particles. He was actively involved in setting up balloon flight experiments, as well as deep underground experiments with cosmic ray neutrinos in the mines at Kolar Gold Fields. He was the President of the Indian Statistical Institute, the Vikram Sarabhai Fellow of the Indian Space Research Organisation, President of the National Academy of Sciences, India, Director of the Tata Institute of Fundamental Research, Mumbai (1966–1975), Chairman of the Board of Governors, Indian Institute of Technology, Bombay and Chairman of the Board of Governors of the Indian Institute of Information Technology, Allahabad. He won the Abdus Salam Award, and was a member of the Pontifical Academy of Sciences. He was one of the most prominent scientists from the state of Kerala and was elected a Fellow of the Royal Society in May 1970. The asteroid 7564 Gokumenon was named in his honour in 2008.

Engineering Division

The Engineering Division caters and co-ordinates the engineering needs, both R&D and infrastructural, of the laboratory, Large Scale Testing Facilities & Residential Complexes. Majority of the needs are non-repetitive in nature, though some are routine ones. The division has two groups called Works Services and Maintenance (WSM) group and Project Planning and Engineering (PPE) Group. WSM group include Civil Engineering Unit, Electrical Engineering Unit and Air-Conditioning Unit, while PPE group consists of the central workshop and drafting units. The type of activities performed by the Division include: Design and Development of prototypes, Project Engineering, Engineering Consultancy, Infrastructural Development, R&D activities of the core areas of the laboratory, Up-keeping of premises, In-house maintenance, Workshop facilities and support services.

Project Planning and design Engineering Group :

The activities of the group may be divided into following categories:

1. Prototype design and development
2. Research and consultancy in the area of welding
3. Setting up of critical infrastructure
4. Finite Element and CFD Modeling
5. Maintenance of equipments
6. Safety infrastructure
7. Central workshop
8. Skill development
9. Technology scale-up and Basic Engineering Packages (BEP)
10. Pilot plant operation and maintenance

Prototype design and development :

In the reported period the division has contributed to the requirements of several projects. The major prototypes designed and developed are as follows :

1. Pellet induration rig for simulation of pellet sintering bed
2. Close loop corrosion rig
3. Design and specifications of material handling system for AKAFLOW equipment
4. Design and specifications of inverse mold simulator
5. 50Kg brass melting furnace
6. Design and outsourcing of machining and shrink fitting for CIMFR canon
7. Consultancy project on setting up of commercial plant for sodium production

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 following :

1. Consultancy for steel gate fabrication for barrage on Kharkai river- Consultancy work was undertaken for weld quality assurance of fabricated steel gates for Kharkai Barrage, Adityapur. In the project 12 service gates of 12m wide and 13.5 m high were being fabricated. M/s Larsen & Toubro has executed this work. In this project CSIR-NML team visited the barrage site for helping the client to ensure quality fabrication work from the contractor.
2. Consultancy for repair of 500 MW LP turbine rotor- M/s NTPC Ramagundam had awarded a project on Consultancy for repair of 500 MW LP turbine rotor by welding. This involved providing technical advice to client for assessing and controlling the quality of the repair being done by M/s Alstom, Vadodara using welding process.
3. Research project on effect of Hydrogen on fracture toughness of welds of API X 80 steel
4. Research project on toughness behavior of simulated heat affected zone (HAZ) of SA 508 and P 91 steels- Engineering division is also leading a BRNS project on Heat Affected Zone (HAZ) Simulation of SA 508 and 9Cr1Mo steel. This project was awarded by

department of atomic energy and is targeted to understand effect of welding parameters on HAZ of the materials used in nuclear plants.

5. Procurement of facilities for welding research laboratory

Setting up of critical infrastructure :

In the reported period the division has been working on the following major jobs for critical infrastructure development:

1. Replacing 2 x 86 T air-conditioning plants for creep laboratory
2. Setting up of industrial shed for the upcoming amorphous electrical steel pilot plant
3. Facility development for Tungsten recovery from scrap raw material

Finite Element and CFD Modeling :

The division is actively leading modeling activities in amorphous electrical steel project. We are also planning to set-up a CFD laboratory in the division for validation of modeling results.

Maintenance of equipment :

The division provides in-house maintenance support to high value equipment of the laboratory. This saves Maintenance costs and reduces breakdown time of the equipment. During the reporting period the following high value equipment were serviced:

1. Annealing simulator furnace
2. Hot Dip Process Simulator
3. Servo Hydraulic Units of MTE Division

Skill Development :

Every year the division provides training to about 20 trade apprentices. This figure is planned to be increased to 28 for the coming year and there are plans to provide hands-on training to diploma and graduate Engineers too. There are also plans to start a skill development course in welding.

Central workshop :

Central Workshop receive jobs from various divisions, for specimen preparation of different materials, fitting, machining & fabrication. All these jobs are completed in time to the satisfaction of the indenters. Major jobs completed are: fabrication of brass melting furnace components, large number of creep test specimen preparation, fabrication of steel structure for MEF division and pot holding structure for beautification of the Laboratory premises (from scraps). 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, Plasma arc welding.

We are in process of procuring EDM wire cut machine in the central workshop.

Works Services and Maintenance Group :

Infrastructure Management

The infrastructure management team has successfully completed new facilities creation jobs as per the requirements of the laboratory. In addition, the division takes annual maintenance and overhauling of infrastructures. Some of the new facilities developed are as following :

1. Infrastructure facility for Tungsten Extraction Programme
2. New Work Centre set-up for Hydrometallurgical bay (DOD bay) of MER Division
3. Beautification of technical block corridor by false ceiling
4. Name plate signage on the main gate and on front top of the main building.

Infrastructure facility for Tungsten Extraction project at Mg Project Area

New Work Centre set-up for Hydrometallurgical bay (DOD bay) of MER Division

Beautification of Technical Block Corridors

Name Plate Signage in Main Building

Name Plate signage on the laboratory main gate

Renovation of Creep Building Front side

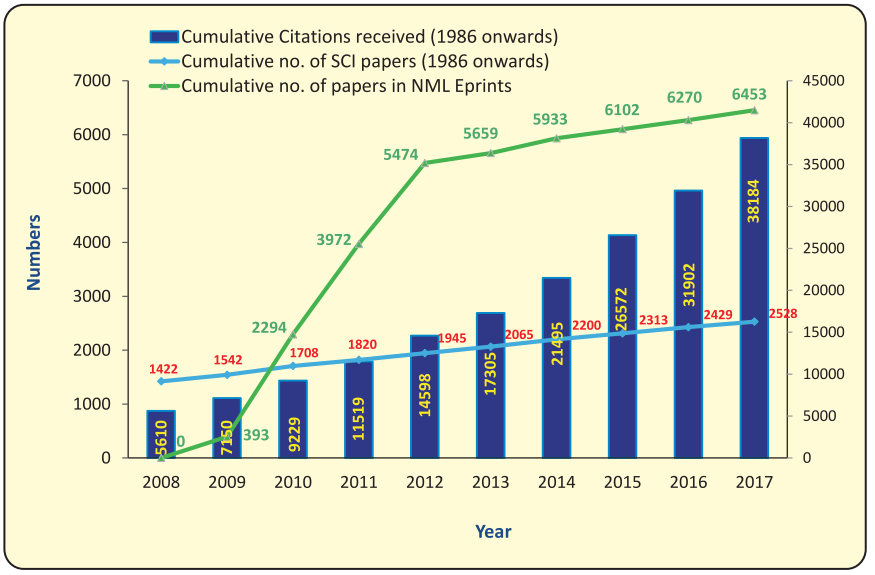
Renovation of Main Building Front side

Knowledge Resources and Information Technology

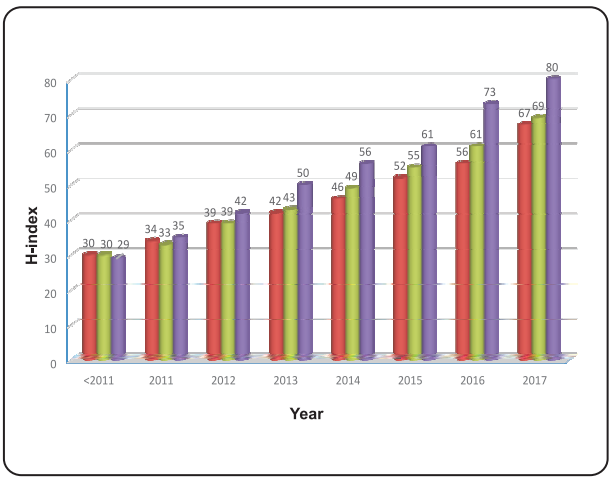
Knowledge Generation

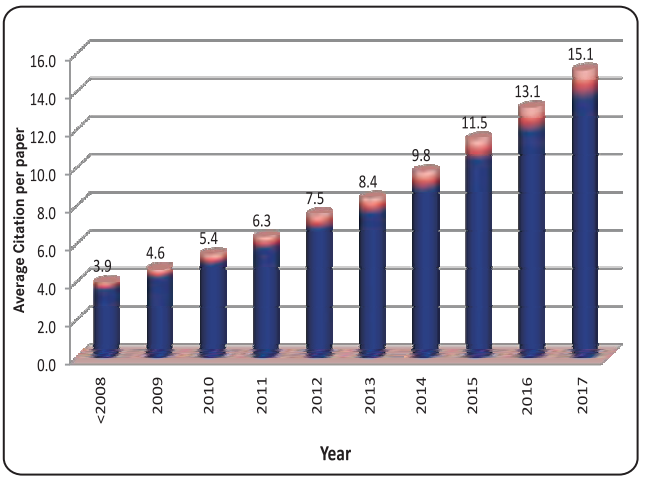
SCI Publications and Citations

99 SCI and 31NON-SCI papers were published from CSIR-NML during Jan-Dec, 2017 (Please see "Publications"). These papers are regularly uploaded in Laboratory's Institutional Repository. The citation of the cumulative SCI publications (1986 onwards) from CSIR-NML has increased from 5610 (in 2008) to 38184 (till Dec31, 2017) registering an increase of 6.81 fold in the citation growth. The average citation per paper is 15.10 against 13.20 in the last year. 120 articles received more than 75 citations/paper (source: Web of science/ Google scholar) as on March 31, 2018.



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

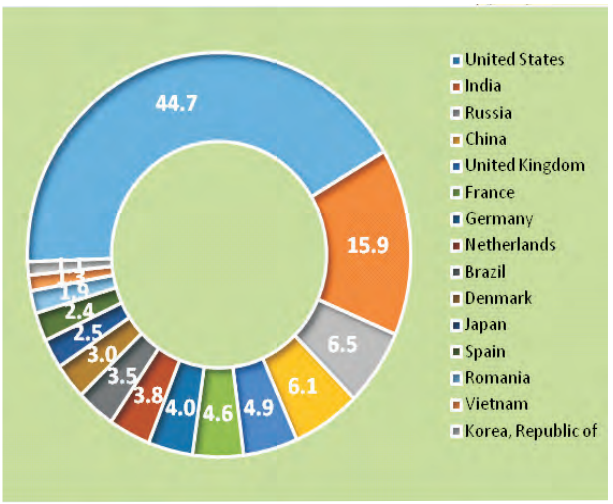




CSIR-NML H-index and Average Citation per paper

Institutional Repository

The CSIR-NML Institutional repository has maintained its global visibility and achieved 26 fold increase in tariff and popularity with average hits of over 0.238 million per month and a cumulative 19.84 million hits since inception (2009). The researchers from 197 countries have accessed NML repository database. Among the global users, the top countries in decreasing order are United States, India, Russia, China, UK, France, Germany, Netherlands, Brazil, Denmark, Japan, Spain, and so on. (http://eprints.nmlindia.org)



Transparency Portal

The CSIR-NML Transparency portal 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 caters to the information need of a citizen. (http://library.nmlindia.org/tp/index.htm)

Information under RTI Act

During the reporting period, 71 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 laboratory's Transparency portal.

Information Products

The following information compendium were prepared and published

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

Information Technology

The existing internet bandwidth of 20 Mbps has been upgraded to 155 Mbps in November 2017 enabling high speed access of internet. A software for intranet based internal complaint portal has been developed & implemented in the ERP system of CSIR-NML by IT group to fulfill the need of employees for redressal of their day to day grievances in relation to issues on Tour Application, Leave Travel Concession, No Objection Certificate, House Allotment, Pay, Allowances, etc.

CSIR-NML had installed Aadhaar Enabled Biometric Attendance System (AEBAS) in the year 2015 on the directives of Government of India. Recently, many of those systems became nonfunctional due to technical obsolence and it became very difficult for the employee to register their attendance in AEBAS system. Fourteen advanced AEBAS systems have been installed at various working areas of the main laboratory, LSTF area, the Magnesium plant and residential areas of CSIR-NML.

IT group has initiated the actions to revamp the existing CSIR-NML website as per directives stipulated in GIGW guidelines based on various feedbacks received from the employees as well as the management. The landing page of Web- site has already been developed and contents of the Web site is in progress and it is expected to be over very shortly.

Documents / Files are important assets to the government organization. Delays in acting on files and misplacements reduce the efficiency of an organization. The IT group has started a pilot level activity named “File Tracing Using QR Code Scanning” as per directive of higher management which will monitor the movement of the file, delays of file movement at any point and also point of misplacement of the file, if any.

Research Planning and Business Division (RPBD)

The laboratory conducts R&D in projectised manner and the RPBD division has a role to play at every stage of conducting R&D projects *(Fig.1)*. As the name of the division suggests, right from generating leads and developing new clients for the organization, the division is designated to help and support a variety of activities during the life cycle of a project i.e. from Initiation to completion.

Fig.1: Divisional activities at various stages of a R&D project

Management Information Systems and Databases

A number of web based information systems, and related databases,were developed and are 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. The management systems in place are *Project Information Management and Monitoring, Documents and Reports Management, Employee Profile Management, Human Resource (Competence and Man days Involvement) Management, Enabling Online Recruitment, and, Online In-house Projects Management*.

A number of databases are maintained at the division for the smooth functioning and decision making of the management. These are databases which store information on Projects, Invoice, Cash flow, Man-Days Project completion reports, Agreements, Equipment utilization, Intellectual property (Patents, Copyrights) and others.

Two web-based information systems were developed by the division in the the present fiscal :

1. **CSIR-NML CSE-Feedback** (*A website to get customer satisfaction feedbacks online*),
2. **CSIR-NML Invoices** (*A web-based information system for managing GST based Invoicing and Billing System*)

CSIR-NML CSE-Feedback

The testimonials of, and feedback from, our customers, add to our efforts to serve them in a better way. Our continued endeavors to satisfy our valued clients are what make us a first choice for the industry and government. This website *(Fig.2)* provides ease of submitting feedbacks against the performance of a project online.

Fig. 2. Customer Satisfaction Evaluation website

CSIR-NML Invoices

A service invoice is a legal document providing detailed billing information for a transaction where a customer receives a service. Businesses tend to use a standardized form for invoicing to make it easier to keep records. The invoice serves as a bill and a record of the services provided. In the event of any argument, both parties have copies of invoices that can be used to resolve the dispute. The software also helps in generating customized reports or statement for submission of GST Taxes e.g. CGST, SGST and IGST calculation *(Fig.3)*.

Fig. 3. Invoice Management website

NABL Accreditation (ISO 17025: 2005) of Creep Laboratory of Materials Engineering (MTE) Divisionof CSIR-NML

CSIR-NML, Jamshedpur is all set for NABL Accreditation of Creep laboratory of MTE Division in compliance with ISO/IEC 17025: 2005 Standard. The complete process of Laboratory Accreditation of MTE Division on ISO 17025: 2005 is under progress in three stages: (a) Internal auditor training and laboratory Quality Management System Training on Management Uncertainty and calibration; (b) To Conduct Mock Audit & GAP Analysis against ISO/IEC 17025: 2005 and Understand Missing Requirements; (c) Document preparations: Quality manual, Quality Assurance Procedures, Laboratory Specific Forms, Instrument/Standard Operating Procedures.

Training Programs

The RPBD division in collaboration with the domain experts from NML as well as outside, conducts a series of training for externals having a range of skill sets. These are provided under "*Skill Training Initiatives*" section.

Administration

The 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 the career development of 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 from single nerve line and facilitates in fulfilling 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 Institute.
- Provide advice to the functional bodies (committees/ functional groups) within the organization.
- Keep liaison with CSIR Headquarters on matters related to administration.
- Provide healthy working conditions and atmosphere to Institute 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 time bond manner. This year 19 administrative staff and 5 Scientist have been recruited in CSIR-NML.

The division is headed by 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 viz. 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. A number of security services for the laboratory are provided by the security department which is headed by Senior Security Officer and supported by Senior Technician-II. The Hindi cell is headed by the Senior Hindi Officer and supported by Junior Translator of Official Language Division ("Rajbhasha Bibhag").

In recent past, the 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.

Finance & Accounts

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 CSIR guidelines. This division provides central accounting and financial information to the Director-NML and CSIR Headquarters through a variety of reports.

Following are the major activities of the Finance & Accounts Division

- Preparation of budget estimate and revised estimate for CSIR-NML and submitting the same to CSIR for allocation of funds.
- To ensure that there are adequate funds available 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 Accounts Manager 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 NML intranet to keep all employees informed about the position of funds.
- To prepare financial documents such as Receipts and Payments account and Balance Sheet of the organization on a given date for submission to CSIR Headquarters and decision makers as well as submission to CAG (Audit) for certification of accounts.
- Preparation and submission of funds 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 the receipts and payments in the relevant ledgers and books of accounts
- Closing of GPF accounts, remittance of funds to NSDL relating to New Pension Scheme and remittance of GST, income tax, etc. within scheduled 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 2017-18

1. Utilized Budget Grant allocated by CSIR: Rs. 6627.919 lakhs + Rs. 4717.240 lakhs (pension)
2. Utilization from Laboratory Reserve: Rs. 410.408 lakh
3. Settlement of outstanding CAG Audit Paras
4. Generation of EBR by investment of surplus funds: Rs. 382.864 lakhs
5. Settlement of 191 numbers of outstanding advances of O.B. amounting to: Rs. 190.250 lakhs
6. Generation of Lab Reserve: Rs. 603.812 lakhs.
7. Bank reconciliation of the Cash Book completed up to 31-3-2018
8. GPF Account as on 31-03-2018 has been reconciled, finalized and closed.
9. Remittance of GST/income tax and submission of returns to appropriate authority has been completed.
10. Issued 1210 numbers of letters in Hindi.

Stores & Purchase Division

The Stores & Purchase Division is mainly responsible for procurement of capital equipments, 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, GFR.

The major procurements for which orders were placed during 2017-2018 were :

- High Temperature Nano Indentation Unit
- Zwick High Frequency Pulsator Vibrophote 100
- Rigaku Model Ultima IV Automatic X-Ray Diffractometer System with solid state I-D Detector.
- ANSYS Academic Associate Mechanical Software
- Inductively Coupled Plasma Optical Emission Spectrophotometer
- TCIN8, MOBNI4, TCHEA, SSOL6 Single user node locked License software/Database.

Apart from these, many other minor equipments, accessories and spares were ordered.

The division has taken up the challenging task of the implementation of the ERP, E-Procurement and Procurement through Government E-Market (GeM) platform, with an objective of automation of process and reducing paper transactions. It is coordinating with 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 equipments and facilities, the division is has also integrated its processes with the newly launched Accounting Software for timely and speedy payments.

Hindi Cell

OFFICIAL LANGUAGE IMPLEMENTATION

CSIR-National Metallurgical Laboratory, Jamshedpur has an active Programme for the Implementation of Official Language, Rajbhasha Hindi. In addition to the regular official works and various 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 have been published in Hindi and English, Which are circulated to CSIR units and various organizations of Govt. of India. Press releases were issued in Hindi and published in daily newspapers.

PROMOTIONAL ACTIVITIES FOR HINDI IMPLEMENTATION

Four inspections were conducted by Hindi Officer covering various divisions for identifying the areas of Hindi implementation and 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. Ten Employees namely Md. Nayeem Ansari, Shri Akhilesh Kumar Nigam, Shri Shital Kumar Singh, Shri Parmarth Suman, Shri Santosh Kumar Rai, Shri Sudhir Kumar, Shri C.R. Chakraborty, Shri Nandlal Paswan, Shri Sanatan Naiya and Shri G. Dharma Rao were given award in this scheme.

HINDI WORKSHOP

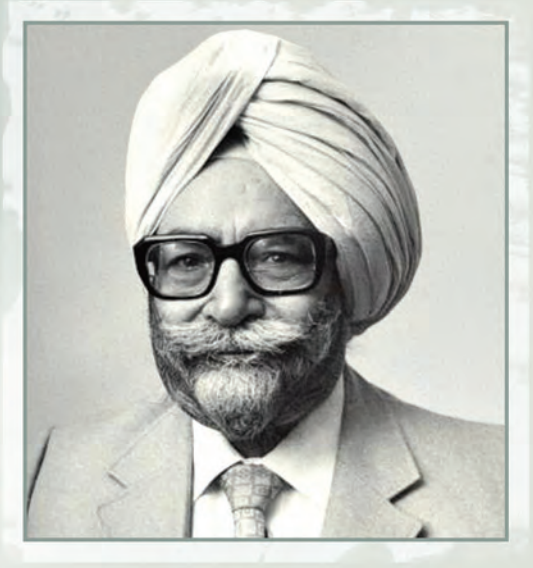
Four Table Workshops were conducted in Administration. The objective of the workshop was to address the issues encountered for preparing the Quarterly Hindi Progress Report, Hindi Noting and Drafting and imparting training of Unicode.

HINDI COMPETITION

“Hindi Competitions" were organized from Sept. 7-14, 2017 for CSIR-NML Employees. Dr. Manoj Kr. Sandilya, Senior Scientist, Department of Atomic Energy, Atomic Minerals Directorate for Exploration & Research, Eastern Region, Tatanagar, Jamshedpur graced the Inaugural function as the Chief Guest. On this occasion, Hindi competitions were organized for NML Staff and Officers. The competitions included: Essay writing, Noting/ Drafting, Hindi dictation and Self- written poetry recitation etc. On the Occasion of Self- written poetry recitation Shri Rajesh Kumar Ray, Prasar Bharati, All India Radio, Jamshedpur judged the participants and delivered a beautiful lecture on the tradition of Hindi Poetry. On the occasion of the Valedictory function Professor Yahiya Ibrahim, Karim City College, 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 14th September, 2017.

ACTIVITIES OF HINDI IMPLEMENTATION FOR TOLIC, JAMSHEDPUR

CSIR-National Metallurgical Laboratory is the Secretariat of Town Official Language Implementation Committee (TOLIC), Jamshedpur. It has 55 Members from all the Central Govt. offices located at Jamshedpur and adjacent. Only the Heads of these offices are members. Dr. Indranil Chattoraj, Director, CSIR-NML is Chairman of this committee. Under his Chairmanship this Committee is playing vital role for enhancement of Official Language Hindi in these offices.



Dr. G. S Sidhu | 1981 - 1984

Dr.G. S. Sidhu's major research theme was the design and development of novel crop protection strategies, to cater to the needs of agrochemical sector specially Indian farmers. He had worked to effectively combine organic chemistry with process technology, crop protection, drug design and sustainable energy.

Awards and Recognitions

International and National Awards and Recognitions

"Scientific Institutional Award 2017" for the exemplary commitment of CSIR-NML towards achieving technological innovations in the field of non ferrous minerals, metals and materials in the 21st International Conference on Non ferrous Minerals and Metals-2017, New Delhi

Fellow of Indian National Academy of Engineers (INAE)

Conferred with effect from November 2017

Dr. I. Chattoraj

- Non- Destructive Testing National (NDT) **Award for International Recognition** (ISNT) for the year 2017
- Elected as a **Member, Scientific Advisory Board** and was invited and attend "Kick-off Meeting of the **Horizon 2020-funded project entitled "NOMAD"** at Fraunhofer Institute for Nondestructive Testing IZEP, Germany during 29 -30 June 2017

Dr. Sarmistha Palit Sagar

Outstanding Reviewer Award

Dr. Thomas Alex

Dr. Abhilash

- **Young Engineer Award** by Mineral Engineering Science Association, Vishakapatnam, India (2017)
- **Membership of National Academy of Sciences**, India

SKOCH Order-of-Merit Award 2017 for the project Institutional Repository : Prospect and its Global Impact

Dr. A.K. Sahu

Dr. A.K.Mohanty

SKOCH Order-of-Merit Award 2017 for the project Technology Dissemination for MSME Brassware Artisans: Energy Efficient, Less Polluting Brass Melting Furnace and New Anti-tarnishing Lacquer

Editorial Board / International Committee Memberships

Dr. T. Mishra

- Associate Editor of Frontier in Chemistry (Frontier, Switzerland)
- International Journal of Materials and Chemistry (SAP, USA)
- American Journal of Physical Chemistry (Science publisher (USA)

Dr. A.K. Mohanty
World Journal of Analytical Chemistry

Dr. Abhilash
Russian Journal of Nonferrous Metals (Springer)

Dr. Sarmistha Palit Sagar
Guest Editor, September Issue, 2017, Journal of Non-Destructive Evaluation

Local and Institutional Awards and Recognitions

Motivation Shield for organizing Voluntary Blood Donation Camp at CSIR-NML during Financial Year 2016-2017

3rd prize in the Annual flower Show, Jamshedpur in the "Institution" category.

22 awards in Horticulture competition, Jamshedpur, held on 31 December 2017.

Runner-up in Cricket in the inter CSIR 49th SSBMT Outdoor Tournament held at CSIR-CSIO, Chandigarh.

Technology Day 2017 Quiz

First prize

Mr. Avanish Chandan

Mr. Gaurav Bansal

Dr. Rajneesh K. Gupta

Dr. Jitender Kumar Sahu

Second prize

Mr. Shivendra Sinha

Mr. Prem Kumar

Mr. A. Ammasi

Dr. Manoj M. Humane

Best Paper/Poster Awards

Authors	Details	Conferred during or by
Mr. Ashok K, Dr. Sheuli Hore, Dr. Gopi K Mandal	Best oral presentation award for the technical paper, "Estimation & analysis of excess oxygen input into ladle during liquid steel tapping"	IMME-17, National Institute of Technology, Tiruchirappalli.

Authors	Details	Conferred during or by
Dr. TC Alex, Mr. DP Sahoo, Dr. Sanjay Kumar	Second best paper award, for the research paper “Cold bonded briquetting of iron ore slime”	Tata Search, 2016
Deblina Dutta, Sudha Goel, Jayanta Bhattacharya, Dr. Jhumki Hait, Dr. Manis Kumar Jha	First prize for oral presentation for the paper “E-waste recycling: An alternative potential resource for Rare, Rare Earth, and Precious metals recovery”	International Conference on “Integrated Solid Waste Management in Developing Countries” CSIR-NEERI, Nagpur
Ms. Charu Singh	Best Poster Award for the poster presentation "Deposition and Characterization of Electroless Ni on fluoride free pretreated AZ91 Magnesium Alloy”	AMPCO-2017, IIT Roorkee.
Ms. Chandrani Sarkar	Two Best Oral Presentations	1st National Conference on Enhancing New Innovation and Challenges in Nano, Chemical & Biological Sciences, Tata College Chaibasa
Ms. Preeti Karmakar, Ms. Suhani Kumari, Dr. Archana Agrawal, Dr. D. Mishra, Dr. K. K. Sahu	First prize for the oral presentation 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)” IIM Bhubaneswar & CSIR-IMMT
Dr. Saswati Chakladar	Best paper award	ICEE 2018, NIT, Calicut

CSIR-NML Foundation Day Awards

P. Ramachandra Rao Award *(for Best Employee)*

Mr. L. Pothal

Mr. Ajoy Puran

Mr. L.N. Singh

Mr. I. Raja Rao

Special Appreciation Award

Mr. Bhola Nath Mandal

B.R. Nijhawan Award

(for best Technical Paper)

Dr. Swapna Dey and Dr. Indranil Chattoraj, for the paper "Interaction of strain rate and hydrogen input on the embrittlement of 7075 T6 Aluminum Alloy", Materials Science and Engineering A, Vol no. 661, pp168-178, 2016

Shilowbhadra Banerjee Award

(for best in-house project)

Dr. Jhumki Hait, Mr. Navneet Singh Randhawa, and Mr. J.N. Patel, for their in-house project "Recovery of Tellurium from de-selenized copper refinery anode slime"

Awards to Meritorious Wards of Staff

CSIR Foundation Day Awards

Awards to Wards for Academic Excellence

Ms. Divya Gupta

Mr. Deepanshu Gupta

Wards of Dr. Rajneesh Gupta

Mr. Jasjit Singh

Ward of Mr. Manjit Singh

Felicitation for 25 Years of Service to CSIR


Mr. A. K Dutta


Mr. P.K. Roy


Mr. B. Dash


Mr. B. K. Dikshit


Mr. M. Singh


Mr. D. K. Sarkar


Mr. P. N. Thakur


Mr. M. Dungri

Essay and Debate Competitions (Hindi and English)

Essay (Hindi)


1st Mr. Amit Prakash


2nd Ms. Aarti Kumari


3rd Mr. Bhupeshwar Mahato

Essay (English)


1st Mr. Robert Barla


2nd Ms. Rekha Panda


3rd Dr. Abhilash

Debate (English)


1st Dr. Saswati Chakladar


2nd Mr. Shivendra Sinha


3rd Dr. Pratima Meshram

Invited Lectures Delivered

Dr. Indranil Chattoraj

1. "Curiosity and Serendipity in Research", NASI Annual Convention, Pune, 8-11 Dec 2017
2. "Science and Technology in India- then and now", COMPOSIT, IIT Kharagpur, 24 Mar 2018
3. "Integrated Computational Materials Approaches in Corrosion", IIM-ATM, Goa, 12-14 Nov 2017
4. (co-authored with LK Meena, MG Walunj) "Advances in Corrosion Science and Technology", ICONEST, Bangalore, 9 -11 Aug 2017

Dr. Rakesh Kumar

1. "Odyssey in Mechanical Activation of Solids – SMILE and Beyond", IX International Conference on Mechanochemistry and Mechanical Alloying (INCOME2017) , Kosice, Slovakia, 3– 7 Sep 2017
2. "Metals and Mineral processing: Past Knowledge and Future Prospects", 3rd World Congress on Vedic Sciences, Pune, India, 10 - 13 Jan 2018

Dr. Amitava Mitra

1. "Application of rapidly solidified magnetic materials for structural health monitoring of engineering components", International Conference on Magnetism and Magnetic Materials, London, 9 -10 Oct 2017
2. "Evaluation of Damage in Engineering Steel Components using Electromagnetic NDE techniques", NDE-2017 by Indian Society for non-destructive Testing, Chennai, 15 Dec 2017
3. "Rapid Solidified Soft Magnetic Materials for Sensor Application", Solid State Physics Symposium -2017, DAE Convention Centre, BARC, 26 -30 Dec 2017
4. "Technology-Incubation Centre-Entrepreneurship Development: Roll of CSIR-National Metallurgical Laboratory", XLRI Auditorium, Organised by CII of Jamshedpur Chapter, 20 Feb 2018
5. "Amorphous Materials- Next Generation Electrical Steel", Tata Steel, Jamshedpur, 08 Nov 2017

Dr. Soumitro Tarafder

1. "Mechanisms, and Quantification of the Resistance to Fracture", Faculty Development Programme on Mechanical Behavior of Structural Materials, SRM University, Chennai, 17 May 2017
2. "The Mechanics of Damage Evolution", International Conference on Materials Engineering (ICME), jointly organized by IIM and IIT Kanpur, IIT Kanpur, 12-18 May 2017
3. "The mechanics of damage evolution in material microstructures", Keynote Speaker in 1st International Conference on Mechanical Engineering (INCOM 18), Jadavpur University, Kolkata, 05 Jan 2018
4. "Future Trends of Metallurgical & Materials Engineering", Panel Speaker in 31st National Convention of Metallurgical and Materials Engineers, The Institution of Engineers (India), Kolkata, 19 Jan 2018
5. "A Catalyst called Science", Keynote Talk in in METALLUM-2018, Indian Institute Engineering Science & Technology, 15-18 Feb 2018

Dr. Ratnakar Singh

1. “Strategy for beneficiation of lean grade tungsten ores with a particular reference to Degana, India”, Workshop on Tungsten Primary and Secondary Resources, DMRL, Hyderabad, 19 Jun 2017
2. “Technology for processing of high aluminous and high siliceous iron ores”, Annual Technical Meeting, NMD, IIM, Goa, 11-14 Nov 2017
3. “Beneficiation of high ash Indian coal – Problems & prospects, Coal for Metallurgical and Thermal Applications: An appraisal of its Characterization and Utility”, Jamshedpur, 22-25 Jan 2018
4. “Development of technology for beneficiation of low and lean grade iron ores”, National Seminar on Make in Steel for Make in India – Perspectives for Iron and Steel Industry, Kolkata, 22-23 Feb 2018

Dr. K.K. Sahu

"Recycling and Value Recovery from Various Nonferrous Wastes", IIM-ATM, Goa, 12-14 Nov 2017

Dr. R.K. Sahu

“Advances in materials science & engineering (AMSE 2017) ”, Faculty Development Programme (FDP), C.V. Raman College of Engineering, Bhubaneswar, 17–23 Nov 2017

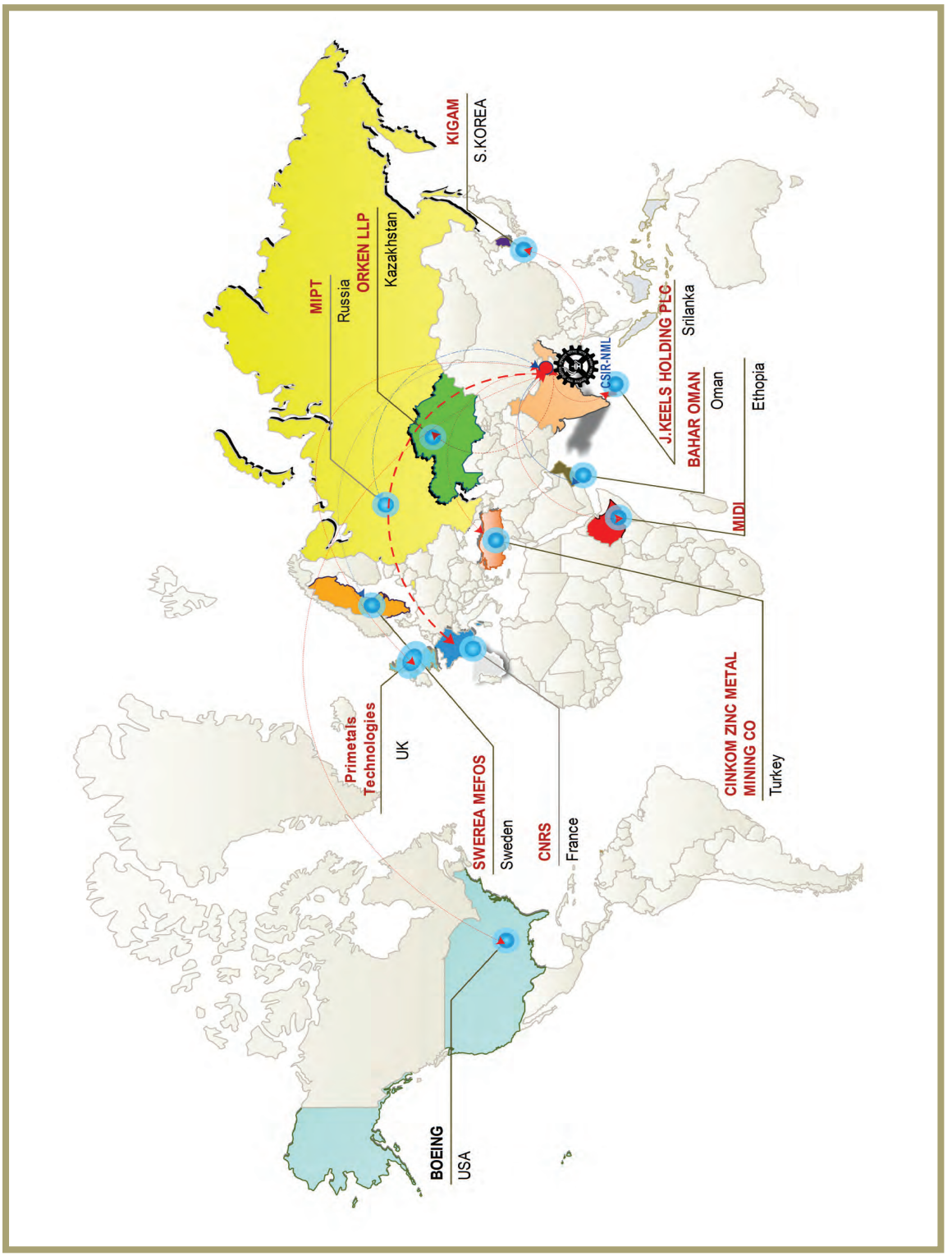
Dr. Abhilash

1. “Sustainable recycling of Mine and Urban Wastes by Environmentally Benign Options”, International Symposium on Sustainability in Science and Engineering, IIT Bombay, 26 Jul 2017
2. "International Conference on Advanced Engineering Functional Materials (ICAEFM 2017)", Bhubaneswar, 21-23 Sep 2017
3. “Sustainable End-of-life Closed Loop Recycling of Battery Wastes”, DST's 3rd India International Science Festival (IISF-2017) (Theme: Swaach Bharat), 13-16 Oct 2017

Mr. Amit Prakash

"Ultrasonic Flaw Detection" Dept. of Mechanical Engineering, IIT Guwahati, 12 Sep 2017

International Collaborations



New Facilities Created

Induction Heating Equipment

Make : AmbrellInc; USA Model: EASY HEAT 0224

Principle of Operation : Electromagnetic Induction coupling of metallic materials and internal eddy currents generation.

Use : To melt metallic materials of smaller quantity ranging 10-35 grams and local heating of components.

Features :

- operates over a broad frequency range (150-400 kHz)
- ideal for heating parts of varied geometries and compositions with precise power control
- single cycle or programmed to deliver continuous heating operations, easy control of the length of the heating cycle with a built-in programmable digital timer
- portable heat station, Can be installed into any pre-existing system like Melt spinning unit

Stationary Bed Pellet Induration Test Rig (PITR)

The Bed height of PITR is 550 mm. LPG is used for heating purpose. It has five numbers of thermocouples to measure bed temperature through the entire bed.

Inductively Coupled Plasma Optical Emission Spectrophotometer (ICP-OES)

Make : AGILENT, USA; Model: 5110 ICP-OES

Use : Precision Chemical Analysis

Features :

- simultaneous or sequential analysis of multiple elements
- high sensitivity (low limit of detection for majority of elements is 10ppb or lower)
- stability and accuracy is high
- high number of measurable elements
- less stabilization time, argon consumption is very low

Scanning Electrochemical Workstation

Make: Biologic Science Instruments, France; Model : SECM 470

Uses :

- study corrosion process/mechanisms at specific locations
- study in-situ corrosion and passivation
- study of pitting and crevices corrosion
- evaluation of coatings
- study galvanic corrosion at specific locations

Features :

- Scanning Electrochemical Microscopy (SECM)
- Scanning Vibrating Electrode Technique (SVET)
- Localized Electrochemical Impedance Spectroscopy (LEIS)
- Scanning Kelvin Probe (SKP) and Scanning Droplet System (SDS)

Closed Loop Corrosion Test Rig

Make : Indigenously designed, fabricated by outsourcing

Use: corrosion study in flow simulated sea water with different controlled O_2 levels

Features:

- two types of test rigs for metallic coupon exposure as well as for electrochemical studies
- control of dissolved oxygen

Creep Crack Growth Testing Machine

Make : ZwickRoell, Germany; Model: Kappa 100 SS

Use : Creep crack growth studies

Features :

- range upto temperatures and loadsof 1000 ˚C and 100 kN, respectively
- as per ASTM 1457 standard

High-Frequency Pulsator (EMR High Cycle Fatigue Testing Machine)

Make : Zwick, Germany; Model: Vibrophore 100

Use : High cycle fatigue testing, fracture mechanics studies

Features :

- high frequency pulsator
- electro-magnetically excited dynamic testing facility
- tensile, compression, pulsating and alternating loads
- round, flat, 3 point bend (TPB), 1 CT and 1/2 CT specimens

Dr. A. P. Mitra | 1986 -1991

Dr. Ashesh Prosad Mitra, FRS (1927-2007) was a physicist who headed the National Physics Laboratory in Delhi, India before becoming the Director General of the Council of Scientific and Industrial Research (CSIR). He was primarily known for his work in Radio & Space. He performed major work in the field of earth's near-space environment, through group based and space techniques. He worked on cosmic radio noise for studying the upper atmosphere which led to a series of discoveries in ionosphere, solar physics and cosmic rays. He was awarded the Shanti Swarup Bhatnagar Prize for Physical Science in 1968. He developed an atmospheric model from observations of satellite drag and initiated new D region rocket experiments. Dr Mitra's work on ion and neutral chemistry in the upper atmosphere, especially on the minor constituent nitric oxide, provided the basis for much of our present knowledge about the lower ionosphere. He has contributed substantially to the establishment and operation of the International Spacewarn System and the International Ursi-gramme and World Day Service.

Prof. S. K. Joshi | 1991 - 1995

The broad areas of his research specialization are Condensed Matter Physics and Collision Processes. Dr. Joshi was elected Fellow of the Indian National Science Academy in 1974. The research interests of Dr. Joshi were high temperature superconductivity and heavy fermion. Prof. Joshi has been awarded the Sarabhai Research Professorship in Physics. He was the Secretary of the National Science Academy during 1983-86 and its Foreign Secretary during 1989-92. He was elected President of the INSA in 1993. He is Fellow, Indian Academy of Sciences since 1974 and was Vice President from 1989 to 1991. Prof. Shri Krishna Joshi (1935) was President of Indian Physics Association during 1989-90. Prof. Joshi is a Fellow of the Third World Academy of Sciences; and a Foreign Member of the Russian Academy of Sciences. He won the Watmull Memorial Prize for 1965, Shanti Swaroop Bhatnagar Prize for Physical Sciences in 1972; CSIR Silver Jubilee Award in 1973, and Meghnad Saha Award for Research in Theoretical Sciences in 1974. He also won Dr. K. S. Krishnan Memorial Lectureship of INSA in 1987, and FICCI Award in Physical Sciences for 1990; Dr. Mahendra Lal Sircar Prize by IACS Calcutta. He was awarded Padma Shri in 1991; Goyal Prize in Physics by Goyal Foundation in 1993; D.Sc. (honoris causa) Kumaun University in 1994; and Indira Gandhi Priyadarshini Award in 1994.

Human Resource Group

Recruitments

18 LDC/UDC recruited and placed in different administrative divisions

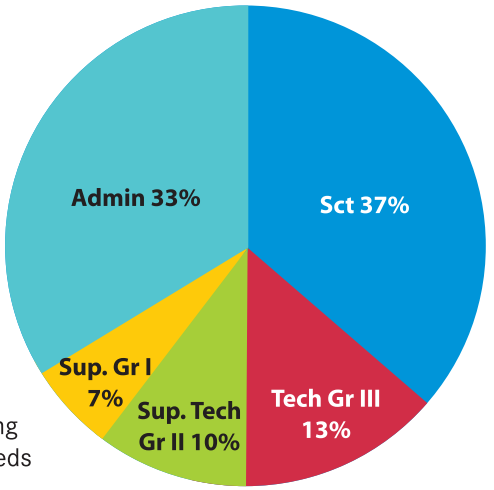
5 Scientists recruited and placed in R&D and R&D Support divisions

12 Scientist positions and 2 Technical Officer positions advertised and 3 Scientist positions re-advertised

Internal Skill Building

An orientation on administrative procedures was organized for all younger (PB3 Grade) scientists

All younger scientists are mandatorily required to participate in institutional colloquium which provides the first public forum to demonstrate their ideas, oratorical skills and techniques. In-house training on different subjects were provided catering to the skill development needs of different sections of employees.



Distribution Cadre Wise

Lecture Series

A series of lectures by eminent professionals and reputed researchers were organized through the seminar sub-committee. The details are provided in "*Distinguished Visitors* "section. Additionally, to commemorate the Platinum Jubilee of CSIR's existence, a series of seven lectures by internationally renowned metallurgists and engineers was organized. Please see "*Platinum Jubilee Lectures*" section for details.

Training for employees and staff

A total of 155 deputations were made of employees from different divisions and cadres to receive training and to participate in conference, workshops, symposiums, etc.

Students 2017-18	60
MTech Students (2017-18)	37
BTech Trainee/project (2017-18)	~92
RA/SRF/JRF	6
Pas in different projects currently engaged	62
Principal investigators	2
SERB NPDF/CSIR TWAS/CV Raman fellow	6

Summer & Winter Training Coordination

The HRG coordinates summer and winter trainings for the B. Tech. and M.Tech students of reputed institutions of the country. In 2017-18, students of IIT Gandhinagar, IIT Kharagpur, BHU Varanasi, IIT Guwahati, NIT Nagpur, NIT Durgapur, NIT Patna, NIT Jamshedpur, NIT Jaipur, NIT Trichy, NIT Jaipur, NIT Srinagar, NIT Surathkal, BIT Mesra, MSU-Baroda, IIEST-Sibpur, JNTUK Vijayanagram, VSJK- Burla, RGKUT-Basar, CVJ-Ranchi, Jadavpur University, MGIT-Hyderabad, BIT-Sindri, SRM University, SIT-Pune, NIFFT-Ranchi, IGIT-Sarang, KIIT-BBSR, Indus University Ahmedabad, PSGCT-Coimbatore, were imparted training in the organization.

Future Plans

In addition to the recruitments advertised as above, CSIR-NML is planning recruitments of Technical assistants as well as Gr II personnel in the coming fiscal. CSIR-NML is also planning to recruit project assistants and research assistants as per the project requirements.

Employee News

Employee (s) Superannuated

Shri Bheshdhari Pd. Mishra
Multi Tasking Staff
30-Apr-17

Dr. J.K. Sircar
Chief Scientist
31-May-17

Shri Shiv Kumar Singh
Lab. Asst.
31-May-17

Shri Jagdish Singh
Multi Tasking Staff
31-May-17

Dr. Kakali Chatterjee
Chief Scientist
30-Jun-17

Shri R D Mahato
Clerk (ACP)
30-Jun-17

Shri H P Gope
Lab. Asst.
30-Sep-17

Shri K N Mishra
Sr. Tech. (2)
30-Nov-17

Shri I.B. Mishra
Chief Scientist
31-Dec-17

Shri Ganesh Prasad
Lab. Asst.
31-Jan-18

Md. Sheikh Mahidul Islam
Multi Tasking Staff
31-Jan-18

Shri B N Mandal
Multi Tasking Staff
28-Feb-18

Shri Shyamal Kr. Sarkar
Sr. Tech. (2)
28-Feb-18

Shri Prem Narayan Thakur
Multi Tasking Staff
31-Mar-18

EMPLOYEE (S) TRANSFERRED FROM CSIR-NML

Shri D. Murmu
Admin. Officer
2017
CIMFR, Dhanbad

Dr. Ashok Kr. Roy
Chief Scientist
21.12.2017
CGCRI, Kolkata

Skill Training Initiatives of CSIR-NML

During 2017-18, CSIR-NML organized four types of training programs as given below:

Type	Category	No of programs	Supported by	Total participants	Reg Fees per person (Rs)
PTP	Professional Training	4	Various Industries Program	60	25000
CTP	Corporate Training	3	CIPET & Rites Program	26	35000
STP	Skill Training	5	CSIR, NRDC, Foundation Program for MSME	99	500/Free
TAOP	Technology Awareness Technology Assessment Outreach Program	6	Foundation for MSME, CSIR-NML	122	Free

The PTP and CTP are organized for developing direct interaction with the collaborators and sponsors of CSIR-NML R & D projects, STP was organized for technology promotion among artisans, faculty members, local youths and senior students and TAOP was for technology awareness and outreach program conducted outside NML. Additionally, several training programs were organized by R&D divisions independently.

CSIR-NML Professional Training Program

Total participants: 60

For business development and for enhancing customer interaction, CSIR-NML organizes Professional Training Programs (PTP) every year. The four days training program includes informative lecture series, laboratory visits and hands-on training on different equipment and on various aspects of their operations. Flyers of professional training programs organized by CSIR-NML during 2017-2018 are shown below.

Delegates from various industries attended the programs as shown below:

S.No	Training Focus	When conducted	Number of Participants	Industrial/Institution participation
1	Monitoring and Prevention of Industrial Corrosion (MPIC 2017)	24-27 October 2017	12	Quaker Chemical, Reliance Industries Limited, Tata Steel, BHEL, BPCL, PFIZER, GEC Gandhinagar, CESE
2	Experimental Techniques in Iron and Steelmaking (ETIS 2017)	05-08 December 2017	14	Gerdau Steels India Pvt Ltd, Tata Sponge Iron Limited, PSG College of Technology, CSIR-NML, B-CSIR, NIT Durgapur, Tata Steel Limited
3	Metallurgy for Engineers (M4E 2017)	12-15 December 2017	13	Bansal Calibration services (Ghaziabad), Tata Steel Limited, B-CSIR, Aditya Birla, Shriram Piston, CSIR-NML
4	Metallurgical Analysis of Failures in Materials (MAF 2018)	16-19 January 2018	21	Global Technical Center India (SKF Technologies), B-CSIR, Shriram Piston, Ambica Steels Ltd., BPCL-Kochi Refinery Ernakulam, Tata Hitachi Construction Machinery Company, RITES Limited, GAIL (India) Limited





Workshop & Pitching Session
Entrepreneurship Opportunities in Minerals, Metals & Materials

Technopreneurship


Professional Training
Programme
ON
Monitoring and Prevention
Of
Industrial Corrosion
MPIC-(2017)
OCTOBER 24-27,2017
WELCOME DELEGATES




Professional Training
Programme(PTP)
On
Metallurgy
for
Engineers
(ME 2017)
Organised by
CSIR - National Metallurgical
Laboratory



Monitoring and Prevention of Industrial Corrosion



CSIR-NML Corporate Training Program

Total participants: 26

Corporate Training Programs (CTP) are organized on request by sponsoring organizations. Following CTPs were organized by and at CSIR-NML:

Sl. No.	Title of the training	Sponsored by	When Conducted	Number of participants
1	Metallurgical Analysis for Quality Assessment (MAQA 2017)	Central Institute of Plastics Engineering and Technology (CIPET)	6-10 November 2017	10
2	Metrology and Calibration for Quality Assurance (MCQA 2017)	RITES Ltd., a Government of India Enterprise was established in 1974, under the aegis of Indian Railways	12-16 February 2017	8
3	Inspection and evaluation of flash butt welded rails (IEFBR 2018)	RITES Ltd., a Government of India Enterprise was established in 1974, under the aegis of Indian Railways	13-16 March 2018	8

CSIR-NML Skill Training Program

Total participants: 99

Five skill training programs were organized, mainly targeting entrepreneurs, artisans and skilled workers:

Sl. No.	Title of the training	Sponsored by	When conducted	No of participants
1	Training on Electroplating	Foundation for MSME, Kolkata	11-12 September 2017	8
2	A Train the Trainers (TTT) program on E-waste Deconstruction (EWD 2018)	CSIR Integrated Skill Training Initiative	27-28 February 2018	22
3	Entrepreneurship Development Program on Skill Training on Energy efficient Brass melting furnace for Production of Brass artifacts (EEF 2018)	National Research Development Corporation (NRDC)	8-9 March 2018	35
4	Skill Training on Energy efficient Brass melting furnace for Production of Brass artifacts (EEF 2018-Balasore)	CSIR Integrated Skill Training Initiative	21-22 March 2018	20
5	Technopreneurship-How to start a Tech Company (TECE 2018)	CSIR Integrated Skill Training Initiative	27-28 March 2018	14

Technology Awareness, Technology Assessment&Outreach Program
Total participants: 110

Title of the Program	Sponsored by	Dates	No of participants
Technology awareness and outreach program on Ni/Zn Electroplating at Howrah cluster	Foundation for MSME	31st August 2017	25
Technology assessment of traditional brass melting for making vessels by the artisans of Bali village of Goghat Block of Hooghly district in West Bengal	Foundation for MSME	1st Sept 2017	15
Technology awareness Technopreneurship at Adityapur	CSIR-NML Organized by CII-Young Indians	1st February 2018	30
* Pitching sessions on Technopreneurship at CSIR-NML *(3 Nos)*	CSIR-NML	i. 22 Sept 2017 ii. 27 Oct 2017 iii. 24 November 2017	40

*The three pitching sessions on "Technopreneurship" were organized at CSIR-NMLIn order to promote CSIR-NML technologies and for creating an open platform for interaction with R & D and industry professionals, aspirants interested to establish entrepreneurial ventures and students.

CSIR-NML's Women Welfare

Each One Teach One (EOTO) training program

The program aims

- To ensure all women employees (permanent, temporary, contract) are literate
- To offer computer training to women who have passed STD X
- To create an environment of sisterhood

The **Training is offered on a one to one basis and comprises of:**

- **Basic Literacy training for women who cannot write their names, addresses, contact information**
- **Basic Computer Literacy for the women who have completed minimum STD X.**

Currently, Twelve NML women employees are benefitting from this program through personal education and guidance based on their respective levels of education and understanding.

Deputations

International Deputations

 	Dr. Indranil Chattoraj, Director-NML, and Dr. Swapan Kumar Das, Senior Principal Scientist, were deputed to Adis Ababa, Ethiopia as a part of CSIR Delegation to MIDI, Ethiopia during 27-05-2017 to 09-06-2017.
	Dr. Sarmistha Palit Sagar, Senior Principal Scientist was deputed to Germany for attending the Kick-off Meeting of NOMAD during 29-05-2017 to 30-05-2017.
	Mr. Sanjay Agarwal, Senior Scientist was deputed to KIGAM, Korea on Raman Research Fellowship during 29-03-2017 to 28-07-2017.
	Dr. Rakesh Kumar, Chief Scientist was deputed to Kosice, Slovakia for Income-2017 during 3-09-2017 to 7-09-2017.
	Mr. Krishna Guguloth was deputed to Dusseldorf, Germany for a Conference during 10-09-2017 to 14-09-2017.
	Dr. Amitava Mitra, Chief Scientist was deputed to Warwick Univ, UK for attending the Project Meeting during 8-10-2017 to 13-10-2017.
	Dr. S. Siva Prasad, Principal Scientist was deputed to Ulm, Germany for an International forum during 15-10-2017 to 20-10-2017.
	Dr. Soumitro Tarafder, Chief Scientist was deputed to Ethiopia, Germany to represent CSIR-NML in the CSIR delegation to MIDI during 06-3-2018 to 16-03-2018.

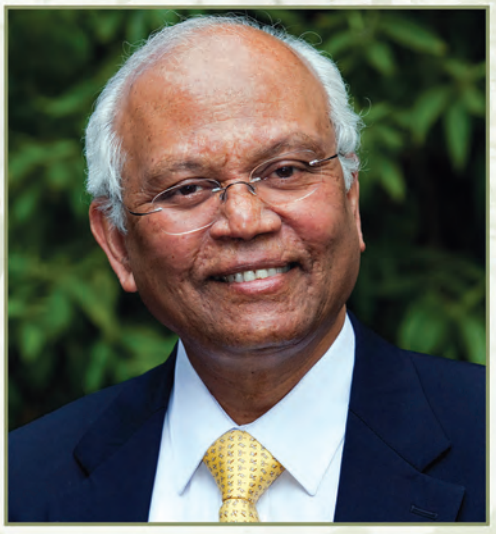
Name and Designation	*Event*	*Place*	*Dates of Deputation*
Dr. PN Mishra, *Principal Scientist*	Training programme on "Effective implementation of RTI and record management"	CSIR-HRDC, Ghaziabad	06-04-2017 to 07-04-2017
Dr. RK Minj, *Senior Principal Scientist*; Dr. D Bandyopadhayay, *Chief Scientist*	National level seminar on "Focus on steel sector"	Vigyan Bhawan, New Delhi	05-04-2017
Mr. Sudip Kundu, *Scientist*; Mr. Birendra Kumar, *Senior Technical Officer*; Mr. AM Pradhan, *F&A Officer*; Mr. Nalin Kumar Singh, *S&P Officer*; Mr. Rachit Ghosh, *Senior Technical Officer*	Workshop cum training program for implementation of procurement in CSIR	CSIR-IICB, Kolkata	24-04-2017 to 25-04-2017
Dr. Sharma Paswan, *Senior Scientist*; Mr. Lalit Meena, *Scientist*	Workshop on "Advance in corrosion in concrete structure-science, Prevention and Repair"	CSIR-CRRI, New Delhi	24-04-2017
Mr. PP Pal, *Technical officer*; Mr. Sanjay Kumar, *Technical Officer;* Mr. Tipu Kumar, *Technical Officer*	Capacity building programme during	CSIR-HRDC, Ghaziabad	24-04-2017 to 28-04-2017
Dr. SG Chowdhury, *Chief Scientist*: Mr. V Rajinikanth, *Senior Scientist*; Ms. Siuli Dutta, *Senior Research Fellow*	International Conference on Materials Engineering (ICME) during	IIT, Kanpur	02-06-2017 to 04-06-2017
Dr. Thomas C Alex, *Principal Scientist*	Seminar on "Management of Industrial and Urban Environment in Indian: The Initiative and Unfinished Agenda"	CGCRI Kolkata	03-06-2017 to 06-03-2017
Dr. Rajat Kumar Roy, *Scientist;* Dr. Shantanu V Madge, *Principal Scientist*	Workshop on 3D Printing	United Club, Jamshedpur	12-06-2017 to 13-06-2017
Dr. AP Murugesan, *Scientist*	National Conference on Physical Simulation of Thermo Mechanical Processing of Materials	IIT Bombay	15-06-2017 to 17-06-2017
Dr. Piyush Chandra Verma, *PA*	Ninth Seminar on Tribology	IIPM, Gurgaon	19-06-2017 to 23-06-2017
Ms. Rupa Das Biswas, *Technical Officer;* Dr. S Chakrarvarty, *Senior Principal Scientist*	Conference on "Indian Coal Mining Sustainable Growth and Way Forward"	Taj Bengal, Kolkata	22-06-2017 to 23-07-2017
Mr. Rajnikant Choudhari, *Technical Assistant*; Mr. RK Mahto, *Project Assistant*; Mr. Ranjan Kumar, *Project Assistant*; Ms. Preeti Karmakar, *Project Assistant;* Ms. Suhani Kumari, *Project Assistant;* Mr. Saurabh Shekhar, *Project Scientist*	Seminar "Behind The Teacher's Desk (BTTD-2017)"	CSIR-NML	22-06-2017 to 23-06-2017

Name and Designation	*Event*	*Place*	*Dates of Deputation*
Dr. Purushotam Kumar, *Senior Hindi officer*	Workshop on Utilization of National Language	CSIR-HRDC, Gaziabad	27-06-2017 to 28-06-2017
Mr. Krishna Kumar, *Principal Scientist*; Dr. NS Randhawa, *Sr. Technical Officer* Dr. Rajendra Kumar Rath, *Principal Scientist*	21st International Conference on Nonferrous Minerals and Metals-2017	CSIR-IICB, Kolkata	07-07-2017 to 08-07-2017
Ms. Minati Km. Sahu, *Senior Research Fellow*; Ms. Sushmita Dey, *Senior Research Fellow*; Ms. Soni, *Senior Research Fellow*	International Conference on "Advanced Materials Development & Performance (AMDP 2017)"	SavitribaiPhule Pune University, Pune	11-07-2017 to 15-07-2017
Dr. AK Pramanick, *Senior Scientist*	Workshop on Challenges in Secondary Metallurgy-Steel Cleanliness and Slag Practice	Center for Excellence Auditorium, Jamshedpur	12-07-2017 to 12-07-2017
Mr. Avanish Kumar Chandan, *Project Assistant III*	International Conference on Electron Microscopy and Allied Techniques and Annual Meeting of the Electron Microscope Society of India	Mahabalipuram, Tamilnadu	17-07-2017 to 21-07-2017
Dr. Abhilash, *Scientist*	Symposium on Science and Engineering for Sustainable Development	IITB, Mumbai	26-07-2017 to 26-07-2017
Dr. VC Srivastava, *Principal Scientist*; Dr. RK Sahu, *Principal Scientist* Dr. GVS Murthy, *Principal Scientist*; Dr. Shobhana Dey, *Principal Scientist*; Dr. Thomas C Alex, *Principal Scientist*	Leadership Development Programme	CSIR-IICB, Kolkata	31-07-2017 to 04-08-2017
Dr. PN Mishra, *Principal Scientist*	11th International CALIBER: Convention Theme: Re-Envisioning Role of Libraries: Transforming Scholarly Communication	Anna University, Chennai	02-08-2017 to 04-08-2017
Mr. Sarbeswar Thatoi, *Technical Assistant* Ms. Monica Sahoo, *Technical Assistant* Mr. RajanikantChoudhari, *Technical Assistant*	Orientation Tanning Programme	HRDC, Ghaziabad	21-08-2017 to 25-08-2017
Mr. Avanish Kumar Chandan, *Project Assistant*	24th congress and general assembly of the IUCR and workshop on "Rigaku Oxford Diffraction: CrysAslisPro and Olex2"	HICC, Hyderabad	21-08-2017 to 28-08-2017
Mr. Avanish Kumar Chandan, *Scientist;* Mr. Snehashish Tripathy, *Scientist*	Course on TEM	R&D Division, Tata Steel Ltd, Jamshedpur	12-09-2017 to 14-09-2017
Mr. AM Pradhan, *F&A Officer*; Mr. Robert Barla, *Section Officer*; Mr. Ashish Kr Upadhyay, *Sr. Technical Officer*; Mr. Santosh Tiwary, *Project Assistant*	Training programme on "Public Fund Management System"	RDCIS, SAIL, Ranchi	15-09-2017

Name and Designation	*Event*	*Place*	*Dates of Deputation*
Ms. Sushmita Dey, *Senior Research Fellow*	"Young Scientist Colloquim-2017"	IIEST, Shibpur	10-10-2017 to 12-10-2017
Dr. Abhilash, *Scientist*; Mr. Premkumar M, *Scientist*	"3rd Indian International Festival"	Anna University, Chennai	13-10-2017 to 16-10-2017
Mr. Sanatan Naiya, *Senior Technician*	"Bonsai Workshop"	Tube Makers Club, Jsr.	15-10-2017 to 15-10-2017
Dr. NS Randhawa, *Senior Technical Officer*; Dr. Manoj Kumar, *Principal Scientist*	Workshop on Design and Analysis of Experiment	Indian Statistical Institute, Kolkata	06-11-2017 to 11-11-2017
Mr. Rachit Ghosh, *Senior Technical Officer*; Mr. RK Minj, *Senior Principal Scientist*; Dr. Ratnakar Singh, *Chief Scientist*; Ms. Minal Shah, *Scientist*; Dr. B Ravi Kumar, *Senior Principal Scientist*; Mr. Avanish Kr. Chandan, *Scientist*; Dr. KK Sahu, *Senior Principal Scientist*; Mr. Gaurav; *Project* Mr. Sumanta Bagui, *Scientist*; Dr. NS Randhawa, *Senior Technical Officer*; Ms. Aarti Kumari, *Scientist*	55th National Metallurgist Day & 71st Annual Technical Meeting (NMD. -ATM 2017)	Birla Institute of Technology & Science, Goa	11-11-2017 to 14-11-2017
Dr. Krishnendu Mukherjee, *Principal Scientist*	Lecture/ course on additive manufacturing	Tata Steel, Jamshedpur	16-11-2017 to 17-11-2017
Dr. RK Minj, *Senior Principal Scientist*; Mr. DP Singh, *Senior Technical Officer*	31st National conference on "Strengthening Green Production: Building Pillars for New India"	Hotel Le-Meridian, New Delhi	23-11-2017 to 25-11-2017
Mr. Lalit Kr. Meena, *Scientist*; Ms. Charu Singh, *Senior Research Fellow*	Conference on "Advance in materials & Production: Challenges & Opportunities (AMPCO-2017)	IIT Roorkee	30-11-2017 to 02-12-2017
Dr. AK Arya, *Senior Medical Officer*	1st RSSDI (Diabetes)	Hotel Kennelite, Jamshedpur	18-11- 2017
Mr. Chandra Veer Singh, *Scientist*; Ms. Y Usha, *Scientist*; Mr. SaurabhShekhar, *Scientist*; Mr. Shivendra Sinha, *Scientist*	Induction Training Programme for newly recruited scientists	CSIR-HRDC, Ghaziabad	15-01-2018 to 24-01-2018
Dr. Gopi Kishor Mandal, *Senior Scientist*; Dr. VC Srivastava, *Principal Scientist*	National Seminar on "Role of Stakeholder in Development of Road Map for Steel Vision"	Sir R. N Mookerjee Hall, Kolkata	19-01-2018 to 20-01-2018
Mr. Pankaj Kumar, *Technical Officer*; Mr. Manoj Kumar, *Senior Technician*; Mr. Dilip Kumar Sumbrui, *Technician*	Workshop on "Latest Tends & Development in CAD/CAM"	IDTR, Jamshedpur	20-01-2018

Name and Designation	*Event*	*Place*	*Dates of Deputation*
Mr. Kalicharan Hembrom, *Scientist* Mr. Abhishek Kumar, *Scientist*	Workshop on "Uranium and Other Mineral in Singhbhum Shear Zone - Historical Perspective and Its New Dimension"	AMD Khasmahal, Jamshedpur	22-01-2018 to 23-01-2018
Mr. C. Soupramanien, *Senior Technical Officer*	2nd Workshop on "Evaluation of Measurement of Uncertainty and ISO 17025"	CSIR- HRDC, Ghaziabad	29-01-2018 to 01-02-2018
Dr. Swapna Dey, *Principal Investigator*; Dr K Gopala Krishna, *Principal Scientist*; Dr. Sharma Paswan, *Senior Scientist*; Mr. Mahesh G Walunj, *Scientist*	Workshop on "Managing Corrosion in the Oil and Gas Sector"	CSIR-HRDC, Ghaziabad	30-01-2018 to 31-01-2018
Ms. Minal Shah, Scientist	"Texture Course"	Tata Steel Ltd, Jamshedpur	31-01-2018 to 03-02-2018
Dr. Manoj Kumar, *Principal Scientist*	Invited Talk at the International Conference IC-RAMSD 2018. .	MS university, Kalabhawan, Vadodra	01-02-2018 to 03-02--2018
Dr. Dayanand Paswan, *Scientist* ; Dr. M. Matahi, *Scientist*	International Conference on "Recent Advance Metallurgy for sustainable Development (IC-RAMSD 2018)".	MS university, Kalabhawan, Vadodra	01-02-2018 to 03-02-2018
Mr. Rohit B. Meshram, *Scientist*	Training programme on "Environment Impact Assessment (EIA)".	CSIR-NEERI, Nagpur	05-02-2018 to 09-02-2018
Mr. SK Nath, *Scientist;* Dr. SK Mishra, *Chief Scientist*; Mr. Avanish Kr. Chandan, *Scientist*; Ms. Minal Shah, *Scientist;* Mr. Gaurav Kr. Bansal, *Scientist;* Mr. Ganesh Chalavadi, *Scientist*	Asia Steel International Conference 2018.	Bhubaneswar, Odisha	06-02-2018 to 09-02-2018
Ms. Paromita Biswas, *NPDF*; Mr. Gopi Kishor Mandal, *Senior Scientist;* Mr. Ashok K, *Scientist*; Dr. LC Pathak, *Senior Principal Scientist;* Mr. Ammasi A, *Scientist;* Ms. RashmiSingla, *Project Assistant III;* Dr. Sharma Paswan, *Senior Scientist;* Ms. Monica Sahoo, *Technical Assistant*			
Ms. Siuli Dutta, *Senior Research Fellow*	GIAN course on "Microstructure and texture of materials".	Jadavpur, Kolkata	07-02-2018 to 15-02-2018
Dr. Sanjay Kumar, *SeniorScientist*; Dr. Navneet Singh Randhawa, *Senior Technical Officer*	Course on "Manganese/chrome ore and ferro-alloys".	Visakhapatnam	-02-2018 to 16-02-2018

Name and Designation	*Event*	*Place*	*Dates of Deputation*
Mr. ShehashishTripathy, *Scientist;* Dr. S Ghosh Chowdhury, *Chief Scientist;* Dr. Jay Chakaraborty, *Principal Scientist*	National conference on "Science and technology of special steel and NANO-Materials(STSSN)".	BIT Sindri	17-02-2018 to 18-02-2018
Mr. AM Pradhan, *Finance And Accounts Officer*	Seminar cum Workshop of "Mother Tongue Based Multilingual Education (MTB-MLE)"	Bhubaneswar	19-02-2018 to 21-02-2018
Dr. Ratnakar Singh, *Chief Scientist*	National Seminar on "Make in Steel for Make in India- Perspectives for Iron and Steel Industry"	CSIR-CGCIR, Kolkata	22-02-2018 to 23-02-2018
Dr. Trilochan Mishra, *Principal Scientist*	Convener, in National conference on "Recent advances in materials for sustainable energy (RAMSE)"-2018	Department of Applied Chemistry, IIT-ISM, Dhanbad, Jharkhand	03-03-2018 to 05-03-2018
Ms. Siulidutta, *CSIR- Senior Research Fellow;* Dr. SaswatiChakladar, *National-Post Doctoral Fellow;* Ms. SushmitaDey, CSIR- *Senior Research Fellow*	National Conference on "Technological Empowerment of Women: Commemorating the International Women's Day".	The National Academy of Sciences, VigyanBhawan , New Delhi	08-03-2018 to 09-03-2018
Dr. Saswati Chakladar, *National-Post Doctoral Fellow;*	First Internal Conference on "Energy and Environment: Global Challenges (ICEE-2018)".	National Institute of Technology , Calicut	09-03-2018 to 10-03-2018
Ms. SuhaniKumari, *Project Assistant-I ;* Ms. PreetiKarmakar, *Project Assistant-I*	National Conference on "Waste to Wealth in Mineral and Metallurgical Industries - 2018.	CSIR-IMMT, Bhubaneswar	09-03-2018 to 10-03-2018
Ms. Y Usha, *Scientist*	"Train the Trainers" program organized by CSIR-Management & entrepreneurship and Professional Skill Council.	CSIR-CLRI, Chennai	12-03-2018 to 16-03-2018
Mr. Modassir Akhtar, *Project Assistant -II;* Mr. PS Manoranjan Jena, *Project Assistant -II*	Course on "Advanced Electron Microscopy for Materials Science".	JNU, New Delhi	13-03-2018 to 22-03-2018
Dr. S. Chakravarty, *Senior Principal Scientist;* Dr. AK Upadhyay, *Senior Technical Officer*	Seminar on "Production of Certified Reference Materials in India".	CSIR-NPL, New Delhi	16-03-2018 to 16-03-2018
Ms. Siuli Dutta, CSIR- *Senior Research Fellow*; Ms. Charu Singh, CSIR- *Senior Research Fellow*	International Conference on Advanced Materials and Manufacturing Processes".	IIM, Vizag chapter	30-03-2018 to 31-03-2018



Dr. R.A. Mashelkar | 1995 - 2006

Dr. Raghunath Anant Mashelkar, (born in 1943) also known as Ramesh Mashelkar, is an Indian chemical engineer. Dr. Mashelkar has made contributions in transport phenomena, particularly in thermodynamics of swelling, superswelling and shrinking polymers, modelling of polymerisation reactors, and engineering analysis of Non-Newtonian flows. Dr. Mashelkar has received over fifty awards and honorary doctorates and is a member of numerous scientific bodies and committees. The President of India honoured him with Padma Shri (1991) and with Padma Bhushan (2000). He was appointed as an International Fellow of the Royal Academy of Engineering in 1996. In 2013, he was awarded Gomant Vibhushan Award, the highest civilian honour of the state of Goa. On 25 January 2014, he was awarded Padma Vibhushan, 2nd highest civilian honour of India by the President of India. Dr. R Mashelkar is presently the President of Global Research Alliance, a network of publicly funded research and development institutes from Asia-Pacific, South Africa, Europe and USA with over 60,000 scientists. He is the Chairperson of India's National Innovation Foundation. He was appointed as the first Chairperson of Academy of Scientific and Innovative Research (AcSIR). He is also the chairman of the Reliance Innovation Council formed by Reliance Industries Limited, India.

Prof. Samir K. Brahmachari | 2007 - 2013

Prof. Samir Kumar Brahmachari (born in 1952) is an Indian biophysicist. He was the Founder Director of the Institute of Genomics and Integrative Biology (IGIB), New Delhi and the Chief Mentor of the Open Source for Drug Discovery (OSDD) Project. He was the recipient of J.C Bose Fellowship Award, DST (2012). Prof. Brahmachari's primary research involves elucidating the role of repetitive DNA in genome function in health and disease using a trans-disciplinary approach, integrating structural biology with genomics, molecular biology and information science. He has more than 12 patents, 23 copyrights and over 150 research publications to his credit. He was conferred the Banga Bibhushan Title, the highest state civilian award by the Government of West Bengal in recognition of his outstanding contributions to the field of Life Sciences in 2013. He has been selected as one of the Fierce's Top 10 Biotech Techies for his outstanding contribution to the field of genomics and open source drug discovery.

CSIR-Platinum Jubilee Celebrations

CSIR Capsule Exhibition (21st-23rd September 2017)

Three-day long CSIR Capsule Exhibition as a part of CSIR Platinum Jubilee Celebrations highlighted the major achievements of CSIR in Scientific & Industrial research. The theme of this exhibition was 'Technologies, Products & Technological Services'. The contributions of all 38 laboratories of CSIR in the context of Nation building was showcased in this exhibition under the broad headings of 'Mining, Minerals & Materials', 'Engineering & Infrastructure', 'Chemical & Petrochemicals', 'Aerospace & Strategic Sectors', 'Ecology & Environment', 'Health Care & Genomics', 'Agriculture & Floriculture', 'CSIR for Societal Interventions', 'Energy', Food & Nutrition', 'Leather' & 'Water'. The objective of this event was to disseminate the knowledge in terms of Technologies, Products & Technological Services of CSIR as a whole to attract Academia, Industries, R&D fraternity and the common people of India to know the contributions of CSIR during the 75 years of its journey towards the development of the nation. Mr. Anand Sen, President TQM and Steel Business, Tata Steel Ltd., inaugurated the exhibition. Chief Executive Officers of various Small Scale, Medium Scale and Large Scale industries of Jamshedpur, Directors of Academic Institutions, Principals/Vice-Principals of Local Schools and Colleges of Jamshedpur, NML retirees, NML scientists and other guests, witnessed the inauguration and participated in the exhibition. Mr. Sen in his address during the inauguration function congratulated CSIR and stressed upon a collaborative - industry interactive model. More than 1500 students from various schools, colleges, technical institutions, and engineering colleges visited the exhibition.

Industry Conclave/Panel Discussion (21st Sept 2017)

An Industry conclave was also organized in conjunction with the Capsule Exhibition to capitalize on the presence of industrialists on the occasion. The main objective of this panel discussion was to calibrate the new R&D problems of the industry as well as to understand the gap areas that limit R&D solutions. Mr. Anand Sen, President TQM & Steel Business, Tata Steel Ltd. acted as the moderator of the discussion and the other panelist were Shri Amitava Sircar, COO [Usha Martin Ltd.], Dr. Ashish Bhaduri, COO [Tata Bluescope], Prof. P.P. Chattopadhyay, Director [NIFFT], Prof. Atul Pathak, [XLRI], Shri AB Lall, Head, M&CVBU [Tata Motors], Shri SK Behera, VC & MD [RSB Global] and Dr. I.Chattoraj, Director, NML. Before the discussion, Mr. Sen delivered a speech on the lack of co-ordination between research institutions and industries and stressed upon collaborations between industry and R&D from anincipent stage of the R&D process to get a better understanding of the real problems as well as practical and feasible view of the proposed solutions. Afterwards the panel discussion was conducted on the topic of "*future role of research institution and industries for the growth of Indian economy*".

Workshop and Pitching Session on Entrepreneurship Opportunities In Minerals, Metals & Materials (Technopreneurship) (21st September 2017)

A pitching session was organized at CSIR-NML in conjunction with the Capsule Exhibition. A number of prospective entrepreneurs pitched their own technologies and technological ideas. Prof. Prabal Sen, XLRI delivered the keynote lecture on "*Entrepreneurship*" and Mr. Munish Sudan, Tata Steel delivered a talk on "*The path from Invention to Innovation - Myths & Realties*".

Platinum Jubilee Lectures

Dr. S.V. Kamat
Director, Defence Metallurgical Research Laboratory, Hyderabad
"Aeroengines : Materials and Manufacturing Processes"
25th May 2017

Sir Prof. H K D H Bhadeshia
TATA Steel Chair Professor, University of Cambridge, Cambridge, UK
"The atomic mechanism of the bainite transformation in steels"
08th Sep 2017

Prof. Kamanio Chattopadhyay
Dept of Materials, Indian Institute of Science, Bengaluru
"Excitement in developing a new alloy class: The example of Cobalt-based Super-alloy"
13th Jun 2017

Dr. Baldev Raj
Director, National Institute of Advanced Studies, Bengaluru
"An approach to Research, Development and Deployment of Advanced Structural Materials"
19th Sep 2017

Prof. Partha P Chakrabarti
Director, Indian Institute of Technology Kharagpur
"Have I Designed What I Desired? – Intent Verification of Safety Critical Embedded Controls Software"
19th Jul 2017

Prof. Indranil Manna
Director, Indian Institute of Technology, Kanpur
"Materials Science, Engineering and Technology: Opportunities and Challenges"
26th Sep 2017

Dr. Debashish Bhattacharjee
Vice President, New Materials Business, Tata Steel
"Making money from materials"
31st Jul 2017

Distinguished Visitors

Speaker	Topic	Date	
Dr. Shantanu Chakrabarti, Former Head of Research Applications, Tata Steel, Jamshedpur	**"Quantify to Qualify: A Vigilant Vision on Energy "**	27th Apr 2017	
Prof. Ashok Ganguli, Director, Institute for Nano Science and Technology, Mohali	**"Design of Nano Structured Materials For Applications In Light Harvesting, Field Emission and Bio-sensing**	18th Apr 2017	
Dr. Arup Roy, Senior Director, Research & Technology, Second Sight Medical Product Inc., California, USA	**"Restoring vision to the blind - The Argus II retinal prosthesis system"**	19th May 2017	
Dr. Anjan Ray, Director, CSIR-Indian Institute of Petroleum Dehradun	**"Precision Research Approaches"**	12th June 2017	
Prof. V S Raja, Dept. of Metallurgical Engineering and Materials Science, IIT Bombay	**"Metallurgical and Electrochemical Factors in Development of High Strength Aluminum Alloys Having High-Stress Corrosion Cracking Resistance"**	14th Aug 2017	
Dr. Subir Bhaumik, CSIR-National Aeronautics Limited,	**"Nickel-Titanium Shape Memory Alloys: An Experience"**	25th Aug 2017	
Dr Nawshad Haque, Scientist, CSIRO (Australia)	**"Techno-economic evaluation (TEE) and life cycle assessment (LCA) of mineral processing and metal production technologies"**	09th Aug 2017	

Speaker	Topic	Date	
Mr. Manoj Kumar, District Judge, East Singhbhum	**Vigilance Awareness related topic(My vision: Corruption Free India"**	31st Oct 2017	
Dr. Suneel TS, General manager - Open Innovation, TATA Services Ltd	**"Open Innovation Talk"**	26th Oct 2017	
Dr. Sourav Pal, Director, Indian Institute of Science Education and Research (IISER) Kolkota	**Dr. B.R. Nijhawan Memorial Lecture on CSIR-NML Foundation Day on the topic "Multiscale Simulation: From Molecules to Materials"**	27th Nov 2017	
Prof Walter Arnold, Dept. of Materials Science & Materials Technology, Saarland University, Saarbreucken, Germany and I. PhysikalischesInstitut, Georg-August Universitat, Fritz-Hund-Platz 1, Gottin	**"Contact Mechanics Applied to Measure the Mechanical Surface Properties of Comet 67P"**	31st Jan 2018	
Dr. DH Van Der Weijde, Program Manager, Tata steel Europe Research and Development , Netherlands (12th Feb 2018)	**"Recent advances in electroplating and Formable polymer coating"**	12th Feb 2018	
Prof. NN Viswanathan, Dept. of Metallurgical and Materials Science, IIT, Mumbai	**"A methodology to quantify the physicochemical phenomena during induration of single magnetite pallet"**	28th Feb 2018	
Mr Ashok Kumar, CTO, Tata Steel	**"With an iron hand"**	21st Mar2018	

Special Events

Seventieth Meeting of CSIR-NML Research Council (11.04.2017)

The meeting was held to discuss major ongoing R&D activities of the laboratory. Chairman-RC, Mr. HM Nerurkar along with other members, Director-NML, Dr. I. Chattoraj, and CSIR-NML staff attended the meeting.

Hindi Narakas (28.04.2017)

This 40th meeting was conducted to review the use of official language in the government offices of the town. Representatives from the all such offices in and around Jamshedpur attended the meeting.

National Technology Day Celebrated (11.05. 2017)

Nineteenth National Technology Day was celebrated on May 11, 2017 at CSIR-National Metallurgical Laboratory, Jamshedpur, Jharkhand. Shri Mahavir Prasad Jalan, Chairman, Ramakrishna Forgings Ltd., Gamariha graced the function as Chief Guest and delivered Technology Day Lecture towards the various challenges faced during his journey of over Forty years for various shape development through his extended experience of forging & foundry technologies. On the occasion of Technology Day, Technology Day Quiz 2017 competition was organized at National Metallurgical Laboratory Auditorium, Jamshedpur. During the function, CSIR-NML Annual Report 2016-2017 was also released by the Chief Guest. Prof. Partha Pratim Chattopadhyay, Director, NIFFT, Ranchi was the Guest of Honour and he delivered lecture on an exciting topics of challenges of bridging the gap between Skill & Education in Manufacturing.

Blood Donation Camp (17.05.2017)

NML Staff Club of CSIR-NML organised a Blood Donation camp at NML Auditorium Foyer on 17th May, 2017. In this occasion NML's S&T, Administrative staff, Research Scholars and students donated the blood. A total of 83 units of blood were collected. NML Director, Dr. I. Chattoraj emphasized on the importance of voluntary blood donation and encourage the staff to donate blood in a regular basis and save life. This blood donation camp was organised with the help of Jamshedpur Blood Bank and supported by State Bank of India, NML Branch, Finance Mitra, Big Mart and Purnima Security.

Inauguration of Tungsten Extraction Pilot Plant at CSIR-NML (25.05.2017)

Dr. Samir V Kamat, Outstanding Scientist & Director, Defence Materials Research Laboratory (DMRL) inaugurated the 'Tungsten Extraction Pilot Plant' at CSIR-National Metallurgical Laboratory (NML) on 25th May, 2017. Defence Research & Development Organization (DRDO) through Defence Metallurgical Research Laboratory (DMRL), Hyderabad has financed for setting-up of this pilot plant at CSIR-NML located at Nildih. The CSIR-NML 'Tungsten Extraction Technology' was demonstrated in this pilot plant before its commercialization by DRDO. CSIR-NML in the recent past has already developed and successfully commercialized tungsten carbide scrap recycling technology.

CSIR Inks $7 Million Twinning Agreement With Midi Ethiopia (17.06.2017)

The Council of Scientific and Industrial Research (CSIR) had inked a nearly 7 million dollar twinning agreement with the Metals Industry Development Institute (MIDI) of the Federal Democratic Republic of Ethiopia located in the Horn of Africa for capacity and capability building of MIDI. This is the largest foreign sponsorship received by CSIR till date. CSIR-National Metallurgical Laboratory (NML) is the nodal laboratory for the twinning programme which will be jointly executed with four other CSIR laboratories Viz CSIR-Central Mechanical Engineering Research Institute (CMERI)), CSIR-Central Electronics Engineering Research Institute(CEERI), CSIR-Central Scientific Instruments Organisation (CSIO), CSIR-Central Leather Research Institute (CLRI).

The steering committee for the twinning from Ethiopia, consisting of eight delegates including their State Minister for Education Teshome Lemma, the Director General of MIDI, Workneh Delelegn, and six other distinguished personalities from Ethiopian industries and academies, visited CSIR-NML on 17th June, 2017, to have a first-hand glimpse and feel of the excellent facilities and expertise of this Jamshedpur based CSIR laboratory. The various technologies developed by CSIR-NML, which may be of relevance to the Ethiopian industries, were also showcased.

Students' Seminar On Metallurgical Engineering "behind The Teacher's Desk" (BTTD-2017) (22-23, June, 2017)

The two-day Students' seminar on metallurgical engineering "Behind The Teacher's Desk" (BTTD-2017), organized jointly by The Indian Institute of Metals (IIM), Tata Steel Limited and CSIR-National Metallurgical Laboratory (NML) kicked off at CSIR-NML. The seminar was inaugurated with the release of seminar souvenir by the Chief Guest Shri Sudhanshu Pathak, Vice President, Steel Manufacturing, TATA Steel Ltd., Jamshedpur, and the Guest of Honor, Dr. Indranil Chattoraj, Director, CSIR-NML, Jamshedpur. This students' seminar is being held at the CSIR-NML for the past six years and has been a great success. Like previous years, this year also more than 80 students from 32 engineering colleges /institutes from different parts of the country were participated, and around 62 technical papers were presented in two parallel sessions.

Contract Bridge Pairs Championship (16.07.2017)

CSIR-NML Staff Football Tournament (12.08.2017)

Independence Day Celebrations (15.08.2017)

Independence day was celebrated at CSIR-NML and its residential complexes. Staff members along with their family participated in the celebrated. On this occasion, the CSIR-NML Staff Club also organized Cultural programme.

5th Prof. S. N. Sinha Memorial Materials & Metallurgy Quiz (SNSM3Q 2017) (17.08.2018)

The Indian Institute of Metals (IIM), Jamshedpur Chapter, organized the 5th "Professor S. N. Sinha Memorial Materials and Metallurgy Quiz 2017 (SNSM3Q-2017) for standard XI and XII students of Jharkhand State in CSIR-NML's Auditorium, Burmamines. In addition to 19 participating schools comprising of 76 students along with teachers, many dignitaries from Tata Steel and CSIR-NML attended the function. The Chief Guest, Dr. Indranil Chattoraj, Director, CSIR-NML, Jamshedpur formally inaugurated the programme.

Six teams qualified in the screening round out of 38 teams, representing from 19 schools. The qualifier schools were – DBMS English School, Vidya Bharati Chinmaya Vidyalaya, Loyola School, Narbheram Hansraj English School, DBMS Kadma High School, Atomic Energy Central School, Jaduguda. After series of interesting rounds, Mr. Prashjot Singh and Nishant Kumar Satyam from Vidya Bharati Chinmaya Vidyalaya were declared champions. Mr. Abhimanyu Shome and Souvik Ghosh from Narbheram Hansraj English School got Second Rank. Mr. Nikhil Nilesh and Abhishek Kr. Patra from Loyola School stood third.

National Workshop on Hot Dip Galvanizing of Steels (HDGS-2017) (21-22 August,2017)

CSIR-National Metallurgical Laboratory (NML), Jamshedpur in association with TSL organized a National workshop on 'Hot Dip Galvanizing of Steels (HDGS-2017)' during August 21-22, 2017 at CSIR-NML with the financial support from (SDF), MoS, Govt. of India and TSL, Jamshedpur. This workshop gives an opportunity for industry, R&D centres and academic institutions

to share their experiences and update the current knowledge base. Shri Neeraj Kant, Managing Director, ISWP, Jamshedpur as a Chief Guest inaugurated the workshop and he narrated that this type of workshop would help the industries & institutions to share their knowledge for any joint venture in future. He also focused on the importance of inter-relations among research institutions, academia and customer for the end fruitful uses of research translations. Dr. Indranil Chattoraj, Director CSIR-NML, delivered the welcome address. Dr. Monojit Dutta, TSL as Chairman of the workshop briefed the contents of the workshop. Shri L Pugazhenthy, Executive Director, ILZDA, New Delhi as Guest of honour explained the genesis & history of Hot Dip Galvanizing in India and it's utilities in the context of any countries of the world.

Hindi Satpah Celebrations (15.09.2017)

NML Celebrates CSIR Platinum Jubilee (26.09.2017)

CSIR-NML celebrated the CSIR Platinum Jubilee Foundation Day. Prof. Indranil Manna, Director of Indian Institute of Technology Kanpur graced the occasion as the Chief Guest. Prof. Manna gave away the CSIR Platinum Jubilee awards in Debate and Essay Competitions (both in English and Hindi categories) and six meritorious student awards.

Workshop on Science and Technology Sensitization program for the Women leading towards Excellence in Science (5-6 October, 2017)

In collaboration with National Metallurgical Laboratory (NML), Jharkhand State Chapter of The National Academy of Sciences, India (NASI) organised a two-day workshop entitled 'Science and Technology Sensitization Program for the Women leading towards Excellence in Science' at NML's Auditorium. More than 300 women participants (research scholars/ faculty) from Jharkhand and other states were attended the workshop. Representatives from BIT, Mesra, Central University of Jharkhand, Ranchi University, Kolhan University, Jamshedpur Women's College, Co-operative College, Graduate College, CSIR-NML, NIT Jamshedpur, SOA University (Bhubaneswar), are participating in it. Chief Guest Prof. Manju Sharma, former Secretary of Department of Biotechnology, Government of India, Prof. U.C. Srivastava, General Secretary, NASI, India, Dr. Rakesh Kmar, Dr. Arvind Sinha and Dr. Niraj Kumar, Executive Secretary, NASI inaugurated the workshop.

Vigilance Awareness Week (31.10.2017)

68th Foundation Day of CSIR-National Metallurgical Laboratory (27.11.2017)

The 68th Foundation Day of CSIR-National Metallurgical Laboratory, Jamshedpur was celebrated in the laboratory's auditorium. The function was attended by many dignitaries, scientists, retirees, and other laboratory staffs and invites. The function started with CSIR-NML Geet along with a slide show on CSIR-NML's journey from the initial days to the present. CSIR-NML Director, Dr. I. Chattoraj briefed about the CSIR-NML activities and performance during the last financial year followed by the recollections by Dr. Raghubir Singh, Ex-Scientist of CSIR-NML. Chief Guest, Prof. Sourav Pal, gave away the laboratory's Annual Awards 2017, namely – Dr. BR Nijhawan Award for best technical paper, Prof. Shilowbhadra Banerjee Award for best in-house project, Prof. P Ramachandra Rao Award for best employee both from technical and non-technical. Dr. I. Chattoraj, Director, CSIR-NML gave away the meritorious Student Awards and also gave away Special Appreciation Award instituted this year. Chief Guest Prof. Sourav Pal, delivered the Nijhawan Memorial lecture on the topic, "On Computational Chemistry".

Seventy-first Meeting of CSIR-NML Research Council (30.11.2017)

The meeting was held to discuss major ongoing R&D activities of the laboratory. Chairman-RC, along with other members, Director-NML, Dr. I. Chattoraj, and CSIR-NML staff attended the meeting.

Coal for Metallurgical and Thermal Applications : An Appraisal of its Characterization & Utility (CMTA-2018) (22-25 January 2018)

The four-day interactive programme on "Coal for Metallurgical and Thermal Applications: An Appraisal of its Characterization & Utility (CMTA 2018)", organized by CSIR-National Metallurgical Laboratory (NML). The Chief Guest, Prof. Rajender Gupta from University of Alberta, Canada, formally inaugurated the seminar. Dr. Indranil Chattoraj, Director, CSIR-NML, Jamshedpur, Dr. D. Bandyopadhaya and Dr. Sanchita Chakravarty were present during the inaugural function. More than 50 delegates from 12 Industry, Academia & Research Laboratory from different parts of the country are participating. The organizations are – NTPC; CCL, Ranchi; ECL, Asansol; ISM, Dhanbad; BCCL, Dhanbad; Inspectorate Griffith; D.B. Power Ltd, Raigarh; CMPDI, Ranchi; JNU, New Delhi; Tata Steel Jamshedpur; Usha Martin, Jamshedpur; NIT, Jamshedpur; CCO, Kolkata and ISP, Burnpur. Around 15 technical lectures were presented by eminent professor and scientist of global repute in seven sessions, namely - *Thermal Coal Characterization, Coal Beneficiation, Behavior of thermal coal, Environmental issues, Metallurgical Coal and Coal Beneficiation.*

CSIR-NML Staff Picnic at Hill View Resort (24.01.2018)

Republic Day Celebrations (26.01.2018)

Republic day was celebrated at CSIR-NML and its residential complexes. Staff members along with their family participated in the celebrated. On this occasion Badminton Tournament (Single and Doubles) were also organized by the CSIR-NML Staff Club.

National Science Day Celebration (27.02.2018)

The Jharkhand Chapter of the National Academy of Sciences, India (NASI) jointly with CSIR-National Metallurgical Laboratory, Jamshedpur celebrated the National Science Day on 27th February 2018 with great pomp and show. In addition to NML Scientific and technical staff more than 200 students from Jamshedpur based institutions like Keonjhar Institute of Technology, Odisha; Tata Steel Technical Institute, Jamshedpur, 50 teachers / principals from different schools in and around Jamshedpur city were also attended as invitees.

The Chief Guest, Prof Murali Sastry, CEO, IIT Bombay-Monash University Research Academy, delivered a popular lecture on Nanotech and Consumer Products: the story of TATA SWACH". The talk encompassed a detail on nanotechnology-based solution to solve the problem of safe and clean drinking water for the poor. The Chief Guest, Dr. Murali Sastry, Dr. I Chattoraj, Director NML and Dr. Arvind Sinha, Chairman of the NASI Chapter gave away the "BEST SCIENCE TEACHER AWARD of

Jharkhand State for the academic session 2017" to four teachers (two in PGT and two in TGT category), sponsored by Jharkhand State Chapter of NASI. The award comprises of Rs. 10000/- each and citation. Following teachers received the award: Mr. Bibhuti Nath Jha, Jawahar Vidya Mandir Ranchi (PGT) and Mrs Sangeeta Chatrath, Little Flower School, Jamshedpur (PGT) and Mr. Manoj Kumar Singh, Upper Middle School, Potka (TGT) and Mr. Amod Mishra, Upper High School, Chaibasa (TGT)

International Women's Day Celebration (08.03.2018)

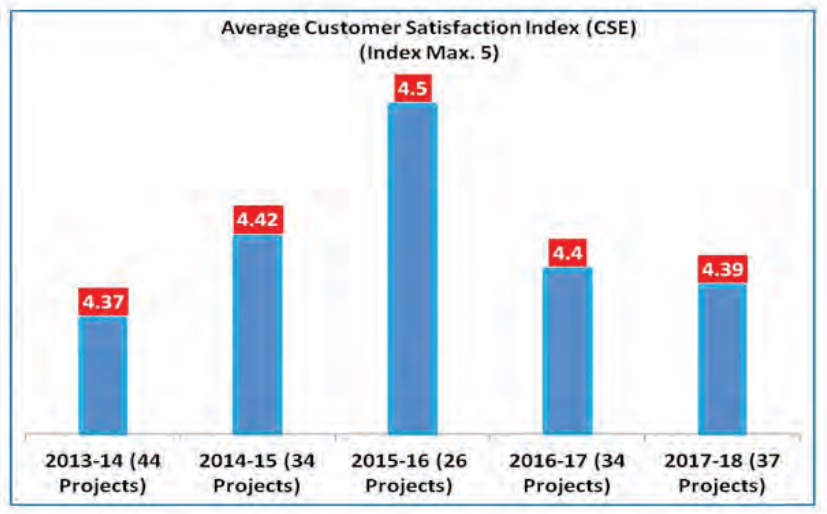
A series of events were organized on the occasion viz. Group dance, Art and Creativity, Food stall, Rangoli by the female staff of CSIR-NML. Two lady staff (contractual) of CSIR-NML was awarded for their contributions and performance through out year.

CSIR-NML In-house Publications and News

Dr. Girish Sahni | 2015 onwards

Dr. Girish Sahni (born in 1956) joined CSIR-IMTECH in 1991 and became its Director in 2005. He is currently the Director General, CSIR. His contributions in the area of protein cardiovascular drugs especially 'clot busters' and their mode of action in the human body is extremely significant. He led teams responsible for producing technology for India's first indigenous clot bluster drug, natural streptokinase (under brand name 'STPase' marketed by Cadila Pharmaceuticals Ltd., Ahmedabad), and recombinant streptokinase (produced by Shasun Drugs, Chennai) marketed in several brand names like 'Klotbuster' (Alembic) and 'LupiFlo' (Lupin). He developed a novel life-saver thrombolytic drug (Clot-specific streptokinase) India's first bio therapeutic molecule which has been patented world wide, and licensed to a US Pharma company in 2006. He has recently, developed fourth-generation 'Anti-thrombotic' clotbusters that have been out-licensed in multi-million dollar deals. Amongst the many awards that he has received for his contributions, the most important ones are: National Biotechnology Product Development Award 2002, CSIR Technology Shield 2001-2002, The Vasvik Industrial Award 2000, Ranbaxy Award in Pharmaceutical Sciences 2003, Vigyan Rattan Award 2014, Shri Om Prakash Bhasin Award 2013, and CSIR Technology Award for Business Development and Technology Marketing 2014.

Customer Satisfaction Evaluation Index and Feedback



Comments from our Collaborators and Sponsors

Technical expertise and core competence is excellent. However, meeting project schedules within stipulated time needs due attention and management focus **(SSP 0919).**

Liquid Propulsion Systems Centre, ISRO, Bangalore

We found solution which we were searching since long **(SSP 0985)**.

Kapilansh Dhatu Udyog Pvt. Ltd., Nagpur

Response from NML team is very good **(SSP 0890)**.

Hindustan Zinc Limited, Rajasthan

Excellent facility and others **(CLP 0141)**.

Tata Steel Limited, Jamshedpur

Accessibility, Commitment, Flexibility. Improvement area: 1) Printing, and 2) Time management **(SSP 0903)**.

The Ramco Cement Ltd., Tamilnadu

Very Innovative approach and supportive **(SSP 0891)**.

Oren Hydrocarbons Pvt Ltd., Chennai

The proposed result of pilot scale level chemistry need to be tried for "controlled filed trials" at plant CO_2-HSM route) for verification & validation of % HER achievement **(CLP 0149).**

Tata Steel Limited, Jamshedpur

List of Patent sent to IPU-CSIR for filing

SN	REFERENCE NO.	Title	INVENTOR
1	PAT-0512/2017/IN	A process for the preparation of high chromium cast iron for grinding media applications	Minal Shah, Swapan Kumar Das, Kanai Lal Sahoo, Gautam Das, Sandip Ghosh Chowdhury and Palash Poodar
2	PAT-0513/2017/IN	A process for preparation of austempered high chrome bainitic Cast iron for grinding media application	Minal Shah, Swapan Kumar Das, Kanai Lal Sahoo, Gautam Das, Sandip Ghosh Chowdhury and Palash Poodar
3	PAT-0515/2017/IN,US	Compositionally modulated zinc-manganese multilayered coatings	Shashi Kant Tiwari, Raghuvir Singh, Sharma Paswan and Lokesh Chandra Pathak
4	PAT-0518/2017/IN	An innovative and user friendly flux for phosphorus removal from steel produced in neutral lined induction furnace	RK Minj, Satadal Ghorai, D Banyopadhyay, DP Singh and A K Upadhyay
5	PAT-0519/2017/IN/Prov	Process for the recovery of rare earth oxide and iron powder from spent Nd-Fe-B magnet of wind turbine	Aarti Kumari, SK Sahu, NS Randhawa and S Ranganathan
6	PAT-0520/2018/IN	High Strength as-cast Mg-Y alloy and a process for the preparation of the same.	Ansu J Kailath, Palash Poddar, Arvind Sinha
7	PAT-0521/2018/IN	An improved process for refining of crude/ sponge magnesium using a modified flux	Krishna Kumar, Manoj Kumar, Navneet Singh Randhawa
8	PAT-0522/2018/IN	An innovative and user friendly flux for phosphorus removal from steel produced in neutral lined induction furnace	RK Minj, Satadal Ghorai, D Bandyopadhyay, DP Singh, AK Upadhyay
9	PAT-0523/2018/IN	Ni-Mn-Cu-Ga based Magnetocaloric materials	Sushmita Dey, Ashis Kumar Panda, Rajat Kumar Roy, Amitava Mitra
10	PAT-0524/2018/IN/Prov	A plant Setup for the production of Amorphous electrical steel	Ashis Kumar Panda, Rajneesh Kumar, Udaya Modalavalasa, Premkumar M, Rajat Kumar Roy, Parvesh Kumar, Amitava Mitra, KK Paul
11	PAT-0525/2018/IN	Hot Rolled quenched and non-isothermally partitioned low alloy steel with high strength, impact toughness and abrasion resistance	Gaurav Kumar Bansal, Snehashish Tripathy, V Rajinikanth, Vikas Chandra Srivastava, Sandip Ghosh Chowdhury
12	PAT-0526/2018/IN	A process for the production of iron powder from iron oxide fines	DC Sau, Manoj Kumar, D Bandyopadhyay
13	PAT-0527/2018/IN	A process for the conversion of fine mill scale particles to magnetite used for heavy media separation	DC Sau, Manoj Kumar

SN	REFERENCE NO.	Title	INVENTOR
14	PAT-0506/2017/IN	Modified white cast iron alloy composition for improved toughness and wear resistance in as cast condition	Jitendra Kumar Sahu, PS Manoranjan Jena, Rajesh Kumar Rai, Swapan Kumar Das
15	PAT-0507/2017/IN	Corrosion resistance and low embrittlement aluminum alloy coatings on steel by magnetron sputtering	LC Pathak, SK Mishra, R Singh and S Paswan
16	PAT-0508/2017/US	Compositionally modulated Zn-iron multilayered coatings	Shashi Kant Tiwari, Raghuvir Singh, Trilochan Mishra
17	PAT-0509/2017/IN	Low carbon batch annealed deep drawable steel with high plastic anisotropy	Biraj Kumar Sahoo, B. Ravi Kumar
18	PAT-0510/2017/IN	A process for preparation of Iron based Rapidly Solidified Alloys from High Phosphorous Pig Iron	Premkumar Murugaiyan, Ashis K. Panda, Rajat K Roy
19	PAT-0511/2017/IN	A process for recovering Zinc from Zinc Dross as different grade of high purity Zinc sulphate salts	Shivendra Sinha, Rajanikant Choudhari, Devabrata Mishra, Kamla Kanta Sahu, Archana Agrawal.
20	PAT-0514/2017/IN	A process for the production of low-density geopolymer block from industrial waste	Rohit Meshram and Sanjay Kumar

Copyright Application sent to IPU-CSIR for registration

SN	REFERENCE NO.	TITLE	AUTHOR
1	CR-0099/2017	In-collaboration (Sahyog)- An Information sharing system for the Collaborative Projects of TATA STEEL and CSIR-NML	BeenaKumari, SK Pal, Ashish Upadhyay, Amitava Mitra, Munishsudan, T Venugopalan
2	CR-0100/2017	Websys: A web based R&D project information management system	Ashish Upadhyay, Beena Kumari, Santosh Tiwary, SK Pal, Mita Tarafder, Amitava Mitra
3	CR-0101/2017	NEURAL_NANO-BAINITE LATH – An artificial neural network code to estimate the Bainite lath thickness in silicon rich steels	Minal Shah, Suchandan K. Das
4	CR-0102/2017	An advanced Software to quantify micro structural information like grain size, number density and size of precipitates, voids, inclusions etc from micrographs (Optical, SEM,TEM) image filtering	Minati Sahu, Chandan Dutta, Arpita Ghosh, Sarmishtha Palit Sagar
5	CR-0103/2018	"NEURAL_NANOBAINITE_MECH" – A model based multi-input-multi-output (MIMO) artificial neural network code to predict mechanical properties of nano-bainitic steel.	Minal Shah, Suchandan K Das

Publications

SCI Publications 2017

S.No.	Authors	Title	Source	IF -2016
1	Abhilash; Meshram, P; Sarkar, S; Venugopalan, T	Exploring blast furnace slag as a secondary resource for extraction of rare earth elements	MINERALS & METALLURGICAL PROCESSING, v34, Iss 4, 178-182	0.692
2	Akcil, Ata and Akhmadiyeva, Nazym and Abdulvaliyev, Rinat and Abhilash, and Meshram, Pratima	Overview On Extraction and Separation of Rare Earth Elements from Red Mud: Focus on Scandium	MINERAL PROCESSING AND EXTRACTIVE METALLURGY REVIEW, v39, Iss 3, 145-151	1.219
3	Alex, TC; Kumar, R	Surface and bulk activation of a siliceous bauxite during attrition milling	INTERNATIONAL JOURNAL OF MINERAL PROCESSING, v160, 32-38	1.518
4	Al-Negheimish, A; Alhozaimy, A; Hussain, RR; Singh, JK; Singh, DDN	Pitting Susceptibility of Concrete Reinforcing Steel Bars Having Manganese Sulfide Inclusions	ACI MATERIALS JOURNAL, v114, Iss 3, 441-451	1.183
5	Ashiq, M; Dhekne, P; Hamada, AS; Sahu, P; Mahato, B; Minz, RK; Chowdhury, SG; Karjalainen, LP	Correlation of Microstructure and Texture in a Two-Phase High-Mn Twinning-Induced Plasticity Steel During Cold Rolling	METALLURGICAL AND MATERIALS TRANSACTIONS A-PHYSICAL METALLURGY AND MATERIALS SCIENCE, v48A, Iss 10, 4842-4856	1.874
6	Bansal, R; Singh, JK; Singh, V; Singh, DDN; Das, P	Optimization of Oxidation Temperature for Commercially Pure Titanium to Achieve Improved Corrosion Resistance	JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, v26, Iss 3, 969-977	1.331
7	Baral, J; Swaminathan, J; Chakrabarti, D; Ghosh, RN	Effect of welding on creep damage evolution in P91B steel	JOURNAL OF NUCLEAR MATERIALS, v490, 333-343	2.048
8	Bhattacharjee, G; Kushwaha, OS; Kumar, A; Khan, MY; Patel, JN; Kumar, R	Effects of Micellization on Growth Kinetics of Methane Hydrate	INDUSTRIAL & ENGINEERING CHEMISTRY RESEARCH, v56, Iss 13, 3687-3698	2.843
9	Bhattacharya, S; Jyoti, D; Sahu, L; Dey, S; Singh, H	Flotation of Low Volatile Coking Coal Fines	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, v70, Iss 2, 421-432	0.533
10	Bhowmick, T; Nayak, B; Varma, AK	Chemical and mineralogical composition of Kathara Coal, East Bokaro Coalfield, India	FUEL, v208, 91-100	4.601
11	Das, Anindya; Ghosh, M; Tarafder, S; Sivaprasad, S; Chakrabarti, D	Micromechanisms of deformation in dual phase steels at high strain rates	MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, v680, 249-258	3.094
12	Das, Arpan	Resurgence of texture in cyclically deformed austenite	MATERIALS CHARACTERIZATION, v123, 315-327	2.714
13	Das, Arpan	Grain boundary engineering: fatigue fracture	PHILOSOPHICAL MAGAZINE, v97, Iss 11, 867-916	1.505
14	Das, Sanjeev; Prasad, R; Singh, RP; Abhilash	Physical, Mechanical and Metallurgical Characteristics of Banded Hematite Jasper of Ghatkuri (Gua), Jharkhand	JOURNAL OF THE GEOLOGICAL SOCIETY OF INDIA, v90, Iss 5, 623-627	0.479

S.No.	Authors	Title	Source	IF -2016
15	Dey, Shobhana and Mohanta, M K and Singh, Ratnakar	Mineralogy and textural impact on beneficiation of goethitic ore	INTERNATIONAL JOURNAL OF MINING SCIENCE AND TECHNOLOGY, v27, Iss 3, 445-450	1.383
16	Dey, Sushmita; Roy, RK; Ghosh, M; Mallick, AB; Mitra, A; Panda, AK	Enhancement in magnetocaloric properties of NiMnGa alloy through stoichiometric tuned phase transformation and magneto-thermal transitions	JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS, v439, 305-311	2.630
17	Djobo, JNY; Elimbi, A; Tchakoute, HK; Kumar, S	Volcanic ash-based geopolymer cements/concretes: the current state of the art and perspectives	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH, v24, Iss 5, 4433-4446	2.741
18	Dwivedi, Deepak and Randhawa, N S and Saroj, Sanjay and Jana, Ranjeet Kumar	An Overview of Manganese Recovery by Hydro and Pyro-Metallurgical Routes	JOURNAL OF THE INSTITUTION OF ENGINEERS (INDIA): SERIES D, v98, Iss 1, 147-154	
19	Gaurav, G; Murtaza, Q; Yuvraj, N; Mandal, D; Sahoo, KL; Murmu, L	Synthesis and effect of Misch metal on mechanical properties of conventional cast Mg-Al-Zn-Sn-Pb alloy system	PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS PART L-JOURNAL OF MATERIALS-DESIGN AND APPLICATIONS, v231, Iss 7, 627-637	1.625
20	Ghorai, S; Mandal, GK; Roy, S; Minj, RK; Agrawal, A; Singh, DP; Kumar, A; Ramna, RBV	Treatment of LF slag to prevent powdering during cooling	JOURNAL OF MINING AND METALLURGY SECTION B-METALLURGY, v53, Iss 2, 123-130	0.804
21	Gopala Krishna K; Das, G; Venkateswarlu, K; Kumar, KCH	Studies on Aging and Corrosion Properties of Cryorolled Al-Zn-Mg-Cu (AA7075) Alloy	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, v70, Iss 3, 817-825	0.533
22	Goudar, DM and Srivastava, V C and Rudrakshi, GB	Effect of Atomization Parameters on Size and Morphology of Al-17Si Alloy Powder Produced by Free Fall Atomizer	ENGINEERING JOURNAL, v21, Iss 1, 155-168	0.384
23	Guguloth, K; Roy, N	Creep deformation behavior of 9Cr1MoVNb (ASME Grade 91) steel	MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, v680, 388-404	3.094
24	Guguloth, K; Swaminathan, J; Roy, N; Ghosh, RN	Uniaxial creep and stress relaxation behavior of modified 9Cr-1Mo steel	MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, v684, 683-696	3.094
25	Hazra, A; Hossain, SM; Pramanick, AK; Ray, M	Gold-silver nanostructures: Plasmon-plasmon interaction	VACUUM, v146, 437-443	1.530
26	Hore, S; Das, SK; Banerjee, S; Mukherjee, S	An adaptive neuro-fuzzy inference systembased modelling to predict mechanical properties of hot-rolled TRIP steel	IRONMAKING & STEELMAKING, v44, Iss 9, 656-665	0.985
27	Husain, MM; Sarkar, R; Pal, TK; Ghosh, M; Prabhu, N	Quantification of Microtexture at Weld Nugget of Friction Stir-Welded Carbon Steel	JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, v26, Iss 5, 2047-2056	1.331
28	Jena, PSM; Rai, RK; Roy, PK; Sahu, JK	Improvement of toughness of high chromium white cast iron: duplex ferritic-austenitic matrix	MATERIALS AT HIGH TEMPERATURES, v34, Iss 3, 299-304	2.764

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29	Jena, PSM; Rai, RK; Roy, PK; Sahu, JK	Role of internal oxidation and iron penta carbonyl formation on creep life of 9Cr-1Mo steel	MATERIALS AT HIGH TEMPERATURES, v34, Iss 4, 239-249	0.802
30	Joseph, OO; Sivaprasad, S; Fayomi, OSI	Comparative study on the effect of $NaNO_2$ in corrosion inhibition of micro-alloyed and API-5L X65 steels in E20 simulated FGE	INTERNATIONAL CONFERENCE ON TECHNOLOGIES AND MATERIALS FOR RENEWABLE ENERGY, ENVIRONMENT AND SUSTAINABILITY, TMREES17, v119, 953-960	
31	Kamaraj, A; Hore, S; Sathyamoorthi, P; Roy, GG; Mandal, GK	Estimation and Analysis of Excess Oxygen Input into Ladle During Liquid Steel Tapping	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, v70, Iss 9, 2465-2476	0.533
32	Kamaraj, A; Mandal, GK; Minj, RK; Misra, S; Bandyopadhyay, D	Characterization and Evolution of Non-metallic Inclusions in Fe-Al-Si-O System	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, v70, Iss 7, 1887-1899	0.533
33	Keekan, KK; Jalondhara, JC; Abhilash	Extraction of Ce and Th from Monazite Using REE Tolerant Aspergillus niger	MINERAL PROCESSING AND EXTRACTIVE METALLURGY REVIEW, v38, Iss 5, 312-320	1.219
34	Kumar, B Ravi; Patel, NK; Mukherjee, K; Walunj, M; Mandal, GK; Venugopalan, T	Ferrite channel effect on ductility and strain hardenability of ultra high strength dual phase steel	MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, v685, 187-193	3.094
35	Kumar, DS; Suman, KNS; Poddar, P	Effect of particle morphology of Ni on the mechanical behavior of AZ91E-Ni coated nano Al_2O_3 composites	MATERIALS RESEARCH EXPRESS, v4, Iss 6, 66505	1.068
36	Kumar, P and Kumar, Rakesh and Rai, B and Subramanian, S and Srikanth, S	Preface	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, v70, Iss 2, 251-252	0.533
37	Kumar, P; Mondal, AK; Chowdhury, SG; Krishna, G; Ray, AK	Influence of additions of Sb and/or Sr on microstructure and tensile creep behaviour of squeeze-cast AZ91D Mg alloy	MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, v683, 37-45	3.094
38	Kumar, Rakesh	Characterisation of Minerals and Ores: On the Complementary Nature of Select Techniques and Beyond	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, v70, Iss 2, 253-277	0.533
39	Kumar, Sanjay; Mucsi, G; Kristaly, F; Pekker, P	Mechanical activation of fly ash and its influence on micro and nano-structural behaviour of resulting geopolymers	ADVANCED POWDER TECHNOLOGY, v28, Iss 3, 805-813	2.659
40	Kumar, Sunil	Effect of applied force and atomic organization of copper on its adhesion to a graphene substrate	RSC ADVANCES, v7, Iss 40, 25118-25131	3.108
41	Kumar, Sunil	Graphene engendered 2-D structural morphology of aluminium atoms: Molecular dynamics simulation study	MATERIALS CHEMISTRY AND PHYSICS, v202, 329-339	2.084
42	Kumar, Sunil; Das, SK	A triaxial tensile deformation-induced nanoporous structure of aluminium: estimation of surface area, solid volume, and dimensionless aspect ratio	PHYSICAL CHEMISTRY CHEMICAL PHYSICS, v19, Iss 31, 21024-21032	4.123

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43	Kumar, Sunil; Srivastava, VC; Mandal, GK; Pattanayek, SK; Sahoo, KL	Single-Walled Carbon Nanotube Engendered Pseudo-1D Morphologies of Silver Nanowire	JOURNAL OF PHYSICAL CHEMISTRY C, v121, Iss 37, 20468-20480	4.536
44	Kumari, Amrita; Das, SK; Srivastava, PK	Data-driven modeling of corrosion and scale deposition rate in economizer	ANTI-CORROSION METHODS AND MATERIALS, v64, Iss 2, 178-187	0.364
45	Kumari, Amrita; Das, SK; Srivastava, PK	Data-driven modeling of fireside corrosion rate	ANTI-CORROSION METHODS AND MATERIALS, v64, Iss 4, 397-404	0.364
46	Kumari, Anjan; Jha, MK; Singh, RP; Ranganathan, S	Investigation of the influence of inert and oxidizing atmospheres on the efficiency of decomposition of waste printed circuit boards (WPCBs)	HEAT AND MASS TRANSFER, v53, Iss 4, 1247-1255	1.233
47	Kumari, D; Sheikh, L; Bhattacharya, S; Webster, TJ; Nayar, S	Two-dimensional collagen-graphene as colloidal templates for biocompatible inorganic nanomaterial synthesis	INTERNATIONAL JOURNAL OF NANOMEDICINE, v12, 3605-3616	4.300
48	Laxman Mani Kanta, P; Srivastava, VC; Venkateswarlu, K; Paswan, S; Mahato, B; Das, G; Sivaprasad, K; Gopala Krishna, K	Corrosion behavior of ultrafine-grained AA2024 aluminum alloy produced by cryorolling	INTERNATIONAL JOURNAL OF MINERALS METALLURGY AND MATERIALS, v24, Iss 11, 1293-1305	0.943
49	Mahato, B; Sahu, T; Shee, SK; Sahu, P; Sawaguchi, T; Komi, J; Karjalainen, LP	Simultaneous twinning nucleation mechanisms in an Fe-Mn-Si-Al twinning induced plasticity steel	ACTA MATERIALIA, v132, 264-275	5.301
50	Mallik, M; Kailath, AJ; Ray, KK; Mitra, R	Effect of SiC content on electrical, thermal and ablative properties of pressureless sintered ZrB2-based ultrahigh temperature ceramic composites	JOURNAL OF THE EUROPEAN CERAMIC SOCIETY, v37, Iss 2, 559-572	3.411
51	Mandal, GK; Kumar, S; Kumar, T; Srivastava, VC	Hot Deformation Behaviour of a Nb-Mo Linepipe Steel	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, v70, Iss 7, 1943-1951	0.533
52	Mandal, GK; Rajinikanth, V; Kumar, S; Mishra, D; Misra, S; Srivastava, VC; Chowdhury, SG	Microstructure Evolution During Hot Deformation of a Micro-Alloyed Steel	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, v70, Iss 4, 1019-1033	0.533
53	Meshram, P; Bhagat, L; Prakash, U; Pandey, BD; Abhilash	Organic acid leaching of base metals from copper granulated slag and evaluation of mechanism	CANADIAN METALLURGICAL QUARTERLY, v56, Iss 2, 168-178	0.596
54	Meshram, P; Somani, H; Pandey, BD; Mankhand, TR; Deveci, H; Abhilash	Two stage leaching process for selective metal extraction from spent nickel metal hydride batteries	JOURNAL OF CLEANER PRODUCTION, v157, 322-332	5.715
55	Mishra, D; Sinha, S; Sahu, KK; Agrawal, A; Kumar, R	Recycling of Secondary Tungsten Resources	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, v70, Iss 2, 479-485	0.533
56	Mishra, G; Chandan, AK; Kundu, S	Hot rolled and cold rolled medium manganese steel: Mechanical properties and microstructure	MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, v701, 319-327	3.094
57	Mishra, SK; Kumari, S; Soni	Development of hard and optically transparent Al-Si-N nanocomposite coatings	SURFACE AND INTERFACE ANALYSIS, v49, Iss 4, 345-348	1.132

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58	Mittal, M; Nanda, T; Kumar, B Ravi; Singh, V	Effect of inter-critical annealing parameters on ferrite recrystallization and austenite formation in DP 590 steel	MATERIALS AND MANUFACTURING PROCESSES, v32, Iss 11, 1231-1238	2.274
59	Mohanty, Sunati; Nayak, B; Konar, J	Beneficiation of High-alumina Bearing Iron-ore Slime: A Case Study From Eastern India	MINERAL PROCESSING AND EXTRACTIVE METALLURGY REVIEW, v38, Iss 6, 403-410	1.219
60	Murugesan, AP; Rajinikanth, V; Mahato, B; Wegner, M; Witte, M; Wilde, G; Chowdhury, SG	Concurrent precipitation and associated texture evolution in AA 6082 alloy during high pressure torsion (HPT) processing	MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, v700, 487-494	3.094
61	Nanda, T; Kumar, B Ravi; Sharma, S; Singh, V; Pandey, OP	Effect of thermal cycling process parameters on recrystallization kinetics for processing of fine-grained pure copper	MATERIALS AND MANUFACTURING PROCESSES, v32, Iss 1, 34-43	2.274
62	Nanda, T; Kumar, B Ravi; Singh, V	A Simplified Micromechanical Modeling Approach to Predict the Tensile Flow Curve Behavior of Dual-Phase Steels	JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, v26, Iss 11, 5180-5187	1.331
63	Nath, SK; Kumar, S	Reaction kinetics, microstructure and strength behavior of alkali activated silico-manganese (SiMn) slag - Fly ash blends	CONSTRUCTION AND BUILDING MATERIALS, v147, 371-379	3.169
64	Nath, SK; Mukherjee, S; Maitra, S; Kumar, S	Kinetics study of geopolymerization of fly ash using isothermal conduction calorimetry	JOURNAL OF THERMAL ANALYSIS AND CALORIMETRY, v127, Iss 3, 1953-1961	1.953
65	Nath, SK; Rajshekar, Y; Alex, TC; Venugopalan, T; Kumar, S	Evaluation of the Suitability of Alternative Binder to Replace OPC for Iron Ore Slime Briquetting	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, v70, Iss 8, 2165-2174	0.533
66	Nayak, B; Meyer, FM	Manganilmenite in the magnetite ore body from Pokphur area of Nagaland, North East India and the possibility of microdiamonds in the ophiolites of Indo-Myanmar ranges	CURRENT SCIENCE, v112, Iss 1, 155-160	0.843
67	Nivas, R; Das, G; Das, SK; Mahato, B; Kumar, S; Sivaprasad, K; Singh, PK; Ghosh, M	Effect of Stress Relief Annealing on Microstructure & Mechanical Properties of Welded Joints Between Low Alloy Carbon Steel and Stainless Steel	METALLURGICAL AND MATERIALS TRANSACTIONS A-PHYSICAL METALLURGY AND MATERIALS SCIENCE, v48A, Iss 1, 230-245	1.874
68	Nivas, R; Singh, PK; Das, G; Das, SK; Kumar, S; Mahato, B; Sivaprasad, K; Ghosh, M	A comparative study on microstructure and mechanical properties near interface for dissimilar materials during conventional V-groove and narrow gap welding	JOURNAL OF MANUFACTURING PROCESSES, v25, 274-283	2.322
69	Pal, J; Ghorai, S; Ammasi, A; Hota, SK; Koranne, VM; Venugopalan, T	Improving reducibility of iron ore pellets by optimization of physical parameters	JOURNAL OF MINING AND METALLURGY SECTION B-METALLURGY, v53, Iss 1, 37-46	0.804
70	Pal, J; Ghorai, S; Rajshekar, Y; Koranne, VM	Development of blast furnace quality pellet optimising blue dust, hard ore and friable ore ratio	IRONMAKING & STEELMAKING, v44, Iss 8, 568-576	0.985
71	Pandya, Achal and Saha, D and Singh, J K and Paswan, S and Singh, D D N	Effect of Environmental Pollution on Corrosion Characteristics of 3003 Aluminium Alloy Exposed in Different Parts of India	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, v70, Iss 6, 1607-1620	0.533
72	Parmar, K; Bhattacharjee, S	Energetically benign synthesis of lanthanum silicate through "silica garden" route and its characterization	MATERIALS CHEMISTRY AND PHYSICS, v194, 147-152	2.084

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73	Parthiban, R; Chowdhury, SG; Harikumar, KC; Sankaran, S	Evolution of microstructure and its influence on tensile properties in thermo-mechanically controlled processed (TMCP) quench and partition (Q & P) steel	MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, v705, 376-384	3.094
74	Patra, AS; Gogoi, G; Sahu, RK; Qureshi, M	Modulating the electronic structure of lanthanum manganite by ruthenium doping for enhanced photocatalytic water oxidation	PHYSICAL CHEMISTRY CHEMICAL PHYSICS, v19, Iss 19, 12167-12174	4.123
75	Paul, SK; Kumar, S; Tarafder, S	Effect of loading conditions on nucleation of nano void and failure of nanocrystalline aluminum: An atomistic investigation	ENGINEERING FRACTURE MECHANICS, v176, 257-262	2.151
76	Paul, SK; Roy, S; Sivaprasad, S; Bar, H; Tarafder, S	Local Ratcheting Response in Dissimilar Metal Weld Joint: Characterization Through Digital Image Correlation Technique	JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, v26, Iss 10, 4953-4963	1.331
77	Poddar, P; Bagui, S; Ashok, K; Murugesan, AP	Experimental investigation on microstructure and mechanical properties of gravity-die-cast magnesium alloys	JOURNAL OF ALLOYS AND COMPOUNDS, v695, 895-908	3.133
78	Pramanick, A K and Das, Goutam and Das, Swapan K and Ghosh, M	Failure investigation of super heater tubes of coal fired power plant	CASE STUDIES IN ENGINEERING FAILURE ANALYSIS, v9, 17-26	0.725
79	Rai, RK; Sahu, JK; Jena, PSM; Das, SK; Paulose, N; Fernando, CD	High temperature tensile deformation of a directionally solidified nickel base superalloy: Role of micro constituents	MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, v705, 189-195	3.094
80	Rao, MA; Babu, RS; Kumar, MVP	Failure investigation of a cooling coil tube in zinc roaster furnace	ENGINEERING FAILURE ANALYSIS, v77, 118-125	1.676
81	Rao, R Govinda; Sahoo, KL; Ganguly, RI; Dash, RR; Narasaiah, N	Effect of Flyash Treatment on the Properties of Al-6061 Alloy Reinforced with SiC-Al_2O_3-C Mixture	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, v70, Iss 10, 2707-2717	0.533
82	Sah, Rakesh and Vidyadhar, A and Das, Avimanyu	Study of cut point density and process performance of Floatex density separator in fine coal cleaning	PARTICULATE SCIENCE AND TECHNOLOGY, v35, Iss 2, 239-246	0.784
83	Sahu, M K and Swaminathan, J and Bandhopadhyay, N R and Sagar, S P	Effect of Precipitation Morphology on the Second Harmonic Generation of Ultrasonic Wave During Tempering in P92 Steel	JOURNAL OF THE INSTITUTION OF ENGINEERS (INDIA): SERIES D, v98, Iss 2, 211-217	
84	Sahu, MK; Swaminathan, J; Bandhoypadhyay, NR; Sagar, SP	Rayleigh Surface wave based non linear ultrasound to assess effect of precipitation hardening during tempering in P92 steel	MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, v703, 76-84	3.094
85	Sameer, Kumar D and Suman, K N S and Poddar, Palash	Effect of particle morphology of Ni on the mechanical behavior of AZ91E-Ni coated nano Al_2O_3 composites	MATERIALS RESEARCH EXPRESS	1.068
86	Sarkar, C and kumari, Pushpa and Anuvrat, K and Sahu, S K and Chakraborty, Jui and Garai, Subhadra	Synthesis and characterization of mechanically strong carboxymethyl cellulose–gelatin–hydroxyapatite nanocomposite for load-bearing orthopedic application	JOURNAL OF MATERIALS SCIENCE, v53, Iss 1, 230-246	2.599

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87	Shekhar, S; Mishra, D; Agrawal, A; Sahu, KK	Physico-chemical treatment of glauconitic sandstone to recover potash and magnetite	JOURNAL OF CLEANER PRODUCTION, v147, 681-693	5.715
88	Shekhar, S; Mishra, D; Agrawal, A; Sahu, KK	Physical and chemical characterization and recovery of potash fertilizer from glauconitic clay for agricultural application	APPLIED CLAY SCIENCE, v143, 50-56	3.101
89	Singh, M and Das, A and Venugopalan, T and Mukherjee, K and Walunj, Mahesh and Nanda, T and Ravi Kumar, B	Impact of Martensite Spatial Distribution on Quasi-Static and Dynamic Deformation Behavior of Dual-Phase Steel	METALLURGICAL AND MATERIALS TRANSACTIONS A-PHYSICAL METALLURGY AND MATERIALS SCIENCE, v49A, 463-475	3.094
90	Singh, Pundan K. and Das, Anindya and Sivaprasad, S and Biswas, P and Verma, Rahul K. and Chakrabarti, D	Energy absorption behaviour of different grades of steel sheets using a strain rate dependent constitutive model	THIN-WALLED STRUCTURES, v111	2.829
91	Singh, R; Dey, S; Sinha, N	Performance of Different Classes of Organic Compounds as Frother in De-ashing of Indian Coking Coal by Froth Flotation	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, v70, Iss 2, 433-442	0.533
92	Singh, Raghuvir; Das, G; Mahato, B; Singh, PK	Aging Degradation of Austenitic Stainless Steel Weld Probed by Electrochemical Method and Impact Toughness Evaluation	METALLURGICAL AND MATERIALS TRANSACTIONS A-PHYSICAL METALLURGY AND MATERIALS SCIENCE, v48A, Iss 3, 1064-1077	1.874
93	Singh, V; Adhikary, M; Venugopalan, T; Chakraborty, A; Nanda, T; Kumar, BR	Role of recrystallization and pearlite dissolution in industrial processing of DP590 steels	MATERIALS AND MANUFACTURING PROCESSES, v32, Iss 16, 1806-1816	2.274
94	Sinha, MK; Pramanik, S; Kumari, A; Sahu, SK; Prasad, LB; Jha, MK; Yoo, K; Pandey, BD	Recovery of value added products of Sm and Co from waste SmCo magnet by hydrometallurgical route	SEPARATION AND PURIFICATION TECHNOLOGY, v179	3.359
95	Sivakumar, B; Pathak, LC; Singh, R	Role of surface roughness on corrosion and fretting corrosion behaviour of commercially pure titanium in Ringer's solution for bio-implant application	APPLIED SURFACE SCIENCE, v401, 385-398	3.387
96	Srivastava, VC; Mandal, GK; Ciftci, N; Uhlenwinkel, V; Madler, L	Processing of High-Entropy AlCoCr0.75Cu0.5FeNi Alloy by Spray Forming	JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, v26, Iss 12, 5906-5920	1.331
97	Sundarapandiyan, S; Renitha, TS; Sridevi, J; Saravanan, P; Chandra sekaran, B; Raju, GB	Photocatalytic degradation of highly refractive phenolic polymer Mechanistic insights as revealed by Electron Spin Resonance (ESR) and solid-state C-13 NMR spectroscopy	CHEMICAL ENGINEERING JOURNAL, v313, 1112-1121	6.216
98	Thanseer, PM; Metya, AK; Sagar, SP	Development of a Non-collinear Nonlinear Ultrasonic-Based Technique for the Assessment of Crack Tip Deformation	JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, v26, Iss 6, 2632-2639	1.331
99	Varshney, A; Sangal, S; Gouthama; Pramanick, AK; Mondal, K	Microstructural evidence of nano-carbides in medium carbon high silicon multiphase steels	MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, v708, 237-247	3.094

Non-SCI Publications 2017

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100	Adeleke A Akanni, M Barath Kanna, Odusote J Kolawole, Malathi M, Lasode O Ajani and Paswan Dayanand	Influence of binder composition on briquettes of coal slacks	3RD INTERNATIONAL CONFERENCE ON SCIENCE AND TECHNOLOGY OF IRONMAKING AND STEELMAKING (STIS-2017)	IIT Kanpur
101	Ammasi, A and Pal, J	Influences of carbonaceous materials on the quality of hematite ore pellets	3RD INTERNATIONAL CONFERENCE ON SCIENCE AND TECHNOLOGY OF IRONMAKING AND STEELMAKING (STIS-2017)	IIT Kanpur
102	Bolfarini, C and Srivastava, VC	Spray forming of novel materials: Bulk processing of glass-forming alloys by spraying deposition	METAL SPRAYS AND SPRAY DEPOSITION ISBN 978-3-319-52687-4, 521-561	SPRINGER
103	Chakrabarty, AK; Khutia, N; Bar, HN; Dey, PP; Sivaprasad, S	Effect of Loading Variations on Damage of SA333 C-Mn Steel	MATERIALS TODAY-PROCEEDINGS, v4, Iss 2, 415-423	ELSEVIER SCIENCE BV
104	Chidambaram, S and Kamaraj, A	Failure investigation of an industrial crank shaft pin.	ADVANCES IN NATURAL AND APPLIED SCIENCES, v11, Iss 8, 25-30	AENSI
105	Chintala, Rajesh and Rath, R K and Kumar, Anil	Effective Utilization of Fly Ash, Iron Ore Slime and LD-Slag in Geopolymer Mortar	RECENT TRENDS IN CIVIL ENGINEERING & TECHNOLOGY, v7, Iss 1	STM Journal
106	Datta, AK; Sivaprasad, S and Prasad, P	Free vibration analysis and shape optimization of offshore tubular structures	JOURNAL OF METALLURGY AND MATERIALS SCIENCE, v59, Iss 3, 133-141	CSIR-NML
107	Ghosh, Mainak; Bansal, Gaurav; Chandan, Avanish; Shah, Minal; Tripathy, Snehasish; Murugaiyan, Premkumar; Sahoo, Biraj; Mukherjee, Krishnendu; Srivastava, Vikas C.; Ghosh Chowdhury, Sandip	Functionally Driven Steels: A Review	STEEL TECH, v12, Iss 1, 13-36	BP SARKAR
108	Jafri, MW and Rath, RK and Dey, Shobhana and Sharma, Mamta and Singh, Ratnakar	Studies on ash reduction of a non-coking coal sample by froth flotation	INTERNATIONAL CONFERENCE ON MINERAL PROCESSING TECHNOLOGY (MPT-2017)	IIME
109	Kamaraj, A; Sankar P and Maruthupandian K	Process evaluation of AOD stainless steel making in Salem Steel Plant, SAIL	JOURNAL OF METALLURGY AND MATERIALS SCIENCE, v59, Iss 4, 173-180	CSIR-NML
110	Krishna, Kumar	Scope of Distillation in Extraction, Purification & Recycling of Strategic Metals- A review	INTERNATIONAL CONFERENCE ON NON-FERROUS MINERALS & METALS, 65-72	ELSEVIER SCIENCE BV
111	Kumar, Nitesh; Kumar, Binay and Pathak, LC	Effect of shapes and compositions of spark plasma sintered ZrB -C composites on performance as EDM tools	JOURNAL OF METALLURGY AND MATERIALS SCIENCE, v59, Iss 4, 143-152	CSIR-NML
112	Kumari, Aayushi; Kedia, Priyanshu; Mandal, Eisha and Mandal, SK	Flaw patterns characterization in material images using linear correlation method	JOURNAL OF METALLURGY AND MATERIALS SCIENCE, v59, Iss 2, 67-74	CSIR-NML

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113	Lal, Radha Krishna; Prakash, Amit; Choubey, VK; Dwivedi, JP; Singh, VP	Spring back analysis of I Sectioned bar of Linear Work-Hardening Materials under Torsional Loading	MATERIALS TODAY-PROCEEDINGS, v4, Iss 2, 2373-2383	ELSEVIER SCIENCE SA
114	Metya, Avijit Kumar and Bar, Himadri Nandan and Tarafder, Soumitra and Balasubramaniam, Krishnan	Nonlinear Lamb wave for the assessment of ratcheting behavior in IF steel	JOURNAL OF NON DESTRUCTIVE TESTING & EVALUATION, v15, Iss 10, 17-21	ISNT
115	Mishra, V and Singh, KN	Microstructural relation of macerals with mineral matter in coals from LB valley and Umaria, Son-Mahanadi basin, India	INTERNATIONAL JOURNAL OF COAL SCIENCE & TECHNOLOGY, v4, Iss 3, 191-197	SPRINGER
116	Panda, Rekha; Kumari, Archana; Jha, MK and Pathak, DD	Recuperation of gold from waste printed circuit boards of small electronic devices	JOURNAL OF METALLURGY AND MATERIALS SCIENCE, v59, Iss 4, 181-187	CSIR-NML
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