वार्षिक प्रतिवेदन 2020-21

Annual Report 2020-21

CSIR-National Metallurgical Laboratory

Jamshedpur - 831007, India

Indian Metal Crafts

Indian Metallurgy on Postal Stamp

Copper Dhoopdaan

Gold GajaLaksmi Lamp

CHOLA period workmanship with lost wax technique. These were casted first and intricate carving and engraving work was done for beautifying the objects.

Issued by Indian Postal Department on 26th August 2016.

Sources:

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https://exclusivecoins.blogspot.com/2016/08/371-indian-metal-crafts-set-of-six.html
http://postagestamps.gov.in/Stampsofyear.aspx?uid=2016
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Contents

Impressions

It's a great pleasure to be able to visit CSIR-NML again. The interactions with young scientists have been very useful and pleasurable. CSIR-NML had a glorious past-serving for more than 70 years, with the younger generation the future is bright too. All the very best to everyone!

Inspiring words from our DG, Dr. Shekhar C. Mande, 19 January 2021

KMML
Spreading Splendour

The Kerala Minerals and Metals Ltd.
(A Govt. of Kerala Undertaking)

Mineral Separation Unit,
Kovilthottam, Chavara,
Kollam - 691 583, Kerala, India.
Ph: 0476-2680047, 2680048, 2682727, 2682700
E-mail: hodms@kmml.com, md@kmml.com
CIN: U14109KL1972SGC002399

KMML/MS/P&Pj/NML/61P/2020

09.07.2020

APPRECIATION LETTER

This is to certify that CSIR - National Metallurgical Laboratory (CSIR-NML) Madras Centre, Chennai in association with M/s. McNally Sayaji Engineering Limited (MSEL), Bengaluru, as their engineering partners, successfully executed the project "Design, Manufacturing, Supply, Erection, Commissioning of 1.0m diameter, 11m height and 120 tonnes per day Column Flotation Cell" for sillimanite flotation at our Mineral Separation Plant. The system was commissioned in the last week of August 2019. It has been in operation since then and we are extremely happy with its performance and the Return on Investment was realized within six months of its operation. We commend the efforts put in by CSIR-NML Madras Centre, M/s MSEL, Bengaluru and other team members.

The challenge of selective flotation of Sillimanite from the "Beach sand minerals" peculiar to the west coast of India, involved extreme R&D work by Dr. T.V.Vijaya Kumar. We cherish our association with CSIR - NML and wish them success in their future endeavors.

For The Kerala Minerals and Metals Ltd.,

Managing Director

Letter of appreciation for our column flotation systems from

KMML
Spreading Splendour

CSIR-National Metallurgical Laboratory

The Inception

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

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

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

...Pandit Jawaharlal Nehru

Glorious Past

CSIR-National Metallurgical Laboratory (CSIR-NML) is a premier Indian research organisation dedicated to various facets of Minerals, Metals and Materials -science, technology, industrial services and human resource development. Since inception, CSIR-NML has diversified its research areas ranging from extractive metallurgy, alloy development and import substitution, refractory material, development, corrosion studies, mathematical and physical modeling of metallurgical processes, mineral research, advanced materials and materials tailoring, integrity evaluation of critical industrial components, surface engineering and cleaner and sustainable metals production. The Laboratory has made notable contributions in the areas of mineral beneficiation and agglomeration, ferrous and nonferrous metallurgy, alloy development and processing, materials science & engineering and, resource conservation & environment. A historical accounts of past achievements (1950-2010) of CSIR-NML is painted in the Diamond Jubilee commemorative volume 'la vintage metallurgie: 60 years of marriage of science to industry' (http://eprints.nmlindia.org/4360/).

Present Focus

Research & Development

CSIR-NML continues to play a vital role in the quest of the country towards scientific and technological leadership and providing scientific solutions to the industries in the areas of minerals, metals and materials. CSIR-NML is also carrying out major activities for creating awareness among the common masses on issues relating to health, environment, rural technology and sustainable development. With a strong and committed staff having a wide spectrum of expertise and modern facilities, CSIR-NML has completed 70 glorious years of existence and still endeavours to move ahead to meet the challenges of the global economy and reach greater heights. The Laboratory has kept pace with changing research scenarios and needs of the country. In the last few years, greater emphasis is given to industry-sponsored research and, alignment with government program; namely, Make in India, Innovate in India, Strategic sector needs, Swatch Bharat, Societal and skill India, etc. The activities of the Laboratory touch upon several major sectors relevant to the growth of India, including iron and steel, power and energy, oil and gas, automotive, railways, strategic, societal, and others.

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

Our Vision Statement

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

Organization Structure

PRESIDENT, CSIR

Shri Narendra Modi,
Hon' Prime Minister

VICE PRESIDENT, CSIR

Dr. Harsh Vardhan,
Hon' S & T Minister

DIRECTOR GENERAL, CSIR

Dr. S.C. Mande,
Secretary, DSIR

DIRECTOR CSIR-NML

Dr. I. Chattoraj

ADVISORS & HRG

MANAGEMENT

Dr. S. Tarafder

HRG

Dr. S. Shivaprasad

R&D

AMP

Dr. Arvind Sinha

MTE

Dr. S.G. Chowdhury

AAC

Dr. S. Chakravarty

MER

Dr. S. Kumar

MNP

Dr. S. Chakravarty

NML-MC

Dr. T.V. Vijaykumar

R&D SUPPORT

RPBD

Dr. S.K. Pal

ENG

Mr. P.K. Dhawan

KRIT

Dr. M. Tarafder

RESEARCH COUNCIL

MANAGEMENT COUNCIL

FUNCTIONARIES

ADMIN

Mr. K. Bhattacharya

S&P

Mr. N. K. Singh

F&A

Mr. A.M. Pradhan

MTE (Materials Engineering), MER (Metals Extracton & Recycling), MNP (Mineral Processing), AMP (Advanced Materials & Processes), AAC (Applied & Analytcal Chemistry), NML-MC (NML-Madras Center), RPBD (Research Planning & Business Development), ENG (Engineering), KRIT (Knowledge Resources & Informaton Technology), HRG (Human Resources Group), ADMIN (Administraton) S&P (Stores & Purchase), F&A (Finance & Accounts)

Research Council (RC)

Chairperson

Prof. Indranil Manna
Vice Chancellor,
Birla Institute of Technology, Mesra
Ranchi, Jharkhand

Members

Prof. Suddhasatwa Basu
Director
CSIR – Institute of Minerals & Materials Technology, Bhubneswar

Dr. Debashis Bhattacharjee
Vice President
(Technology & New Materials Business)
Tata Steel, Kolkata

Dr. Indranil Chattoraj
Director
CSIR – National Metallurgical Laboratory, Jamshedpur

Prof. Jyotsna Dutta Majumdar
Department of Metallurgical and Materials Engineering,
IIT Kharagpur

Dr. R.M. Mohanty
Principal Scientist,
TMD (SEMI)
CSIR, New Delhi

Dr. G. Padmanabham
Director
International Advance Research Center for Powder Metallurgy & New Materials (ARCI),
Hyderabad

Prof. Prita Pant
Department of Metallurgical Engineering and Materials Science,
IIT Bombay

Dr. Beena Rai
Chief Scientist and Head,
Tata Consultancy Services,
Mumbai

Dr. G. Madhusudan Reddy
Director
Defence Metallurgical Research Laboratory
Hyderabad

Prof. Rajiv Shekhar
Director,
Indian Institute of Technology (IIT –ISM),
Dhanbad

Indian Metal Crafts

Indian metal crafts originated from Indus Valley Civilization. Various states and districts of the country possess their own style of metal crafting viz. Dokra at Madhyapradesh, Sheet Metal Art in Telangana and Cast Sculptures at Varanasi.

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https://www.ancient.eu/image/11429/mehrauli-iron-pillar/

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https://www.thebetterindia.com/86046/training-new-generation-keep-art-bone-carving-alive/

FOREWORD

In the past fiscal (2020-2021), we had expected to come out of the shadows of the economic and other hindrances caused by the pandemic. Unfortunately, that was not to be. Consequently, industrial research, which apart from active sponsorships and collaborations, require on-site activities, were muted. Most of the year had our laboratory see limited attendance of personnel mandated by central and state guidelines on the pandemic. As a result, our research pursuits were largely hampered. Anticipating the aftermath of the pandemic, we had targeted a modest ECF generation of Rs. 32 Crores for the fiscal, but we lagged behind in this matter, largely due to our lack of government sponsored projects. In spite of the severe limitations on industrial productions and therefore on the industry's desire for research sponsorship, our ECF generation from Industrial sponsors was significant, making up more than 90% of total ECF generated. Matters have improved inre the pandemic and there are initial signs of revival. We are expecting for a much better year in terms of research sponsorship as well as our full-fledged involvement, unhindered by past encumbrances on travel, office attendance, physical meetings, onsite activities, and others.

In spite of our muted activities in research, our somewhat limited research deliveries were well appreciated. The laboratory earned the high satisfaction ratings from most of our important stakeholders, the average customers satisfaction index, like the previous year, was 4.8 out of 5. Our SCI publications were reasonable in terms of numbers (124) but it was indeed gratifying to note the significant improvement in quality with the average impact factor of SCI publications improving to 3.7 from 2.2 for the previous year. We could file 20 Patents and 1 Copyright against respective targets of 25 and 5. Eight Technologies were developed in the reporting year and three technologies were transferred.

Let me recount some of the important scientific and technological achievements in 2020-21.

In the areas of materials and devices development we achieved the following. An important strategic development was a technology for on-board spacecraft life detection, for which the device fabrication is in-progress and it is expected to be delivered for testing in early 2021-22. Development of biodegradable Mg and Zn based alloys for orthopedic implants with required mechanical strength were successfully completed, in an industrially sponsored project.

In the areas of mineral processing, advanced gravity concentration of tailings of chromite beneficiation plants was carried out, and concentrate with an assay of 40% Cr_2O_3 was produced and around 32 % of chromite

was recovered. Studies on beneficiation of low-grade manganese ore samples, involving gravity, magnetic and reduction-roasting, was carried out and a process route for upgradation of low-grade manganese ore for application in production of ferro-manganese was developed. CSIR-NML in association with an engineering partner is involved in the installation and commissioning of a 200 tons per day flotation column for fine coal flotation at Belatinda Coal Preparation Plant. The erection and dry run was completed, the commissioning with coal slurry will be completed in 2021-22. Pilot plant scale trials (1 ton per hour) of newly developed environment friendly flotation reagents for limestone beneficiation at M/s Vedam Calcimin, Telangana, has been completed. One important activity, accounting for significant ECF for the laboratory is Coal Core Analysis. Almost 15000 refereed samples and 5000 band by band coal core samples, were analysed, well beyond the set targets for the year. It is satisfying to note that five new certified reference materials (CRMs) have been developed which include Coal, H_2 Standards, Ferroalloys and Alloy cast iron.

The need to use secondary and tertiary resources including industrial wastes is a top priority for our country, given the severe shortage for primary resources for several strategic metals. NITIAYOG had instructed the creation of a consortium of three research institutes and three industrial organizations to collaborate and arrive at a holistic solution for red mud, with emphasis on Rare Earths recovery. CSIR-NML is the nodal laboratory co-ordinating this effort. The collaboration with Hindalco, Nalco and Vedanta, as industrial partners, and CSIR-IMMT and JNARDDC, as research partners, has been formalised and activities initiated. This marks the first large scale collaborative effort on holistic utilization of red mud. The urban ore recycling centre created at CSIR-NML, has been instrumental in developing a number of technologies and at present is flooded with requests for either technology transfer or collaborations, from multiple entities across the country. A CSIR mission on “Bulk Chemicals” had identified NML as the nodal laboratory for developing Li extraction technology from end-of-life batteries. This project has progressed well and a number of enquiries have been received on the technologies being developed on Li extraction from wastes.

CSIR-NML has been implementing the CSIR Integrated Skill Training Initiative since 2017, with the prime objective of utilizing CSIR knowledgebase and infrastructure for contributing to national skill mission. In 2020-21, low cost or free trainings were provided to unemployed youths through a number of training in diverse areas like metallurgical furnaces, materials processing and heat treatment, quantitative chemistry and intellectual property rights. More than five hundred trainees benefitted from these programmes. In our other significant social impact programme, we are involved in the upliftment of the brass as well as silver cluster artisans of West Bengal.

There has been a depletion of manpower due to superannuations. To maintain a critical mass, it is important to replenish human resources. The laboratory plans to recruit eighteen scientists at different expertise levels in the forthcoming fiscal year. At the same time, it is very heartening to see our young colleagues taking on more responsibilities in leading research as well as other co-curricular activities.

I extend our gratitude and appreciation to the members of our Research Council, our esteemed sponsors, and numerous other friends and mentors, for their sustained support and advice. Our Director General, has been a guiding force and a major motivator for all of us. I appreciate all CSIR-NML staff for their perseverance and diligence in very difficult times. During the pandemic, several of my colleagues showed exceptional fellow feeling and brotherhood/sisterhood. They are appreciated by the entire NML family. We look forward to a much better 2021-22 for the world, as well as for NML and its extended family and alumnus.

(Dr. Indranil Chattoraj)
Director, CSIR-NML

Indian Metal Crafts

The Dancing Girl
Metal: Bronze
Mohenjo-Daro, Indus Valley Civilization
(c. 300 BC – c. 750 BC)

The Iron Pillar

Originally erected during the time of King Chandra and bears his inscription in Sanskrit. He was possibly Emperor Chandragupta II (c. 375 - 413/14 CE) of the Gupta dynasty. It is believed to have had the emblem of the mythical bird Garuda, the symbol of the Guptas, at the top, but is now missing. The fluted bell capital is characteristic of the Gupta architecture. The total length of the pillar is 7.2 metres, of which 93 cm is buried underground. The pillar is believed to have been brought from somewhere else by a king of Delhi in the late ancient or early medieval period.

Sources:
https://blog.aboutamazon.in/supporting-small-business/earth-to-chisel-magnificent-metal-crafts-of-india
https://www.ancient.eu/image/11429/mehrauli-iron-pillar/
https://www.indianmirror.com/culture/indian-specialties/Bonecarving.html
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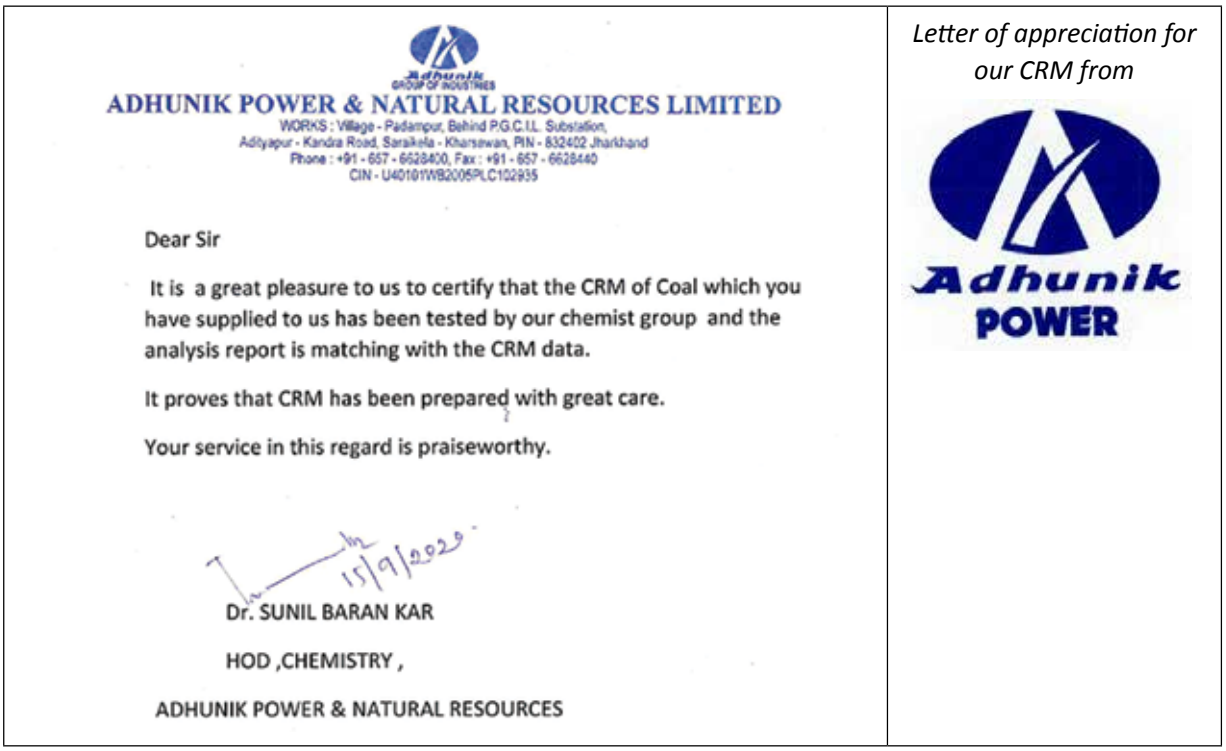
Impressions



ADHUNIK POWER & NATURAL RESOURCES LIMITED

WORKS : Village - Padampur, Behind P.G.C.I.L. Substation,
Adityapur - Kandra Road, Saraikela - Kharsawan, PIN - 832402 Jharkhand
Phone : +91 - 657 - 6628400, Fax : +91 - 657 - 6628440
CIN - U40101WB2005PLC102935

Dear Sir

It is a great pleasure to us to certify that the CRM of Coal which you have supplied to us has been tested by our chemist group and the analysis report is matching with the CRM data.

It proves that CRM has been prepared with great care.

Your service in this regard is praiseworthy.

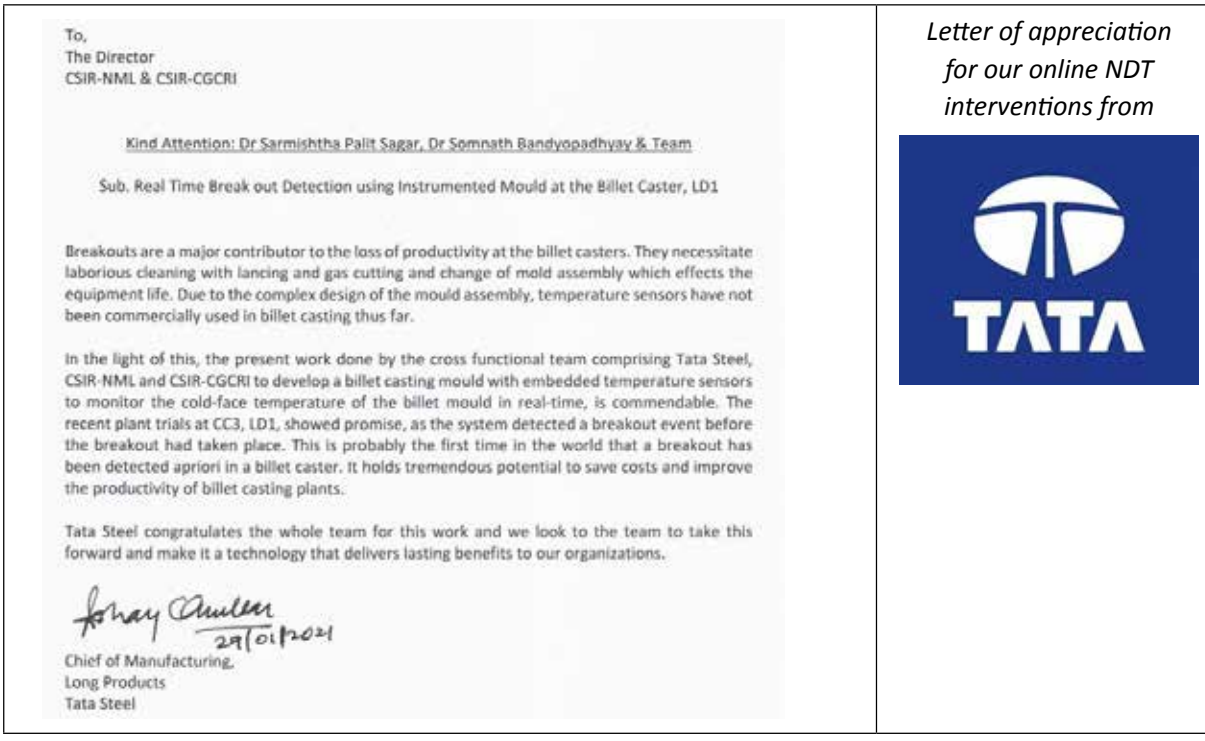
15/9/2020

Dr. SUNIL BARAN KAR

HOD ,CHEMISTRY ,

ADHUNIK POWER & NATURAL RESOURCES

Letter of appreciation for our CRM from



To,
The Director
CSIR-NML & CSIR-CGCRI

Kind Attention: Dr Sarmishtha Palit Sagar, Dr Somnath Bandyopadhyay & Team

Sub. Real Time Break out Detection using Instrumented Mould at the Billet Caster, LD1

Breakouts are a major contributor to the loss of productivity at the billet casters. They necessitate laborious cleaning with lancing and gas cutting and change of mold assembly which effects the equipment life. Due to the complex design of the mould assembly, temperature sensors have not been commercially used in billet casting thus far.

In the light of this, the present work done by the cross functional team comprising Tata Steel, CSIR-NML and CSIR-CGCRI to develop a billet casting mould with embedded temperature sensors to monitor the cold-face temperature of the billet mould in real-time, is commendable. The recent plant trials at CC3, LD1, showed promise, as the system detected a breakout event before the breakout had taken place. This is probably the first time in the world that a breakout has been detected apriori in a billet caster. It holds tremendous potential to save costs and improve the productivity of billet casting plants.

Tata Steel congratulates the whole team for this work and we look to the team to take this forward and make it a technology that delivers lasting benefits to our organizations.

29/01/2021

Chief of Manufacturing,
Long Products
Tata Steel

Letter of appreciation for our online NDT interventions from

Impact Making Technology

Flaw Guard : A Real time Defect Detection System for Cold Drawn Wires at Affordable Cost

Since wire diameters by definition are small and their length are in kilometers when manufactured, detection of defects on the surface are difficult to spot. Often the defects get revealed during processing of the wire at the customer end. While this is huge pain point for the wire manufacturer who has to ship back all the supplies of wires from the defective lot including those in transit, it is fortunate that the defective wire does not make it to the final product. Depending on the application, the presence of defects in the wire could cause failure during service with serious repercussion.

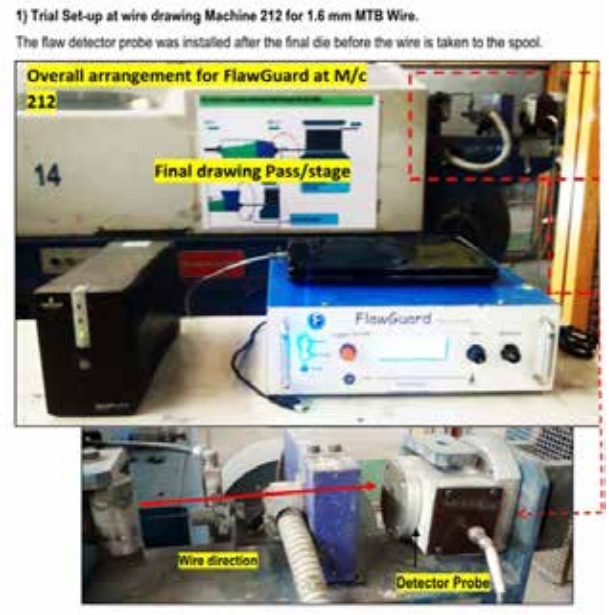
Thus, detecting the defects and isolating the spools based on defects severity during manufacturing is a need of utmost importance. The importance is heightened if the product is used for high end application such as Tyre Bead used in vehicle tyres. Wires of diameter 1.5 mm to 2 mm are used in tyres of trucks and buses to hold the rubber tyre against the wheel rim. A failure of this wire during operation of the vehicle can have serious consequences. Such high-end applications need wires free from any surface cracks. A system to detect the fine surface cracks during wire drawing at a high speed is clearly the need of the hour. Since there are several wire drawing lines, it is necessary to have the system on each of the lines. To fulfil this objective the cost of the defect sensing system must be affordable for it deployment in large numbers.

CSIR-NML “Make-in-India” technology, “FlawGuard” made it possible to identify fine cracks during drawing of wires of diameter ranging from 1.5 mm to 13 mm. It is a cost effective, smart sensing system for real-time defect detection and identification in wires drawn at speeds as high as 12-15 m/s. It is capable of working in harsh environment while providing immediate feedback on product quality during production. It comprises a sensor/probe, central processing electronic unit and interfacing & display unit. The electronic is embedded in an enclosure which can be placed away from the drawing line and the sensor placed in the line of wire drawing is connected through a coaxial cable. The software runs on the PC that can be placed at the operator’s end and the real-time data access through internet is included in the system. Performance evaluation of the system has been carried out and validated through several field trials at two reputed wire mills in India. The system is capable of detecting defects like seams, cracks, pits, fin, slivers, weld-line defects etc at a speed of 15 m/s with a depth resolution ~ 100 µm. Some of the important features of the system are as follows:

- Test material : Ferro and non-ferro magnetic wires/rods
- Test material diameter : 1.5 mm – 13 mm
- Depth Resolution : 100 µm
- Drawing line speed : up to 15 m/s
- Defect characterization : defect location, defect type and severity
- Real time data in ASCII format
- Graphical representation, data logging and post processing
- Interfacing through LAN
- Customized software for smart monitoring & control, real time data through IOT, SMS & E-mail facility.

Real time data availability in ASCII format for defect type identification at high speed drawn wires makes it unique and its **affordable cost** makes it an economically viable option for large scale implementations.

Applicability of the technology received formal recognition by the user Industry. Significance and appreciation of the technology are highlighted in the below letter received from the *largest manufacturer of Tyre Bead Wires in India,*



The Device : Flawguard


TATA

Sub: Contribution towards FlawGuard technology development

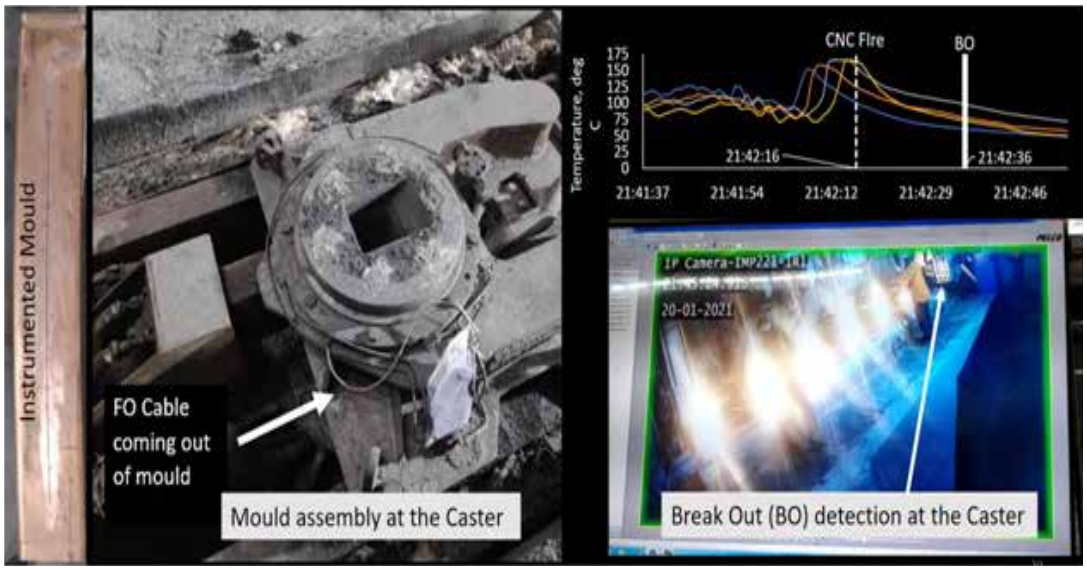
Appreciation letter from Tata Steel

"FOBOP": A Fiber Optic based Break out Prediction system for Billet Caster

Breakouts are containment losses of liquid steel from the still solidifying steel cast product before the point of full solidification. They are the major contributor to loss of productivity and equipment life at a continuous caster. These often lead to long outages which may involve laborious equipment cleaning with lancing and gas cutting and/or change of mould assembly/segments all together. Breakout detection systems are a mandatory part of most commercial slab and thin slab casters. For billet and bloom casters though, they are almost completely absent. This could be due to the size and shape of the billet mould which impose restriction in installing temperature sensor to measure the temperature on a commercial billet caster. Thus, the breakout detection in the billet caster remains an unmet need.

CSIR-NML in collaboration with CSIR-CGCRI provided an innovative solution to use Fibre Bragg Grating (FBG) as a temperature sensor. Work was carried out under the projects sponsored by M/S Tata Steel. Multiple sensors were written on a single optical fibre and embedded along the length of a billet mould. The "interrogation" of these sensors allowed for temperatures to be obtained along the length of the mould from a single strand of the optical fibre. In addition to the development of the FBG sensor, its installation in the harsh conditions (high temperature, high pressure, restricted space) of an operating caster has called for considerable engineering ingenuity. This too has been successfully accomplished. Two instrumented moulds

were installed in one of the casters of Tata Steel and the sensor output helped to detect the breakout well in advance. This is **First Time in the world,** that a breakout has been detected a-priori in a billet caster. It holds tremendous potential to save costs and improve the productivity of billet casting plants.



Urban Ore (E-Waste) Recycling

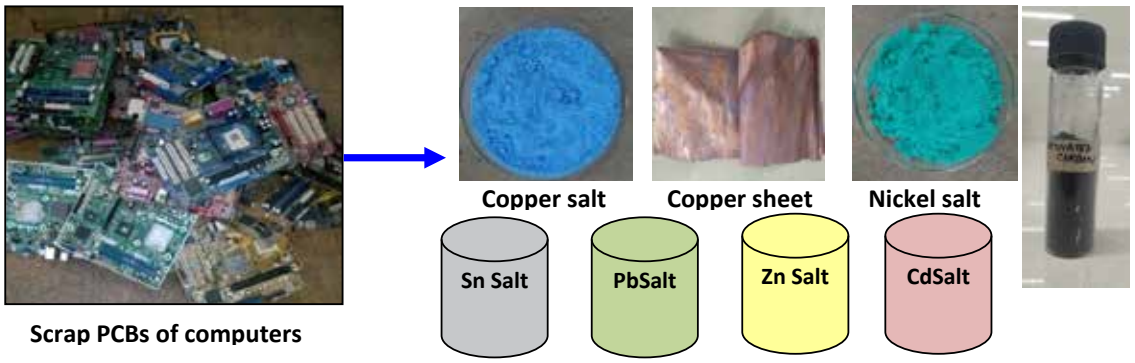
Electronic waste (e-waste) has emerged as growing topic of concern worldwide due to rudimentary disposal, improper collection system as well as lack of cost-effective technology for processing e-waste. E-waste includes scrap computers, laptops, hard disk, mobile phones, etc. According to a report about 53.6 million metric tonnes (Mt) of e-waste was generated in the year 2019 where as only 17.4% was reported to be collected and recycled. In the Indian context, out of all e-waste generated, only 5% of gets actually recycled. 95% recycling is usually carried out by the informal sector in an unorganized manner with high risk to their lives. Lack of proper collection system, illegal recycling by unorganized sector as well as lack of cost-effective indigenous technology for processing of e-waste, adversely affects the environment. Thus, it is essential to keep a watch on type, quantities and flow of e-waste in order to have a sustainable society and economy.

CSIR-NML has contributed a lot in the area of development of feasible process for recycling of e-waste to reclaim the metals, materials and valuables which are as follows:

1. Recovery of Cu, Ni, Pb, Sn, Cd and Zn from printed circuit boards (PCBs) of personal computers

Advanced technological equipments essentially contain printed circuit boards (PCBs) which constitutes a heterogeneous mixture of organic materials, metals, glass fiber, rubber, plastics and epoxy resins. An innovative process was developed at CSIR-NML to recover Cu along with Ni, Zn, Cd from waste PCBs using the process of mechanical pre-treatment/ organic swelling/ pyrolysis followed by physical beneficiation, leaching, solvent extraction and electro-winning. Initially, the waste PCBs were pyrolysed at various temperatures and gaseous atmosphere, the poly-cracked PCBs were subjected to comminution to separate the metallic from non-metallic parts. The obtained metallic fraction was leached using suitable lixiviants

for maximum dissolution of metals. Subsequently, the leach liquor, was processed by solvent extraction technique to obtain purified solution of metals. From the purified solution, salts/ metals could be obtained by precipitation, evaporation or electro-winning technique. The developed technology has been transferred to M/s Eco Recycling Company, Mumbai, India.

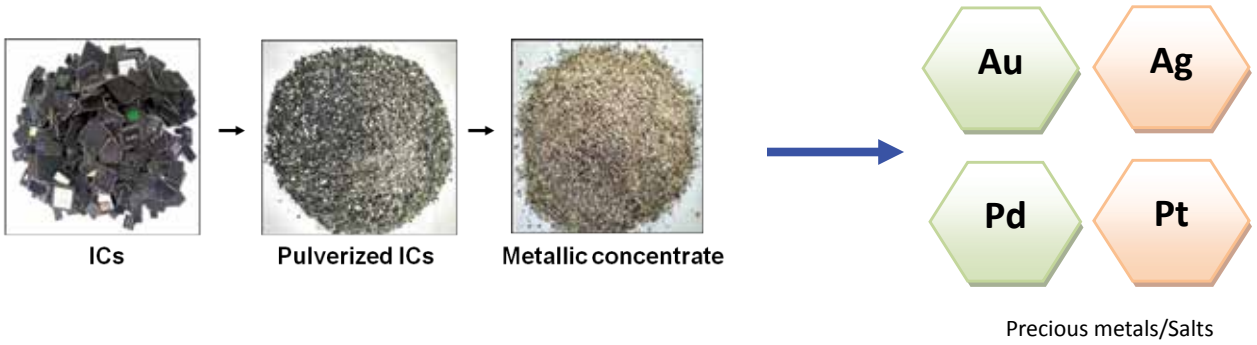


2. Recovery of precious metals from plated e-waste and telecom connectors

CSIR-NML, Jamshedpur has successfully developed a hydrometallurgical process to selectively recover gold from gold plated surface of e-waste such as PCBs of mobile phones, connectors and part of telecom exchange equipments. The gold plated e-waste were immersed in suitable medium for selective leaching of gold followed by the process of charcoal adsorption. The gold adsorbed charcoal was further burnt at elevated temperature (~1350°C) to obtain gold metal (high purity). The process was carried out in closed system following proper safety measures and the generated effluent was properly treated using electrolytic/ chemical oxidation. This technology has been transferred to three different recycling companies M/s ADV Metal Combine Pvt. Ltd., New Delhi, M/s Eco Recycling Company, Mumbai and M/s EXIGO Recycling Pvt. Ltd., New Delhi.

3. Recycling of waste integrated circuits (ICs) to recover Au, Ag, Pt and Pd

Another hydrometallurgical process flow-sheet to recover Ag, Au, Pd and Pt from the waste integrated circuits (ICs) present in e-waste has also been developed. Initially, the ICs were pre-treated and physically beneficiated to separate the metallic and non-metallic fractions. The enriched metallic concentrate was hydrometallurgically processed for the selective separation of Ag, Au, Pt and Pd. In first stage of leaching, maximum dissolution (~98%) of non-ferrous metals along with Ag was achieved leaving Au, Pd and Pt in the leached residue. Subsequently, precipitation of Ag followed by the selective separation of Cu and Ni using solvent extraction technique was carried out. In the second stage, the leached residue containing Au, Pd and Pt was dissolved in suitable lixiviant to dissolve more than 95% precious metals. The obtained leach liquor was processed for precipitation to get salt of Au, leaving Pt and Pd in the filtrate which was further selectively separated by solvent extraction method. From the pure solution, Pt and Pd were recovered as salt using the method of evaporation. The process has been transferred to M/s Evergreen Recyclekaro (India) Pvt. Ltd., Mumbai.



VISIT OF DG, CSIR TO URBAN ORE RECYCLING CENTRE

CSIR-NML has been working for development of application oriented e-waste recycling processes, fulfilling zero waste concepts to recuperate non-ferrous, rare earth and precious metals from e-waste. In order to carry out scale-up and pilot scale trials, a centre dedicated for the development of feasible technologies to recover non-ferrous, precious and rare earth metals from secondary resources has been established. Dr. Shekhar C. Mande, Director General of CSIR and Secretary of the Department of Scientific and Industrial Research (DSIR), Govt. of India inaugurated this centre named as Urban Ore (E-waste) Recycling Centre at CSIR-NML, Jamshedpur, on 20th April 2019. Under this banner, In the last two years under the banner of UORC, NML, the five-waste recycling technologies have been transferred to various Indian Recycling Companies viz. (M/s Evergreen Recyclekaro Pvt. (India) Ltd., Mumbai; M/s EXIGO Recycling, New Delhi; M/s SBCON Recycling Pvt. Ltd., Ahmedabad; M/s ADV Metal Combine Pvt. Ltd., Durg; M/s UNQ IND Pvt. Ltd., Firozabad; and M/s Eco Recycling Company, Mumbai) for the recovery of rare, rare-earth, precious and strategic metals. This initiative will create self-employment, entrepreneurship and promote cottage industries.

Indian Metal Crafts

Copper was one of the first pure metals that was used on a large scale. Pure metals used to be vulnerable so the artisans developed the mixed metals (alloys) to increase their strength.

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IMPACT ON SOCIETY

Detailed Project Report Preparation - Common Facility Centre for Silver Cluster

The jewellery artisans are still following an age-old traditional process for making ornaments. Lack of innovation and modernization, has resulted in a variety of problems, ranging from raw material to the marketing of products. Government and non-government organizations are coming forward with assistance. In one such initiative, Directorate of MSME, Government of West Bengal has helped the silver clusters to form a co-operative society, the 'Jafarnagar Astha Silver Ornaments Artisan's Welfare Foundation'. CSIR-NML, based on the discussion with various stake holders, and site visits, has prepared a Detailed Project Report (DPR). The DPR contains the details of the cluster, benchmark survey, proposed business model, machinery required, bill of quantity for civil estimation, commercial viability and demand and scope for diversification.

Knowledge delivery : CSIR Integrated Skill Training Initiative

CSIR-NML has been implementing CSIR Integrated Skill Training Initiative since 2017. The objectives of this program are i) to utilize CSIR knowledgebase and infrastructure for contributing to national skill mission; ii) to implement special up-skilling/training programs for societal benefits; iii) to implement identified skill/ training programs of national skill mission; and, iv) to promote entrepreneurship/ technopreneurship in CSIR through skilling, Training of Trainers and Incubation.

The following categories of training are provided:

• Corporate Training (CTP)	• Professional Training (PTP)	• NSDC Training (NTP)
• Societal Training (STP)	• International Training (ITP)	• Others Training (OTP)

The target groups for PTP & CTP are Professionals. These are paid trainings. Low cost or free trainings are provided to unemployed youth the through NTP, STP and OTPs. Specially designed low cost trainings for women are also conducted. In FY20-21, CSIR-NML organized the following training programmes, in the Societal Skill Trainings category:

#	Name of the Programme	Qualifications of trainees	Start	End	Duration (in days)	Number trained
1.	Industrial Training on Metallurgical Furnaces	10th pass	3rd Nov '20	9th Nov '20	10	140
			7th Dec '20	11th Dec '20		
2.	Faculty Development on materials processing and heat treatment	Graduate	11th Jan '21	15th Jan '21	5	54
3.	Scientist -Science Teacher conclave	Graduate			4	145
4.	Udyam Registration	10th Pass	5th Mar '21	5th Mar '21	1	22
5.	Intellectual Property Rights	10th Pass	17th Mar '21	19th Mar '21	3	25
6.	Quantitative Chemistry	10th pass	23rd Mar '21	1st Apr '21	6	15

#	Name of the Programme	Qualifications of trainees	Start	End	Duration (in days)	Number trained
7.	Industrial Training on IPR & Quantitative Chemistry	10th Pass	17th Mar '21	1st Apr '21	10	138
					Total	539

CSIR Virtual Laboratory

The project "CSIR Virtual Laboratory" aims to develop content for encouraging students to learn science with fun, by creating innovative learning tools through a Virtual Laboratory (VL), utilizing advanced digital technology in the areas of minerals, metals, materials and metallurgy. Under this project, CSIR-NML will develop innovative content for the VL by focusing on R&D activities of CSIR-NML. The CSIR-VL will be popularized among students through various publicity modes (print, digital, social media, road show, etc.). For improving the content of the CSIR VL, feedback from students and faculty members will be obtained through focused group discussions and by conducting brain storming sessions. Competitions will be organized among students for making innovative tools/devices based on scientific concepts. In addition, the CSIR-VL interface will be utilized to upload "2-Minutes-Talk" by women scientists, to encourage girl students to take up career in sciences.

Outreach programs : Jigyasa, School-NML Interaction Programmes, CSIR Model Village

Scientists-Science Teachers Conclave

Scientists - Science Teacher Conclave (SSTC) was organized by CSIR- National Metallurgical Laboratory under the aegis of CSIR Skill Initiative. This training was conducted in 4 phases. The objective of the programme was to provide various innovative teaching techniques to science teachers, which they can incorporate in their teaching methods to make science more interesting and comprehensible to students. The attendees for this training programme were science teachers from various schools and colleges all over India.

CSIR Model village

Under the CSIR Integrated Skill Initiative, CSIR-NML has started working on the project "Model Village" through which entrepreneurial skills will be offered to villagers. The idea of the model village project was suggested by the CSR committee constituted by DG, CSIR. The objective of this project is to develop a model village using CSIR technologies and innovations and to obtain CSR funding from corporates. The team of CSIR-NML selected Kedo village, which is located in Hitku panchayat, in East Singhbhum district, Jharkhand. The team visited the village and had a meeting with the villagers. The villagers raised many concerns, including lack of clean drinking water. CSIR-NML conducted test to check the level of Iron (Fe) and found it to be beyond the permissible limit, which gives rise to various health issues. It has been planned to offer training to the villagers for making simple water filters to remove iron. Other facilitating devices and means are also in the pipeline.

Performance Targets Achieved in 2020 - 2021

	Objectives	Planned	Achieved
1.	Total External Cash Flow (ECF)*	32 Crores	22.06 Crores
A.	Grant-in-Aid		1.99 Crores
2.	Industrial ECF (a part of ECF)	24 Crores	20.08 Crores
	a. Foreign Sponsored		0.1 Crore
	b. Public Sector Units (PSUs)		14.83 Crores
	c. Private Industries including Testing		5.15 Crores
3.	Customer Satisfaction Index	4.8	4.8
4.	SCI Publications (no.)	130	124
5.	Patents (no.)	25	20
6.	Copyrights (no.)	5	1
7.	Technologies Developed# (no.)	5	8
8.	Technologies Transferred* (no.)	5	3

**Cash flow generated from sponsored projects of industrial, PSU and government agencies.*

#Technologies Developed:

1. Zincometer: A sensing device for real-time Zinc weight measurement in galvanized wire lines
2. Indigenous Sodium metal production technology
3. Technology for beneficiation of low-grade Limestone containing finely disseminated Silica grains for utilization in the cement making industry
4. Energy-efficient production of low/medium Carbon Ferromanganese
5. Conversion of Hematite fines to Magnetite using Compressed Natural Gas (CNG)
6. Technology for production of Tungsten metal powder from plant tailings or waste sample
7. Low cost work hardenable Hadfield steel for heavy impact gouging wear-resistant application
8. Know-how for preparation of hydrogen standard (CRM) in steel

*Technologies Transferred:

1. Transfer of Know-How (Lab scale) for extraction of valuable and precious metals (Cu, Au, Ag & Co, Mn) from scrap of electronic waste & waste Li-Cobalt Batteries (Walle Infotech, Ranchi)
2. Transfer of Know-How for extraction of cobalt metal/salt from Black Powder of Lithium Batteries (UNQ IND PVT. LTD. Firozabad)
3. Transfer of technological KNOW-HOW for the extraction of Cu, Al and Au from waste PCBs (KNOW HOW) (Metaore Recycler Pvt Ltd)

Major Administrative & Business Targets Planned and Achieved in 2020-2021

Major Administrative & Business Targets Planned	Major Administrative & Business Achieved
• Recruitments: o Gr (IV) scientists: 10 nos. o Gr III, Gr II: 15 nos. • Training & development of higher and advanced skills of scientists/employees o Workshop & conference: 30 scientists and 10 employees o In-house: 15 employees o Through HRDC: 10 employees	• Formalities for advertising recruitment of Scientists has been completed • Finalization of Gr.III/II requirement is in the progress • Advertisement for recruitment of Security Officer has been made. • 27 Scientist/Technical staff attended Conferences/ Seminars/Workshops • 12 persons attended skill development/ capacity building programme

Major Technological & Scientific Targets Planned and Achieved in 2020-2021

Major Technological & Scientific Targets Planned	Major Technological & Scientific Targets Achieved
• Development of coatings to control the corrosion behavior of Mg-alloys in simulated body fluid for application as degradable bioimplants • Technology for on-board spacecraft life detection for ISRO • Sensor & device for damage assessment of components exposed to high temperature • Development of biodegradable alloys for orthopedic implants • Development of process for MAX phase synthesis for large application of metal carbides/ nitrides based 2D materials	• Proof of concept established, process being optimized • Device fabrication is in-progress. Expected to be delivered for testing by May 2021. • Eddy current Sensor susceptible to 750°C has been designed and characterized • Mg and Zn based alloys are developed with required mechanical strength. However, degradation rate needs to be controlled. • Process for layered Ti_3AlC_2 is established with phase purity of 80%. Efforts are on to improve the purity of the desired material
• Holistic utilization of red mud • Li extraction technology from end-of-life batteries on 1 kg scale.	• The detailed project proposal has been finalized and agreed by all six partners. MoU between all parties has been signed. • The project on Li extraction from end of the life batteries has been started and is progressing well. The technology at 1kg scale will be established.
• Q&P processed steel for higher Ms • Material data base for Fatigue crack propagation characteristics of Ti-6Al-4V under cyclic loading	• Technical part of the project is cleared; some terms and conditions are being worked out. The project approval letter is expected in first quarter of 2021-22.

Major Technological & Scientific Targets Planned	Major Technological & Scientific Targets Achieved
• Advanced Gravity Concentration of Chromite Beneficiation Plant Tailings • Identifying the Enablers to Reduce K_2O and SiO_2 in Dolomite Samples • Studies on Beneficiation of Low-grade Manganese ore Samples	• Concentrate with an assay of 40% Cr_2O_3 was produced and around 32% of chromite was recovered • Detailed characterization studies were completed for all the three dolomite samples. Developed a froth flotation studies for the reduction of K_2O and silica contents in concentrate to desired levels. • Beneficiation involving gravity, magnetic and reduction-roasting was carried out. Process route for upgradation of low-grade manganese ore for application in production of ferro-manganese was developed.
• Analysis of 10,000 refereed sample and 5000 core coal sample • Determination of trace and rare earth elements in Indian soil and sediment samples (3000 no) • Coal sampling, preparation and quality assessment of CCL coal washeries • 3 new CRMs of Brass, Alloy cast iron and H_2 pin standards • Development of Ceramic Coating and Self healing coating	• Analyzed almost 15000 refereed samples and 5000 band by band coal core samples • Not achieved, Samples not received • Coal sampling work at Rajrappa, Kedla, Kathara and Swang are continuing effectively • 5 new CRMs have been developed which includes Coal, H_2 Standards, Ferroalloys and Alloy cast iron • Developed technology to impart corrosion resistance to brass ammunitions
• Installation and Commissioning of 200 tones per day flotation column for fine coal flotation at Belatinda Coal Preparation Plant • Industry (plant) scale trials (5 tones per hour) of newly developed environment friendly flotation reagents for sillimanite at M/s Kerala Minerals and Metals Ltd., Kerala • Pilot plant scale trials (1 ton per hour) of newly developed environment friendly flotation reagents for limestone beneficiation at M/s Vedam Calcimin Pvt. Ltd., Telangana	• Erection and dry run completed. Commissioning with coal slurry is pending. Delayed due to Covid-related restrictions. Will be completed in 2021-22. • Reagent in bulk is ready. However, trials at commercial plant scale operations at M/s Kerala Minerals and Metals Ltd., Kerala were delayed due to Covid-related restrictions. Will be completed in 2021-22 • Completed

Indian Metal Crafts

A traditional Indian kitchen of copper/brass metals' utensils

There is a one-of-its-kind Utensil Museum in Gujarat. It showcases over 4,500 pieces crafted from brass, bronze, silver and gold inlay that tell us the evolution of metals from utility to art in India.

Sources:

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https://www.thebetterindia.com/86046/training-new-generation-keep-art-bone-carving-alive/

Performance Targets planned for 2021-2022

Sl.	Objectives	Planned
1.	External Cash Flow (ECF)*	25.0 Crores
2.	Industrial ECF (a part of ECF)	20.0 Crores
3.	ECF from Private organization including testing activity (a part of Industrial ECF)	7.0 Crores
4.	Customer Satisfaction Index	4.8
5.	SCI Publications (no.)	124
6.	Patents (no.)	25
7.	Copyrights (no.)	5
8.	Technologies to be Developed (no.)	5
9.	Technologies to be Transferred (no.)	5

Major Technological & Scientific targets Planned for 2020-2021

Advanced Materials Processing

Technology:

1. FOBOP: Fiber Optic based Break Out Prediction technology for Billet Caster
2. IoT based system for health assessment of blowpipe to avoid sudden failure
3. Improved corrosion resistance of the developed zinc and magnesium alloy as bio-implant for practical application.
4. Improve the purity of Ti_3AlC_2 (MAX) to >95% with an indigenous process

Technology Transfer : 04

Patents : 07

Publications : 25

Materials Extraction & Recycling

- Preparation of BEP for Li extraction on 1 kg scale from end-of-life batteries
- Production of 50 tons of briquette and supply to FSNL for carrying out trials at Bhilai Steel Plant
- Development of geopolymer cement for immobilization of radioactive waste. Preparation of cylinder samples of 100 kg and supply to BARC for evaluation.

Materials Evaluation

- Benchmark data generation for HCF and LCF for No base alloys
- Rejuvenation of Gas collector for Indian Navy

Minerals Processing

1. **Industrial projects:**
   - Pilot Scale beneficiation and agglomeration of dolomite concentrates (Tata Steel), Rs. 25 lakh
   - Effective utilization of middlings and fines of Coking coal washery for recovery of carbon values (Coal India Ltd.), Duration: 02 Years, Rs. 0.63 Lakh (for first year)
2. **CSIR Funded Mission project: Duration: 02 Years, Around 0.80 Cr**
   - Development of process for production of high purity (>99.9%) silica concentrate and metallic silicon from natural silica sand/quartzite for catalyst and electronic applications (CSIR-Silicon Mission Project)
3. **Proposal sent to BCCL for future activities**
   - Development of the novel gravity based beneficiation scheme for coal preparation which includes gravity separator such Spiral, MGS and compare the separation performance with exiting scheme
4. Studies on feasibility of low grade iron ore dry beneficiation using controlled air fluidization

Analytical and Applied Chemistry

1. Industrial Sponsored Project

   Band by band coal core chemical characterization will be carried out for geo-chemical mapping of coal mines sponsored by CMPDIL, Ranchi.
2. Coal India Sponsored Project

   Lab Scale Study on Reducing Ash Content (Mineral Matter) from Washery Grade Coking Coal (Grade III-VI) and High Ash Non-Coking Coal Through Oil Agglomeration
3. Referee sample analysis of Coal challenged by different coal industries
4. Self-healing Anti-corrosion Coating for Steel

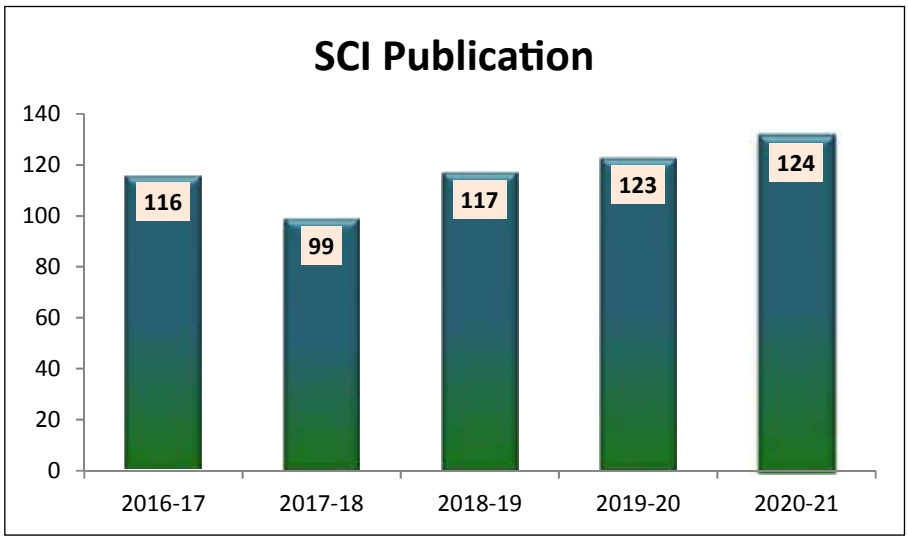
   CSIR-NML has recently developed self-healing coating for corrosion protection of steel. The coating prevents corrosion of steel even after formation of scratch or cut in the coating. The scratch self-heals in presence of water and prevents corrosion. The coating passes 1000 hours of salt spray test after breakage of coating. The coating can be applied by brushing or spraying and it is suitable for onsite application.

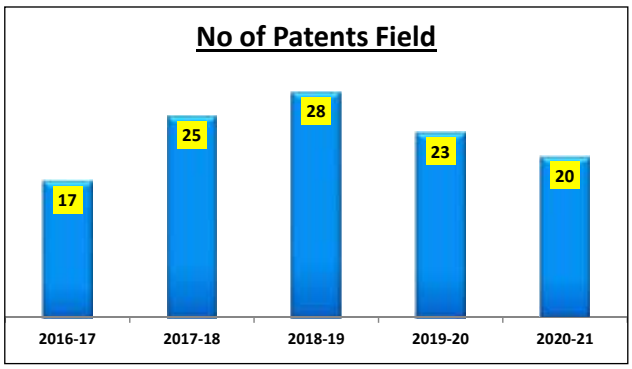
   Rare earth and trace element analysis of sediment & rock samples supplied by Geological Survey of India.

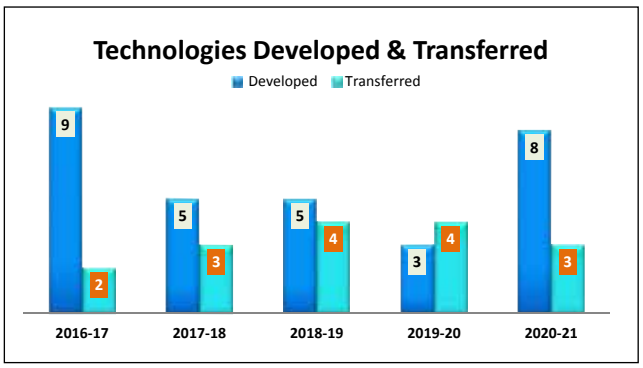
NML-Madras Centre

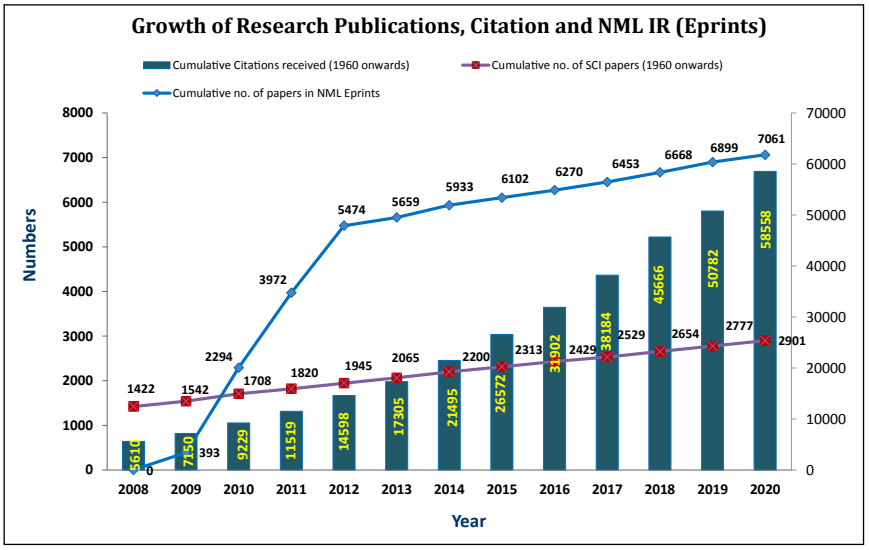
- Installation and Commissioning of 200 tonnes per day flotation column for fine coal flotation at Belatinda Coal Preparation Plant of M/s Tata Steel Ltd.
- Industry (plant) scale trials (5 tonnes per hour) of newly developed environment friendly flotation reagent for sillimanite at M/s Kerala Minerals and Metals Ltd., Kerala

R & D Output Graphs









CSIR-NML Publications and News

Advanced Materials and Processes

Advanced Materials and Processes (AMP) Division focuses on the development of advanced materials, processes & techniques for the improvement of materials functionality, component's performance and mitigation of environmental problems related to materials application in the sectors of energy, space, oil & gas, iron & steel, biomedical and infrastructure. The division has, broadly, two major themes namely (i) Development of sensors and devices for non-destructive evaluation (NDE) & structural health monitoring (SHM) and (ii) Development of advanced materials and coatings for energy, health and environmental sectors. The Two themes are made operational through three research verticals (research groups) of the division, namely (i) Non-destructive Evaluation and Magnetic Materials (NDEMM) group, (ii) Surface Engineering and Coatings (SE) group and Functional Materials (FM) group. With a strength of 19 scientists, 2 technical officers, 2 technical staff, 01 post-doctorate and 4 Ph.D students, the mission of the division is to evolve and translate end to end solution to the stake holders, dealing with advanced materials and processes under different technological sectors. Such a business plan could only be put in place due to constant and close lab-industry interactions.

The note-worthy divisional contributions under the two themes, during 2020-2021 are briefly described in the following sections:

Theme 1:

Sensors & Devices for NDE & SHM

With Industry 4.0 becoming increasingly pervasive, the importance and usage of sensors has increased several folds. Industry 4.0 refers to a new phase in the industrial revolution that mainly focuses on interconnectivity, automation, machine learning, and big data. Real-time structural health monitoring (SHM) of components in the industrial process is one of the crucial and important facets of Industry 4.0. CSIR-NML has established its presence in the area of component integrity assessment and sensors and devices over the last three decades. Our work on sensors & devices for structural health monitoring is categorized under the following sub-heads:

[I] Thermal sensing in Harsh Environment,
[II] Sensors for Materials Property Evaluation,
[III] Sensors for Wires/Rods and
[IV] sensors for Remaining Life Assessment.

[I] Thermal Sensing in Harsh Environment:

During "Continuous Casting" in a steel plant, liquid steel is solidified into long solid bars with rectangular cross sections (billets) during its passage through water-cooled copper mould. The quality of the solidified billet is dictated by the manner in which heat is extracted from liquid steel in the copper moulds. Quality as well as "breakout" are the issues in the billet caster. A breakout is a liquid steel containment failure in which the solidifying shell of a continuously cast strand ruptures allowing the liquid steel within to 'break out'. Breakouts

are a major contributor to loss of productivity and equipment life in a continuous caster. These often lead to long outages. In conventional slab casters, the impact of breakout is most severe with the caster having to be put down for up to 20 hours after a breakout. At billet casters, breakouts by themselves usually need only a change of mould (20 to 30 mins) to restart, but they still do cause significant production loss as the mould can only be changed when all strands are stopped and the tundish removed. Thus, in effect, a break out could cause one strand to be unavailable for casting for an entire tundish sequence. Slab casters are equipped with breakout detection system but no breakout detection systems were in use at any of the billet casters. Due to the size and shape restriction of the billet mould, it has not been possible to install temperature sensors to measure the temperature in a commercial billet caster. Thus, the assessment of the quality of the billet as well as the breakout detection in the billet caster remained an unmet need.

CSIR-NML in collaboration with CSIR-CGCRI provided an innovative solution to use Fibre Bragg Grating (FBG) as a temperature sensor. Work was carried out under projects sponsored by a steel multinational. Multiple sensors were written on a single optical fiber and embedded along the length of a billet mould. The "interrogation" of these sensors allowed for temperatures to be obtained along the length of the mould from a single strand of optical fiber. In addition to the development of the FBG sensor, its installation in the harsh conditions (high temperature, high pressure, restricted space) of an operating caster, called for considerable engineering ingenuity. This has been successfully accomplished. Two instrumented moulds were installed in one of the casters of the sponsor, and the sensor output helped to detect the breakout well in advance. This is *globally the first time* that a breakout has been detected a-priori in a billet caster **[Figure 1**]. It holds tremendous potential to save costs and improve the productivity of billet casting plants.

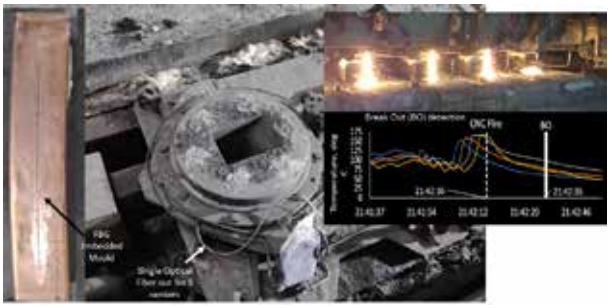


Figure 1 : Breakout detection through temperature sensing in Billet Caster

Blast furnace, the heart of a steel industry, is used to smelt iron ore to produce iron. In blast furnaces the raw materials are charged from the top and hot blast is blown through tuyeres from the bottom level. These tuyeres draw the hot blast from bustle pipe through blowpipe and then they inject it into the blast furnace. Therefore, the blowpipe and tuyere are exposed to high temperature flowing fluid, directly. This makes them vulnerable components in the blast furnace. In addition, a blow pipe carries pulverized coal particles and any failure can lead to leakage of coal and hot gas outside. Such failures not only affect the productivity in terms of breakdown, but it also causes safety threats as the blowpipes carry flammable pulverized coal and hot blast together. In the last two financial years, four blowpipes failure in only one BF of a Steel Multinational had happened. Challenges of assessing the critical condition of the blow stock lies in its inaccessibility for measuring temperature, and, in locating of the hot-spot zone. Embedding FBG sensors equipped with IoT to map the temperature of blow stock and sensing the critical condition will help the steelmaker to tackle this serious problem. The feasibility of the sensing system has been established through real time

trial at one of the blast furnaces of the sponsor. Presently, development of an ANN based trained system to detect the location of critical hot zone from the output of optimum number of sensors, is being carried out. Simulated blow pipe and its thermal profile are presented in **Figures 2a and 2b** respectively.

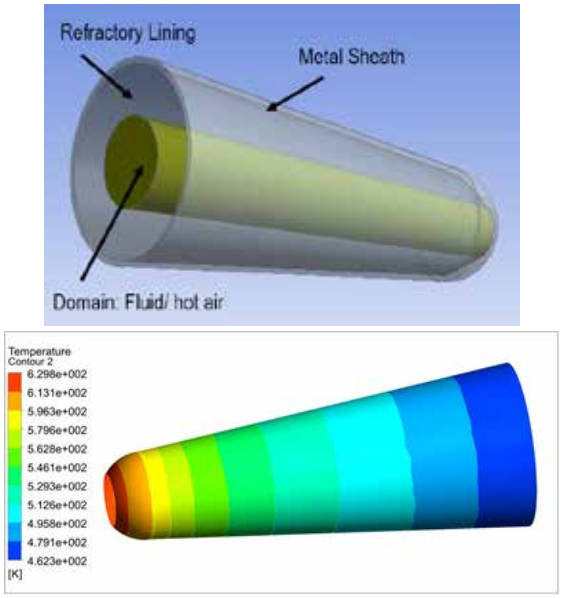


Figure 2:(a) Simulated blow pipe and (b)its thermal profile

[II] Sensors for Materials Property Evaluation

Tungsten-Carbide (TC) rolls are manufactured through powder metallurgy route. The tungsten carbide powder is mixed with some binder material such as cobalt or nickel, then compacted in a die and finally sintered in a furnace. The tungsten-carbide component thus manufactured have good thermal conduction property, wear resistance and strength along with high hardness, which makes this material an excellent choice for roll rings used in the production of wire rods, plain bars and deformed bars, etc., at high rolling speeds. In these TC rings, the percentage of binder contributes largely in controlling the mechanical properties of the components. Density, Young's Modulus, wear resistance, and compressive strength decreases with increase in percentage of binder, which ultimately affects the life span of the Rings. Generally, the TC rings are supplied by the manufacturers along with a datasheet and are inspected at the plant end only for checking physical dimensions and damages. Thus, in components where the binder percentage is more, it may undergo unscheduled roll breakage, reduction in pass life, variation in wear pattern, which are major concerns for the operators. There is no such technique to verify the quality of supplied components on site, in a non-invasive way. Under this project, CSIR-NML has developed a non-invasive methodology for detecting the binder % and density variation across the roll. A joint patent has been filed. A portable device for binder % and homogeneity detection of TC rings has been fabricated and handed over to the client.

A major concern faced by the copper wire industry, is the presence of a substantial number of defects in terms of inclusions and porosity in the coils being produced. However, due to the lack of information on bulk defects, it is difficult to categorize the copper wire coil for a certain application/segment. Copper wire rod application areas cover a wide variety of different disciplines, which include manufacturing, construction, energy and automotive sectors. It is extensively used as building wires, communication cables, co-axial cables, power cables and cables for industrial applications. These high-precision applications have led to the escalation in demand for better quality defect-free copper rods with fewer wire breaks, i.e. superior drawability. Identification and characterization of defects is therefore extremely important at an early stage not only for categorization but also to reduce the rate of rejection. Under a sponsored project, feasibility of in-line ultrasonic scanning technique for real-time defect detection was established. Different diameter rods of different grades were supplied by the sponsor for defect detection and quantification

at different scanning speeds. Results of gradation of rods based on the quality were verified with the plant data and was found fully satisfactory. This project led to a pilot scale system development for in-line defect detection of Cu-rods.

The weld joint is one of the weakest point in thermal power plant tubes and pipelines. The weld region typically consists of the base metal, heat affected zone (HAZ) and fusion zone. It causes wide variation of microstructural phases and related stress along the weld joint. It is important to develop non-invasive techniques to distinguish all these three zones. In a sponsored project, it was aimed to evaluate all the three zones of 2.25Cr-1Mo steel boiler pipes by magnetic hysteresis loop (MHL) technique. After post-weld heat treatment (PWHT), the generated stress along the welded joints is relieved with increasing temperature and holding time. A linear decrease of coercivity was observed as a function of time. This was done on the laboratory processed samples at high PWHT temperature for a long holding time and for service exposed pipelines (~17000h). The result shows promise of using magnetic technique for non-destructive characterization of weld joints of service exposed power plant tubes and pipelines. This needs to be explored further for the creep-exposed weld joints.

[III] Sensors for Wires/Rods

Wire drawing is a widely used forming process in which the diameter of a wire is reduced by using a converging die. The drawn wire is coated with Zinc through the hot-dip galvanizing. Galvanised wires are used in a number of applications such as in farming, fencing, poultry and so on. Generally, the coating thickness is controlled in two different ways: Nitrogen wiping (for thick coating) and Pad wiping (for commercial line, thin coating). The Zinc weight control system exists in N_2 wiping line but there is no such system for commercial lines**.** Automatic coating weight control in the HDG line is essential for uniform production with minimized zinc consumption. CSIR-NML under a Fast Track Translation project, developed a sensing device coupled with feedback control facility to measure the coating weight ranging from 52 GSM – 350 GSM in real time. The sensing device and sensor sensitivity was benchmarked with respect to the imported system available in the thick N_2 wiping line and then was tested for the commercial line at a commercial wire drawing unit in Mumbai and found to be suitable for measuring coating weight in the commercial line in real time. The trials were carried out for a period of 20 days in one line for 53-60 GSM and also for 90-120 GSM, at another wire producer. The device, Zincometer™ and its performance is depicted in **Figure 3.** Fabrication of five sensors along with a device for implementation in the commercial GI line, at one of the renowned wire mills in India, is in progress.

Figure 3: The device, Zincometer™ and the performance of the sensor w.r.t to the Laboratory result for 53-60 GSM line for 5 days

In order to provide an adherent, defect free and long-lasting galvanized coating on the steel surface, the pretreatment of surface is an important aspect. In all the galvanizing lines, whether batch or continuous, the pickling and rinsing of the surface is invariably carried out to remove oxides scales. The pickling involves use of Hydrochloric acids. The acid

disposal and its treatment for disposal are banned in the developed world and now these norms are also in force in India. To address these issues through a green technology, under a collaborative project, Ultrasonic Assisted Electrochemical Technique (UAET) has been evolved. Under this collaborative project, we have come up with a technique, which combines high intensity ultrasound and an alkaline electro-chemical process to remove the oxide scale of wires. A real time setup is in progress at the user industry.

[IV] Sensors for Remaining Life Assessment

Structures/components have a fixed life span depending on the conditions to which they have been subjected. The life of engineering components is affected by various damage mechanisms such as creep, fatigue (mechanical and thermal), corrosion, erosion, etc. Generally, the damage assessment consists of specialized metallurgical inspection on samples taken from the structure. It is often important to know what fraction of the life span has been consumed and the remaining life, in a non-invasive way. CSIR-NML is working on the development of various non-destructive evaluation (NDE) techniques and methodologies for remaining life assessment of different engineering components such as power plant components, pipes, reactors, and even for space crafts.

Under a project sponsored by DST, New Delhi, a magnetostrictive sensing device for structural integrity evaluation of long range pipes is under progress. In the magnetostrictive sensing (MsS) system, the mechanical wave generation in plates and pipes is a pivotal phenomena controlled by magnetisation system. The intensity of the reflected MsS signal from any defects is dependent on the contribution of magnetising field operating in the frequency range of few tens of kHz. An amorphous /nanocrystalline FeSiB alloy ribbon is pasted on the pipe and acts as a transducer and simultaneously as an actuator element, synergistically functioning for magnetostrictive and Villary effects respectively. The transduction efficiency of the a.c magnetising field can be altered using a dc biasing field. However, such transduction is supposed to be dependent on pipe material properties as the guided waves generation in the present case is controlled by magneto-mechanical interactions. Sensitivity of the sensor was tested in aluminum (#Al), galvanized iron (#GI) and mild steel (#MS) pipes. It was observed that impact of dc magnetizing field on MsS signal is much higher in non-ferrous (# Al) pipe as compared to ferrous pipes (#GI, #MS). This behavior has been associated to higher magnetic flux concentrations around sensor element in non-ferrous pipe as compared to the ferrous pipes. A patent has already been filed on the effect of magnetization in the detection sensitivity of the MsS sensor.

Advanced ultra super critical (AUSC) power plant with enhanced steam temperature and pressure is essential for improved plant efficiency and reduced carbon foot print. In the Indian AUSC programme, Inconel 625 and 617M have been identified as candidate materials for some of the key components. As these are relatively new materials, there are no reported literatures on non-destructive evaluation to assess the progression of creep, which are essential for design and the condition monitoring to ensure structural integrity during service. This initiative, under the AUSC project, aimed to understand the inter-relationship between the NDE parameters and the material microstructure. Various non-destructive techniques with an emphasis on attenuation of ultrasound wave, non-linear ultrasonic (NLU) and electromagnetic (EM) would be used to study the progression of creep damage in alloy 617M, which is one of the proposed materials for the

AUSC power plants. Interrupted creep tests were conducted at two conditions, 650°C/305MPa and 750°C/165MPa followed by NDE measurements using NLU, Ultrasonic and Eddy current techniques. Under this project, eddy current system and sensors have been fabricated indigenously for point-to-point as well as area scanning. It was observed that the NLU parameter and eddy current signal are quite sensitive in predicting the onset of creep strength deterioration. Image of eddy current voltage variation and the corresponding line-scan at various creep exposure time of the sample tested at 750°C/165MPa is depicted in **Figure 4**.

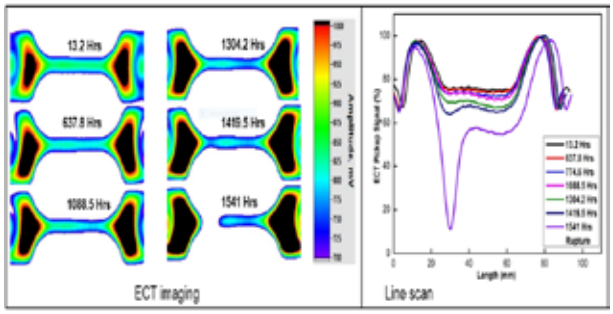


Figure 4: Eddy current voltage variation and the corresponding line-scan at various creep exposure time of the sample tested at 750oC/165MPa

Most component damage evaluation is based on periodical inspection during shut-down. Non-availability of sensors operative at high temperatures and pressures is a major handicap for in-situ assessment and monitoring of degradation during operation. Efforts are being made to bridge the gap by developing application specific high-temperature sensors. In this work, a low temperature co-fired ceramics (LTCC) technology is being used to develop a planar eddy current (EC) sensor in order to improve the feasibility and reliability of the condition monitoring of components in harsh and high T environments. The sensor consists of a micro-fabricated primary (drive) winding and a secondary winding adjacent to the primary for sensing the response to a material under test. Multiple coils are cascaded/stacked together to increase the SNR and sensitivity of the sensor. A finite element (FEM) based simulation model has been developed over COMSOL Multi-physics simulation software for sensor parameter optimization prior to the final fabrication. Automation of furnace with impedance analyzer for high temperature electrical property evaluation has already been done. A couple of sensors applicable up to 850°C have been fabricated and tested at high temperature. The sensor fabricated through LTCC process is shown in **Figure 5.** Successful development and installation of these sensors will be useful in assessing the remaining life of power plant components in real time.

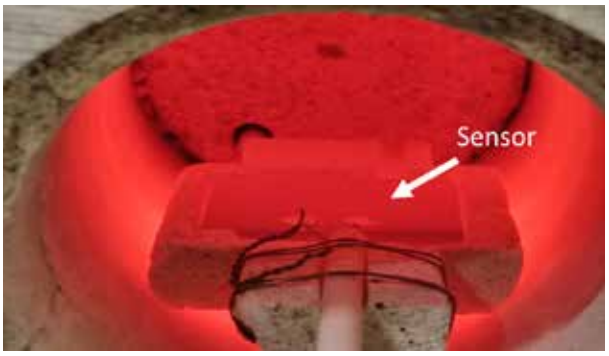


Figure 5: The sensor fabricated through LTCC process characterized at high temperature

Spacecraft propellant gauging is one of the important activities that allows estimating the amount of propellant available onboard in a spacecraft. The propellant availability dictates the life of the spacecraft; also the data related to the propellant availability determines the mission sequence and decisions. CSIR-NML along with LPSC, ISRO, Bangalore are collaborating to fabricate four systems using flight qualified electronics for on-board propellant gauging of space craft. This project is the outcome of the successful demonstration by CSIR-NML in fabricating and developing a system for measuring the flow rate of fluids through a narrow tube. Qualification tests of the devices

for continuous and pulsating modes for further use in Indian spacecraft will be carried out. The electronic package development involves pulsar, receiver, onboard storage and signal processing, which will enable acquisition, analysis and delivery of data from spacecraft to the ground stations. Design and components for the master module has been confirmed and the fabrication of the master module is in progress.

Theme 2 : Advanced Materials & Coatings

A continuous improvement in the functionality of advanced materials and their designed and controlled interaction with environment, has brought a *paradigm shift* in the science and technology of materials. Development of contemporary materials is now on the basis of design where desired functionality is introduced through a designed structure property correlation. Such a development has not only solved the age-old technological problems in the field of energy, health and environment, it has also given birth to knowledge based industries. Keeping in view the upcoming and contemporary demands of such materials industries, AMP Division has been constantly involved in the development of such materials and coatings in collaboration with Indian materials industries and line ministries. Notable developments are listed here:

Amorphous Electrical Steel (AES) for Energy Applications

CSIR- National Metallurgical Laboratory (NML), Jamshedpur is working on a pilot scale project titled "Amorphous electrical steel for energy application" sponsored by the Ministry of Steel (MoS), Government of India. The project aims to establish a 100kg pilot scale melt spinning facility for the production of FeSiB based amorphous electrical steel sheet having dimension 100mm wide and 25-30μm thick. In addition to the development of pilot plant facility for the production of such ribbons, research is also being carried out on a series of marginally glass forming Fe-rich alloys having nominal compositions of $Fe_{82}B_{14}Si_2Nb_2$, $Fe_{83}B_{13}Si_2Nb_2$, $Fe_{83}B_{12}Si_2Nb_2Cu_1$ and $Fe_{85}B_{13}Nb_2$, (assigned as Fm_{82}, Fm83, $Fm_{83}Cu_1$ and Fm_{85}, respectively). The work aims at increasing the magnetization level and understanding the magnetization behaviour of Fe-rich hetero-amorphous type ribbons. The annealing temperature (T_a) dependence of coercivity (H_c) shows monotonous, irreversible increase for Cu- free alloys, highlighting magnetic property degradation during nanocrystallization event **(Figure 6)**. Moreover, the degradation in magnetic property of annealed ribbons has been observed at temperatures below the primary onset of crystallization. The as-quenched FM82 ribbons exhibit initial H_c of 25.8 A/m, increases marginally to 26.5 A/m (325ºC) and shows drastic increase to 285 A/m at 500ºC. Further, the FM83 and FM85 ribbons annealed at 380ºC show rapid deterioration of soft magnetic behaviour, exhibiting large H_c of 397A/m and 588 A/m from an as-quenched value of 24 A/m and 22 A/m respectively. In contrast, the FM83Cu1 alloy shows magnetic softening at 350ºC and gradually increases to 190 A/m at 500ºC. The work outlines the heterogeneous, multi-stage crystallization process in Fe-rich high induction alloys.

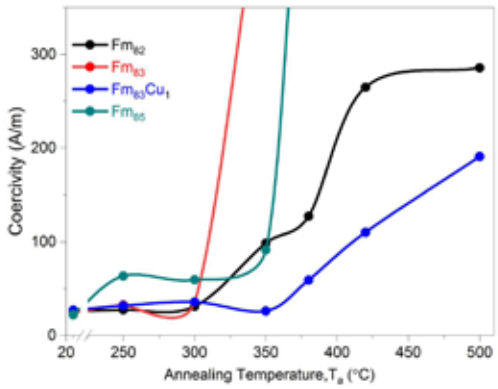


Figure 6: Monotonous, irreversible increase for Cu- free alloys, highlighting magnetic property degradation during nanocrystallization event

3D architecture with hierarchical porosity for energy storage application

Under a DST sponsored project, the development of various electrode materials for green energy storage system, super-capacitor, is going on. In materials, graphitic carbon and 2D-MXene were explored as electrodes for super-capacitors to be used for different applications like running calculator, glowing LEDs, etc. In this context, one patent (application number 2020111002157) is already filed on 2D-MXene and bimetallic chalcogenide based energy storage electrode. Further development of MXene based materials were carried out by doping phosphorous on Ti_3C_2 MXene. Phosphorous doping on 2D-Ti_3C_2 MXene sheets remained highly challenging as it is very prone to produce phosphates. However, a modified process was developed successfully to dope phosphorous on 2D-Ti_3C_2 MXene sheets. This study will reveal the high science to create knowledge on MXene doping process. Moreover, activated graphitic carbon based materials were also developed for application in super-capacitor. A process was developed for large-scale production of activated graphitic carbon from bio wastes, like vegetable and fruit skin, coffee grounds, tea leaves, etc. This is a single step process where different microwave power (400 W - 1000 W) is used. Activated graphitic carbon and a nickel based composite was also developed and it appears as an effective electrode material for super-capacitor.

Process development for layered transition metal carbides/nitrides/carbonitrides (MAX)

During the exploration of 2D-MXene which is derived from the MAX phase, we realized that high quality MAX phase is not commercially available in India, and thus, researchers procure it from overseas at a very high price. Through a CSIR sponsored FBR project, development of an advanced material Ti_3AlC_2, which is known as MAX is going on. This MAX phases are the parent of 2D-MXenes. Therefore, this project is important to support self-reliant program through import substitution. Ti_3AlC_2 is required to produce 2D-Ti_3C_2 (MXenes) which shows very high electrical conductivity, high hydrophilicity, diversity in redox centers and many interesting properties. Looking at the present importance we have also initiated the programme to produce different MAX phases at a large scale. Initial result of Ti_3AlC_2 is promising and further optimizations of the process are going on to control the purity of the initially produced MAX powder.

Development of high strength Zn-based bio-degradable alloys for orthopedic applications

The project on the development of Zn alloys for biodegradable orthopedic implant applications is sponsored by a reputed Biomaterials Manufacturer. Different Zn alloys were prepared in an electrical resistance furnace**.** The as-cast alloys were investigated for their microstructure, structural and mechanical properties. The ultimate tensile strength of the as-cast alloys varied from 130 MPa to 206 MPa. Zn-Mg alloy exhibiting high strength was homogenized and extruded to produce plates. The extruded Zn-Mg plates exhibited an ultimate tensile strength of ~ 310 MPa and an elongation of 19 % as compared to the UTS (206 MPa) and elongation (2%) of as-cast alloy. This is sufficient for bio implant application. However, the degradation of the alloy under body fluid condition needs to be improved.

Development of adherent Zn coating on Mg-Zn-Mn for enhancing implant life:

In another project, and as a continuation of above project, the focus is on the development of adherent Zn coating on the developed Mg-Zn-Mn alloy to enhance the life of the implant to a desired extent. An adherent Zn was electrodeposited on Mg-Zn-Mn

alloy from an aqueous bath without using Cr(VI) or HF. The substrate was pretreated using standard industrial sequence. The electro deposition was optimized using different current wave forms. The pulse reverse deposition produced compact and defect free coating **(Figure 7).** Pure Zn and Zn with prior barrier coatings show corrosion rate of 0.44 and 0.08 mm/y in simulated body fluid (SBF) solution. The Zn coating and Zn with prior barrier layer sustained 5 and 44 days during exposure to SBF solution. A multilayer coating (two alternate layers each) sustained more than 120 days during continuous exposure to SBF solution **(Figure 8).**

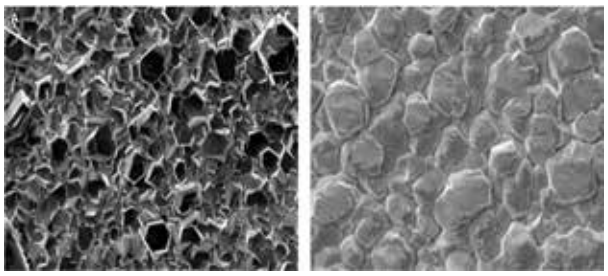


Figure 7: Coating produced by pulse reverse deposition is much more compact.

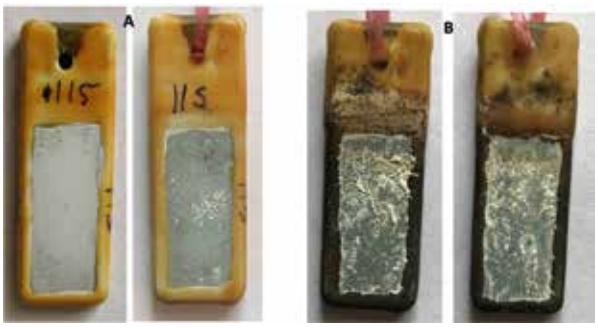


Figure 8: The multilayer coating (two alternate layers each) sustained more than 120 days during continuous exposure to SBF solution

Development of Tin-Selenide based thermoelectric thin films to harvest the waste heat in metallurgical and other industries:

Thermoelectric materials are well-known heat to electricity converters, and vice versa. They are considered to have great potential for harvesting the waste heats in different industrial processes ranging from the metallurgical industry to electronic industry. The thin film research on various thermoelectric materials of different figure of merit (ZT) at different temperature ranges has shown tremendous prospects to tap industrial waste heat. However, development of a thermoelectric thin film with a high ZT at moderate temperature (≥773 K) is still a challenge to the scientific community. Recently, Tin-Selenide (SnSe) single crystal (bulk form) has been reported to have ZT value of the order of 2.6. However, the fabrication of SnSe single crystal is a tedious process and these crystals are very brittle. The industry environments need mechanical robustness and hence these single crystals are not good for application. At the same time, perfect single crystals achieved till date are of very small sizes. Efforts are on to improve the performances of these materials in the form of thin or thick films, which will be ultimately required for making devices. Thin films can be grown in single direction, coated on large areas, and has the potential for use in recovery of waste heat. The research on SnSe thermoelectric thin films are at an infancy stage and needs a lot of understanding and development to fabricate thermoelectric generators. The polycrystalline SnSe targets/pellets have been prepared through powder metallurgical route. The optimization of power factor of the prepared targets has been done against the sintering parameter. The high value of the power factor is essential to get the ZT > 2. The maximum obtained power factor at 773 K of the SnSe target at the optimized sintering parameter is 1.5 **(Figure 9a).** The maximum obtained power factor is comparable to the reported power factor (in 'a' direction at 773 K) for the single crystal SnSe. The same target has been used to deposit SnSe thin films on various substrates (Glass, Steel, and Si (111) wafers) through thermal evaporation route.

Figure 9b shows the preferentially (111) oriented microstructure and the morphology of the SnSe thin film deposited over glass substrate. A preferred texture is desired for the proposed application and is obtained by optimization of the deposition parameters. The thermal properties of the deposited films have not been studied yet and are under progress.

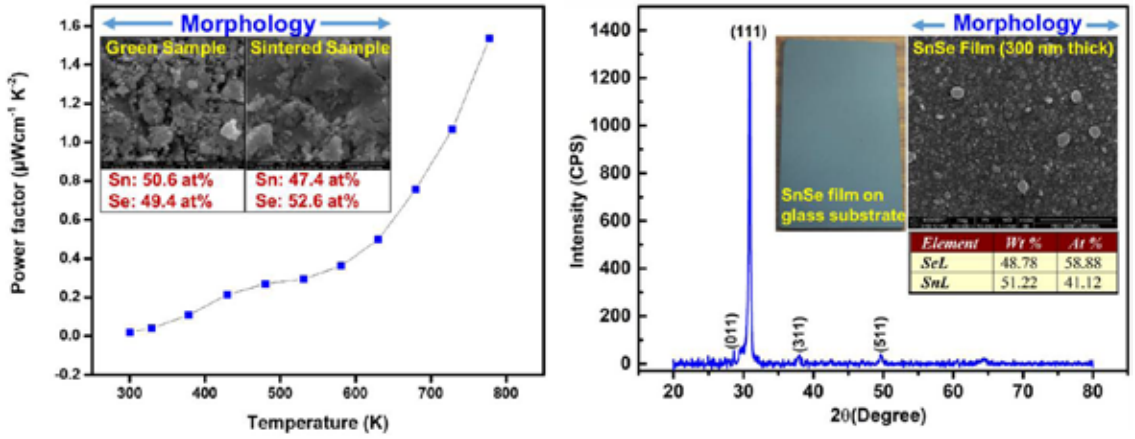


Figure 9: (a) Maximum obtained power factor at 773 K of the SnSe target at the optimized sintering parameter is 1.5
(b) Preferentially (111) oriented microstructure and the morphology of the SnSe thin film deposited over the glass substrate

Staff of Advanced Materials & Processes (AMP)

Analytical & Applied Chemistry

The focus of Analytical & Applied Chemistry (AAC) Division is ascertaining the chemistry of metallurgical products and application of chemistry for improvement of metallurgical processes. Basic and applied research projects are executed in the areas of Analytical chemistry, Inorganic chemistry, Mineral & Materials chemistry, Corrosion protection, and Coal chemistry. AAC division also develops and markets Certified Reference Materials (CRMs) for metallurgical products like ores, minerals, Coal, Steel, Ferro-alloys and other metal alloys. AAC department is fully equipped with state of the art analytical instruments to provide analytical support to the ongoing R&D projects of CSIR-NML and provides analytical testing service to outside agencies. AAC Division of CSIR-NML is a NABL accredited Laboratory for chemical testing as per ISO/IEC 17025:2017. Below are some of the major achievements/activities of AAC Division in 2020-21.

1.0 Coal Quality Assessment

India produces about 700 MT of coal annually and quality assessment of the coals produced is of national importance. The AAC Division carries out quality assessment of both coking and non-coking coals through chemical characterization using its state-of-the-art coal characterization laboratory. The test facilities available include :

- Coal core logging and sample preparation
- Band by band analysis (Ash+ Moisture)
- Proximate analysis (both conventional & microprocessor based equipment)
- Determination of GCV
- Ultimate analysis, Carbonate CO_2
- Moisture at 60% RH & 40 ^{0}C
- Phosphorus
- Ash Analysis
- AFT range (IDT, ST, HT & FT)
- HGI
- Free Swelling Index
- LTGK Coke Type
- Plastometric test

1.1 Band by band analysis of coal core samples

The study of borehole coal cores involves visual separation of different bands present in the coal seams and its characterization for qualitative and quantitative estimation of exploitable reserves of the coal block. Band by band analysis of coal core samples collected from different coal mines of different sponsors, has been investigated to understand the quality of coal seams. The coal core samples are lithologically identified according to the depth and weight of the band. Ash and Moisture of each band is determined. Finally, the actual lithology of each band is determined for each borehole. This is very important to understand the quality of coal seam of individual boreholes. The collaborator after receiving the results of band by band coal core analyses, conducts coal seam mapping using actual latitude and longitude data. This information is very useful for price evaluation of each coalfield.

1.2 Seam overall analysis

Seam overall analysis is the most important characterization of individual coal seams of each borehole after completion of band by band

analysis. Different parameters like Ash, Moisture at 60% RH at 40°C, Gross Calorific Value, Ash Fusion Temperature, Ash composition analysis, Ultimate analysis, and Hard Groove Index are determined to understand the characteristics of coal. We use advanced analytical techniques like atomic emission spectrometry (AES), atomic absorption spectrometry (AAS), and X-ray fluorescence (XRF) spectrometry for determination of major, minor, and trace elements in coal and coal ash. Seam wise variation of different parameters is investigated statistically. For quantitative analysis of coal ash, (ashing temperature of 525 °C), the elements Cd, Cu, Li, Mg, Mn, Na, Pb, and Zn are determined by AAS, and Al, Ca, Fe, K, Mg, Mn, Na, P, S, Si, and Ti are determined by XRF spectrometry. Hg is determined by cold-vapor AAS; Cl and P are measured by XRF spectrometry. Furthermore, study on Ash composition analysis and Ash Fusion Temperature reflect the staging and clicking probability of a particular seam which have a negative impact during combustion. All this information is very helpful for understanding the combustion mechanism of a particular coal seam. All these information are important for the coal blending mechanism of thermal power plants.

2.0 Coal Beneficiation through Oil Agglomeration

The high ash content in Indian coals makes its utilization considerably challenging, be it for thermal power plants or metallurgical purposes. Therefore, coal beneficiation to reduce the ash content is a major requirement for Indian coals. Oil agglomeration is a superior method compared to other beneficiation processes owing to its simplicity, suitability to low rank and oxidized coal and high combustible recovery. Researchers at CSIR-NML have developed an oil agglomeration process for beneficiation of high ash Indian coking and non-coking coals. Process flow sheets have been developed for oil agglomeration of three non-coking coals from the coalfields at Bhubaneshwari (35.8% ash), Kaniha (35% ash) and Hingula (26% ash). Castor oil (10%) was used as the bridging liquid to efficiently demineralize these coals by 55-60%. Similarly, work is ongoing to develop process flow sheet for beneficiation of 6 coking coals of another collaborator. Several physical parameters associated with oil agglomeration process, like, particle size of coal, agglomeration time and intensity, pH, pulp density of coal slurry, electrolyte requirement, type and concentration of bridging oil were optimized **(Figure-1)**.

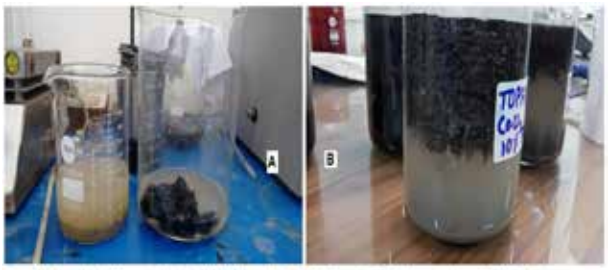


Figure-1 : Aglomerated coal forming a big chunk (A); Agglomerated coal floating on the top leaving mineral matter at the bottom.

3.0 Coke Making Using Non-coking Coal

India's steel industry is heavily dependent on import of coking coals to meet its coke demand. This has compelled researchers of this division to look into possibilities of making coke from non-coking coals. Absence of thermal plastic properties (coking property) in non-coking coals is the prime hindrance for coke making. To address this issue, several novel additives have been identified to induce coking properties in non-coking coals. CSIR-NML has developed three different processes to prepare coke from non-coking coal at a laboratory scale. Three patents have been filed in India for these processes. In one process, coking component isolated from coking coals using organic solvent extraction is used as an additive to prepare coke from non-coking coal. In another process, expandable graphite is used along with molasses as additives to prepare coke from non-coking coal.

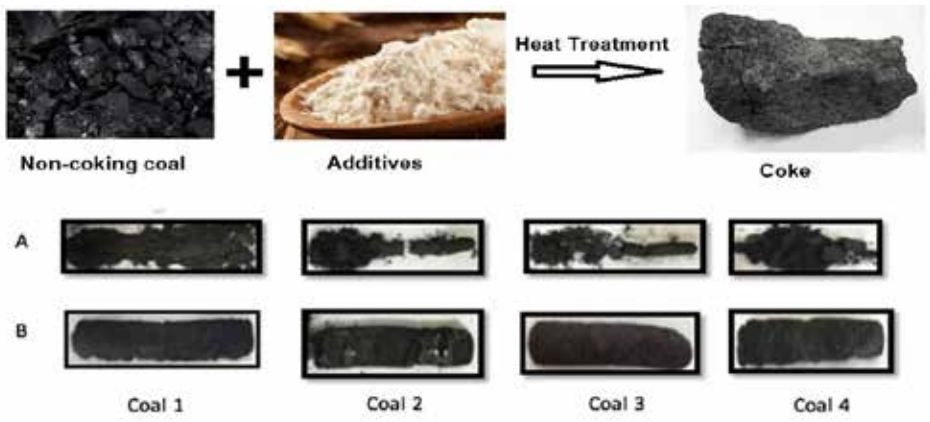


Figure-2 : Type of coke produced after LTGK assay of coals. Row A : parent non-coking coals, Row B : heat treated non-coking coal blends with 2% Expandable Graphite, 30% molasses and 5% water

In a third process, use of natural gums followed by heat treatment has been found to induce coking properties in non-coking coal. Low Temperature Gray King (LTGK) assay of non-coking coals modified with above additives yielded G_1 to G_3 grade cokes. Presently, scientists of AAC Division are working in a CSIR sponsored project to develop process flowsheet to make coke from non-coking coal at a 7 kg scale as shown in **figure-2**.

4.0 Analytical Services

As a part of analytical protocol development for analysis of inorganic matrix real life samples, Analytical & Applied Chemistry Division of CSIR-NML has a collaboration with Geological Survey of India for quantification of rare earth and trace elements in sediment samples. The study involves development of methodology for quantitative analysis of rare earth elements found in stream sediment samples using inductively coupled plasma mass spectrometer (ICP-MS). The samples were prepared using multiple methods i.e. by fusion and digestion. The trace elements were quantified using X-ray Fluorescence (XRF).

5.0 Certified Reference Materials

Certified Reference Materials (CRMs) are most critical requirements to obtain accurate chemical analysis results and to maintain traceability of the results. CRMs are required to calibrate instruments and to validate the accuracy of analytical results. In tune with "Atmanirvar Bharat" and "Make in India" initiatives, AAC Division is manufacturing and marketing 39 types of CRMs in the areas of ores, minerals, coal, steel and Ferro alloys as shown in **Figure 3**. Standard procedures and strict quality control processes are followed to make the CRMs, and the analytical values are certified through Inter Laboratory Comparison (ILC) and Proficiency Testing (PT) programs. CRM's of NML has created its own market value and has more than 600 Industrial customers across India.

Figure-3 : Certified Reference Material (CRM) produced by CSIR-NML

6.0 Rebar Anticorrosion Treatment Chemical

Mild steel rebar is commonly used for the reinforcement of concrete. Although naturally coated with a corrosion resistant black oxide layer (i.e. mill scale), mild steel rebar is prone to atmospheric corrosion forming red rust during storage and transport, which negatively influence its customer acceptance. The rusting problem is particularly severe in a marine atmosphere, in the rainy season and in hot and humid climates. In addition, corrosion of steel rebar in concrete is known to occur over a period of time due to diffusion of aggressive agents through the concrete resulting in flaking and failure of concrete structures. Therefore, there is a need to improve the corrosion resistance of steel rebar in an economical and scalable manner.

Researchers of AAC Division have recently developed an anti-corrosive treatment process for rebars using inorganic chemicals. The chemical treatment process involves spraying of the water-based chemical on rebar surface after the water-quenching step. The process is green, economical and is suitable for integration to the rebar production line. The treated rebar passes 72 hours of salt spray test and 6 months of outdoor exposure test without formation of red rust as shown in **Figure-4**. Effort is going on to commercialize the rebar anticorrosion treatment process in collaboration with steel industries.

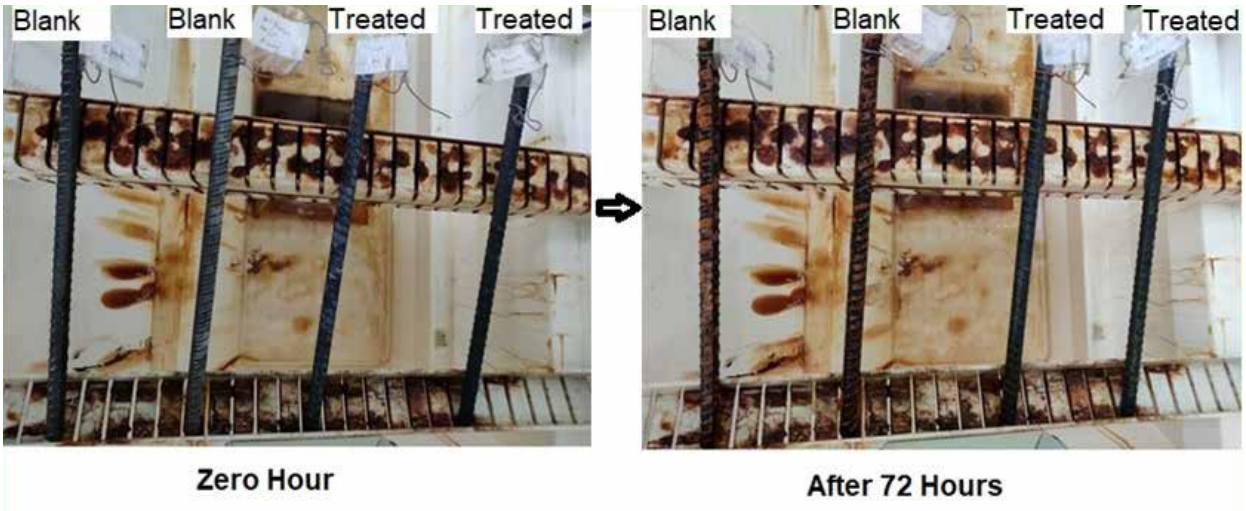


Figure-4 : Salt spray test (ASTM B117) results of Bank and treated rebars

Materials Engineering

Materials Engineering Division, works mainly in four domain areas: Materials processing, Microstructural engineering, Materials mechanics, and Corrosion engineering. The division has 35 scientists. The projects being executed in this financial year are not restricted to only one specific domain; rather those are mostly interrelated. Those are classified in sub-sections based on their topical relevance.

1. Nano-pearlitic steels

Under this category, two projects are presented which are unique based on their functionality.

a. Thermodynamic and kinetic assessment of interfacial equilibrium conditions in multi-component based bulk nano-pearlitic steels.

Bulk nano-pearlitic steels are now widely attempted by various steelmakers across the globe as they possess excellent combination of strength and toughness and find application in many areas. Usually in steels, when a refinement of microstructure is targeted through non-equilibrium processing, it may undertake various thermodynamic equilibrium paths depending upon the composition. Such theorized thermodynamic equilibrium models predict kinetics of phase transformation in steel under the following assumptions:

(1) Ortho equilibrium (OE, full equilibrium), where both thermodynamic equilibrium as well as mass balance are satisfied for all the components locally at the interface; (2) Para equilibrium (PE), where only C reaches equilibrium locally at the interface with no partitioning of substitutional elements across the interface and (3) Negligible Partitioning Local Equilibrium (NPLE), where the transformation proceeds under full local equilibrium (i.e. chemical potential of all the components across the interface are respectively equal), but the substitutional solutes do not partition over a long range, rather maintain a spike ahead of moving interface.

Under each of these thermodynamic models, the knowledge of operational tie line during phase transformation is essential for describing the transformation course and effects. Unlike free energy curves of the binary system, the ternary system has free energy surfaces and therefore, a tangent plane instead of a line is used on free energy surfaces in a free energy vs. composition space. In the ternary system, the tangent plane common to the Gibbs energy surfaces can move over them there by leading to a set of common tangent lines/tie lines between two phases. This leads to a possibility of an infinite number of tie lines in the ternary system, at a given temperature.

The non-isothermal pearlitic transformation involves pearlite formation at temperatures where austenite is metastable. Thus, it is essential to evaluate the metastable austenite phase boundaries and the corresponding tie lines at such temperatures to determine the kinetics of phase transformation. The Wagner interaction parameter formalism has been adopted in the present work to calculate the composition of phases in equilibrium with each other. The thermodynamic data used in the simulation of Wagner formalism were Thermo-Calc software package coupled with TCFE9 database. The equilibrium compositions across the tie lines at various temperatures for the Fe-C-X system, where X is Mn and Cr, were collected and then used to determine the Wagner interaction parameters. The trend for interaction parameters and Standard Gibbs free energy change

with respect to temperature were established and then extrapolated to metastable regions. These extrapolated results were then used to determine the equilibrium compositions across the tie lines for metastable regimes. The demarcation of Negligible Partitioning Local Equilibrium/Partitioning Local Equilibrium (NPLE/PLE) for the Fe-Mn-C and Fe-Cr-C systems has also been generated by superimposing isoactivity lines of carbon in austenite upon the metastable isothermal phase diagrams generated by the aforementioned approach. It is implied by such demarcation that if the nominal composition lies to the left of the boundary in case of ferrite/austenite and to the right of the same for cementite/austenite, then NPLE might be possible for both the product phases (ferrite and cementite) during transformation. One of such metastable phase diagrams at 660°C along with tie lines between corresponding ferrite/austenite and cementite/austenite solvus curves is shown in **Figure 1**. The NPLE/PLE envelopes for ferrite/austenite region (marked by blue dotted curve) and cementite/austenite (marked by red dotted curve) have also been incorporated in **Figure 1**. In case of Fe-Mn-C system, the NPLE/PLE boundary of austenite/

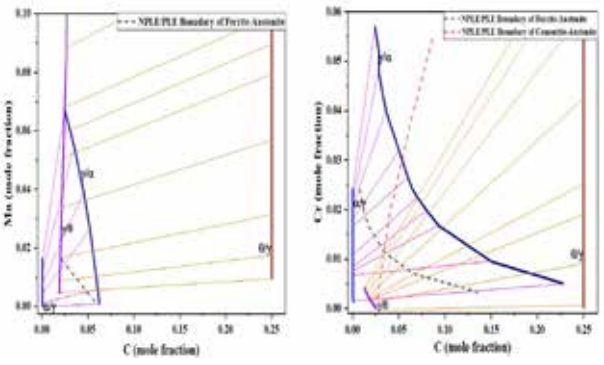


Figure 1: Metastable isothermal phase diagrams for Fe-Mn-C and Fe-Cr-C at 660°C along with tie lines between corresponding ferrite/austenite and cementite/austenite solvus curves. The blue and red dotted curves in each phase diagram depict the NPLE/PLE envelopes for ferrite/austenite and cementite/austenite regions, respectively.

cementite region merges with the γ/θ solvus curve indicating no possibility of PLE at the temperature under consideration, which further implies that cementite can form under local equilibrium with austenite containing similar Mn content as of the nominal composition lying within the austenite/cementite phase region.

b. Development of thicker section (> 6 mm) abrasion resistant grade steel with relatively higher coiling temperature

As per available data, among different wear mechanisms, abrasive wear alone contributes to about 63% of the total loss. The abrasive wear is generally categorized into sliding and impact wear. Therefore, it requires the use of steel with high strength for weight reduction, and improved impact toughness and ductility to absorb higher energy during heavy impact. At present, components used in abrasive environments are mostly dominated by medium to high carbon steels with martensitic or tempered martensitic microstructure. These steels are produced through direct quenching (DQ) and/or tempering (DQ&T) processes as shown in **Figure 2**. This tempering process is performed to relieve the brittleness of martensite. A recently developed quenching and isothermal partitioning (Q&IP) process can produce martensite and retained austenite for improved strength-ductility-toughness combination. However, both the DQ&T and Q&IP processes are energy-intensive due to the requirement of additional furnaces for heat treatment. The present work aims to utilize the heat available with hot rolled coil for achieving the martensite and austenite in the microstructure. This process is known as quenching and non-isothermal partitioning (Q&NP) process as shown in **Figure-2**. Moreover, a high coiling/quench temperature is aimed to retain sufficient heat for carbon partitioning in thicker-sections.

The secondary electron micrographs and the mechanical properties for two different quench temperatures are shown in **Figure 3**. The microstructure shows the presence of martensite, carbides and M-A constituents. The processing at higher quench temperature has led to the achievement of higher ductility, accompanied by a concurrent decrease in the strength value. This is due to the coarseness of microstructural constituents at higher temperature. Further efforts are ongoing to investigate the variation in microstructure and mechanical properties for steels with still higher thicknesses.

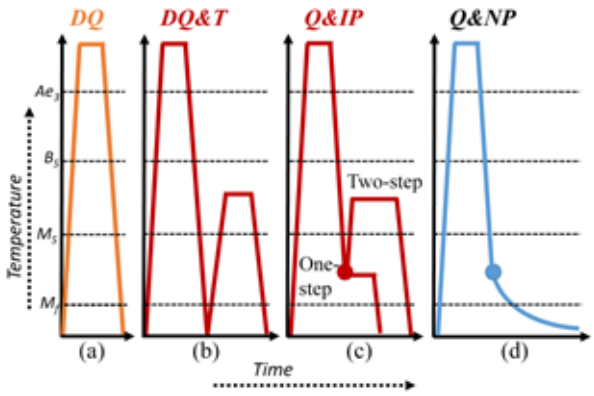


Figure 2: Schematic illustration of different processing methods applied to hot rolled steels

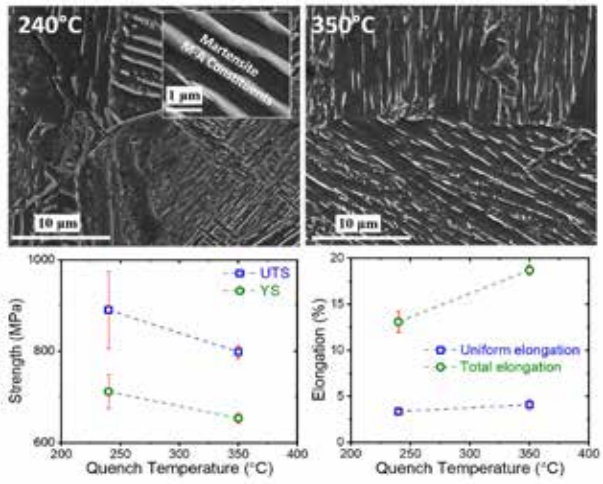


Figure 3: Secondary electron micrographs and tensile properties

2. Line Pipe Steels

In this category, the projects related to various aspects of line pipe steel ranging from design, processing as well as welding, have been highlighted

a. Investigation on Hydrogen Trapping Characteristics of Precipitate / Matrix Interfaces in Micro Alloyed Steel

Hydrogen is a ubiquitous element that enters materials from many different sources. Hydrogen is well known for its deleterious effect on the mechanical properties of high strength steels in most of the cases. One way of preventing hydrogen induced attack is the addition of microalloying element such as Nb, Ti, V, etc., to obtain fine carbides and nitrides that acts as irreversible hydrogen traps and to also impart high precipitation strengthening to the alloy. The carbides and carbonitrides have high binding energy for hydrogen atoms and locks them in the lattice rendering them immobile. The trapping capacity of the precipitates can be modulated by altering their coherency with the matrix phase, their morphology and their distribution in the matrix phase, the type of interfaces formed, etc.

The present work, investigates the ability of niobium (Nb) and vanadium (V) carbides/carbonitrides to act as the trapping sites for the hydrogen in API grade micro-alloyed steels. The microstructural factors influencing the strain field around the precipitate particle were varied in order to obtain maximum trapping of hydrogen, which was charged deliberately using a laboratory hydrogen charging setup. The size and volume fractions of the precipitates were varied. Different duration of isothermal holding ensured variation in the size of the precipitate.

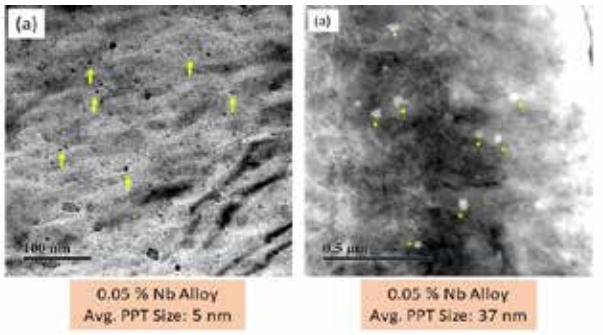


Figure 4: Distribution of precipitates in the 0.05 wt.% Nb alloy (a) TEM bright field micrograph (b) STEM HAADF micrograph.

Figure 4 presents the TEM micrographs showing variation in the size of the Nb(C,N) precipitate in a Nb containing alloy. The volume fraction was varied using alloys containing increasing Nb/V content (0.05 and 0.1 wt. % in the present study).

TMP processed tensile specimens, having different size and volume fraction of precipitate, were hydrogen charged employing a laboratory setup. Tensile tests were performed in the specimen both in uncharged and hydrogen charged conditions. The extent of the deleterious effect of hydrogen was ascertained by comparing the degradation in the tensile properties in the specimens with varying nature of precipitate (Nb/V(C,N)), size and volume fraction. An embrittlement index was utilized to estimate the impact of hydrogen induced degradation in different specimens:

It was found that fine Nb(C,N) precipitates having size lesser than 5 nm were most effective in terms of hydrogen trapping and thereby, in preventing the hydrogen induced degradation. In comparison to the uncharged samples, the lowest degradation in the tensile properties and in embrittlement indices **(Figure 5)** was observed in the A2-5Mins (0.05 wt.% Nb, 5 nm PPT size) and A3-5Mins (0.1 wt.% Nb, 4.7 nm PPT size) samples after the hydrogen charging. The fracture appearance of the hydrogen charged tensile specimen remained full of dimples which was similar to that of the uncharged tensile sample **(Figure 5)**.

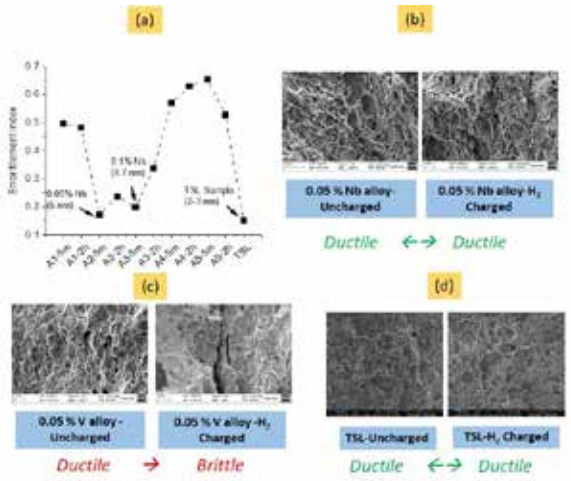


Figure 5: (a) Embrittlement index in various alloys; (b-d) Fracture surface appearance before and after hydrogen charging in different alloys

The primary reason for low degradation in the Nb alloys with finer precipitate size is that the binding energy ($-E_b$) of the Nb based precipitates for hydrogen is greater than 50 kJ/mol which qualifies Nb precipitates to be irreversible hydrogen traps and effectively decrease hydrogen diffusivity in the ferrite lattice. The trapping efficiency remained nearly similar with the increase in the volume % of the Nb based precipitates, which indicated that the hydrogen induced degradation was controlled by the other interfaces such as ferrite-cementite/carbide, etc., which overruled the advantageous effect of the increased volume of the Nb(C,N) precipitate. V containing alloys showed least resistance to the hydrogen induced attack, irrespective of the size and volume fraction of the precipitates in various alloys. The size of the V(C,N) precipitates was varied from 3.5 nm to 35 nm. No improvement in the embrittlement index was observed with the variation in the precipitate size and also with the volume fraction of the precipitate, owing to the low binding energy of V based precipitates for the hydrogen entrapment. The fracture appearance of the hydrogen charged tensile specimen of a V containing alloy changed

from full of dimples in the uncharged specimen to brittle fracture containing cracks and facets **(Figure 5)**. An industrial sample provided from the sponsor also performed optimally in presence of hydrogen **(Figure 5)**. The sponsor's samples possessed ultrafine (size ~ 2-3nm) complex precipitates of Ti and Nb. The binding energy associated with the Ti precipitates for hydrogen atoms are highest of all types of microalloying precipitates and therefore are strongest hydrogen traps. Hence, the degradation in the tensile properties and the embrittlement index of the hydrogen charged specimen was least for the samples obtained from the sponsor.

b. Effect of deformation and chemistry on X70 line pipe steel properties

In case of hot-rolling of line pipe steel, the austenite to ferrite and bainite transformation is designed to occur from unrecrystallized austenite, to obtain suitable texture of the final product. The effect of austenite grain refinement on the final microstructure formed from unrecrystallized austenite was studied in a Gleeble 3800 Simulator. It was observed that in case the BCC transformation products form from unrecrystallized austenite, they inherit the elongated shape of the hot-rolled and unrecrystallized austenite, creating a morphological (structural) shape anisotropy. In contrast, when the BCC transformation products form from recrystallized austenite they result in equiaxed and coarser microstructure. **Figure 6(a)** shows the final microstructure of a Nb-V-Mo microalloyed X70 steel formed from a fine and severely unrecrystallized or pancaked austenite. Significant microstructural refinement is observed in **Figure 6(a)**. **Figure 6(b)** shows the final microstructure of a Nb-Mo microalloyed X70 steel (having lesser Mo and Nb than in the steel shown in **Figure 6(a)** formed from a comparatively coarse and mildly unrecrystallized or recrystallized austenite. The microstructure in **Figure 6(b)** is coarser as compared to **Figure 6(a)** as it has formed from (i) a coarser austenite, (ii) mildly unrecrystallized or recrystallized austenite and (iii) has a chemistry with lower Mo and Nb microalloying. In this project the characterization of microstructure of industrially produced X70 steels was also done. **Figure 7(c)** shows the TEM of the industrial X70 line pipe steel microalloyed with Nb-V-Mo. Coarse Ti-Nb containing precipitate is observed along with many fine precipitates. The fine precipitates contribute to the high yield strength for this steel.

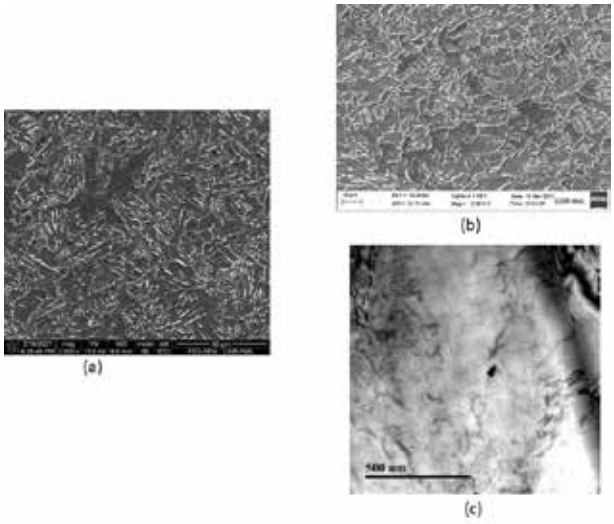


Figure 6 : Results from thermomechanical simulation (a) Microstructure of a Nb-V-Mo microalloyed X70 steel formed from a fine and severely unrecrystallized austenite; (b) Microstructure of a reduced amount of Nb-Mo microalloyed X70 steel formed from a coarse and mildly unrecrystallized austenite; and (c) TEM showing precipitates in an industrial Nb-V-Mo microalloyed X70 steel.

c. Effect of microstructure evolution in the weld heat affected zone, on the fracture toughness and fatigue of API steel (X70 / X80) weld joints

The heat affected zone (HAZ) simulation of X80 and X70 line pipe grade steels were carried out using 11mm square specimen in a Gleeble3800 Simulator. A non-standard grip was also fabricated to hold single edge notch (SEN) specimen for

Gleeble HAZ simulation and its subsequent fracture toughness evaluation. The different HAZ zones like Coarse Grained (CG) HAZ, Inter-Critical (IC) HAZ and a dual cycle resulting in both CG and IC-HAZ were simulated on the linepipe steel. The weld cycle was simulated by heating at a rate 100^{0}C/s up to the peak temperature, followed by exponential cooling considering a weld heat input corresponding to $t_{8/5}$ of 20°C/s (**Figure 7(a)**). The detailed microstructure and hardness studies of the simulated zones were carried out. The phase transformations that can occur during the weld simulation were obtained by simulating the HAZ cycles in dilatometry (**Figure 7(b)**). The CGHAZ resulted in a coarse bainite microstructure (**Figure 7(c)**) and ICHAZ showed fine grained ferrite with some bainite. The dual cycle resulted in a mixed microstructure comprising coarse bainite and fine ferrite. The Charpy and SEN specimens were fabricated by EDM notch cutting and subsequently pre-cracked. These samples were Charpy impact loaded for Dynamic fracture toughness evaluation (**Figure 7(d)**) and SEN specimens were tested to evaluate the fracture toughness of the simulated HAZ zones, respectively.

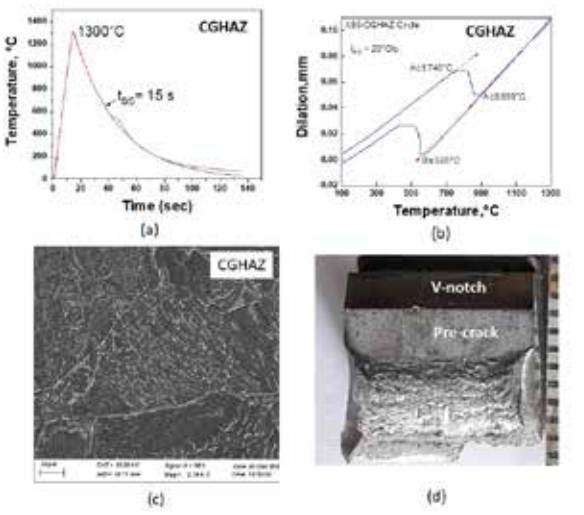


Figure 7: HAZ simulation of X80 linepipe steel: (a) CGHAZ cycle; (b) Dilatometry of CGHAZ cycle; (c) CGHAZ microstructure and (d) Fractography of Charpy specimen with pre-crack.

3. Advanced High Strength Steels (AHSS)

a. Dual Phase (DP) Steels:

Dual-phase (DP) steels have received attention from several researchers chiefly owing to their potential applications in the automotive sector. Imparting high strength to the steel adds on high alloying cost and demands higher capability of manufacturing plant to shape these steels, which needs intense capital investments. To circumvent these limitations, alternative methods of manufacturing DP steel involve intelligent microstructural engineering with optimum cost of alloying additions. A novel idea of creating a special microstructure in a low alloyed dual-phase (DP) steel gives very good strength and ductility combination. There are two projects on processing of DP steels:

a) Development of new techniques for producing AHSS steels by optimizing annealing process parameters; and

b) Establishing suitable microstructure for improving high strain rate tensile behaviour of advanced high strength steel, which aims to simulate a variety of microstructures in high strength DP steel grades for the given compositions using an annealing simulator and optimizing its properties.

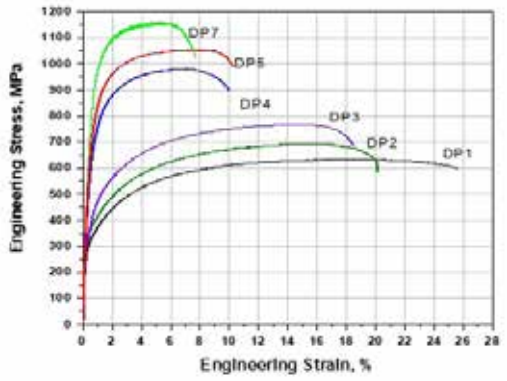


Figure 8: Effect of martensite volume fraction and morphology, obtained by varying annealing parameters, on tensile properties

Under this activity, a range of DP steels; DP600, DP780, and DP980, etc. were processed and evaluated for their properties. The effect of microstructure modification on the tensile properties is presented through the Engineering stress-strain plot in the **Figure 8**.

Apart from experimental simulations, various microstructure modelling efforts were also made to understand the damage evolution mechanisms at the high strain rates of tensile deformation. For this research work, the representative volume element (RVE) was generated from the actual microstructures of the DP steels developed via experimental simulations. The realistic 2D geometric reconstruction of the microstructures was carried out by using the meshing program OOF (object oriented finite element analysis software) developed by NIST, USA. The microstructure mesh created by OOF is imported to Abaqus for tensile deformation simulations. The simulations were conducted both at quasi as well as dynamic deformation environments. A typical example of Von Mises stress accumulation in martensite at high strain rates of tensile deformation simulations for DP600 steel is shown in **Figure 9** at different strain rates. These microstructure simulations are found extremely useful in the understanding of damage evolution in dual-phase steels.

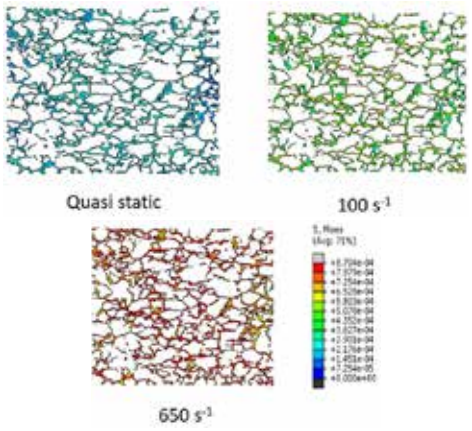


Figure 9 : Von Mises stress accumulation at 6% of strain in martensite at different strain rates of tensile deformation simulations for DP600 steel is shown here

b. Industrial hot rolling run out table and continuous annealing line simulations for developing Advanced High Strength Steels

The property engineering of the AHSS are done via chemistry modulations in conjunction with controlled cooling variations, on finishing hot strip mill Run Out table (ROT) or during strip continuous annealing line (CAL) process of cold rolled products. At the ROT stage, the structure and properties of the steel are determined through important process controls linked to phase transformation and precipitation kinetics. The process control on the ROT is a technology that controls the *radiation temperature* and the *cooling medium* flow rate. With the advancement of sensor technologies for determining various physical properties of materials, newer possibilities for on-line process exploration are coming into the fray. Application of these on-line techniques can be very useful because most of the new generation advanced high strength steel properties are governed by the presence of two or more than two phases in the microstructure. A schematic illustration of the proposed Run Out table is shown in the **Figure 10**.

The main goal of the proposed research project is to develop an indigenous simulator for Run Out Table and Continuous Annealing Line process integrated with indigenous electro-magnetic sensors for online process monitoring and control.

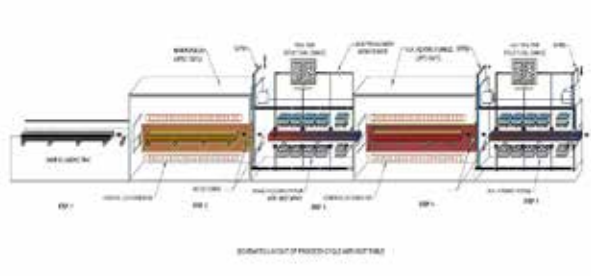


Figure 10: A schematic illustration of the proposed Run Out table

4. Special Alloys and Materials

a. Optimisation of Al-based metallic foams production method and development of metal foam

Closed cell aluminium foams show good shock absorbing capability and are light weight, with density of around 0.4-0.6 g/cc. The project was undertaken to optimize foam preparation parameters for obtaining uniform pores, good distribution and required properties. In this developmental work, various material compositions were tried, and optimized process parameters were established in terms of sintering parameters, compositions, foaming time, foaming temperature, etc., so as to obtain the desired properties. More than 70 samples, 50 mm x 50 mm x (6-10) mm sandwich, were supplied to the sponsoring agency for testing at their end. The process employed was powder forging and rolling. The powders used were pure aluminium, Al-8wt.%Si alloy, Al-12wt.%Si alloy and Al-Cu alloy with different Cu content. These powders were forged and rolled along with the foaming agent TiH2 followed by sintering to obtain sintered precursor with a uniform distribution of foaming agent. In case of Al-Cu alloy, elemental powders of Al and Cu (2-5wt.%) were used to produce the foamable precursor. These precursors were then foamed at temperatures in the range 750-900oC for various foaming times. **Figure 11** shows the Sandwich foam produced and their pore structure.

One lot of samples of Al-Si alloy sandwich foams was supplied to the sponsoring agency and the test results showed shock attenuation of around 30%. The 2nd and 3rd lot of the samples (71 in total) of other compositions, e.g., Al-Cu and pure Al, were supplied to the agency for further testing. The shock attenuation reached up to 40% in the Al-Cu samples, in drop weight tests. However, this value was only 20% for the samples of pure aluminium. The static energy absorption obtained for these samples were in the range of 0.50-0.66 MJ/m^3 at a strain of 0.40. However, this value reached 2.8 MJ/m^3 at a strain of 0.74. The values obtained for the shock attenuation and the static energy absorption have been found to be satisfactory as per the requirements of the sponsoring agency.

Figure 11: Sandwich foams produced and their pore structure

b. Development of high ballistic strength armour steel with 2 GPa tensile strength and 50MPam$^{1/2}$ fracture toughness

During the past several years, there has been a significant rise in the threat level to the armour materials. Despite many exotic armour materials being available, the cost-effectiveness and easy fabrication of steels make it a material of choice considering the mass production of military vehicles. Generally, a steel with high yield/tensile strength and better stiffness is expected to provide better ballistic/impact resistance. The elastic modulus for different grades of steel is quite similar (about 210 GPa). Hence, an increase in stiffness necessitates the use of thicker sections in a given application, which increases the weight of the component. Therefore, steel with higher strength is desired for light-weighing; and sufficient ductility and toughness are required to delay the crack propagation. Although the presently available armour grade steels show tensile strength as high as ~ 2000 MPa, their toughness and ductility are quite low, restricting their energy absorption capability during high energy impact. Moreover, these grades with a fully martensitic structure are usually given a tempering heat treatment, which

improves their toughness and ductility but with a concurrent decrease in the strength level. The tempering treatment also necessitates an additional facility and energy after hot rolling, adding to the production cost. The present investigation aims to develop steel compositions and process methodologies to achieve ultra-high-strength combined with better ductility and toughness for armour application. A combination of high strength with extended ductility will be achieved through solid solution strengthening, engineering of phase transformation, precipitation hardening, grain refinement, etc. The results of theoretical calculations for retained austenite predictions are shown in **Figure 12.** It has been observed that an increase in carbon content in the alloy from 0.2 to 0.5 wt.% can lead to more than two-fold increase in the austenite retention. The designed alloys have an optimum amount of Si to prevent carbide precipitation. Moreover, some amount of Mn is also added to improve hardenability and achieve solid solution strengthening. These designed alloys are being investigated with the use of Gleeble and lab-scale furnaces to arrive at an optimized alloy composition and process technology.

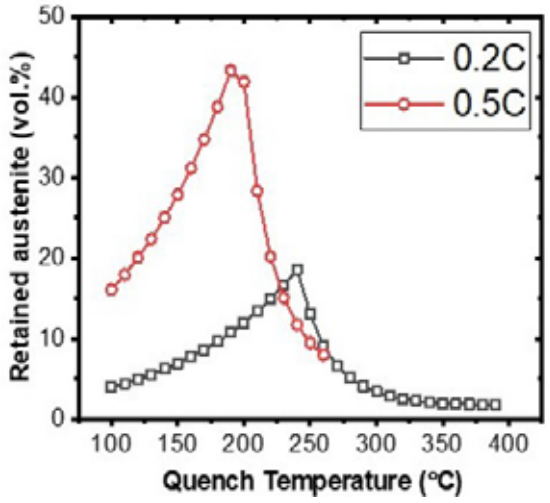


Figure 12: Predicted variation of austenite retention with change in quench temperature below M_s

c. Creep-fatigue (CF) interaction behaviour of ODS-austenitic steels and ODS-iron and nickel aluminides

In this project it is proposed to study the creep-fatigue interaction behaviour of ODS-austenitic steels and ODS-iron and nickel aluminides as alternative materials for Indian advanced ultra-supercritical (AUSC) power plants. CF interaction in ODS-austenitic steels and ODS-iron and nickel aluminides is known to some extent, however, the behaviour of these alloys under AUSC conditions are not known completely. CF data in AUSC operating temperature range is required to understand the performance of these alloys, plan life assessment procedures and develop damage detection protocols. The aim of the proposal is to evaluate the creep-fatigue (CF) life, understand the micro-mechanisms of CF damage, examine the applicability/develop models for predicting CF life. The material is expected to withstand the fluctuations in operating conditions over prolonged duration, and thus calls for an understanding of CF interaction. The major objectives are

- Evaluation of the CF behaviour over a range of temperatures
- Examination of the influence of dwell time
- Investigation of the influence of various waveforms
- Examination of the applicability of CF life prediction models/ methodologies

5. Traditional Metalworking

Under this category, some of the societal projects have been reported.

a. Preparation of need based DPRs for brass and bell metal utensils clusters of West Bengal

Brass and bell metal handicrafts are cultural heritages of the Indian society. The brass and bell

metal artisans are still following age-old traditional processes for making brass artefacts, utensils, etc. Aesthetic and utilitarian values of the product are the sustaining forces that encouraged continuation of such traditional products and production processes. However, lack of innovation and modernization, and a variety of problems ranging from raw material to marketing of products, are severe hurdles. NML has developed energy efficient eco-friendly brass and bell metal melting furnace for brassware artisans and clusters. The technology has been transferred to various medium and micro-enterprises.

Considering the expertise of CSIR-NML, Directorate of MSME, Govt. of West Bengal awarded the job of preparing Detailed Project Reports (DPRs) for setting up Common Facility Centre (CFC) for the following clusters-

1) CFC for brass and bell metal utensils cluster, Kashipur, Purulia.
2) CFC for bell metal cluster, Suklai.
3) CFC for bell and brass cluster, Lalbazar, Shyamnagar, Bankura.
4) CFC for brass and bell metal utensils cluster, Khagra, Murshidabad.

After discussion with GM/ Industrial Development Officer (IDO) of District Industry Centre, artisans, and site survey, the intended DPR has been prepared which contains present art (survey data), SWOT analysis, requirement of CFC, technology intervention, details of CFC including proposed business model, cost analysis, impact on environment and health and civil estimation.

The artisans, at present, collect the raw materials like scrap from "Mahajan" and deliver finished goods to the same "Mahajan". In return, the artisans receive the "conversion charges" from the "Mahajan". As the entire process is individual centric, it was felt that the earnings of artisans can be improved substantially by proper technological intervention through creation of common facility centre (CFC), efficient process and equipment without altering significantly their traditional practices. The traditional process of utensil manufacturing is presented in **Figure 13**.

Figure 13: Traditional process of utensil manufacturing

b. Preparation of detailed project report on common facility centre for silver cluster, Jafarnagar, Nadia, West Bengal

India is one of the world's largest silver markets, with a very traditional core in a diverse market. The artisans are still following age-old traditional processes for making ornaments. Lack of innovation and modernization results in a variety of problems. In view of these, several governmental and non-governmental organizations are assisting the sector. Directorate of MSME, Government of West Bengal has asked CSIR-NML to provide technical advise to the silver artisans cluster "Jafarnagar Astha Silver Ornaments Artisan's Welfare Foundation".

Based on the inputs from General Manager (GM)/ Industrial Development Officer (IDO) of District Industry Centre (DIC), artisans, site survey, and discussion with vendors, a Detailed Project Report (DPR) has been prepared which contains the basic details of the cluster, benchmark survey, proposed business model, machinery required, bill of quantity for civil estimation, commercial viability and demand and scope for diversification.

6. Evaluation of Advanced Alloys

In this category, evaluation of various alloys subjected to fatigue and creep have been reported.

a. Effect of creep-fatigue interaction on disc forging

Aero-engine disk alloys are undergoing continuous evolution for enhancing their temperature capability. There is a constant endeavor to develop wrought alloys for manufacturing turbine discs, with enhanced mechanical properties up to 700°C. Alloy SU 718, which is extensively used for manufacturing turbine discs, is not capable of withstanding temperatures higher than 650°C due to coarsening of γ''. SU 720, which is strengthened by γ' phase, has greater temperature capability and can be processed by conventional forging route. This ability to be processed by conventional route make this alloy a cost-effective alternative for application up to 720°C in comparison with alloys processed through powder metallurgy route such as Rene88DT, N18, and RR1000. The sponsor has also identified SU 720 as a candidate alloy for

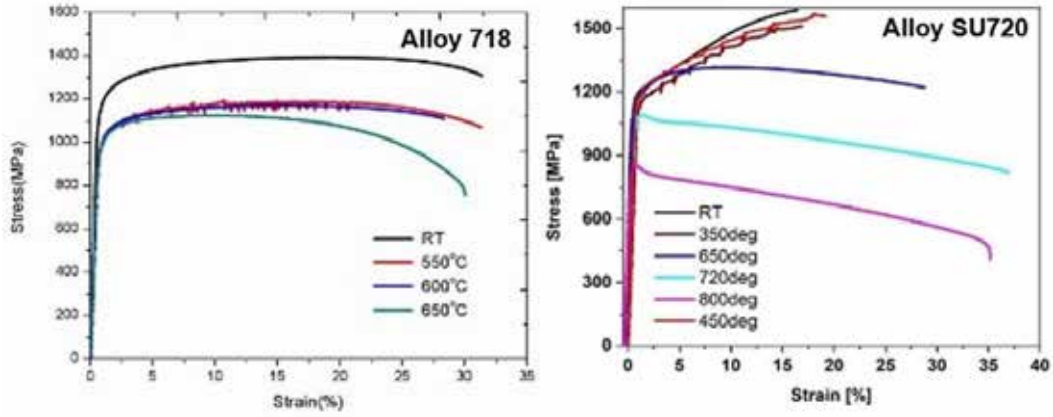


Figure 14: Engineering stress-strain curves of SU 718 and SU 720 alloys at different temperatures.

manufacturing turbine discs for current and future projects. This has provided impetus to undertake a detailed program for studying the relevant high temperature mechanical behavior of alloy SU 720 vis-à-vis SU 718 and to understand their complex mechanical behavior. The present project aims at studying isothermal low cycle fatigue (LCF), and creep-fatigue (CF) interaction behavior of

SU 718 and SU 720 disc alloys, which are used for manufacturing turbine discs. The engineering stress-strain curves corresponding to tensile tests of alloy SU 718 and SU 720 at different temperatures are shown in **Figure14**.

b. Investigations of fracture and fatigue crack growth rate behaviour of Aero engine fan disk of Ti-6Al-4V Alloy

The specimens were extracted from disks, machined as per standard design and tested as per ASTM E 647 or ASTM E 1820 standard at elevated temperature. In both fatigue crack growth and fracture toughness tests, the crack length measurement was made employing unloading compliance technique. Fracture toughness experiments were carried on 0.5CT specimen, extracted from Rim, Bore and Web section of Fan discs, at three different temperatures, ambient, 100/200/300°C. The toughness values were evaluated as shown in **Figure 15**. The effect of stress ratio and temperature on fatigue crack growth rate has been studied on disc material (**Figure 16**). It reveals that, at elevated temperature, the crack growth rate is superior than at ambient.

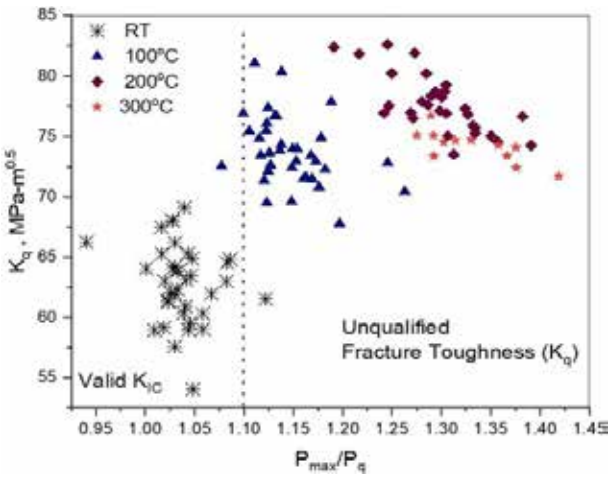


Figure 15: Summary of fracture toughness at three locations and two orientations

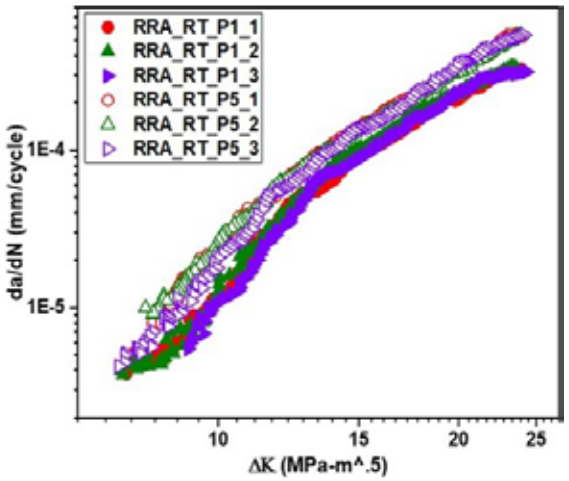


Figure 16: Comparison of crack growth behaviour RA direction in RIM section with Stress Ratio (R)

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

Corrosion fatigue is one of the degradation mechanisms in the piping of nuclear power plants. Estimation of life of the components is determined principally by two mechanisms, i.e. fatigue in general, and corrosion fatigue in particular, in presence of the corrosive media flowing through the piping. In the present investigation, stainless steel pipe and its welds have been used for carrying out tests under simulated reactor water environment. Tests were performed under air and water environments. Dissolved oxygen (DO), strain rate (or loading frequency), temperature, pH, sulphur content, and electrolytic conductivity (EC) are the main parameters that have significant role on fatigue damage of material in the present context. The results are summarized in **Figures 17 and 18**.

The signature of fatigue loading was endorsed by the presence of striations, the variation in striation spacing was insignificant irrespective of test conditions. Deformation induced phase transformation became common for metastable austenite during plastic deformation.

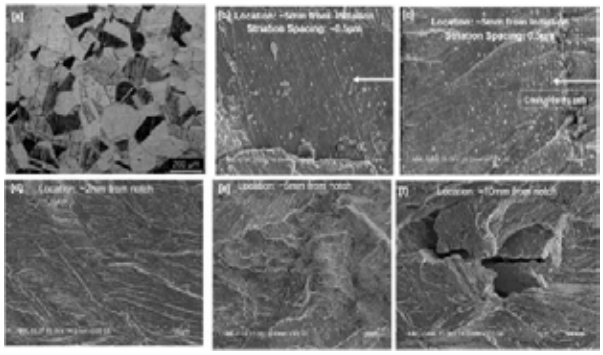


Figure 17: Images of LCF tested specimens (a) optical micrograph for sample tested in water with 300ppm dissolved O_2 at RT, (b) fractograph showing striations at RT tested specimen in water with 10 ppm dissolved O_2, (c) fractograph showing striations for sample tested in water of 10 ppm dissolved O_2 at 300°C, (d) fractograph of air tested sample (at RT) showing transgranular cracking, (e) mixed type fracture for specimen tested in water with 10 ppm O_2 at RT, and (f) intergranular fracture of RT tested sample using water with 300 ppm dissolved O_2.

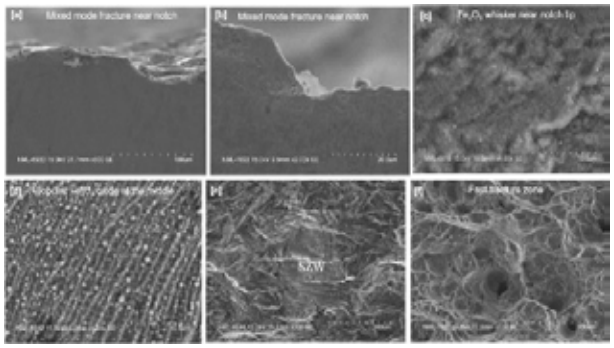


Figure 18: Characteristics of LCF tested specimens (a) tested at RT in water with 300 ppm O_2, (b) tested at HT in water with 300 ppm O_2,(c) RT tested specimen using water containing 200 ppm O_2, (d) tested in water with 300 ppm dissolved O_2 at HT, (e) RT air tested specimen (~600 µm, 0^0 tilt), and (f) tested at HT in water with 10 ppm dissolved O_2.

The volume fraction of martensite was ~ 58-90%; however, no clear trend was observed in the volume fraction of martensite with respect to change in dissolved oxygen in water. Presence of martensite reduced the ductility of parent austenite leading to transgranular cracking. Higher strain (higher test frequency) resulted in more amount of adiabatic heating and suppressed martensitic transformation. FCGR test at room temperature and in water environment with 10 ppb dissolved oxygen, did not reveal any oxide formation over the fracture surface. All high temperature tests in water environment with variable dissolved oxygen or water with high quantity of dissolved oxygen revealed oxide formation at different locations of the fracture surface. When the dissolved oxygen quantity was increased to 200 ppb, oxide appeared at the notch tip, however it was not found away from the notch. The stretch zone width (SZW) was maximum when the sample was tested in air at room temperature (RT). Increment in dissolved oxygen quantity, keeping other test conditions same, revealed a drop in the stretch zone width.

Change in test frequency created an anomalous result on striation spacing. At the lowest frequency of 0.1Hz, the striation spacing was small and then reached maximum value and finally reduced with an overall average of ~0.4µm. In this respect, highest striation spacing was obtained for sensitized specimen with an ultimate average of ~0.7µm. DIM was in the range of 79-88% without any clear trend. Irrespective of environment and dissolved oxygen concentration, fast fracture zone of specimens revealed ductile dimple fracture.

d. Studies on creep rupture behaviour of Alloy 690 base and weld materials

Nuclear waste vitrification is a process that fixes the nuclear waste in a glass matrix. This vitrification is done in process pots made of Alloy 690. Failures have occurred in these process pots prematurely during service. The temperature of operation is in the range of 1000-1050°C and failures have occurred within 100-200 hours of service, in some cases. The process pots were deformed through severe bending / sagging in some cases. This kind of deformation may be an indication of creep damage. To understand the exact cause of these,

failures, a project work was carried out on creep rupture behaviour of Alloy 690. Earlier project work on this material indicated presence of high nitrogen (N) content of the alloy resulting in the formation of chromium nitrides (CrN and CrN_2) after few hours of oxidation. These nitrides led to increase in volume and promoted long tertiary creep life with high creep strain at temperature above 900°C. The current project aims to compare the tensile and creep behaviour between Alloy 690 obtained from indigenous manufacturer with N content less than 50ppm and the material sourced from abroad. Tensile testing of three heats (two indigenous and one imported) of Alloy 690 base metal was carried out at 900-1100°C (**Figure 19**). Since the process pot is welded structure, Alloy 690 plates from indigenous and imported sources were welded with two different weld filler wires (INCO52 and INCO82). Subsequently, tensile testing of the assembly has been attempted at the above temperatures. Fracture surfaces of the failed specimens have been examined in SEM and in-depth analysis is in progress (**Figure 20**). Tensile tests on base and welded plates have been completed along with short term (500h) creep rupture tests. Long term (3000 h) creep rupture tests are in progress. Obtained results show indigenously developed Alloy 690 matches with the imported material. Further, reduced N content resulted in longer rupture life with normal creep behaviour with nominal nitride precipitation.

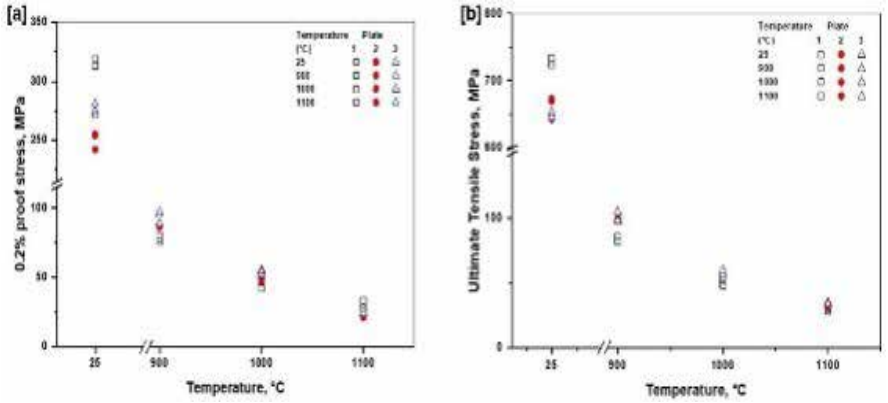


Figure 19: Tensile properties of Alloy 690 at different temperatures (a) alloy with >50 ppm N_2 and (b) alloy with < 50 ppm N_2. Square symbol indicates imported and other two are indigenous alloy of different heats

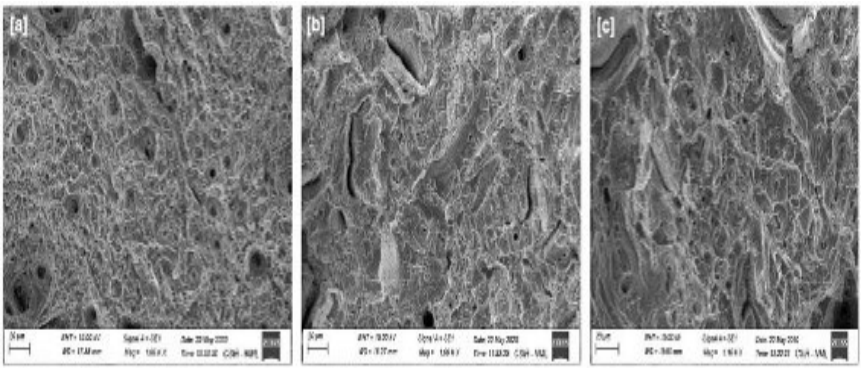


Figure 20: Fracture surface of Alloy 690 specimens with >50 ppm N_2, failed under tensile loading (a) imported alloy, (b) and (c) indigenous alloy of two different heats

e. Big data assimilation and synthesis for materials creep degradation

Extensive literature review has been done for the creep properties of steel. Simultaneously, simulation scripts and python codes for the simulation of creep properties of steel with varying compositions have been written. Few simulations at nano and mesoscales have also been attempted and results are at par with the expectation. At nano-scale, molecular dynamics simulations have been done to investigate creep properties of iron at various loads (1GPa to 0.5GPa) and a fixed temperature T=1500K. In order to implement intra-atomic interactions, embedded atom method potentials for iron has been employed during molecular dynamics simulations. The total interaction potential energy of iron, is given by, where and are the separation between and iron atom, lattice parameter and other positive constants for iron atoms. is the pair atomic potential energy for iron atom, and the local charge density. The Nose-Hoover thermostat has been used to control the variation in temperature and pressure of the iron simulation system. Large Scale Atomic/ Molecular Massively Parallel Simulator (LAMMPS) was used for the molecular dynamics simulations. Visualization of simulation data have been carried out by Open Visualization Tool packages. **Figure 21** shows the snapshots for the creep deformation of iron at 1GPa (externally applied uni-axial load) for temperature T=1500K. From snapshots, the slippage and merging of grains during deformation process are evident. Common neighbour analysis indicates the maximization of fcc crystalline structure along with stacking faults during early and mid-stage of creep deformation process.

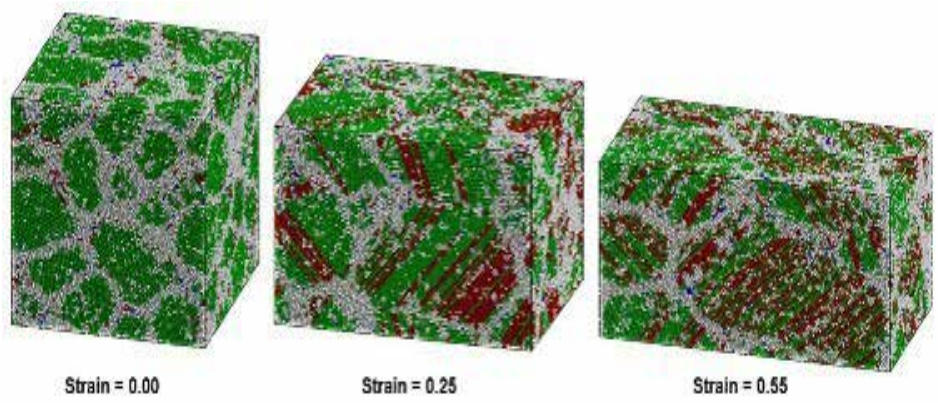


Figure 21: Snapshots of simulation of iron system during uniaxial creep deformation at applied load of 1GPa and temperature 1500K

Creep plots from molecular dynamics simulation at a wide range of applied load and fixed temperature are well matched with the published simulation data and very much analogous to the experimentally reported data at nano-meter length scale. At mesoscale, multi-phase field model separating phase field parameters for grain growth has been utilized. The phase field parameters correspond to local fractions of each phase or grain. **Figure 22** shows the snopshots for the grain growth obtained from phase field simulation using MICRESS

Further, simulations scripts for the quantum scale simulations to bring out material information like cohesive energies, lattice constant, and elastic properties of iron along with alloying ingredients have been written. Python scripts for the data assimilation for the iron and iron with alloying ingredient are also in the process of development. This will help to create a comprehensive creep database.

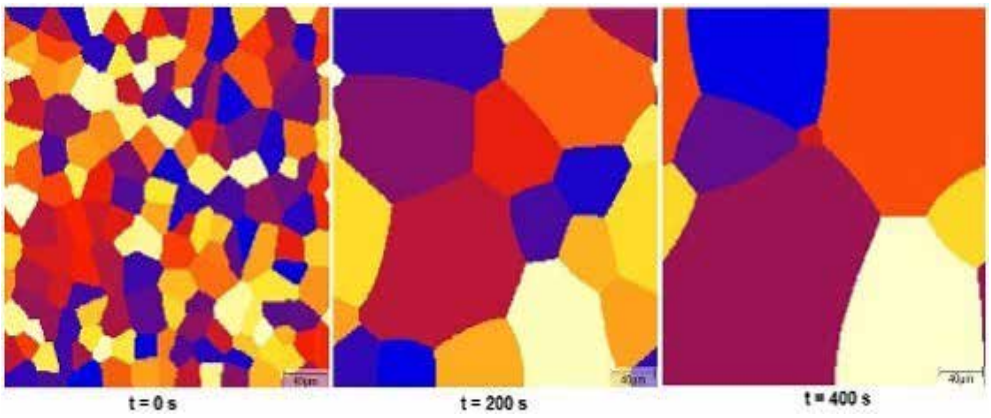


Figure 22: Grain growth is simulated in MICRESS for a given set of equiaxed grains. One of the rate controlling parameters is the grain boundary mobility. For this calculation a mobility of 5.0E-03 cm^4/Js is used. Inclusion of the effect of precipitates in pinning the grain boundaries and hinder the grain growth is yet to be introduced

7. Evaluation of materials for AUSC

The combined demand on providing abundant, cheap electricity and maintaining coal as the chief power generation option with reduced CO_2 emission, necessitates development of Advanced Ultra Super Critical (AUSC) power projects worldwide. Aimed to operate with steam temperature above 700°C and steam pressure of 25MPa, the AUSC power plants are expected to considerably reduce the emissions and waste products, and enhancing saving on fuel costs. In India, a National Ultra Supercritical Technology Mission has been set up with a goal to establish indigenous 800MW supercritical power plant. One of the agenda and challenge before this *Indian Mission* is to develop and evaluate appropriate advanced high temperature materials.

Worldwide, the material research for AUSC power plants has resulted in numerous advanced high strength alloys for heavy section piping, boiler tubes and rotors, for the casing, bolting, and for the blading required to build steam turbines. In the *Indian Mission*, the choice of material has been defined on the basis of science, technology, performance assessment and experience. It has been planned to concentrate on codified materials for this purpose and some of the materials have been indigenously developed and produced. One of the important issues in the selection of materials is the appropriate evaluation of their mechanical behaviour so that the component can be designed and operated at the desired steam conditions safely. CSIR-NML is involved in the following activities :

- evaluation of creep properties of Alloy 617M (forging), Alloy 625 (casting) materials
- evaluation of fatigue crack growth and fracture behaviour of 304HCu stainless steel
- evaluation of fatigue crack growth and fracture behaviour of 10Cr-Alloy 617 bi-metallic weld joint
- characterization of creep crack growth behaviour in 304HCu stainless steel
- characterization of creep crack growth behaviour in 10Cr-Alloy 617 bi-metallic weld joint
- fireside corrosion behaviour of 304HCu and Alloy 617M in simulated Indian coal fired AUSC boiler conditions

Creep properties of Alloy 617M (forging), Alloy 625 (casting) materials

This activity involved a total of 32 creep tests with an expected life in the range of 500h to 10000h in order to develop (i) creep strain - time curves, (ii) stress rupture time, (iii) isochronous strain-stress data, (iv) time to 1% creep strain curve and (v) Norton-Bailey coefficient. A majority of the tests far exceed the anticipated duration and are continuing. A typical minimum creep rate data is given in **Figure 23**.

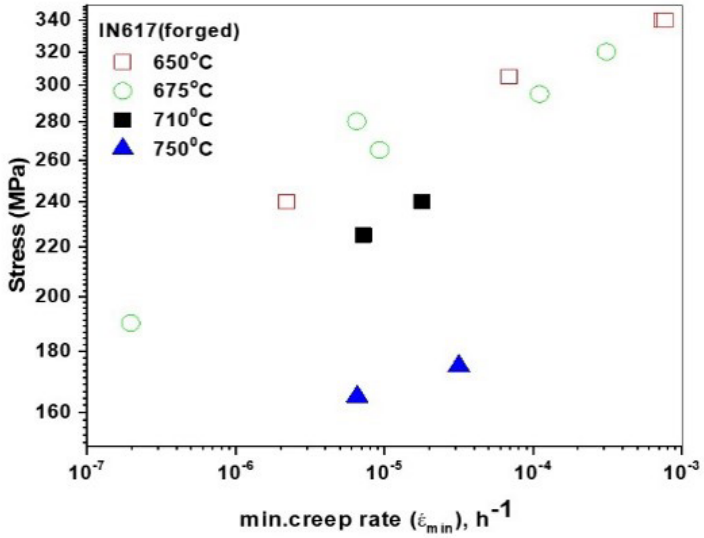


Figure 23: Creep rate data for IN617 alloy

Fatigue crack growth and fracture behaviour of 10Cr-Alloy 617 bi-metallic weld joint

Evaluation of fatigue crack growth rate (FCGR) and the fracture behaviour at room and various elevated temperatures, on as-received and aged 304HCu are the primary objective of this work. Typical FCGR and fracture data for selected test conditions are given in **Figure 24**.

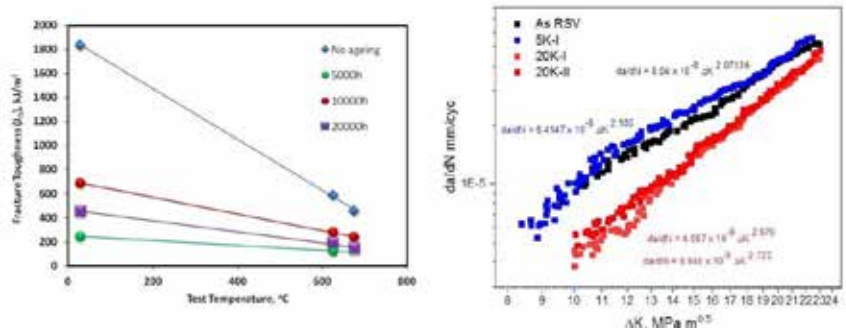


Figure 24: Typical fracture and FCGR data

The interface of 10Cr and Alloy 617 buttering layer is the region of interest in this study. Different material conditions, as-received and aged to different durations, are considered for the investigation. Investigations were made at both room temperature and elevated temperatures

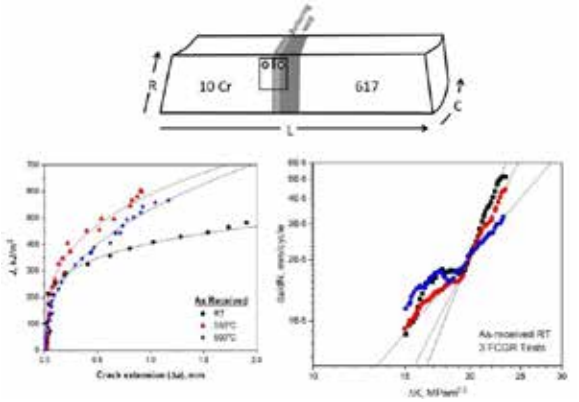


Figure 25: J_{IC} and FCGR data for bi-metallic weld joints

Creep crack growth behaviour in 304HCu stainless steel and 10Cr-Alloy 617 Weldment

This activity is primarily to investigate the crack growth behaviour of above materials under creep deformation conditions. The creep crack growth rate is being characterized by crack growth data (da/dt) as a function of time dependent fracture parameter, C*. As in the fatigue and fracture activities, the materials conditions were both as-received and aged alloys and the test temperatures were room and elevated temperatures, including the service temperature. This is a relatively new fracture mechanics concept and not many test facilities are available in the country. One of the primary requirement thus is to create a creep crack growth test facility at NML. **Figure 26** shows the facility created at CSIR-NML for this purpose.

Figure 26: Creep crack growth testing facility created at CSIR-NML

Fireside Corrosion Behaviour of 304HCu and Alloy 617M in simulated Indian coal fired AUSC boiler conditions

The primary objective of this activity is to generate hot corrosion/oxidation data in the selected materials and to understand corrosion mechanism by oxide and microstructural characterizations. The hot corrosion study of 304HCu and IN617 has been performed at 500-900°C for 1200 h in corrosive mediums such as coal ash and salt mixture, in a flue gas purged tube furnace. A large weight gain along with severe thickness loss and depth of attack is observed in salt containing medium as illustrated in **Figure 27**. The weight gain by specimens in coal ash medium were significantly low (<30 g/m^2) as opposed to that in salt (>100 g/m^2). Cr-rich oxide was noticed to form close to the base alloy (in both 304HCu and IN 617) at all the corrosive conditions; the outer oxide was rich in Fe and in Ni, in 304HCu and IN 617 alloy, respectively

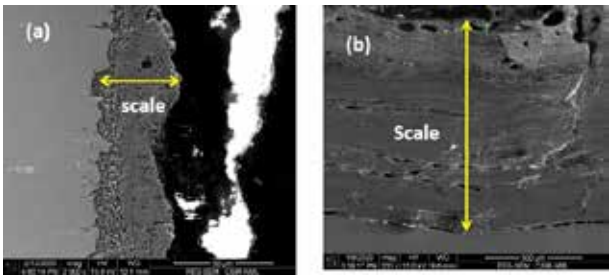


Figure 27: SEM (BSE) Cross-sectional image of Fireside Corrosion Behaviour in simulated Indian coal fired AUSC boiler conditions: (a) IN617 and (b) 304HCu

8. Failure investigations

a. Failure Investigation of Reactor Effluent Air Cooler 132-EA-201C in Hydrocracker Unit.

It was attempted to identify the root cause of failure of reactor effluent air cooler (REAC) 132-EA-201C in the Hydrocracker Unit of an Indian Petroleum giant. The failed components were visually examined on site, and same was received at the laboratory. Detailed microstructure and

fracture surface analysis were carried out using SEM-EDS. Tensile, hardness and impact properties were evaluated. Finite element analysis was done to understand the stress distribution in the failed components. The stiffener had undergone an initial ductile fracture followed by brittle fracture, which is mainly due to incomplete through thickness welding with tube / plug sheet. This might have led to early failure of stiffener followed by catastrophic failure of bottom plate.

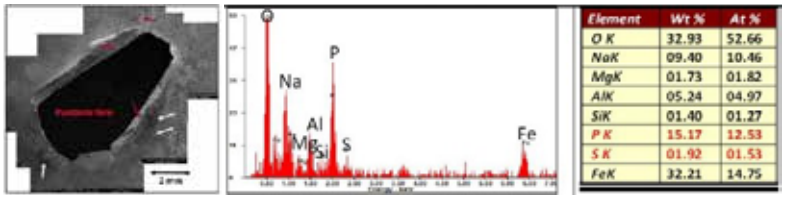


Figure 29: EDS analysis around the puncture on the tube

b. Complete analysis of failed water wall tubes of a boiler

In this investigation, a case of premature failure of water wall tubes of a state power plant, was carried out. The tubes were made of standard SA 210 grade C steel and failed by puncture after 8 years of service (**Figure 28)** against a design life of 20. Mechanical properties and microstructure of the failed tubes were analysed and they conformed to the specified

Figure 28: Failed water walled tubes

grade. SEM-EDS analysis of outer surface around the puncture and of the deposits showed the presence of elements (P, S, Na, Mg, Ca and Si), as shown in **Figure 29**. Presence of high amount of phosphorous and sulphur in the coal ash deposits indicated either corrosion by phosphoric acid and sulphuric acid at lower temperature (near dew point), or phosphate and sulphide corrosion at higher temperatures. Severe ash corrosion thinned down the wall thickness of the tubes which eventually punctured when hoop stress became equal or exceeded the yield stress at the thinned region. It was concluded that the tube failed because of ash deposition followed by ash induced corrosion.

It was recommended that periodical checking, cleaning and removal of ash deposits on outer surface especially the pocket regions of the tubes should be carried out to prevent/reduce ash induced corrosion failures. Better quality coal may be used to prevent/reduce the amount of corrosive elements in the ash (S, P, Cl, Na, K, Ca, Al and Si).

c. Root Cause Analysis of failure of pelton runner of a Hydel Power Plant

One bucket of a Pelton runner got damaged and dislodged from the runner during operation. Subsequently, the failure investigation was carried out at CSIR-NML, Jamshedpur. The photograph of the fractured region of the bucket highlighting various fracture characteristics is shown in **Figure 30.** Failure investigation was carried out through visual examination, chemical composition analysis, evaluation of hardness, tensile and charpy impact properties, microstructural investigation, fractography and X-ray diffraction analysis. Microstructural investigation revealed the presence of tempered martensite and retained austenite (15-19 vol. %) along with δ-ferrite. The chemical composition, hardness, Charpy impact properties and average tensile property of the bucket was found to be as per the specified standards. However, a large variation in tensile properties was also observed with decrease in elongation and

reduction in area in the tensile tested samples. Further investigation revealed the presence of local heterogeneities like shrinkage cavities, dendritic structure, excessive MnS particles and clusters of Ca-Si-Al based oxides in the bucket. These defects acts as potential sites for fatigue crack initiation. Signatures of fatigue failure such as beach marks and striations were also observed on the fractured surface. It was concluded that the bucket failed because of fatigue. The fatigue crack originated near the surface in the root region of the bucket. A cluster of non-metallic (Ca, Si, Al) based oxides was found in the sub-surface microstructure below the fatigue origin. As the root region of the bucket experiences high concentration of stress during operation, it is confirmed that the presence of cluster of oxides particles (Ca, Al, Si) at the root region has eventually led to the initiation of fatigue crack.

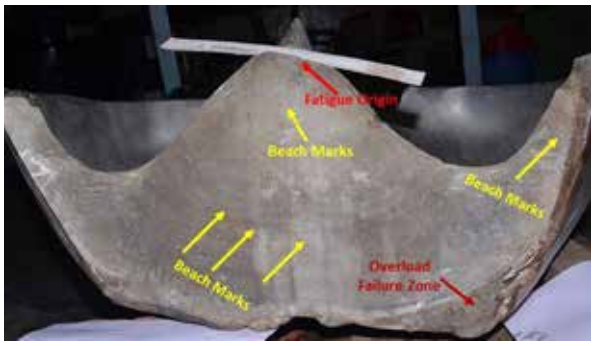


Figure 30: Failed Pelton turbine blade

d. Metallurgical failure investigation of penstock steel in a hydel power plant

During a trial run, the penstock part made of steel ruptured under a very low stress. The different fragmented parts of damaged penstock at the site is shown in **Figure 31**. The penstock was supposed to be made up of ASTM 517 Gr.F steel; however, owing to the unavailability of the alloy, it was recommended to use an alternative equivalent 550 HI steel grade. The damaged penstock material (service exposed) along with virgin plates of ASTM 517F and 550HI, were received at CSIR-NML to investigate the root cause of failure and ascertain the quality of steel plates. Failure investigation was carried out through visual examination, bulk chemical composition analysis, evaluation of hardness, tensile test, Charpy impact test, microstructural investigation, and fractography. From the investigation, it was revealed that there was a significant difference between the service exposed alloy and ASTM 517F in terms of chemical composition, microstructure, tensile properties and Charpy impact properties. With respect to the virgin 550HI plate and standard specifications for the same, the service exposed alloy exhibited variations in chemical composition. The bulk hardness of serviced exposed 550HI revealed wide variation along the component; near the fracture, it was close to virgin values, and away from fracture, it was very high. Impact properties at -20°C, 0°C and 25°C for serviced exposed 550HI was significantly lower than virgin as well as standard specifications. Considering the room temperature tensile properties, the service exposed 550HI was at par with the specifications, however, the ultimate tensile strength was too high in comparison to specification (exceeds by ≈ 200 MPa) and even the virgin 550HI exceeded specifications by ≈100 MPa. The microstructure of service exposed / virgin 550HI contained banded ferrite-pearlite/bainite, while the ASTM 517F had tempered martensite structure. Service exposed 550HI also contained large size oxide / complex oxide inclusions (as high as ≈ 35 µm). No significant heterogeneity has been observed near welded regions. The fracture surfaces were covered with thick oxide scale and could not be examined properly to observe characteristic features. The lower impact properties of service-exposed material with respect to others can be attributed to the absence of Ni, the formation of large-sized oxide inclusions and high quantity of microalloying elements along with carbon.

Figure 31: Failed Penstock components

9. Remaining life assessment

Remaining life assessment of Hydrogen Reformer, Pig tail, Visbreaker-1 and Visbreaker-2 tubes.

The items of interest, a Phase-1 Visbreaker heater (VBU-1) and Phase-2 Visbreaker heater (VBU-2) were in operation since 1996 and 1999, respectively. The reformer tubes had completed 100,000 hrs of design life. Both the heater tubes of Visbreaker unit and Hydrogen Reformer had run for more than 11 years. An estimate of the remaining life at the operating hoop stress and temperature was made by analysis of creep rupture data using Larson–Miller Parameter (LMP), as shown in **Figure 32**. Estimation of balance life is based on accelerated stress rupture data. Apparently, it seems, all components have remaining life greater than 10 years. Coarsening of the precipitates were observed for crept samples and it is recommended to carry out another health check-up of the tubes after 5 years in service.

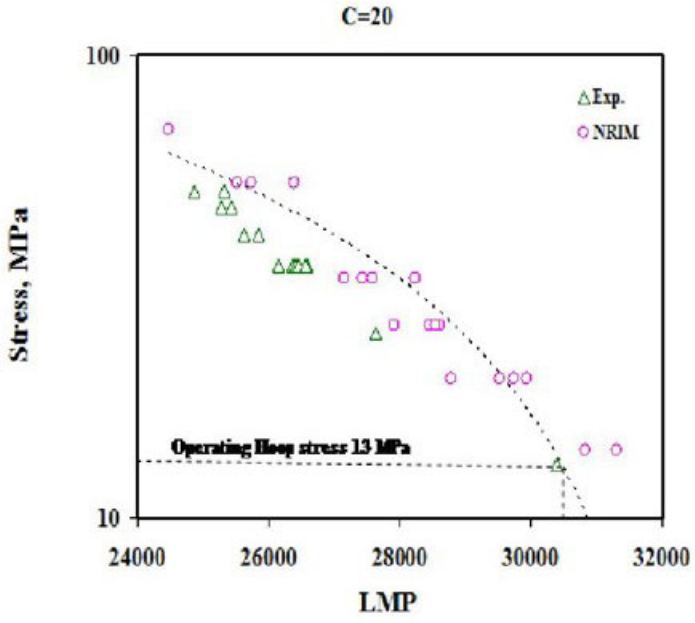


Figure 32: Creep rupture data using Larson–Miller Parameter (LMP)

10. Residual Stress Determination:

a. Residual stress investigation of rails from DFCCIL Mughalsarai & from DFCCIL Agra

40 as-received rails from Dedicated Freight Corridor Corporation of India Ltd (DFCCIL), Mughalsarai, and 44 rails from DFCCIL, Agra, were investigated for residual stress. After rust removal and polishing of 1 metre length cut from the rails, strain gauges of 120Ω were pasted at head and foot centres (**Figure 33)**. This microstrain (10^{-6}) measured was multiplied by Young's modulus (205 GPa) to give the residual stress.

Figure 33: Placement of strain gauges and strain measurement

b. Residual Stress measurement on bent axle beams

Hollow axle beams of vehicles were supplied by a major Auto Ancillary Producer to a major Vehicle manufacturer. Axle beams were found to fail during rig level testing at the vehicle manufacturer's site. The failure was suspected to occur because of high tensile residual stress levels. For this, the auto ancillary producer as well as the vehicle manufacturer approached CSIR-NML for measurement of residual stress at different locations in these axle beams during different stages of manufacturing. These different stages were hollow tube making, roll bending, shot peening, sand blasting, fixture welding, etc. **Figure 34** shows the schematic of bent axle beam with locations of residual stress measurement. In all the tubes, measurements were made on the maximum curvature regions wherein each measurement comprised of an average of three points taken at a distance of 10 mm. The residual stress measurements were done using a portable X-Ray Diffractometer having a Cr Kα source. It was observed that post welding and after final shot peening, the prevailing residual stress was compressive in nature; however, the magnitudes were not adequate. Based upon these residual stress measurements, the weld fixture design and shot peening parameters were optimized by the auto ancillary producer.

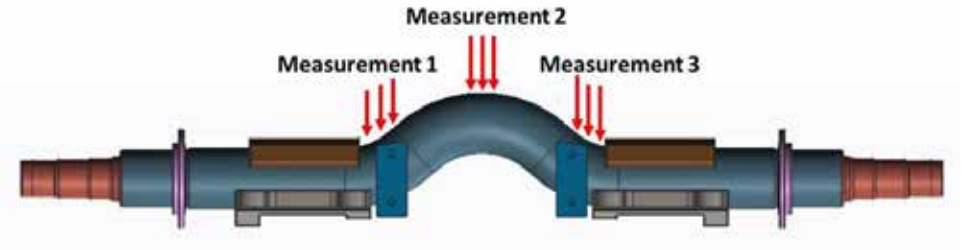


Figure 34: Bent Axle Beam with locations of residual stress measurement

11. Corrosion Assessment:

a. Corrosion aggressivity of mine water samples

Investigations on corrosivity of water samples obtained from iron ore mines, to ascertain the corrosion rate of line pipe steel under various conditions, were made. Monitoring the corrosion rate within the design limits to achieve the required pipeline life is essential. Keeping the above in view, corrosion investigations of line-pipe steel (grade API-X65) were carried out in the water samples obtained from iron ore mines, to check the corrosion aggressivity of each water in open and closed cell conditions. The corrosion rate and pitting potential were monitored by electrochemical polarization methods with varying amounts of dissolved oxygen, pH and exposure time. The influence of different dissolved oxygen contents on the conductivity of water samples vis-a-vis corrosion rate of pipeline steel was also studied. Some of the major findings obtained through the exposure of line pipe steel to the mine water with varying dissolved oxygen and

pH in open and close cell conditions are as follows. The corrosion rates were found to decrease with increasing exposure time and became almost constant after certain duration of exposure. This is attributed to the stability of the oxide films as an optimum time is required to form a stable oxide film and once a stable film forms on the surface, the corrosion rate becomes constant. Also, the corrosion rates were found lower in closed cell condition as compared to open cell condition due to the unavailability of the oxygen for the cathodic reaction. An increase in pH from near neutral (pH~7.62) to pH~10.65 resulted in an increase in corrosion rates in open cell conditions, due to less likelihood of formation of stable oxide films in alkaline medium. The results indicated oxygen-controlled degradation of API-X65 steel. Dissolved oxygen > 4000 ppb accelerates the corrosion rate of pipeline steel in neutral as well as alkaline water (**Figure 35)**. This, in spite of the fact that the conductivity of water was found to decrease with increasing oxygen content.

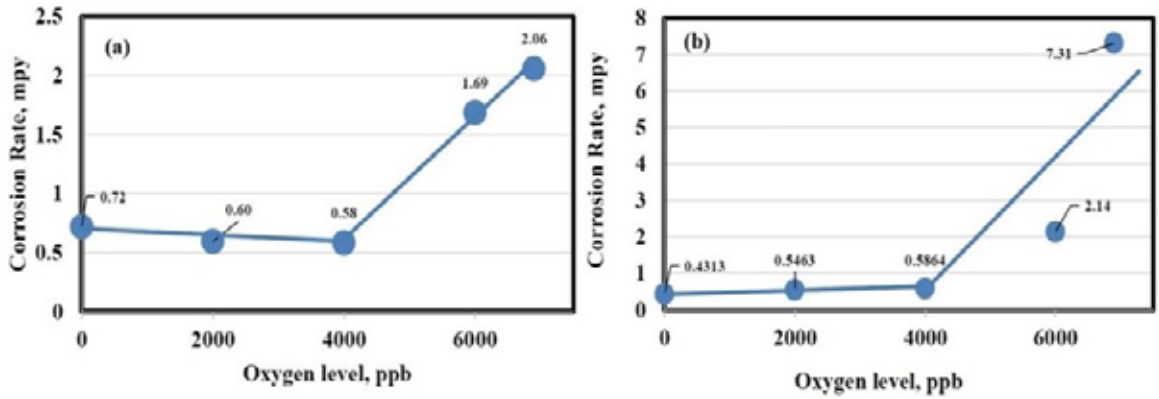


Figure 35: Corrosion rate variation with oxygen concentration in (a) as received (pH~7.62) and (b) modified (pH~10.65) mine water in closed cell condition.

b. High Temperature Oxidation and Hot Corrosion behaviour of selected materials for Clean Coal Technologies for Power Plant Applications

The project aimed to study the oxidation and hot corrosion behaviour of as-received IN 617, P 91 alloys and laser hybrid welded IN 617 (W) and P 91(W) alloys exposed at 600-800°C in air/flue gas environment. The characterization with respect to hardness of the laser hybrid welds is done using Vickers's Hardness equipment; the values obtained for P91 alloys are: 450 and 413Hv_{gf} for weld zone and HAZ respectively versus 210 Hv_{gf} for P91 base. These values for IN 617 alloys are: 300 and 280Hv_{gf} for weld zone and HAZ respectively versus 267 Hv_{gf} for IN 617 base. The post weld heat treatments given to the laser welded specimens of P91 alloys, clearly show reduction in hardness values in comparison to the as-welded conditions. This investigation clearly advocates that the post weld heat treatment is desirable and essential for P91 alloys to keep the hardness values close to desired as per the standards and literature. For oxidation studies, IN 617 and P91 alloys were exposed to the temperature ranges 600-800°C for 100 h in a TGA furnace. Hot corrosion tests were conducted on the as-received and welded specimens after coating with synthetic coal ash as well as salt mixture and exposed to 700°C for 1000 h in flue gas environment in tubular furnace (Figure 36). The P91 weld has considerably lower

oxidation resistance than that of its as-received counterpart. Insignificant difference in oxidation resistance is observed between as-received IN 617 and its weld counterpart. The XRD of the oxide scale formed on P91 alloy (base) exposed to 600-800°C in air- oxidation for 100 h revealed phases such as Cr_2O_3, Fe_3O_4 and $MnCr_2O_4$ with traces of Fe, $Mn(SiO)_4$. Some sites on the P91 alloy surfaces were found to have Fe_3O_4 and a little amount of Cr. No spallation of the external oxide scale was observed during oxidation tests of P91 alloy. The XRD analysis of IN 617 alloys confirms the presence of oxides of Na_2SO_4, Cr_2O_3, $FeCr_2O_4$, $NiCr_2O_4$, Fe_2O_3 at 700°C after 1000 h of exposure. $FeCr_2O_4$ is more protective in nature as compared to Fe_2O_3. In case of P91 alloys, presence of Fe_2O_3 in the outer scale is non-protective, which allow for ingress of oxygen through it to form more oxide which leads to increase in weight for P91 alloys.

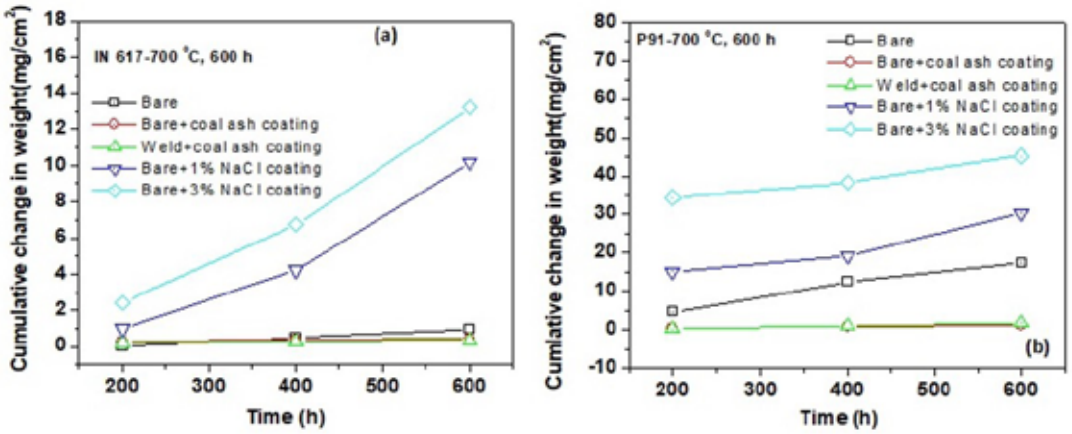


Figure 36: Oxidation kinetics curve of IN 617 & P91 alloys exposed at 700°C for 600 h in flue gas environment.

12. Corrosion prevention

a. Coating thickness measurement of metallic (Galvanized/Galvalume) coated steel

The samples from 7 different sources across India (Delhi, Jaipur, Guwahati, Kolkata, Bangalore, Mumbai & Silliguri) were investigated for variation in coating thickness (Galvanized/Galvalume) using standard methods for compliance. Triplicate samples for each coating having 50 mm diameter was cut from the given/supplied samples. GSM of each single side for top and back coating is determined and corresponding values were reported in tabular form for each site. The coating compliance followed the trends: Bangalore (16/20)> Guwahati (14/20) ~ Silliguri (14/20)> Mumbai (14/20)> Kolkata (9/18) ~ Delhi (6/12)> Jaipur (2/19).

b. Performance Evaluation of Protective Coating

Differently coated/ painted samples (HRS, CRS & GI) were evaluated for salt exposure, cyclic salt exposure corrosion testing, electrochemical impedance measurement, adhesion test and chemical resistance test as per ASTM-B117, G85, D3359 & D1308 under a sponsored project. Salt exposure test was carried out for 1000 h. Cyclic salt exposure corrosion testing was done for a duration of 2000 h. The electrochemical impedance measurements test was carried out for up to 4000 h. exposure. The objective of the project is to do the comparative performance evaluation of protective coatings. On the basis of size and frequency of the blister, the performance of coated specimens followed the trends: For *Scribed samples* : HRS> GI > CRS; For

Un-scribed samples: CRS>HRS>GI. On the basis of creepage rating, the performance of specimens followed the trends: *Scribed*: HRS> GI > CRS. The overall change in colour is found to be lower for the samples exposed in NaOH than in HCl, H_2SO_4, NaOH or Acetic acid, whereas overall change in gloss is lower for sample exposed in HCl, Acetic acid, NaOH and H_2SO_4.

c. Galvanizing coating simulation using hot dip process simulator

C-Mn grade steel sheet, produced by an International Steel major, was investigated for developing special hot dip coating using different bath compositions. Prior to in-line production of such hot dip coatings, the sponsor wanted to simulate the process conditions for new continuous galvanizing line (CGL) with a purpose to produce good quality coating at varying bath compositions. CSIR-NML Jamshedpur carried out hot dip coating experiments using Hot Dip Process Simulator (HDPS) based on the plant recommended process parameters and bath compositions. Good quality adherent hot dip coated steel samples, free from bare spots on the coated surface, were produced at a laboratory scale based on the systematic consideration of annealing atmosphere and time-temperature schedule. A pictorial view of all the galvanized specimens obtained using different bath composition for selected process conditions is shown in **Figure 37**. Visual examination of the galvanized coupons exhibits good quality adherent coatings almost free from any bare spots on the coated surface.

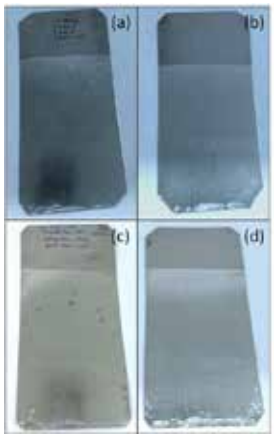


Figure 37: Pictorial view of galvanized specimens with varying bath composition and process parameters (a) Bath composition 1,
(b) Bath composition 2,
(c) Bath composition 3 and
(d) Bath composition 4

Indian Metal Crafts

Nataraja statue in Chola Bronze

Kalyan Sunder statue

The Lost Wax (Dokra) Process of casting

The method of lost wax in mentioned in the ancient texts. There are two primary metals used: Bronze and Panchola which comes from five metals: Copper, Tin, Gold, Silver, and Lead. The origin of Bronze images lies in the urge to take out the Gods in palanquins from the temples. Since this was not possible with huge stone idols, smaller idols carved in metal were light and easy to be taken around.

The Dokra art (lost wax metal technique) is one of the most popular metal art form with distinctive variations across Andhra Pradesh, Odisha, Madhya Pradesh and Chhattisgarh. These metal artefacts are made from brass metal scrap filled with clay.

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Metal Extraction and Recycling (MER)

Metal Extraction and Recycling (MER) Division is one of the core R&D divisions of the laboratory with 60 researchers including 32 scientists. The division is involved in basic research and in development of processes, products and technologies. Equipped with state-of-the-art bench and pilot scale facilities, the division concentrates its expertise primarily in the areas of ferrous and non-ferrous metals, value addition and value extraction from various secondary resources and industrial wastes. Some of the unique facilities of the division are Urban Ore Recycling Centre, Geo-polymer pilot plant, Melting furnaces of various capacities, and Solvent extraction units. The division consists of three major groups, Ferrous Processes, Non-ferrous Processes, and Secondary and Resources Utilization. The Ferrous Processing group is primarily involved in process advancement in agglomeration and utilization of iron ore fines and ferruginous wastes of steel plants, standard reference materials developments for steel, preparation and quality improvement of different ferro-alloys. The Non-Ferrous Process group is actively pursuing research activities in harnessing the secondary and lean grade resources for extraction of non-ferrous metal values in either elemental form or as useful compounds and extraction of strategic metals for specialty applications. The activities in Secondary and Resources Utilization group is directed towards use of secondary resources for rare earth extraction and value addition to all types of industrial wastes by converting them to products for a variety of applications such as refractory, construction materials and cementitious products.

This division has charted out its future research planning that are important for national economy, strategic sector, mobility, and infrastructure. These include technology establishment for the extraction of critical metals including REE from secondary resources, E-waste management, strategic metals like tungsten and sodium, development of hybrid materials for speciality applications, immobilization of low-level radioactive wastes in geopolymer cement, etc.

Ferrous Process Group

Ferrous process group works in the sub-areas of agglomeration, iron making, steel making, ferro-alloy making for developing technologies, process development and providing support to industries for process improvement. This group has expertise in process modeling, thermodynamics, and kinetics analysis. It is primarily involved in process advancement in agglomeration and utilization of iron ore fines/ferruginous wastes of the steel plant, preparation as well as quality improvement of different ferroalloys, alloy steel making, and inclusion control in steel. The main projects under this group are as follows:

Replacement of bentonite with an alternative binder for iron ore pelletization

Bentonite is presently used as a binder for iron ore pelletization in steel industries because of its good binding property in cold as well as in hot conditions. Since bentonite contains a lot of silica and alumina, it increases the gangue content in the pellet. Replacement of bentonite with some organic binder may be done, because organic binder (OB) also gives good strength. As OB loses its strength at high temperatures, pellets may get crumbled during heating in an induration strand. Therefore, another additive with the organic binder, in minor quantities, needs to be used to

provide strength to the pellet at relatively higher temperature (above 400°C). In this study, certain steel plant wastes will be used to prevent the strength loss at this temperature. This will give in-situ heat on oxidation and provide diffusion bonding at a lower temperature. Pellets have been made in 2-3 kg batches with only bentonite as the binder (plant comp.), and with different organic binders with minor additives in varying proportions (without any bentonite). Strength deterioration in organic binders has been found at 300-400°C during heating of the pellets. However, the use of 3-4% steel plant wastes with 0.3% organic bonded pellets has prevented the strength loss considerably, at 300-400°C temperature range. The above combination has shown its potential to replace bentonite completely. Characterization of the developed pellets will be carried out to assess their usability in BF operation.

Development of Briquetting technique for utilization of steel plant solid waste

Several iron-oxide fines such as Basic Oxygen Furnace (BOF) sludge, Blast Furnace (BF) sludge, Electro Static Precipitator (ESP) dust, sinter returns, BF flue dust, etc., are generated in different units of a steel plant. All these fines have a substantial quantity of iron oxide content. A major portion of these fines is not used in steel plants because of their extreme fineness and inappropriate chemistry. These fines can be used as a coolant in BOF converter if agglomerated properly. However, a suitable agglomeration technique is required. The present study, aims at utilizing steel making sludge and other wastes, viz., blast furnace sludge, ESP dust, and sinter return generated in the steel plant, to produce briquettes. First, the process parameters (mix ratio, suitable binder, quantity of binder) for good quality briquettes have been optimized at a laboratory scale. Finally, cylindrical briquettes were developed, which can provide 280 kg/cm^2 cold crushing strength. Pilot-scale study at 150 kg scale has produced pillow shaped briquettes (30x38 mm) having cold crushing strength of 130-150 kg/briquette. The second phase of the project, targeting large-scale production of briquettes of around 50 tons, is being carried out. After the large-scale preparation of briquettes, its performance will be assessed in a BOF of 100-ton capacity.

Process feasibility for utilization of low-grade iron ore and slime in shaft based DRI technology

The present investigation deals with the feasibility of Utilization of lean grade iron ore fines and slime in shaft-based directly reduced iron (DRI) Technology. Four different lean grade iron ore fines including iron ore slimes were obtained from the sponsor's mines. These iron ore fines and slimes were characterized for their chemical composition, and ground in a ball mill to make them suitable for pelletization. Pellets were made in a disc pelletizer, with different percentage binders as an additive, in the presence of optimized moisture. These pellets were air-dried and indurated in a muffle furnace at 1250°C to 1320°C for 10 - 20 minutes, to obtain the optimum crushing strength suitable for further processing in a shaft kiln. Characterization of indurated pellets, reduction studies in a shaft furnace and further characterization of the product are in progress.

Development of a cost-effective refractory lining material for induction melting furnace suitable for production of quality steel: Phase II (industrial trials)

Indian secondary steel production through induction furnace route, contribute to about $1/3^{rd}$ of the country's steel production. Owing to the non-continuous power supply, economics, and other considerations, these furnaces use acidic ramming mass for furnace lining. It is well known that in the acidic lined furnace, no refining

reactions particularly the removal of sulfur and phosphorous can be carried out. Almost all the melting furnaces located in Eastern, Southern and Central parts of the country use about 80% DRI as charge material that contains phosphorous as high as 0.10%. Under basic or neutral lining conditions, refining reactions are possible with suitable slag cover, which is very difficult under acidic lining conditions. A newly developed basic ramming mass in the industry is highly needed. CSIR-NML has developed a flux for the dephosphorization of steel in an induction furnace. Simultaneously, CSIR-CGCRI has developed a ramming mass for induction furnaces to use basic slag. Dephosphorization experiments were performed at CSIR-NML **(Figure 1)** using CSIR-CGCRI's ramming mass. It has been found that phosphorus content in steel is reduced successfully to 0.01-0.03 wt % after using the CSIR-NML's developed flux in the liquid steel in a 5-40 kg capacity induction furnace. The lining life of the induction furnace was found to be 25-30 heats. The industrial trial for dephosphorization of steel in 8–10 ton capacity induction furnace using CSIR-NML developed flux and CSIR-CGCRI developed ramming mass will be performed shortly.

Figure 1: Dephosphorization Experiment in Induction Furnace

Smelting of vanadium pentoxide for preparation of Ferro-Vanadium (FeV)

$FeO.V_2O_5$ produced from the hydrometallurgical treatment of pet coke cinder will be used for the preparation of high-quality Fe-V alloy. A suitable smelting process will be developed to produce Fe-V from vanadium pentoxide concentrate. In this study electro-aluminothermic or aluminothermic process in 10-15 kg scale will be developed to produce Fe-V alloy from both $FeO.V_2O_5$ and V_2O_5 obtained from pet coke cinder. First, the process parameter will be optimized for the preparation of Fe-V from available commercial-grade V_2O_5, subsequently, preparation of Fe-V alloy from the supplied $FeO.V_2O_5$ and V_2O_5 obtained from hydrometallurgical treatment of pet coke cinder will be done.

Studies on De-siliconization of high silicon ferro chrome in 50 kVA EAF

In general, ferrochrome is produced in a submerged arc furnace by the carbo-thermic reduction of chromite ore. The silicon content in such ferrochrome is as high as 2.5-3.5%. However, there is a high demand for ferrochrome with low silicon. To reduce the silicon content to less than 1.5 wt %, different processes are attempted as per the present requirement. The addition of lime and low-grade chromite ore was used which reduces silicon content to around 1.3 wt%. When calcium ferrite was added with lime and low-grade chromite ore, the extent of desiliconization further improved, which yields 1.1-1.2 % Si in ferrochrome. However, the use of high-grade chromite ore did not show any encouraging result for desiliconisation. Reducing Si content in ferrochrome has potential for implementation in ferroalloy industries.

Development and fabrication of cannon liners for explosive testing

Cannon available with CSIR-CIMFR, Dhanbad, made up of three concentric steel parts, are deployed for

explosive testing to qualify the explosives used in underground mines. This cannon assembly and the liners were imported 50 years back from UK and the know-how for manufacturing the same was not available with CSIR-CIMFR. Due to the non-availability of cannon inner membrane at present, there is a need to manufacture it indigenously. The only technical information regarding the inner membrane available is "*HADFIELDS HECLA 138H 2.5 NI CR Mo forged steel inner membrane in the oil hardened and tempered condition with a Brinell hardness of 340/360*". With this information, CSIR-NML started the developmental activity, which consisted of (i) benchmarking, (ii) in-house design and development of cannon liner steel, and (iii) fabrication of cannon inner membrane in a reputed steel industry. Know-how generated in-house was shared with M/s. MIDHANI Hyderabad and the cannon liner alloy steel of dimension 1600mm length x 220mm diameter cylindrical rod were manufactured (pilot scale heat). Its mechanical properties were found to be superior to the imported and lab scale developed steel **(**Figure 2**).** These cylindrical rods will be machined to required cannon inner membrane dimension and shrink fitted at M/s. Hindustan Engineering Corporation (HEC), Ranchi. Thereafter, the fitted cannon will be subjected to explosive testing field trial. This is the indigenous development of cannon liner steel in India for explosive testing, which is a cost-effective import substitution. This will help in the production of steels for strategic applications in Indian laboratories.

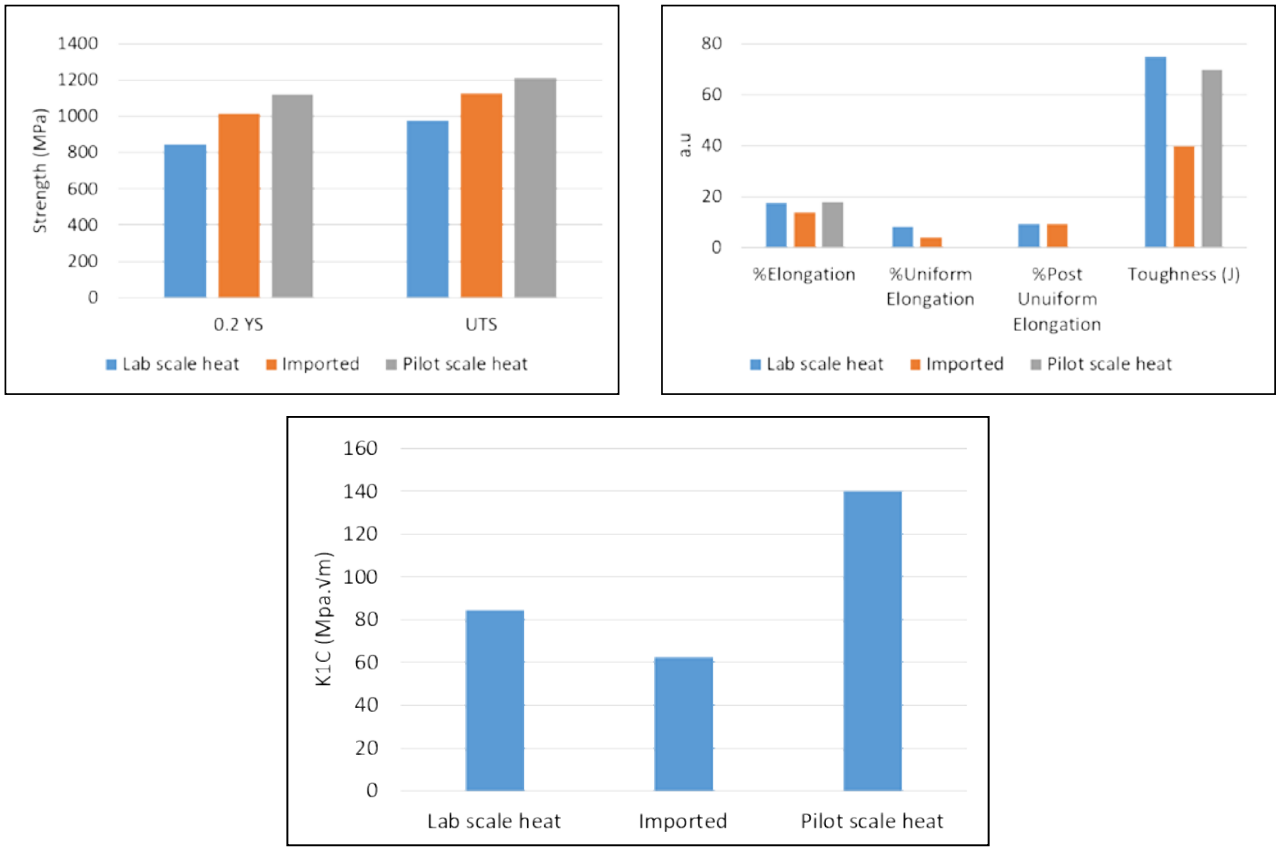

Figure 2: Comparison of Developed Canon Liner

Non-Ferrous Process Group

The Non-Ferrous process group primarily concentrates on the extraction of non-ferrous metals as value added products from primary ores, low grade ores, and secondary wastes including waste sludge/residue, urban waste and waste solutions. The group consisting of 14 scientists and 3 technical officers has successfully established several pyro/hydro/electro metallurgical processing schemes (at lab scale and pilot scale) in the areas of strategic metals, e-waste and base metals. This group is well equipped with high temperature furnaces, rotary kilns, submerged arc furnaces, leaching-solvent extraction facilities at bench scale and pilot scale, high temperature autoclaves, electrolysis cells, high temperature distillation units, etc. The group is actively involved in the areas of strategic, rare and critical metal extraction from various scraps, lean grade ores/tailings and waste sources for development of process flow-sheets. In the recent past, several such technologies have been demonstrated on bench and pilot scale and transferred to several Indian and Foreign Industries. A few ongoing and recently completed project details are elaborated below :

Piloting of the process for Vanadium recovery from Coal slag

An International Petrochemical giant has started working on the world's largest coal gasification projects. The envisaged plant would treat more than 30 million tons of coal/coke per annum for production of fuel grade synthetic gas (Syngas). It is also estimated that, this plant would generate 200–250 kilo tonne/annum gasification slag containing valuable metals such as V and Ni (~6% V and 1.2% Ni). The sponsor has developed an in-house process at a bench scale for extraction of V and Ni from such slag and converting it to highly marketable Fe-V (containing about 80% V), and nickel salt/hydroxide. The developed bench scale process comprises of several unit processes like roasting, leaching, purification, precipitation, Alumino-thermic reduction, and, processing of the leaching residues. This bench scale process needs to be up-scaled with generation of vital techno-economic data for further piloting and ultimate commercialization. Through this project the sponsor would use the expertise and facilities of CSIR-NML for scaling-up of the process. In this project, it is planned to process about 4.5 metric ton of coal slag and generate more than 160 kg of high purity desired grade $FeO.V_2O_5$ for further processing to FeV. Till date more than 1.5 metric ton of slag sample have been pre-treated to generate about 1.2 metric ton of -100 mesh powders suitable for alkali roasting **(Figure 3)**.

Figure 3: (a) The As Received Coal Slag (b) The Dried, Pulverized and Screened Slag Sample to Be Used For Alkali Roasting

E-waste recycling technologies

CSIR-National Metallurgical Laboratory (CSIR-NML), is an Indian pioneer in the development of application-oriented e-waste recycling processes, fulfilling zero waste concepts. For the last 12 years, a group of scientists at CSIR-NML have been working for development of processes to recycle non-ferrous metals from printed circuit boards (PCBs), rare earth metals from various types of magnets and precious metals from e-waste. In order to carry out scale-up and pilot scale trials, a centre dedicated

for the development of feasible technologies to recover non-ferrous, precious and rare earth metals from secondary resources has been established. Dr. Shekhar C. Mande, Director General of CSIR and Secretary of the Department of Scientific and Industrial Research (DSIR), inaugurated this centre named as Urban Ore Recycling Centre at CSIR-NML, Jamshedpur, on 20th April 2019. Under this banner, CSIR-NML has recently transferred five technologies to various Indian recycling companies (M/s Evergreen Recyclekaro Pvt. (India) Ltd., Mumbai; M/s EXIGO Recycling, New Delhi; M/s SBCON Recycling Pvt. Ltd., Ahmedabad; M/s ADV Metal Combine Pvt. Ltd., Durg; M/s UNQ IND Pvt. Ltd., Firozabad; M/s Eco Recycling Company, Mumbai) with high Customer Satisfaction documented. The transfer of technologies is a great step towards the **"Swachhata Abhiyan"** initiated by Government of India. The developed processes are fully indigenous, economically feasible, less energy intensive and yield high value of metals and materials. The e-waste recycling sector will contribute to the country's economy and create employment. In recent years, CSIR-NML has contributed a lot in the area of development of feasible processes for recycling of e-waste to reclaim the metals, materials and valuables **(Figure 4)**.

Figure 4:Urban Ore Recycling Centre

Production of Fe-Ni/Co-Mo metallic alloy & alumina rich slag from Ni-Mo/Co-Mo spent catalysts

Globally, about 200,000 metric ton of spent catalysts are being discarded by oil refineries every year (in India about 3000 ton/year), which pose severe environmental challenges. They provide an opportunity for value harvesting since spent refinery catalysts contain several critical and strategic metals, such as Mo, Ni, Co, W, etc. in appreciable quantities (total metal content could be as high as 25 – 30%). Indian steel sector imports almost all of its' ferro-alloys requirements, as India is deprived of any primary ore deposits of most of these alloying metals (Co, Ni, Mo etc.) and/or produce meagre quantities of such metals from various sources. Spent oil-refinery catalysts could be treated as rich grade urban ore/open mine source for such metals/ materials provided economically competitive indigenous technologies are available. The target technology is highly competitive and superior to several existing technologies in terms of product(s) grade, cost of production and environmental load. Once successful, this will promote indigenous ferro-alloy production, and reduce import burden (by a few million USD). Recycling technologies based on hydrometallurgy lack complete recycling of spent refinery catalysts, while the smelting-based technologies generate slag, which finds little utility and are dumped. This technology addresses these issues through appropriate raw materials blending with careful flux choice for carbothermic smelting of spent catalysts followed by post processing steps to produce saleable ferro-alloys (Fe-Ni-Co-Mo), and calcium aluminate slag suitable for construction/ cement industries. This project intends to scale-up the developed technology (100 kg scale) and test its suitability with a variety of spent refinery catalysts. A few industries have shown their interests on the bench scale know-how, scale-up studies will further

reinforce the prospect of technology transfer and commercialization.

Figure 5: Fe-Mo Alloy and Calcia-Alumina Slag from Spent Catalyst

Effective extraction and separation technology to extract rare earth elements from Waste Electrical and Electronic Equipment (WEEE)

The rare earth metals are widely used in many applications such as electric vehicle, wind mill, electronics industry, defence system, etc. The primary resources of rare earths are limited and associated with radioactive elements, which makes their extraction and separation difficult. The spent NdFeB permanent magnet have huge potential to serve as an important secondary resource to fulfil the demand of rare earths. Therefore, the objective of the present project is to develop an effective extraction and separation technology to selectively extract rare earth metals from spent NdFeB magnets. The project collaboration was established with Marcoule Institute for Separation Chemistry (R&D, France), Terra Nova Development (Industry, France) and TRDDC, Pune. This Indo-French project is sponsored by "Indo-French Centre for the Promotion of Advanced Research (CEFIPRA)". The emphasis has been on the development of an energy efficient and environment friendly process for the recovery of rare earths from spent NdFeB magnet **(Figure 6)**. Two different process approaches (i) Oxidation roasting-acid leaching (ii) Chlorination roasting-water leaching were developed in CSIR-NML for the quantitative and selective recovery of rare earths from spent NdFeB magnet. The mixed oxide of neodymium, praseodymium and dysprosium obtained had a purity >99%. Iron oxide was obtained as a by-product of the process, which could be used directly in many applications. The developed processes for treating spent NdFeB magnet waste have the potential for commercialization. For the individual separation of rare earths, studies have been carried out using extractants such as D2EHPA+TOPO, Mextral 503A (N,N-Di(1-methyl heptyl) hexanamide) and Cyanex 572. Novel lipophilic EDTA based ligands have also been synthesized in ICSM, France, for effective separation of rare earths.

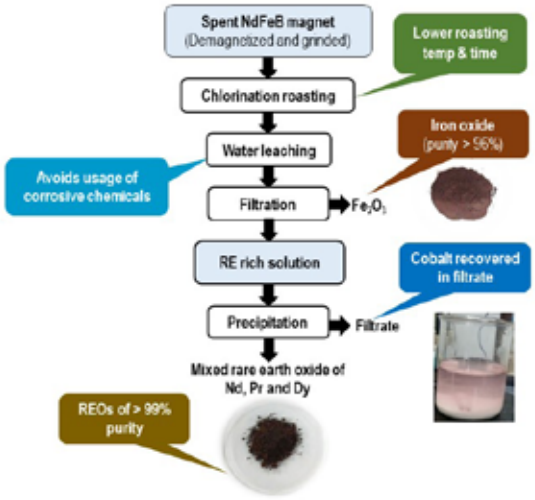

Figure 6: Process for Recovery of Rare Earths And Iron Oxide From Spent NdFeB Magnet

Development of Alternate Gaseous Reduction of low-grade Mn Ore

The present EMD manufacturing process employs high temperature coal-based reduction process prior to acid leaching of Mn ore. The process is found to be highly inefficient, besides environmentally polluting. In view of the projected expansion of EMD production by the sponsor up to 40,000 MTPA by 2022, it is necessary to develop an efficient reduction process, which could be less polluting. In this context, gaseous reduction of Mn ore has been conceived and taken up for further studies.

Two different types of Mn ore samples; one having low MnO_2 (~ 26%) and another having high MnO_2 (~ 46%), have been taken up for thermal reduction at low to medium temperature by using several gaseous reductants such as CNG, LPG and Producer's gas. Bench scale feasibility and optimization studies of reduction of Mn ore(s) with these gaseous reductants have been carried out. It has been observed that, reduction of Mn ore(s) with LPG is techno-economically competitive with respect to the coal-based reduction processes besides giving emission dividends. Low temperature (<800°C) thermal reduction of Mn ore with LPG was scaled-up to 20 kg/batch scale by using a rotary furnace. The results indicated more than 93% reduction efficiency at 800 °C. Preliminary results on reduction of Mn ores with Producer's gas is found to be not so encouraging, probably due to the low calorific value of used coal sample.

Improvement of Manganese Recovery from Reduced Manganese Ore

Electrolytic Manganese Dioxide (EMD) is an essential ingredient of lithium-ion batteries, the demand of which is expected to increase further in near future. India is producing only about 0.2% of the global demand of ~4.5L metric tonnes. Manganese ore India Ltd. (MOIL), is the only producer of EMD in India with an installed capacity of ~1500 MT. They are using a reduction roasting - leaching and electro-winning process for production of EMD with leaching stage recovery of about 65%. It was proposed to further improve the Mn recovery prior to setting-up of new production plant and MOIL sponsored a project to CSIR-NML for improvement in Mn recovery from their reduced ore. The unreduced manganese dioxide present in reduced ore was targeted to improve manganese dissolution. MnO_2 can easily be dissolved by in-situ chemical reduction using various low-cost reductants. Waste iron powder which is available cheaply from various sources was used for improvement in Mn recovery. Under optimized condition about 18-20% improvement in Mn recovery was achieved during leaching with addition of about 30-40 kg waste iron powder per ton of reduced ore. High purity EMD containing <30 ppm Fe was produced from purified Mn leach solution. The chance of over roasting, which is one of the causes for lower Mn recovery in the existing process, can be avoided by the improved process. The process was demonstrated on a kg scale to MOIL and Ministry of Steel personnel with about 20% higher Mn recovery. The process was also demonstrated at MOIL Dungri plant, with similar improvement in Mn recovery **(Figure-7)**.

Figure 7: Demonstration of the Process at (a) CSIR-NML and (b) MOIL Dungri

Development of a cost-effective green technology for pre reduction of chromite ore in tunnel kiln and production of high carbon Ferro Chrome in SAF

This work was sponsored by Ministry of Steel to utilize chromite ore fines to produce ferrochrome in an innovative way to reduce the power consumption during the process. The proposed process is aimed at application of a tunnel kiln furnace for pre-reduction of a mixture of chrome ore, solid reductant, fluxes and binder to around 1350-1400°C to form a direct reduced ferro chrome (DRFC). This DRFC will be further processed in submerged arc furnace (SAF), to produce high carbon ferro chrome. Tunnel Kiln consumes low energy as it is a closed furnace with much better heat transfer efficiency and utilization. Hence, the pre-reduction in tunnel kiln is expected to reduce the overall energy requirement for the production of high carbon ferro chrome **(Figure-8)**. In conventional SAF process, specific energy for the production of high carbon ferro chrome is approximately 4500 kWh/Ton to 5000 kWh/Ton. In the proposed project, the pre-reduction of chromite ore in tunnel kiln furnace coupled with smelting reduction in SAF furnace would bring down the overall energy requirement to about 3500– 4000 kWh/Ton, thus saving ~1000 kWh/Ton of electrical power equivalent. The overall carbon emission would reduce significantly. Therefore, the proposed process is expected to be an environment friendly process and economically more viable process, compared to the conventional process. Five MT of reduced chrome pellet were received at CSIR-NML from M/s MECPL, for reduction smelting trials. 50 trials have been conducted on 100 kg scale in submerged electric arc furnace by varying the reduction parameters to produce 2 MT high carbon Ferrochrome having 52-55% Cr. 1 MT each of Ferrochrome alloy and slag has been sent to M/s MECPL, Rairangpur to carry out the market survey for commercial use of produced FeCr alloy.

Reduced Chromite in Tunnel Kiln

Submerged electric are furnace

Ferrochrome alloy

Figure 8: Production of High Carbon Ferro Chrome in SAF

Electrolytic iron powder from mild steel scrap

Electrolytic iron can be considered as the purest form of iron and is derived from the electrolysis of iron solution. The purity of this type of iron makes it suitable for various purposes in manufacturing, chemicals, and food & pharmacy industry and certain types of steels. Iron powder plays an important role in automobile industry, it accounts for 80% by weight of all metal powders produced annually. It is used extensively in the manufacturing of various automobile sintering parts and electromagnetic materials, some industrial applications and cosmetic applications. Iron powder is also used as a carrier for toner in electrostatic copying machines and as a chemical raw material to recover metals from process effluents. Electrolytic iron powder is produced by electrolyzing from a dilute iron solution. Scrap iron is used as anode for continuous supply of iron during deposition of iron powder on cathode. Through sponsorship from M/s Sree Rayalseema Hi-Strength Hypo Limited (SRHHL), Kurnool, CSIR-NML has developed the process

for production of electrolytic iron powder from steel scrap. During development of the process, various parameters such as iron concentration, electrolyte composition, current density, pH, etc., were optimised at 10-20A as well as at 100-150A cell currents. Dendritic shape iron powders of different sizes were produced by varying both iron concentration and bath composition. Electrolytic iron powder of size ranging from 2-50 microns were produced with purity above 99.8% and current efficiency above 85%.

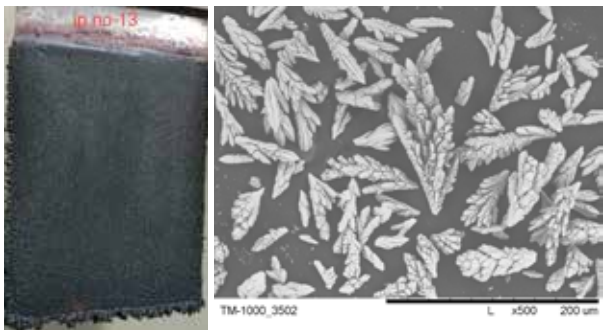

Fig.-9(a) Electrolytic iron powder produced from MS scrap (b) SEM image of Electrolytic iron powder

Secondary and Resource Utilization Group

The Secondary and Resource Utilization (SRU) group focuses on valorization of low grade resources as well as industrial wastes. The primary emphasis is on finding suitable ways of utilizing the industrial by-products and off-grade resources, to conserve the natural resources, and to minimize the environmental and ecological impacts. The activities of the group involve recovering the valuables from the by-products and/or their utilization, preparation of detailed project report for the developed processes and life cycle analysis (LCA). Current activities are centred around extraction of rare earth metals and critical metals from industrial wastes, immobilization of nuclear wastes in geopolymer matrix, light-weight fire resistant hybrid geopolymer materials, energy efficient process for siliceous ores, etc. The group has personnel having varied expertise and experience. The group has collaborated with academic research institutions from abroad, and has hosted/trained many students/research scholars from these institutions.

Rare Earth and Critical Elements Extraction from By-Products/Industrial Wastes

Alternative resources for rare earth elements (REE) are being explored, particularly in countries like India, which depend highly on REE import; this section details the endeavours in this direction from large volume industrial wastes, like, blast furnace slag and red mud. This would eventually reduce our dependence on others for these critical elements besides creating employment.

Blast furnace slag

The origin of the REE in the blast furnace slag may be the coal used for coke making or other raw materials such as iron ore/fluxes. The granulated blast furnace slag has a total REE content of 600 ppm. The REE extraction strategy involves dissolution using mineral acids, followed by subsequent solid-liquid or liquid-liquid separation. The process developed is at 1 kg scale. RE extraction (from ground granulated blast furnace slag) in acid is: 83% La, 76% Ce, 57% Er, and 79% Nd. The pregnant leach solution (PLS) is subjected to solvent extraction (SX), ion-exchange (IX), and precipitation. IX has yielded 90% pure mixed REOs having 32% Ce. Resorting to multi-stage solvent extraction of the PLS (to improve the separation and purity), two REE-based products, namely, pure La oxide and pure Ce (both having purity > 98%) are produced **(Figure 10)**. Suitability of the leach residue obtained after the RE recovery for building materials applications (strength up to 30MPa) ensures complete utilization of the slag.

The process is slated for a joint patent with the sponsor of this work, a multinational steel giant.

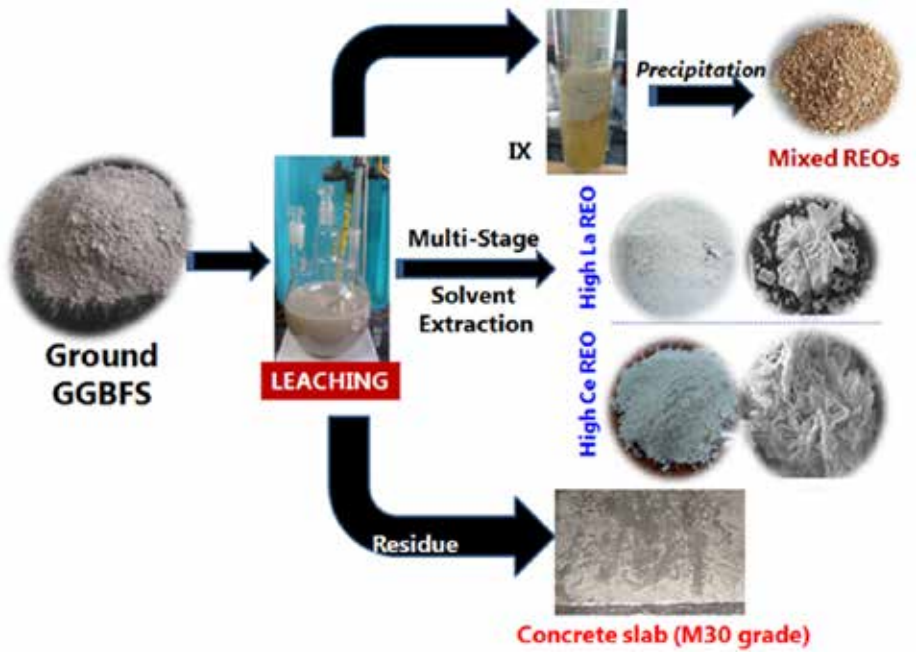

Figure 10: Formulated Flowsheet for Holistic Utilization of Blast Furnace Slag

Red mud

Another industrial waste of importance for REE recovery is red mud, which has been a concern of the alumina industry for over a century. Despite various attempts towards extraction of the various constituent elements (Fe, Ti, Al, Si), none of them finds a technological implementation (indicating technical / operational / economic inadequacies of the processes). Currently, a program with a comprehensive, zero-waste, product-centric focus, is being explored under the DST-SERB scheme. Besides REE recovery, the extraction of other metals like Fe, Ti, etc., is also envisaged from the red mud and phosphogypsum. Utilization of the final residue/slag in building materials application makes it a 'zero waste' strategy of red mud utilization **(Figure 11)**.

CSIR-NML is also coordinating a comprehensive program of red mud utilization under the aegis of the 'NITI Aayog Rare Earth Committee' wherein research institutions (CSIR-NML, CSIR-IMMT, and JNARDDC) and aluminium industries (HINDALCO, NALCO and VEDANTA) are actively participating.

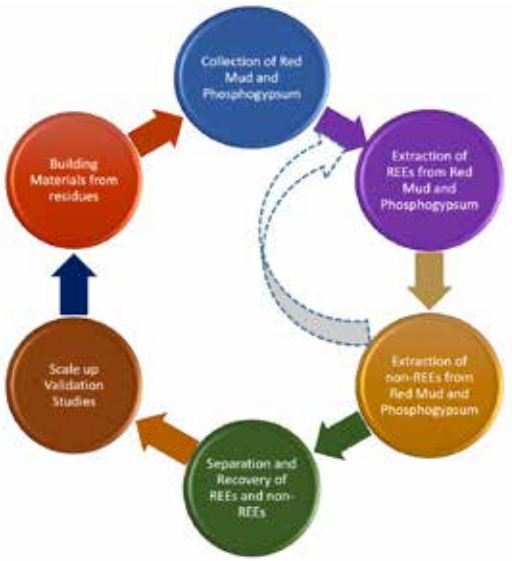

Figure 11: Formulated Flowsheet for Holistic Utilisation of Red Mud

Extraction of critical metals from used lithium-ion batteries

Tremendous growth in the use of lithium-ion batteries (LIB) is expected to generate a large number of spent LIBs. Disposing of the spent LIBs will cause serious environmental problems due to their hazardous components; besides, valuable resources like Co, Li, Ni, Mn in the spent LIBs are wasted. For a country like India where Co, Li resources are scarce, such wastages cannot be accepted. Recycling the valuables from the spent LIBs not only prevents environmental pollution, it additionally provides a means of utilizing secondary resource for these scarce elements. In view of the huge accumulation of spent LIBs, and to meet the lithium demand for indigenous battery manufacturing, CSIR under the "Bulk Chemical Mission" has initiated a program 'Extraction of Critical Metals from Used Lithium-ion Batteries'; CSIR-NML is the nodal laboratory for this activity, with CSIR-CSMCRI and CSIR-IMMT as participating laboratories. The project is based on the two prime objectives: Demonstration of 100 kg LIB dismantling; and Processing of electrode material to extract Li, Ni, Co, Mn, Al, Cu and Graphite at 1kg scale. Framework flowsheet for metal extraction from used LIBs is presented in **(Figure 12)**.

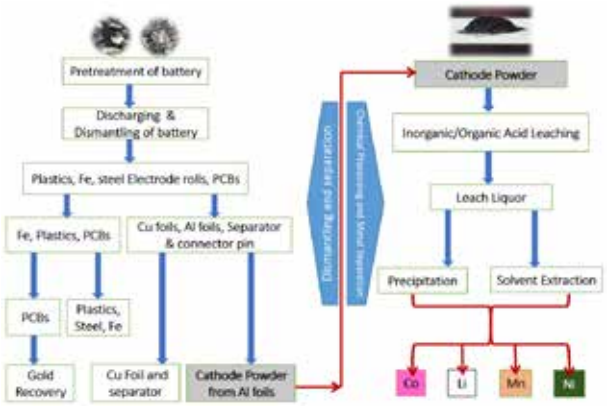

Figure 12: Framework Flowsheet for Critical Metal Extraction from Used LIBs

Geopolymer Applications in Newer Domains

Beyond the typical uses as a replacement of conventional binder (cement) in building/ construction applications, geopolymer is being explored for other applications as well. Currently, studies are being undertaken (1) to develop light weigh fire resistant geopolymers, and (2) develop a suitable geopolymer formulation for nuclear waste immobilization.

Hybrid geopolymers

Lightweight structural materials which can retain strength under fire exposure, and limit fire spread for tactical shelters and other structures as well as in aerospace and other transport sectors are being developed. The approach is to develop a process for novel hybrid geopolymers (HGP) having good compatibility between the organic and inorganic polymers with targeted characteristics. The hybrid geopolymers developed have enhanced mechanical properties. The compressive strength (28 day) of the HGP is 2.5 times higher than the corresponding inorganic geopolymer while the flexural strength increase is 46%. EDS spectra **(Figure 13)** for a hybrid geopolymer showing similar distribution profiles of C, Si and Al in the geopolymer gel, illustrates the simultaneous presence of the inorganic and organic phases, implying good compatibility between the inorganic and organic components and chemical reactions between them. Density and fire resistance studies of the products developed are being carried out.

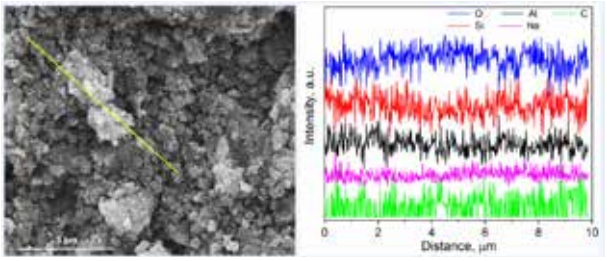

Figure 13: SEM-EDS of the Hybrid Geopolymer Depicting

Figure 14: Smelting of Copper Slag in Electric Arc Furnace

Individual Elemental Distribution Profiles Across the Line

Immobilization of nuclear wastes

Geopolymer is also being explored as a matrix for immobilization of toxic and harmful by-products. An ongoing work (externally sponsored) focuses on developing a geopolymer matrix for immobilization of nuclear wastes. Aluminosilicate materials from natural and industrial by-products have been explored. The work so far has achieved the targeted strength and porosity characteristics. Large scale (100 kg) optimization is being worked out. Nuclear waste immobilization will soon be carried out by the sponsor.

Better Utilization of Industrial By-Products

Hot stage engineering of copper slag

Bulk of the copper slag (40 million ton globally) generated, barring a small amount used in low-end applications (aggregates in road construction and concrete, mine backfilling, etc.) is generally dumped, occupying large space for long durations. As a result of such dumping, its high iron content (~35-60%) is wasted. Under the waste management program of DST, efforts to recover Fe, and to modify the slag for building material applications is in progress. The process involves carbothermic reduction smelting of the copper slag to remove Fe from the copper slag, and modifying the liquid slag composition using lime (CaO) to create slag suitable for application in blended cement. The chemical composition of extracted metal was 94-96% Fe, 3.5-5% C, and Si 0.5-2%, which can find application in general usage similar to cast iron. The resulting slag is tapped and subjected to water quenching to get a high reactive glassy material. This modified slag after grinding is mixed with clinker and tested for Portland slag cement composition. The physical properties of the blended cement prepared with the modified slag and clinker is found to meet the Indian standard IS 4031:1988.

Utilization of coke fines

Utilization of significant amount of coke fines generated is difficult because of their fine particle size. The problem is being addressed by transforming the coke fines into a suitable form for its handling and usage as a fuel/reductant in ferro-alloy plants; The methodology used is cold bonding of the coke fines for its transformation to a briquette of suitable size for its use as a fuel/reductant in ferroalloy industries**.** Various binders, both organic and inorganic, are being tested to yield briquettes of sufficient strength and yield.

Indian Metal Crafts

Bidri art

The exquisite “Bidri” work of Andhra Pradesh, where molten zinc and copper are folded into moulds and engraved to make grooves. These are then inlaid with silver and pearl before being oxidised to give it that distinctive black finish. The Bidri artisans procure soil for oxidisation from the vicinity of Bidar Fort in Karnataka, a sacred land for this artisan community. Hence, Bidri artisans believe that their art cannot be reproduced in any other part of the country.

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Mineral Processing

Mineral Processing (MNP) Division of CSIR-NML has been engaged in R & D in characterization, beneficiation and agglomeration of ores and mineral fines. The Division with its extensive Characterization, Beneficiation and Agglomeration facilities has been around since the inception of the laboratory in 1950. An integrated mineral beneficiation pilot plant was installed in 1962 to study the feasibility of commercial exploitation of the technologies, process flowsheets and products developed in the laboratory. The division is well equipped on modern lines to carry out planned research and development work on all types of ores and minerals for their rational utilization and conservation.

Working closely with industry partners, Mineral Processing Division has attempted innovative mineral processing methodologies leading to state-of-art technologies in the management of mineral resource base, and in enhancing productivity with sustainable environmental compliance. Expertise has been developed for new efficient processing options for beneficiation of ferrous, non-ferrous, strategic and industrial minerals and coals (coking and non-coking). It has created confidence in the industry towards developing technology for converting waste to resource thereby enhancing mining life while maintaining raw materials quality.

Based on the technical know-how provided by CSIR-NML, a number of commercial beneficiation and agglomeration plants have been commissioned in the public and private sectors. The know-how has also significantly contributed to the development of mineral based industries. In addition to catering to the needs of mineral processing industry in India, CSIR-NML has maintained a strong international presence in mineral processing and has successfully executed a number of projects on samples of foreign origin from countries of South-Asia, Middle-East, Africa and Europe. Presently, the Mineral Processing Division is focusing on Fine particle processing, Dry beneficiation, Mathematical modeling and simulation, Plant performance auditing and improvement, and Equipment development. The following are some important programmes and projects being executed.

Mission mode project on strategic mineral : Production of lithium salt from ores

Lithium is soft, silver white, and the lightest alkaline metal. Lithium compounds such as lithium carbonate, lithium hydroxide and lithium bromide find various applications in glass, ceramics, lubricant and grease manufacturing, to improve temperature resistance, in aluminium production, as a catalyst in pharmaceutical and rubber industry, in air-conditioning, in de-humidification system, lithium-ion-technology in electric automobiles and energy storage devices. Due to emerging applications, lithium and lithium based chemicals are now being considered as the strategic materials of the future. Globally, lithium resource is broadly of two categories : 1. Brines from Chile and Argentina and 2. Hard rock ores (pegmatites) from Australia, Canada, Zimbabwe, Portugal, and Brazil. Most of the lithium mineral concentrates are supplied to China where the concentrate is processed for production of lithium carbonate and hydroxide, which find application in Lithium ion battery. Lithium supply security has become a top priority for technology companies around the world due to the threat of China as the major global supplier with strategic control. India has limited deposits of Lithium, some under exploration. Our laboratory is working on the development of indigenous technology for production of Lithium from hardrock ores under a CSIR-Mission Mode Project on Bulk Chemicals. The objective of the research is to develop process flow-sheet for beneficiation and extraction of lithium salts from ore.

Three lots of lepidolite bearing rocks and one spodumene bearing rock were sourced for the research. The Li_2O-content in sourced lepidolite samples varies from 1.9% to 2.8% whereas that in spodumene sample is 3.1%. Mineralogical study reveals that albite, quartz and muscovite are the major gangue minerals in both lepidolite-bearing and spodumene-bearing rock/pegmatite (See Figures: 1-3) Preliminary beneficiation study reveals that Li_2O-content in lepidolite concentrate is 4% and spodumene concentrate is 5.1% and the work is in progress. Preliminary hydrometallurgical processing reveals that roasting of lepidolite-bearing rock followed by mineral acid leaching results in recovery of 99% Li in the leach liquor.

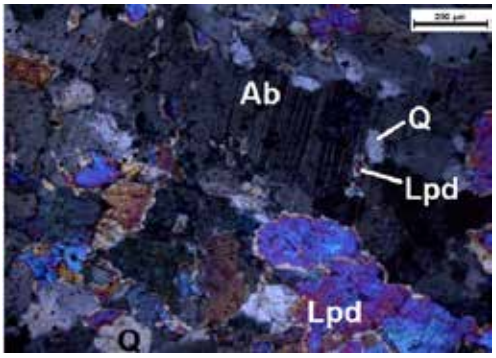

Figure 1: Photomicrograph of lepidolite-bearing rock. Ab= albite, Q= quartz, Lpd= lepidolite

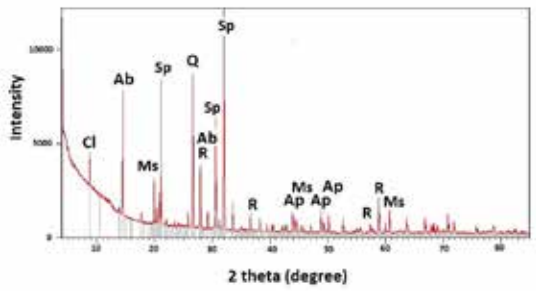

Figure 2: XRD of Lepidolite bearing rock. Ab= albite, Q= quartz, Lpd= lepidolite, Ms= muscovite, Bt= biotite

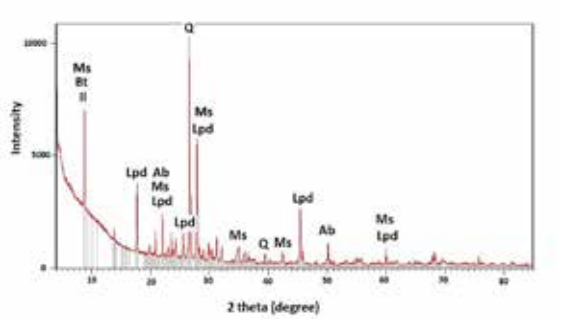

Figure 3: XRD of spodumene bearing pegmatite. Ab= albite, Q= quartz, Sp= lepidolite, Ms= muscovite, Cl= clay (kaolinite), Ap= apatite, R= rutile

Dry Beneficiation of Limestone Samples for Removal of Iron Bearing and other Magnetic Impurities

The objective of the present study is to beneficiate limestone samples through dry magnetic separation and Air table for reducing of iron from 1.5% to 0.08% Fe_2O_3 for rejected limestone and from 0.2% to 0.08% for regular limestone. The high-grade limestone resources for white cement clinker production are depleting day by day. With depletion of high cement grade limestone, presently, white cement industry is facing an acute shortage of cement making raw materials. To prepare clinker for white cement, it is pertinent to minimize the iron and other transition elements (titanium, chromium, manganese, nickel and zinc) in the raw mix composition. High-grade limestone containing less than 0.068% Fe_2O_3 and less than 0.015% MnO is generally used for such purpose. Limestone deposits in BWC mines is highly associated with lateritic coating. The iron in laterite adversely affects the white cement quality. The current project will explore the possibility of removal of iron and other transition elements from limestone of BWC to improve the clinker quality. Based on characterization and liberation studies, it is proposed to beneficiate limestone through dry magnetic separation and Air table for the separation of contaminants from limestone. In addition, it is also proposed to develop beneficiation process for reduction of impurities present in rejected limestone sample at the mining site for its ultimate utilization.

Continuous Pilot Scale Reverse Flotation of Iron Ore

The objective of the present study is to validate the results of continuous operation of pilot scale flotation studies that were done earlier by treating 15 tonnes of iron ore through reverse flotation. Extensive iron and steel production has resulted in depletion of high grade iron ores. As a result, the thrust is on beneficiation of low grade ores. Moreover, decrease in threshold value of tailings/reject Fe (< 45%) as per statutory norms demands beneficiation of inferior grade iron ore. These ores comprise hematite, goethite (iron minerals) along with kaolinite and quartz (gangue minerals). Reverse flotation method is used for beneficiation of iron ores wherein silica gangue is selectively floated from iron ore using reagents. The sponsor had carried out studies on different reagent scheme to improve the selectivity of the flotation process. With the encouraging results of batch scale studies (20-25 kg) in an earlier project carried out at CSIR-NML, continuous pilot scale flotation of 15 tonnes of iron ore will be experimented for the validation of the bench scale results.

Pilot Scale Study on Hydrocyclone

Weir EnSci is a global leader in developing new hydrocyclone systems. They have developed a new Cavex Hydrocyclone with a double effect overflow (DEO) system for a high capacity performance with an efficient classification performance. M/s Weir Mineral EnSci, Bangalore approached CSIR-NML for conducting the pilot scale testing with their newly developed Cavex 100 cyclone. With mutual consultation pilot scale testing was conducted by using iron ore slime at different operating conditions. The products were analyzed for particle size distribution in Malvern Laser Particle Size Analyzer. The mass balancing as well as size wise data recovery was obtained for all experiments to predict the performance of this newly designed hydrocyclone. A much finer cut size can be achieved with this DEO system compared to conventional hydrocyclone. With the help of this DEO system, final loss to overflow can be minimized.

Advanced Gravity Concentration of Chromite Beneficiation Plant Tailing

Around 50-55% of chrome ore is discarded as a tailing during the beneficiation of low-grade chromite ore. The chromite ore beneficiation plant

of the sponsor is generating around 1200 tpd tailing apart from the accumulated tailing of 5 million tones with Cr_2O_3 content of 12-18%. This causes loss of chromite value in addition to its adverse impact on the environment. As per IBM's guideline, the assay of chromite tailing should be below 10% Cr_2O_3. The storage, handling, and processing of fine tailing are the major concern of the operating process plants. There has been a need to develop a suitable process for pre-concentration/concentration of tailing for use in the production of ferrochrome or for further value addition through the synthesis of an inorganic compound. In this connection NML has undertaken bench scale beneficiation studies to recover chromite values from plant tailing sample to produce preferably 40 % Cr_2O_3 using water only cyclone and Falcon concentrator.

Detailed characterization of the tailing sample was carried out which revealed the presence of chromite, goethite, hematite, and clay silicates in the sample. Goethite is the major constituent of the tailing sample. Chromite is interlocked in silicate minerals or the goethite hematite matrix. The separation performance of Falcon concentrator and Water-only cyclone for recovery of chromite value from plant tailing was investigated. The experimental scheme was designed and the process parameters were optimized by the design of experiment software. It was observed that around 32% of chromite value is recovered from plant tailing by Falcon concentrator with a chromite content of 40% in a single-stage operation. Results also indicated that it is difficult to enhance the chromite content of the product to 40% using water-only cyclone. It can enhance the chromite content to a maximum of 25.3% with 25.8% of mass yield in a single-stage operation with the present granulometry. The performance of the Falcon concentrator was also compared with conventional gravity concentrator, such as the Wilfley Shaking table. Experimental investigation revealed that the separation performance of the Shaking table is better than the Falcon concentrator with the present granulometry of the sample. However, the throughput rate of the Falcon concentrator is much higher than the Wilfley Shaking table.

Processing of Low Grade Dolomite Ore

The dolomite ores are used as flux material in Iron and steel making applications. Higher alkali content in the ore increases the basicity of the slag. A collaborative project has been undertaken for characterization and beneficiation studies of three different types of dolomite samples from Gomardih mines near Rourkela, Odisha, for reduction of alkali and silica content for iron and steel making applications. The acceptable grade of dolomite can have maximum 0.3% K_2O for Iron making and less than 1% K_2O for Steel making. The ratio of silica and alumina should be >1.5%. Chemistries of the samples were found to be different. The objective was to develop a process for reduction of K_2O to < 0.2% and, SiO_2 to 0.5% for ROM sample containing 5% silica, and to 3% silica for low grade samples containing around 12% silica.

Mineralogical characterization of the samples was carried out by optical microscope and XRD studies to identify the mineral phases in the as-received samples, their textural relationship, optical characteristics, mode of occurrence and distribution. The valuable mineral in all the samples is dolomite with gangue minerals like calcite ($CaCO_3$), plagioclase feldspar (Na, Ca (Al, Si)$_3O_8$), muscovite ($KAl_2(AlSi_3O_{10})(OH)_2$), biotite ($K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$), orthoclase feldspar ($KAlSi_3O_8$) and quartz ($SiO_2$) in different proportions **(See Figures: 4 & 5)**. Due to the interlocking of the gangue minerals within the carbonate matrix, beneficiation studies were carried out with the fine feed material for all the three dolomite samples. As the density of the dolomite and gangue minerals are very close to each other, and as the minerals lack magnetic

susceptibility, gravity and magnetic separation could not be performed. Therefore, froth flotation is the only method for reduction of SiO_2 and K_2O content. It was found that suitable dosage of sodium silicate used as depressant and collector dosage together was effective for reducing the K_2O and silica content to the desired level.

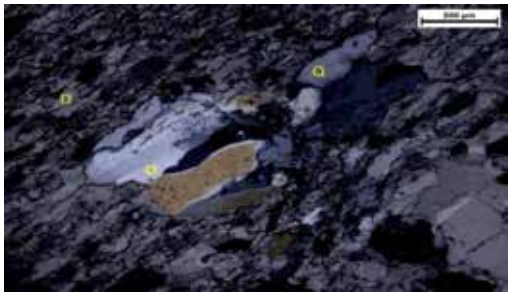

Figure 4 : Photomicrographs representing the association of orthoclase feldspar (O), and quartz (Q) in the carbonate matrix.

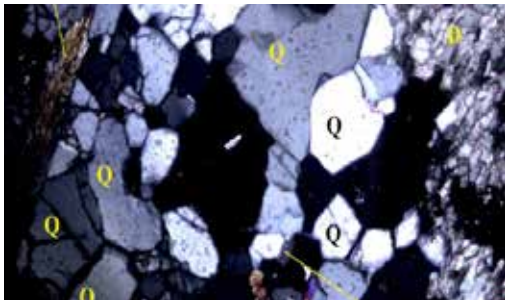

Figure 5: Photomicrographs representing the interlocked grains of quartz (Q) and muscovite (Ms) within dolomite (D).

Studies on beneficiation of Bauxite Sample for Reduction of Reactive Silica

The third most abundant element available in earth's crust is Aluminium and it is extracted from bauxite ore. It is also an essential ore for refractory and chemical industries. Over the years good grade bauxites are depleting fast and the available bauxite contains significant amount of reactive silica along with a fair amount of aluminium. In the present investigation, studies were undertaken on processing of bauxite samples sourced from Chhatisgarh region for possible reduction of reactive silica to ~4% from a feed containing high reactive silica ranging from ~6-11.5%. Characterisation of the bauxite ore revealed that the sample exhibits various types of textures, like, oolitic, colloform and replacement. The sample contains abundant gibbsite and boehmite, followed by clay, altered/ translucent silicate and opaque minerals (Fe-oxides /hydroxides) and anatase (See Figure 6). The beneficiation study included scrubbing and washing, gravity separation, magnetic separation and froth flotation studies. Scrubbing and washing studies demonstrated that there is significant reduction in reactive silica content (~2%) with increase in total available alumina content in the washed product. The project is in progress.

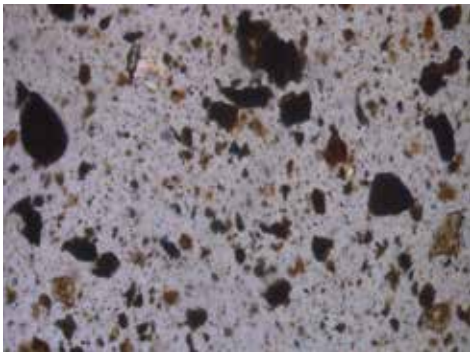

Figure 6: Photomicrograph showing distribution of gibbsite (Gibb.), clay and opaque (opaq.). Gibbsite grains are coated with ferruginous material.

Beneficiation Studies on Low Grade Manganese Ore Samples

Manganese ore finds application mainly in Ferro-alloys like ferromanganese/silico-manganese, Iron & steel and dry battery electrode making apart from its use as chemicals. Pyrolusite, MnO_2, Psilomelane, Manganite, $Mn_2O_3.H_2O$ and Braunite, $3Mn_2O_3$, $MnSiO_8$ are important types of manganese ores available on the basis of manganese content. Manganese ores can be broadly classified into two types; Siliceous and ferruginous. India has manganese ore deposit of 495.87 million tonnes and

produce ~3000 thousand tonnes annually. Indian deposits are in Madhya Pradesh, Maharashtra, Gujarat, Odisha and Andhra Pradesh.

Earlier, selective mining practice in India, which utilised good grade manganese ores of +10mm in ferromanganese application, caused rejection of 25–30% of mined ore as fines (i.e. less than 10mm size fraction). This fines fraction is presently stacked as dumps at the mine site because of low Mn content and incompatible size range for metallurgical operation. The fines cannot be discarded as they have Mn (>10%). In the present investigation, it was aimed to design beneficiation process flowsheet for upgradation of the low grade manganese ores for use in ferromanganese/silico-manganese with the reject containing < 10% Mn. For this purpose, three different low grade manganese samples were sourced and characterised. The samples were ferruginous in nature. Mineralogical studies showed that the manganese ore samples had predominantly pyrolusite, goethite/limonite and manganomelane with minor amounts of cryptomelane, clay, lithiophorite and hematite. Todorokite, manganite, quartz, mica (muscovite, biotite), feldspar (orthoclase), and gibbsite are noticed in very minor to trace amounts **(See Figure 7)**. Different beneficiation schemes were studied on these samples and their responses were observed. It is possible to produce desirable concentrate for ferromanganese/silico chrome application maintaining 10% Mn in reject using combination of physical beneficiation followed by low intensity magnetic separation on pretreated sample.

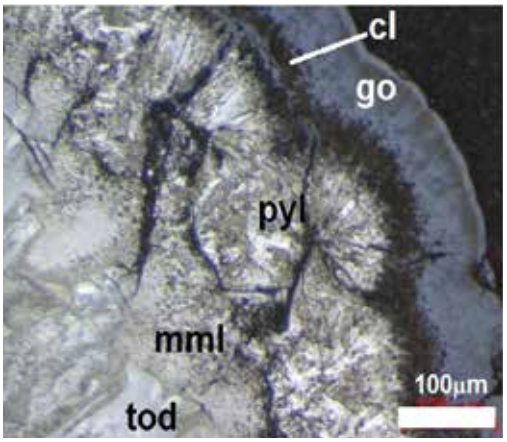

Figure 7 : Photomicrograph showing 80-100 µm ore grain with manganomelane/psilomelane with todorokite is surrounded by a layer of prismatic crystalline pyrolusite and is sheathed by 80-100 µm thick goethite.

CSIR-NML-Madras Centre

Consultancy on design, erection, commissioning of flotation column, at Belatinda Coal Preparation Plant

The supply and installation of 2.0m diameter, 200 tpd capacity flotation column, at Belatinda Coal Preparation Plant, is being executed in collaboration with M/s McNally Saya ji Engineering Ltd. (MSEL), Bengaluru. The objective is to reduce the ash content in fine coal (-0.5mm) to ≤15% with maximum possible weight recovery of froth/concentrate, preferably > 50%.

Under the scope of MoU between CSIR-NML and the M/s MSEL, this project pertains to providing consultancy services for the supply and installation of commercial flotation column and necessary accessory equipment. The consultancy involves providing details for column design, formulation and drawing of accessory equipments specifications. It would be followed by assistance in erection, commissioning of flotation column, process stabilization using flotation column and guidance in preparation of operation manual. The installation is almost nearing completion and would be commissioned shortly.

Figure 1: 2.Om diameter, 200 tpd capacity flotation column installation at Belatinda Coal Preparation Plant

Development of graphene-based membranes from graphite ore for desalination

Beneficiation studies on a low-grade graphite ore from a sponsor was studied, using flotation employing a newly developed plant extract-based flotation reagent. Petrography studies indicated that the as-received ore consists primarily of quartz and graphite with minor quantity of mica (biotite) with 87.71% ash, 9.07% fixed carbon, 2.25% volatile matter and 0.97% total moisture. The reagent extraction and flotation process optimization using this eco-friendly flotation reagent resulted in a final concentrate of 5.39% ash and 91.30% fixed carbon on a coarse grind of d_{80}: 937µm with 6-stages of cleaning in the laboratory D12 Denver at 6.05% weight recovery. This concentrate was further treated to reduce the ash content by removing the ash bearing mineral phases by chemical process to improve its purity, so as to be used as a precursor for graphene synthesis.

Figure 2:
Eco-friendly flotation reagent

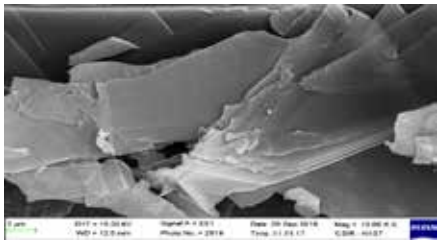

Figure 3: SEM image of graphite concentrate flakes by flotation

Failure Investigation of Waste Heat Recovery Boiler Tubes of a Zinc plant

Various metallurgical characterization techniques were used to establish the failure including Scanning Electron Microscopy with Energy dispersive spectroscopy and X-Ray Diffraction studies. Based on the results obtained in the present investigation, it was concluded that the tubes failed mainly due to the **dew point corrosion** on the fireside surface of the tube due to SO_2, SO_3 and H_2O in the flue gas. Accumulation of deposits on the tubes surface by the incoming gas constituents resulted in the simultaneous operation of corrosion, wall thinning, and localized heating and led to the failure of the tube. The pearlitic disintegration or ferrite formation in the microstructure, formation of creep voids in the microstructure, loss of hardness near failure region supports the exposure of tube surface to localised heating.

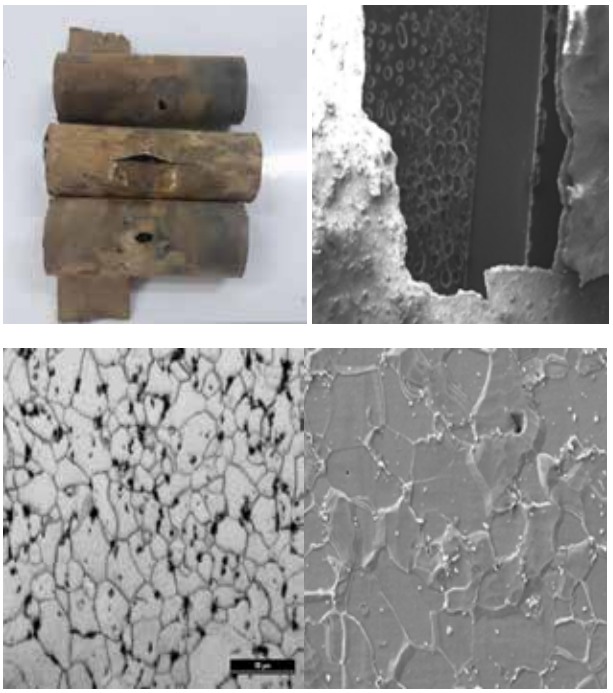

Figure 4: Different facets of a failure investigation

Staff of CSIR-NML, Chennai Centre

Indian Metal Crafts

Pembharti of Warangal district in Telangana is popular for its sheet metal art. Used extensively during the Kakatiyas Empire, this form of art was used in chariots and in temples.

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https://blog.aboutamazon.in/supporting-small-business/earth-to-chisel-magnificent-metal-crafts-of-india

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Impressions

With warm regards, I would like to convey my feelings of gratitude to CSIR-NML. Sir, I had previously worked as a Graduate Apprentice Trainee (EWBG011170600859) in the Engineering Division. It is with immense pleasure that I would like to share that I am presently working as a Trainee JEE in Indian Railways. I am posted as a Technical Assistant to CTA(G) in the office of Sr. Divisional Electrical Engineer (G) , Kharagpur Division. I firmly believe that my previous experience in CSIR-NML has paved the way to secure this position. I started my career as a novice engineering graduate in the Engineering Division. I had no prior experience and lacked skills and confidence to deal with real life engineering problems. Under the guidance Head Engineering, Mr. P.K. Dhawan and further enhanced by my guide Mr. Udaya Bhaskara Rao, I gradually learnt to apply theoretical knowledge into practical work. I will be grateful *to Uday Sir for his daily inputs and his continuous support. I am also thankful to all the staff of the Engineering Division particularly to EEU. Sir, I would be grateful to you for providing me with a learning experience through the Graduate Apprenticeship Training Program and I shall be forever grateful.*

An appreciation from one of our trainees

Debdyuti Roy Chakraborty

19 January 2021

Research Planning and Business Division (RPBD)

RPBD functions in different verticals viz. *Business Development & Client Interfacing, Research Management, Information Systems & Database Management, Negotiations & Contracts, IP Services and Technology Marketing.* The Division interacts with various internal and external stakeholders to perform its functions. The division has competent manpower to cater to the variety of needs of the stakeholders' **(see Figure 1)**.

Figure 1: Verticals of RPBD Functions

Research Management

RPBD has a role to play in all stages of R&D project execution viz. Initiation, Execution, Completion and Post Completion **(See Figure 2)**.

Figure 2: Role of RPBD in Project Life Cycle

In the reporting year, the Division was able to bring 20 new customers for the Lab., drafted 40 agreements (including 1 international, executed two Bonds and obtained one security and sensitivity clearance for the international party. In the reporting year, more than 75 new projects were evaluated for their compliance to the CSIR guidelines. These included 13 Collaborative, 03 Consultancy, 04 Grant-in-Aid/ Major Lab. projects and 55 Sponsored projects. The division also sent 728 invoices to customers for payments. The division has systemized the collection and distribution of project reports to the customers. 18 Customer Satisfaction Evaluation Feedbacks were received by the Division.

Business Development & Client Interfacing

The Division primarily acts as an interface between the laboratory and the collaborators from Industry, Academia and Government. The Division is the first point of contact for the new clients that are seeking solutions for their R&D problems. Further, the Division serves as a gateway to reach the concerned technical area expert and helps the client to find appropriate solutions. The Division then suggests the feasible mode of collaboration and facilitates in completing all required formalities **(see Figure 3)**.

Figure 3: RPBD as a Business Interface for the Lab.

Negotiations & Contracts

The Division shoulders the responsibility of negotiating with the prospective customer on the terms of collaboration. While doing so, the Division ensures that the nature of customer business is categorically taken care of. A number of iterations and meetings are generally required in the process. In the reporting year, around 40 MoUs were drafted and 13 MoUs were executed by the division **(see Figure 4 & 5**).

Figure 4: CSIR-NML signed an MoU for Technology Transfer on e-Waste Recycling with M/s. Metaore Recycling on 06th March 2021

Figure 5: CSIR-NML signed and MoU for Technology Development for Holistic Utilization of Red Mud for Extraction of Metallic Values & Resource Utilization with Vedata, Hindalco, IMMT, NALCO and JNARDDC

E-Tendering

The division brings new projects by participating in the Tendering process of various parties. In the reporting year 21 tenders were filled by the Division, out of which, 12 projects were awarded to the Lab.

Procurement of Intangible Products

As per the new CSIR Purchase procedure 2019 a guideline has been given for procurement of intangible products by the Planning Division of the respective CSIR Laboratory. Accordingly; an SOP has been evolved and came into force with effect from 15th January, 2020. Subsequently a number of such work order have been placed.

New Clients Added in 2020-21

- *IRC Engineering Services Pvt. Ltd*.
- *SLK Metaliks*
- *Sree Rayalaseema Hi Strength*
- *Weir Minerals india Pvt. Ltd.*
- *Maharashtra State Powers*
- *Geological Survey of India*
- *Beas valley Power Corporation*
- *Reliance Industries*
- *Sai Surface Coating Technologies*
- *Indian Navy Vskp, INS Eksila, Visakhapatnamunq Ind Pvt. Ltd., Firozabad*
- *Maharashtra State Power Generation Company Ltd.*
- *Geological Survey of India*
- *Mahanadi Coalfields Ltd.*
- *Beas Valley Power Corporation Ltd.*
- *CMPDIL, Ranchi*
- *Director of MSME*

- *Mageba Bridge Products Pvt. Ltd. Kolkata*
- *Mangalore Refinery and Petrochemicals Ltd.*
- *Metaore Recycler Private Ltd.*

Information Systems & Databases

A number of web based information systems and related databases are continued to be developed and maintained in-house at CSIR-NML for the digital inclusion and efficient overall functioning of the laboratory. These information systems and databases provide input for managerial decision making by enabling a number of e-initiatives like—***Research Planning, Manpower Planning, Optimum Manpower Utilisation, Enabling Online Recruitment, Online In-house Projects Management.;*** as well as support numerous key activities of the laboratory, e.g., *Project Information Management and Monitoring, Documents and Reports Management, Employee Profile Management, Human Resource Management (Competence and Man days Involvement.,* A number of databases are maintained in the division for smooth functioning and decision making of the management like—***Industry Database, Project, Invoice, Cash flow, Man-Days Involvement of Scientists, Project Completion Reports, Agreements, Equipment Utilization, Intellectual Property (Patents, Copyrights), Industry Databases and others (see Figure 6).***

Figure 6: E-Information Management in key functional areas of laboratory

Development of web-based industry directory of metals, materials, mineral's sector to facilitate the researchers with industry contacts and other relevant information like R&D Budget

The directory is a comprehensive listing of Indian industries **(see Figure 7)**. The listing is categorized into various sectors like - Iron & Steel, Metals & Mining, Oil & Petroleum. The list is indexed in alphabetical order. The list and the website have been developed as an endeavor to build a readily available repository of varied Information including Current & Future S&T needs of the Indian Industry. The information can also be utilized to upkeep the basket of R&D solutions to offer and inherit R&D planning.

Figure 7: Industry-Directory Website

Development of website for CSIR-NML Intellectual Property facilitation Center (IPFC) to connect the existing and probable MSMEs seeking services related to IP.

The IP facilitation Centre at CSIR-NML is one step towards providing support for the development of MSMEs. The issues pertaining to Intellectual Property Rights (IPRs) have become quite critical for the sustainability of MSMEs. In order to compete

with global standards and technological challenges, MSMEs are now focusing on management of their IP assets to achieve competitive advantage and technological gains. The website is an endeavor for reaching out to the MSMEs that have a new idea(s) or need a solution to their IP related issues.

Figure 8: IPFC Website

ERP-R&D Module Management

RPBD takes care of the R&D module of the CSIR-ERP and activities like *New Tender management, and R&D Project Approval and Data management are handled by RPBD* **(see Figure 9)**.

Figure 9: ERP-Activities

Interaction with Internal & External Stakeholders

RPBD regularly interacts and updates the stakeholders of the laboratory for seamless integration between the laboratory functions and expectations of stakeholders. The division has developed, updates and maintains a number of databases that enables the division to have quick access on a variety of data about various entities viz. *Projects, Manpower, External Cash flow, Intellectual Property, Agreements and others*. Hence, the division is well equipped to facilitate data-intensive reporting to the stakeholders.

Reporting to CSIR-Headquarters and State and Central Government Bodies

As a part of Make in India, survey of CSIR scientific equipment has been launched by the Department of Science & Technology (DST). RPBD surveyed more than 250 primary scientific equipment of NML and ensured participation of NML in this event of national importance. Recently, Technology Information Forecasting and Assessment Council (TIFAC) has initiated profiling technologies that have high readiness level i.e. TRL 8 and above at the national level. RPBD prepared the profiles of such technologies at NML and ascertained the entry of important NML technologies in the national listing. Throughout the year, RPBD keeps preparing and sending a variety of reports that are regular as well as periodic in nature, to the internal and external entities. To name the major ones: A) **Internal Reports (HOD/ Director) for Decision Making and Planning:** *Data for HR-Collegia for Performance Appraisal of Staff, Outstanding Payments, Project Database Reports e.g. Projects Ongoing, Completion, Cash flow, Top Clients Served, Research and Development carried by CSIR-NML for Specific Clients, MoU/ Awards, Database reports for Research Council Meeting, Database reports HOD Meets, Data for Director's meet and others*. **B) External Reports (Headquarters/ PMO/ Parliament/DST) :** *Key Performance Indicator (KPI) Document, PMO Portal Data, Research Utilization Data, Monthly Reports, Quarterly Reports, Annual Plan Document, Audit Reply, Inputs to CSIR-Annual Report, Award Documents, Monthly Progress*

Reports, Research Utilization Data, Replies to PMO & Parliament Queries.

Institutional Publications

RPBD publishes monthly newsletters about the significant activities of the laboratory viz. S&T services, Significant Project Outcomes, Technologies Developed, Awards Received, Visits Abroad, Conferences Organized, Significant Events and MoUs Prepared. The newsletters are generated and maintained through the e-documentation platform "e-reports" developed in-house by RPBD. Further, the information contained in the monthly report act as major input to the NML Annual Report **(see Figure 9)**. The publication of Annual Report is also coordinated by the division jointly with Knowledge Resource & Information Technology Division of the laboratory.

Figure 9: Glimpses of Newsletter and Annual Report

Coordination of Meetings

RPBD has another major role in coordinating Research Council (RC) Meetings. The RC are the guiding body of the laboratory and the distinguished members from various reputed institutions provide their valuable advice for the current and future growth of the laboratory. The Management council Meetings is also coordinated by the Division jointly with the Administration Division. These meetings are conducted for approval of internal matters of the laboratory as per CSIR guidelines.

IP Services

Business Development group provides IP search and analysis services to its clients as well as in various projects undertaken by the Laboratory. **(see Figure 10 & 11)**. During 2020-21 the Business Development group provided (i) IP search and Analysis, (ii) Evaluation of FTO Space, (iii) Patent Landscaping, (iv) Patent portfolio Analysis, (v) Patent Mapping, (vi) Patent Citation Analysis, (vi) White Space Mapping and (vii) Competitive Intelligence services in various technological domains in the area of Minerals, Materials and Metals.

Figure 10: RPBD Division Patinformatics Services

Figure 11: White Space Mapping Methodology

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

Technology Marketing

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

E-Showcasing of Technologies

RPBD division manages technology e-portfolios for the laboratory as well as for CSIR. The division has designed and developed a website for the e-profiling & e-archival of the technologies **(see Figure 12)**. Moreover, the division maintains an e-repository of centralized technology database of CSIR, wherein so far around 70 technology profiles have been populated.

Figure 12 : E-Profiling Technologies

Scientific & Technical Services

RPBD provides S&T Service to its customers (Internal / External) through testing of their raw material /product, within the facilities & expertise domain of the laboratory. A number of testing solutions are provided to various organizations every year. Last year the testing services were provided to the following customers : Desmet Reagent, Jamshedpur; Oswal Engineering & Co., Jamshedpur; Kalyani Steel, Karnataka; Indian Steel & Wire Products, Jamshedpur; Tata Steel, Jamshedpur; Tata Pigment, Jamshedpur; Tinplate Company of India, Jamshedpur; Central Coalfield, Ramgarh; Jamil, Jamshedpur; Nuvoco Vistas Corp, Jamshedpur; Easel Mining & Industries, Gujarat; Inspectorate Griffith India, Kolkata; Uranium Corporation of India, Jadugura; Star Wire (India), Haryana; Customs, Haldia; Steel Authority of India (SAIL), Bhilai; and Customs, Chennai;

Intellectual Property Facilitation Centre (IPFC)

The NML-IP centre was inaugurated virtually on the 12th of October 2020. IP experts from different spheres were part of this event. The curtain raising event was graced by the IP industry luminaries like Mr. K Gupta, IEDS, Director, MSME-DI, and Mr. Munish Sudan, Head-IP, Tata Steel Ltd., Jamshedpur, The event garnered huge attention amongst MSMEs especially in and around Jamshedpur. On the inauguration day, the centre unveiled its first ever website to facilitate MSMEs digitally. The following link takes us to the website *CSIR-NML_Intellectual Properties Facilitation Center (nmlindia.org)*. NML-IP centre is in the process of empanelling an IP firm for availing legal & IP advisory services out of the IP firms based in Kolkata IP jurisdiction. The center has a dedicated marketing team to promote the IP awareness and activities to reach the masses. Already, the center has organized a webinar as an inaugural program on the 12th of October 2020 with huge number of participants, voluntarily involved **(see Figure 12)**. I.P.F.C. collaborated with RGNIIPM-Nagpur, a reputed national IP training institute, to come up with IP training, seminars, and workshops in a big way which will bring the awareness amongst the aspiring entrepreneurs and stake holders.

Figure 12: Glimpses of IPFC Promotional Activities and Webinars Organized

The center has already started providing IP related services like patentability, patinformatics, patent landscaping analysis, copyrights registration services, trademark & design registrations, and other techno legal advisory services. So far the centre helped to file 09 trademarks, 05 patents, 01 Copyright, 05 prior art reports were generated to establish patentability of inventions, and 01 more patent registration is in the process. The details of IP services provided by the IPFC to MSMEs are discussed hereinafter **(see Figure 13 & 14)**.

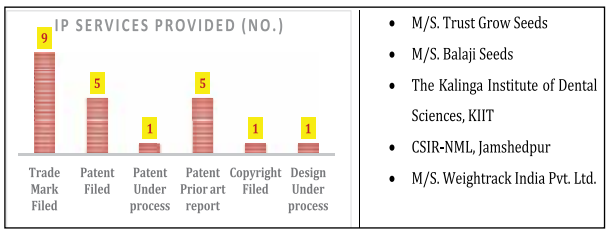


Figure 13: Various IP Services Provided (Count and Parties)

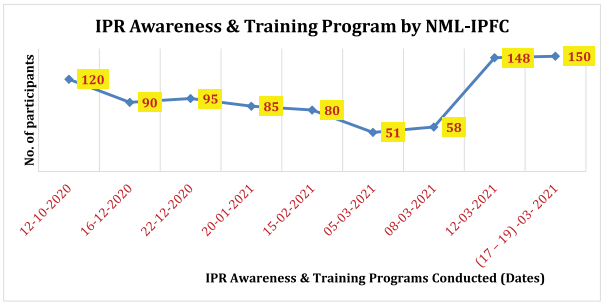


Figure 14: Details of Trainings Organized

More webinars with defined agendas to address the MSMEs IP related issues will be organized. Apart from this, the centre tentatively is planning for a week long training program on Intellectual Property to train MSMEs people in the matters of IP. To enhance the IP business portfolio, the centre has done a survey to garner Indian MSMEs data and created repository of MSME industry database. This database helps us to interact with the local MSMEs to serve them betters. A few copyrights and patents filings are under process and a few more trademark application filings are in line.

Team-RPBD

Indian Metal Crafts

Enameling : a glass substance is fused with metal at high temperatures.

Jaipur is the center for lacquering and brass engravings in Rajasthan. Beautiful designs are embossed on the glossy surface of the pots, plates, boxes etc. It is also well-known for bronze sculptures and Koftagiri, which is the art of encrusting one metal with another.

Moradabad in Uttar Pradesh is famous for a range of household items made from brass. The items are also widely decorated with intrinsic designs. Similarly, Varanasi is where cast sculptures of deities, as well as household utensils are made using copper and brass.

Sources:

https://blog.aboutamazon.in/supporting-small-business/earth-to-chisel-magnificent-metal-crafts-of-india

https://www.ancient.eu/image/11429/mehrauli-iron-pillar/

https://www.indianmirror.com/culture/indian-specialties/Bonecarving.html

https://www.thebetterindia.com/86046/training-new-generation-keep-art-bone-carving-alive/

Engineering

The Engineering Division caters and co-ordinates the engineering needs of the laboratory in both R&D and infrastructural aspects, Majority of the needs are non-repetitive in nature, though some are routine. The division has two groups called Works Services and Maintenance (WSM) group and Project Planning and Engineering (PPE) Group. WSM group includes Civil Engineering Unit, Electrical Engineering Unit and Air-Conditioning Unit, while PPE group consists of the central workshop and new projects unit.

Project Planning and Design Group:

The responsibilities and activities of this group in various areas in the reporting year are provided:

Prototype/ Product design and development: The major prototype design and development activities undertaken were:

i. Non-contact magneto-impedance sensing device for evaluation of high-temperature magnetic phase transition;

ii. Foot operated sanitiser dispenser -installed at office and residential colonies;

iii. Pulsated air stratifier prototype for PIV studies;

iv. Tool post for buffing amorphous melt spinning wheel;

v. Setup for preheating of clay mould and resin recovery for melting furnace;

vi. Development of touchless water dispenser - installed at ten places of main office.

Research and consultancy : The division scientists were involved in four sponsored projects, two of which were completed. Additionally, the division is leading four in-house projects. A state-of-the-art welding laboratory is also being developed.

Setting up and operation of critical infrastructure: The following critical infrastructure were operationalized:

i. Facility maintenance for 24×7 controlled atmosphere testing conditions for the Creep Laboratory.

ii. Setting up of infrastructural requirements for upcoming amorphous electrical steel pilot plant.

iii. Operation of 493KWP solar power plant for catering to the electrical load requirement of the Laboratory, due to which huge saving the per month in the running expenditure has been observed.

Finite Element and CFD Modeling: The division is actively leading modeling activities in Amorphous Electrical Steel project. Expertise was enhanced in Particle Image Velocimetry (PIV) technique, which can be used for studying insights of fluid flow systems and for validation purposes. Following are the major contributions:

1. Study of fluidized angles and boundary wall effects on density stratification in pulsated air stratifier using Particle Image Velocimetry (PIV)

2. Optimization of FBG sensors requirement for locating the critical zone of blow pipe by numerical simulation and ANN.

Basic Engineering Packages: The group has been involved in preparation of Detailed Project Report(DPR) for Jafarnagar Silver Cluster, Nadia, West Bengal.

Pilot plant operation and maintenance:

1. Construction of energy efficient brass melting furnaces in various clusters of Bengal, Jharkhand and Odisha, and demonstration to artisans to construct themselves.
2. Support in carrying out campaigns in annealing simulator facility.
3. Support in conducting campaign in Magnesium refining pilot plant facility: Electrical & Instrumentation systems, Signal flow SCADA systems for the Magnesium pilot plant facility has been designed and brought into operations.
4. Support in revival of critical R&D equipment.

Maintenance and up-keeping of equipment : The division is actively involved in providing in-house maintenance support to high value equipment of the laboratory. This saves on AMC and reduces breakdown. Some important equipment in this regard are: Amorphous melt spinning wheel setup, Rolling Mill, AKA flow system, Water circulation system of Servo Hydraulic Units, etc.

Skill Development : Hands on training were provided to about 40 apprentices. In addition, skill development training in the areas of welding, was also provided.

Central workshop

Central Workshop receives jobs from various divisions, for specimen preparation of different materials, fitting, machining & fabrication of prototypes and repairing of miscellaneous jobs. All these jobs were completed in time to the satisfaction of the indenters. Major facilities available in the workshop are: CNC Lathe, Universal Milling, Shaper, Radial drill, Pillar Drill, Double column band saw, Shearing, Pipe bending m/c, TIG/ MIG welding, EDM wire cut machine.

Works Services and Maintenance Group:

This group has diverse responsibility to upkeep infrastructure, create new infrastructure and renovation of facilities in 7 campuses (Main laboratory, 2 pilot plants, 4 residential campuses) of CSIR-NML. These services include civil engineering, electrical engineering, refrigeration and air conditioning, maintenance of lifts, water supply, etc. The work accomplished by the group can be categorized in 3 major categories: New infrastructure, renovation, and routine maintenance .

New Infrastructure:

Roof-top Solar Panel for supply to the grid was installed

Renovation Jobs:

Renovation of Cubicles and Chemical Lab was completed.

New works centre of ICP-MS

Team Engineering

Indian Metal Crafts

Artisans in Goa make beautiful divlis (diyas or long, brass lamps)

Sources:

https://blog.aboutamazon.in/supporting-small-business/earth-to-chisel-magnificent-metal-crafts-of-india

https://www.ancient.eu/image/11429/mehrauli-iron-pillar/

https://www.indianmirror.com/culture/indian-specialties/Bonecarving.html

https://www.thebetterindia.com/86046/training-new-generation-keep-art-bone-carving-alive/

Knowledge Resource & IT

Knowledge resource and Information Technology division deals with knowledge resource management and provides IT infrastructural support to CSIR-NML. There are two groups, led by group leaders: 1) Knowledge Resource Group (KRG) and 2) Information technology Group (ITG).

KRG is essentially managing the library resources including e-library, developing multimedia content, publishing the Journal of Metallurgy and Materials Science (JMMS) and conducting CSIR integrated skill trainings which is a new development in the knowledge transfer and skill management activity of the group. Aligning with the vision of CSIR knowledge resource centres, KRG strives continuously to adopt the best practices to make CSIR-NML's information system effective and vibrant. The activities of KRG are

- Library : *Collection development, Circulation, Document delivery;*
- *e-library : Website development and maintenance, Maintenance of Online Public Access Catalogue (OPAC) and institutional repositories (e-print);*
- *In-house Publication : Journal of Metallurgy and Materials Science (JMMS);*
- *Knowledge delivery : CSIR Integrated Skill Initiative, Development of contents for CSIR Virtual Laboratory; Public information delivery: RTI and PG Portal; Scientiometric analysis;*
- *Outreach programs : Jigyasa, School-NML interaction programmes;*
- Publicity & Exhibitions : Press release, advertisement, maintaining archive and museum;

CSIR-NML Library Collection:

Currently the CSIR-NML library managed by the KRG has the following collections:

Print

- 55,515 documents including text-books, reference books, Hindi books, technical reports, manuals, conference proceedings, standards, theses, maps, etc.
- Approximately 21,000 bound volumes of journals collection, dating from 1950.
- Full text reprints of research publications of S&T members of NML.
- Collection of Annual Reports of CSIR labs.
- The laboratory subscribes to 24 Foreign Journals and 5 Indian journals in the printed form.

E – Collection (online)

- More than 40, through NKRC/Direct subscription.
- **Journals** of all S&T Publishers like Nature, Emerald, Elsevier, T&F, ACI
- **Science database :** Web of Science

Standards

- ASTM, BIS (CD), Indian Standards (CD)

Patents : Information on patents is available as under

Commercial	Open access
1. Derwent Innovations Index	1. Patent Lens
2. KCI – Korean Journal Database	2. Google Patent Database
3. Russian Science Citation Index	3. Intellectual Property Library
4. SciELO Citation Index	

Institutional Membership

- **Indian :** ISCA, IBC, IGBC, IE(India), IGS, INSDAG
- **International :** CIB, FIB, RILEM

E-library:

Under e-library, KRG has developed and maintains the following e-resources

1. Knowledge resource centre: http://krc.nmlindia.org/
2. E-prints : http://eprints.nmlindia.org/
3. Transparency portal: http://library.nmlindia.org/tp/index.htm
4. CSIR-NML website: www.nmlindia.org

In-house Publication:

The Journal of Metallurgy and Materials Science (JMMS) publishes original articles, review reports and short communications in the areas of minerals, metals and materials, tracing the overall life cycle of structural as well as functional materials. The journal lays special emphasis on fundamental sciences related to metallic materials and their applications. The JMMS is a quarterly publication. In 2020-21, the volume 62 having four issues were published in the following themes:

1. *Issue 1 & 2 : Special issue on Specialized and Smart Coatings*
2. *Issue 3 & 4 : Special issue on Advanced Materials*

Public information delivery : RTI and PG Portal

Information under Right to Information Act

During the reporting period, CSIR-NML received 72 RTI applications. 6 appeals were successfully disposed of as per RTI guidelines. One appeal was received from the Central Information Commissioner (CIC), New Delhi for hearing. The decision of CIC was in favor of CSIR-NML and the case was resolved. The RTI applications, emanated from seventeen states of India. Since November, 2016, CSIR-NML has switched over to the online mode for the transaction of the RTI application through the "RTI Request and Appeal Management Information System" (RTI-MIS) portal. A good number of RTI applications were also received physically.

PG Portal Statistics

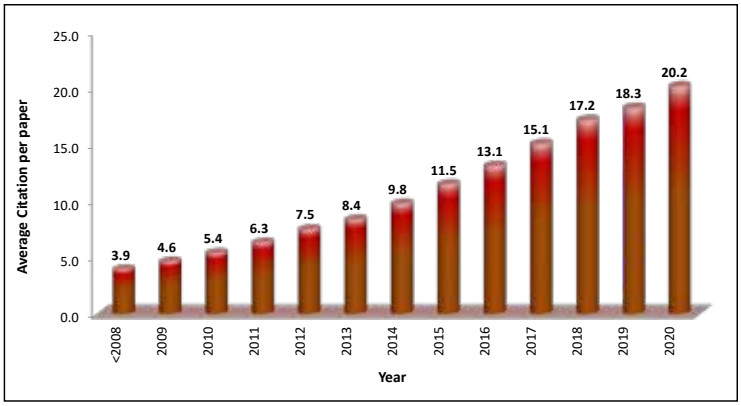
In the matter of Public Grievances, received through the portal, the total of 4 received in the FY were disposed off and closed within times ranging from 15 to 69 days.

Scientiometric analysis/ Publications

SCI Publications and Citations

During January-December, 2020, 124 research papers were published in SCI journals from CSIR-NML. These papers are also maintained in the Laboratory's Institutional Repository (http://eprints.nmlindia.org). The citation of the cumulative SCI publications (1960 onwards) from CSIR-NML has increased from 5610 (in 2008) to 58558 (till December 31, 2020). The average citation per paper is 20.19 on date. As on December 31, 2020, 124 articles had received more than 100 citations/ paper (source: Web of science/ Google scholar).

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



Institutional Repository

The CSIR-NML Institutional repository (http://eprints.nmlindia.org) has maintained its global visibility and achieved 19.3 fold increase in popularity with average hits of over 0.378 million per month and a cumulative of over 28.24 million hits since inception (2009). The researchers from 65 countries have accessed NML repository database during 2020-21. Among the global users, the top countries in decreasing order are United States, China, UK, Germany, Canada, Taiwan, Netherlands, Russia, France, Australia, India, Mexico, and so on.

Transparency Portal

The CSIR-NML Transparency portal (http://library.nmlindia.org/tp/index.htm) contains all information as per the requirement of THE RIGHT TO INFORMATION ACT, 2005 No. 22 of 2005. This information is updated periodically.

Publicity & Exhibitions : Press release, advertisement, maintenance of archive and museum

Special Events & Press Release Statistics

NML transferred e-waste recycling technologies to M/s Metaore Recycling Pvt. Ltd., Kolkata	Published in 14 newspapers
Blood Donation Camp (05th June 2020)	Published in 4 newspapers
e-BTTD-2020 (28th August 2020)	Published in 6 newspapers
Hindi Week Celebrations (08 -14th September 2020)	Published in 6 newspapers
"NML Celebrates 79th CSIR Foundation Day 2020 through virtual medium (MS Team)" & "CSIR Best Technology Award 2020	Published in 17 newspapers
Vigilance Awareness Week (27th October to 2nd November 2020)	Published in 6 newspapers
India International Science Festival - Curtain Raiser (2nd November 2020)	Published in 9 newspapers
SN Sinha Memorial Materials and Metallurgy (SNS3Q) Event (07th November 2020)	Published in 4 newspapers
CSIR-NML Foundation day Celebrations (26th November 2020)	Published in 12 newspapers
Signing of MoU between Indian Air Force and CSIR-NML (7th December, 2020)	Published in 12 newspapers
India's aim is to become self-reliant and work for global welfare (17th December, 2020)	Published in 18 newspapers
Visit of Secretary, DSIR, Govt. of India & Director General of CSIR (19th January 2021)	Published in 20 newspapers
CSIR-NML Staff Picnic (31st January 2021)	Published in 4 newspapers
National Science Day Celebration & Best Science Teacher 2021, awarded by NASI Jharkhand (28th February, 2021)	Published in 13 newspapers
CSIR-NML signed an MoU for Technology Transfer on e-Waste Recycling with M/s. Metaore Recycling on 06th March 2021	Published in 14 newspapers
Women's Day Celebration 8th March 2021	Published in 6 newspapers
CSIR-NML signed and MoU for Technology Development for Holistic Utilization of Red Mud for Extraction of Metallic Values & Resource Utilization with Vedanta, Hindalco, IMMT, NALCO and JNARD	Published in 10 newspapers

Information technology Group (ITG):

The Information Technology Group [ITG] caters to and co-ordinates the lab-wide needs for IT resources and management in terms of creation of IT infrastructure, its services and maintenance. The group is mainly looking after the development and services of IT facilities and infrastructure at CSIR-NML from basic to advanced level. The group is well equipped with computational facilities in terms of hardware and software. The team IT consists of scientists and technologists who are actively involved to support the lab level R&D activities by providing reliable and efficient IT infrastructure with uninterrupted Internet service. CSIR-NML is making use of the IT infrastructure primarily for data transfer, communication, exchange of manuscripts and data with authors and referees, generation of knowledge bases through internet, Email communication, ERP, conducting HR interviews/assessments, important project meetings around the globe through video conferencing/ Skype/ MS Team, etc. Besides day-to-day routine activities, following are some of the major milestones achieved while equipping the three campuses of CSIR-NML and two residential dispensaries with the requisite IT infrastructure during the year 2020-2021:

(a) Upgradation of existing server in terms of hardware & Software.

(b) Planning, estimation & installation of IT facility required by user at various renovated locations of CSIR-NML.

(c) Coordination and management of lab wide maintenance services for IT assets of CSIR-NML.

(d) Preventive maintenance of IT infrastructure installed across campuses of CSIR-NML .

(e) Provisioning of IT facilities in terms of network connections and utility services to new recruits.

(f) Development and maintenance of several in-house utility web applications.

(g) IT support to Human Resource Group (HRG) for performing various HR activities (interviews/ assessments/DPC).

(h) Conduction of Video Conferencing sessions for important meetings and various project review activities.

(i) Procurement and installation of Large Format Display (LFD) for various locations of NML.

(j) Upgradation and hardware maintenance of CCTV. Resolution of various technical issues related to CCTV.

(k) IT support for conduction of seminars, workshops & conferences at NML.

(l) Up keeping of turnstile based attendance system at CSIR-NML for employees and pensioners.

(m) Verification of data and printing of employee identity card.

(n) Technical maintenance and upkeep of Aadhaar Enabled Biometric Attendance System (AEBAS).

Team KRIT Division

Policy, Process and Logistics

The three divisions of CSIR-NML, which provide crucial logistic, policy and process support are the Administration, Finance and Accounts, and, Stores and Purchase divisions. Their responsibilities and performance are provided below:

Administration Division

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. The Administration connects all the staff 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, like the Director, Advisor Management, Head Human Resource Group, for decisions on administrative matters.
- Implement instructions of the Director on various matters.

The division is headed by the COA, who is over all In-charge of the activities and supported by Administrative officers, Section Officers, and a group of Assistant Section Officers and other supporting staff. The division is also responsible for the health care centre, security services and Hindi cell. In recent past, the Administration has undergone major shift in terms of work culture, 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.

Finance and Accounts Division

Finance & Accounts Division of CSIR-NML is actively engaged in planning, organizing, directing and controlling the financial activities of the Lab including accounting of all the financial transactions of the year as per GFR and CSIR guidelines. This division provides a central accounting and financial information to Director, NML, to CSIR Headquarters and to other stakeholders through the management information system.

Following are the major activities of the Finance & Accounts Division :

- Preparation of Budget Estimate and Revised Estimate
- 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
- 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 fund position.
- To prepare financial documents such as Receipts and Payments account and Balance Sheet of the organization on a given date for submission to CSIR and decision makers including submission to CAG (Audit) for certification of accounts.
- Preparation and Submission of Utilization Certificate to sponsors of the projects as and when required.
- Pre-audit of all the bills before making final payment to avoid any irregularity or deviation from the financial Rules.
- Processing promptly all payment payable through Treasury Single Account (TSA) at RBI in PFMS system of the Government of India.
- Promptly, accurately and efficiently recording all the receipts and payments in the relevant ledgers and books of accounts.
- Closing of GPF/CPF accounts, remittance of funds to NSDL relating to National Pension Scheme and Professional tax, income tax, etc., within due date to appropriate authority.
- Accounting, processing and ensuring timely filing of various GST returns and payment of GST due to the Government.
- To provide progressive reports on monthly expenditure, OB, Bank reconciliation, Audit Paras, etc. to maintain transparency.

Performance Highlights for the Financial year 2020-21

1. Utilized Budget Grant allocated by CSIR- Rs. 5925.142 lakhs + Rs. 4575.550 lakhs (pension)
2. Utilization from Laboratory Reserve - Rs. 537.102 lakhs
3. Generation of interest by investment of surplus funds - Rs. 679.596 lakhs
4. Generation of Lab Reserve- Rs. 2074.435 lakhs.
5. Bank reconciliation of the Cash Book completed up to 31st March, 2021
6. GPF Account as on 31-03-2021 has been reconciled, finalized and closed.
7. During the year new cases of 8 pensions and 8 family pensions have been completed with issuing of PPO and pension papers on time.
8. As directed by the Govt. of India, w.e.f. October 2020, NML finance successfully switched over to PFMS system for payments out of Govt. grant, where payments are directly made to vendors by RBI under Single Treasury Account system.

Stores & Purchase Division

The Stores & Purchase Division is mainly responsible for procurement of capital goods, spares and consumable items and annual maintenance services. Different committees like Technical & Purchase Committee, Purchase Committee, Equipment Prioritization Committee, Vendor Registration Committee and Standing Disposal Committee help the division in arriving at suitable decisions as per CSIR Manual on Procurement of Goods 2019. The major procurements for which orders have been placed during 2020-2021 were:

1. Servo Hydraulic Closed Loop Universal Testing System of 100KN
2. Annealing and runout Table Simulator with process control sensors
3. Instrumented Experimented rolling Mill
4. Magnetostrictive Sensing (MsS) Prototype Device for pipe inspection
5. Microwave Digestion Table Top System.

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

The division has taken up the challenging task of implementation of the ERP, E-Procurement through CPP portal and procurement through Government E Market (GeM) platform, with an objective of automation of process and "less paper" office. It is coordinating with CSIR Team and others in ensuring a speedy implementation of ERP, E-Procurement and GeM. The Stores & Purchase Division is headed by Controller of Stores and Purchase (CoSP). The CoSP is supported by Stores & Purchase Officer (SPO), Section Officers, Assistant Section Officers, Junior Secretariat Assistants, Stenographers and MTS staff. The Stores and Purchase Division is a team of hardworking professionals under the leadership of Controller of Stores and Purchase, who strive to keep the system of R&D and other supporting services running in smooth condition by taking care of procurement activities related to materials / services in time and within the ambit of public procurement rules/guidelines.

Indian Metal Crafts

Traditional hand engraved Samovars used in Kashmir till today.

Sources:

https://blog.aboutamazon.in/supporting-small-business/earth-to-chisel-magnificent-metal-crafts-of-india

https://www.ancient.eu/image/11429/mehrauli-iron-pillar/

https://www.indianmirror.com/culture/indian-specialties/Bonecarving.html

https://www.thebetterindia.com/86046/training-new-generation-keep-art-bone-carving-alive/

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, Hindi Magazine - Samanvay, 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 the 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.

Hindi Workshop

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

Hindi Competition

- Due to the pandemic, Hindi Competitions were organized online from 8th to 14th September, 2020 for CSIR-NML Employees. Online Hindi competitions were organized for NML Staff and Officers. The competitions included: Discussion on Implementation of Hindi, Self-written poetry recitation and singing. Many participants took part in the online programme and made it a grand success.

Activities of Hindi Implementation for TOLIC, Jamshedpur

- CSIR-National Metallurgical Laboratory is the Secretariat of Town Official Language Implementation Committee (TOLIC), Jamshedpur. It has 62 Members from all the Central Government offices located in Jamshedpur and adjacent towns. Director, CSIR-NML is Chairman of this committee. Under his Chairmanship, this Committee is playing a vital role for enhancement of the Official Language, Hindi, in these offices.
- Due to the pandemic, all the Hindi competitions, workshop & Programmes are being organized online by TOLIC Jamshedpur.

In-house Project Support Group (i-PSG)

In-house Project Support Group (*i*-PSG) at CSIR-National Metallurgical Laboratory strives to achieve excellence in in-house research by enabling the researchers and supporting their aspirations. The group supports the research in pre-identified thematic areas, on technology development initiatives and researches of scholastic nature leading to masters or doctoral degrees. The aim of these projects is directed towards improvement in performance, relevance and impact of research undertaken. A total of thirty-nine i-PSG supported projects were in progress during the year 2020-21. Some of the significant outcomes/achievements of these projects are as follows:

*Successful demonstration of a cheap, affordable, eco-friendly and simple process to develop a good quality carbon and metal oxide/sulphide/phosphide-based composite and also its real application as electrode for a prototype supercapacitor.

*A method for producing indigenously developed hydrogen standard in steel with improved reduction in variance. These hydrogen standards are with lower expanded uncertainty in comparison to the market available products for commercial purpose.

*"Study of electrochemical behavior, hydrogen permeation and diffusion in pipeline steel", published in Material Science Forum, 1019 (2020), 145-156.

*"Temperature dependent deformation behavior and stacking fault energy of $Fe_{40}Mn_{40}Co_{10}Cr_{10}$ alloy", published in Scripta Materialia, 199 (2021) 113891.

*"Microstructure-mechanical property evaluation and deformation mechanism in Al added medium Mn steel processed through intercriticalrolling and annealing" published in Materials Science & Engineering A 799 (2021) 140100.

*"Heat transfer modelling of dropwise condensation behaviour of magnesium vapours in the electrothermal production of magnesium", published in Canadian Metallurgical Quarterly, 59 (2) (2020), 134-150.

S. Banerjee award for best in-house project completed in 2018


Dr. S. Agrawal


Mr. S. Sinha


Mr. S. Shekhar


Mr. R.K. Choudhari


Mr. D.R. Mahato

Dr. Sanjay Agrawal and his team received '*Prof. Shilowbhadra Banerjee Award 2020*' for the best in-house project 2018 entitled, "Production of Fe-Ni/Co-Mo metallic alloy and alumina rich slag from Ni-Mo/Co-Mo spent catalysts in electric arc furnace" from Professor Indranil Manna, Vice Chancellor, Birla Institute of Technology, Mesra, Ranchi, during 71st CSIR-NML Foundation Day function held through virtual medium.

NASI-NML Report

Joint Activities of CSIR-NML and The National Academy of Sciences, India, Jharkhand Chapter

In association with CSIR-NML and Socio Economic and Education Development Society (SEEDS), Jamshedpur, Jharkhand chapter of The National Academy of Sciences, India (NASI) organized various programs during FY2020-21 under the theme of tribal empowerment through S&T interventions and motivation of science students and science teachers of the state, in spite of the difficulties due to the pandemic. The jointly organized programs are highlighted hereinafter.

1. Skill Development Training Programme on horticulture for Migrant Workers

Duration and Venue: 4th -6th August 2020, Reyarda Utkramit Madhya Vidyalaya, Village – Reyarda, Chandil Block, Seraikela-Kharsawan District, Jharkhand.

40 workers, in the age group of 20-35 years, participated, of whom nearly 90% belonged to the scheduled tribes – Munda, Santal and Bhumij. The remaining 10% trainees belonged to the Other Backward Class category. The training was conducted in batches in order to adhere to the Covid-19 guidelines of social distancing. Migrant workers developed a theoretical and practical understanding of scientific methods of papaya and lemon cultivation at a commercial scale.

2. Skill Development Training Programme on dry land farming for Migrant Workers

Duration and Venue: 7th-9th August 2020, Reyarda Utkramit Madhya Vidyalaya, Village – Reyarda, Chandil Block, Seraikela-Kharsawan District, Jharkhand.

This training was aimed to develop skills of migrant labourers for gainful self-employment in the farm and non- farm sectors leading to sustainable livelihoods. This will enable them to adopt agricultural practices that are resilient to climate change. This would be initiated on the farms as well as the cultivable wastelands through organic cultivation of millets, pulses, oilseeds, tubers, vegetables and fruits. 80 participants attended the training. Migrant workers developed a theoretical and practical understanding of scientific methods of farming with a focus on dry land/upland farming, multi –layer farming and mixed farming.

3. Training on Purification of Drinking Water for Tribal Families

Duration and Venue: March 19-20, 2021, Udaypur and Sardabera Village of Saraikela Block, Jharkhand

The basic objectives of the training were: a) Generation of awareness regarding consumption of safe drinking water; and, b) Developing the skills of youth to purify water through scientifically proven methods using seeds of the locally grown moringa. The training was attended by 78 participants in two villages. Using natural materials to clarify water, is a technique that has been practiced for centuries and of all the materials that have been used, the seeds of the Moringa (commonly known as drumstick, locally as *munga/sahjan*) have been found to be one of the most effective. Studies have been conducted since the early 70s to test the effectiveness of the Moringa seeds for treating water. These studies have confirmed that the seeds are highly effective in removing suspended particles from water with medium to high levels of turbidity. This intervention is of utmost importance in the context of the prevailing unsafe water being consumed by the villagers of Sardabera and Udaypur.

4. Awareness Workshop on COVID-19 Vaccine

Duration and Venue: March 21, 2021 at Panarol Village of Saraikela Block, Jharkhand

The workshop was attended by 48 participants from the village. Dr. Ganga Dhar Mahato was the main resource person for the workshop. Objectives of the worshop were 1) Create awareness about the COVID -19 vaccine - its need and urgency. 2) Motivate the villagers to take the vaccine doses. The Doctor explained in detail about Corona and COVID-19 and the importance and need of taking the vaccine. The majority of villagers had a negative attitude towards the vaccine. After nearly two hours of discussions and convincing, finally they agreed to take the vaccine. The younger participants would publicize this in the village and help the senior citizens to take the vaccine. The Workshop proved to be very useful in dispelling the fears of the tribal villagers.

5. Training on Vermicompost Making

Duration and Venue: 7th-11th September, 2020; Lapaibera Village, Chandil Block, Seraikela-Kharsawan District, Jharkhand

A six days Training on Making Vermicompost was organized for migrant workers. The first five days were devoted to the theory and the demonstration of making vermicompost. After about 40 days, the vermicompost was ready and trainees assembled again to see how it was taken out, weighed and packed. There were 30 participants in the training. Migrant workers developed a theoretical understanding of the method of vermicompost making.

National Science Day Celebrations by CSIR-NML & NASI (Jharkhand Chapter) Best Science Teacher Award 2020-2021

CSIR-National Metallurgical Laboratory, Jamshedpur jointly with The Jharkhand Chapter of the National Academy of Sciences, India (NASI), celebrated the National Science Day on 26th February, 2021. **Dr. Rajendra Joshi**, Founder and CEO, RI Instruments & Innovation Pvt. Ltd, and Managing Director, RINZTECH NZ LTD, New Zealand, was the Chief Guest of the function. In addition to NML Scientific and technical staff, more than 50 researchers participated in the programme through online platform with direct telecast in YouTube. The Chief Guest, **Dr. Rajendra Joshi** delivered a lecture on "Cost effective Raman and Fluorescence spectroscopy in India". On behalf of Jharkhand state chapter of NASI the chief guest gave away the "BEST SCIENCE TEACHER AWARD-2020-2021 for Jharkhand State to **Mr. Sumit Kumar Gorai** (TGT), Delhi Public School, Bokaro Steel City, **Mr. Asheesh Mishra** (PGT), Atomic Energy Central School, Jaduguda and **Mr. Ramanuj Kumar** (PGT), Kendriya Vidyalaya, Tatanagar.

Indian Metal Crafts

'Tarakasi' With Silver Linings, An Art from Orissa

Artisans in Odisha create lovely silver *jaali* work. This ancient art form is battling for its survival in the hands of a few craftsmen families in Cuttack, Odisha. The number of families practising this art is decreasing with time.

Sources:
https://blog.aboutamazon.in/supporting-small-business/earth-to-chisel-magnificent-metal-crafts-of-india
https://www.ancient.eu/image/11429/mehrauli-iron-pillar/
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Awards and Recognitions

International Recognition

Ranked amongst top 2% scientists in the world

based on an independent study done by Stanford University

Dr. Archana Agrawal
Chief Scientist

Dr. Manis K. Jha
Sr. Pr. Scientist

Dr. Kamal Kant Sahu
Chief Scientist

National Recognition

CSIR-Best Technology Award 2020 in Physical Sciences

Dr. Manis Kumar Jha, Sr. Pr. Scientist

Dr. Jhumki Hait, Sr. Pr. Scientist

Mr. Ranjeet Kumar Singh, Principal Scientist

Dr. Pankaj Kumar Choubey, Senior Res. Fellow

Dr. Archana Kumari, Senior Res. Fellow

Ms. Rekha Panda, Senior Res. Fellow

Mr. Om Shankar Dinkar, Senior Res. Fellow

MASCOT National Award

Dr. Raghuvir Singh
Sr. Pr. Scientist

for the outstanding and sustained contributions made in corrosion science, engineering and technology by The Electrochemical Society of India (ECSI)

Special Achievement

Dr. Sanjay Kumar
Sr. Pr. Scientist

High Paper Citations : Dr. Sanjay Kumar's publication has received 560 citations in the calendar year 2020 at Google Scholar

CSIR-Raman Research Award for 2020-2021

Dr. Pratima Meshram
Principal Scientist

SKOCH Order of Merit 2020

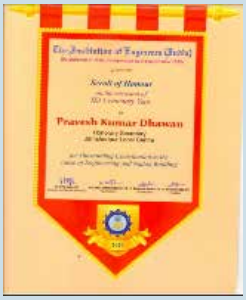
Dr. Beena Kumari
Principal Scientist

Dr. B. Ravi Kumar
Sr. Pr. Scientist

Dr. Sital Kumar Pal
Sr. Pr. Scientist

Scroll of Honour 2020 from the Institution of Engineers (India)

Mr. Parvesh Dhawan
Chief Scientist



Editorial Board Membership(s) / National / International Committee Membership(s)

Dr. Sandip Ghosh Chowdhury Chief Scientist

- Editor : Trans. of The Indian Institute of Metals

Dr. Sanjay Kumar, Sr. Pr. Scientist

- Review Editor in Frontiers in Chemistry Journal in Apr 2020.
- Member, Editorial Advisory Board Trans. of Indian Ceramic Society, Taylor & Francis
- Nominated Member, Committee on Making Emission Standards for Secondary Metallurgical Industry, by Ministry of Environment, Forest & Climate Change
- Member, International Committee, 3rd International Bauxite Residue Valorisation and Best Practices Conference, Sep 29 - Oct 01, 2020, KU Leuven, Belgium

	**Dr. Abhilash,** Principal Scientist
	• 1st Edition - Critical and Rare Earth Elements- Recovery from Secondary Resources *Edited By - Abhilash, Ata Akcil* • Editorial Board Member, Mineral Proc. & Extractive Metall. Review (Taylor & Francis) • Editorial Board Member, Russian Journal of Nonferrous Metals (Springer) • Editorial Board Member, Materials Science: Materials Review
	**Dr. Shobhana Dey,** Sr. Pr. Scientist
	• Editorial Board member of International Journal of Coal Preparation & Utilization.
	**Dr. Ranjan Kumar Sahu,** Sr. Pr. Scientist
	• Editorial Board Member in Journal - Current Material Science, Publisher-Bentham

Invited Talks / Keynote Lectures Delivered by CSIR-NML Staff

	**Dr. Soumitro Tarafder,** Chief Scientist
	• "Fatigue & Fracture behaviour of Pressure Boundary Materials" Webinar on "Processing, Microstructure and Properties of Engineering Alloys for Critical Applicaations" on 23rd March 2021, Jadavpur University, Kolkata. • "Fatigue, Fracture and Integrity Assessment" on : 12th March, 2021, Dept. of Civil Eng., IIT Guwahati, Assam. • "Fracture Mechanics for Structural Components operating at High Temperatures", Indian Structural Integrity Society (InSIS) on *Fracture Mechanics and its Impact on Structural Integrity: 100 Years of Griffiths' Theory*, on 19th March 2021. • "Mechanical evaluation of high temperature materials" Vaibhav Summit on Materials & Processing Technologies, 07th October 2020. • "Integrity Assessment & Health Monitoring of Engineering Structures and Components" Webinar on "Business Opportunities in Structural Health Monitoring and Predictive Maintenance of Engineering Components" IITJ-Technology Innovation and Start-up Centre (TISC) on 08th August 2020. • Keynote Lecture "Fracture Mechanics based Characterization for Structural Integrity Assessment" in National Conference on "Research and Developments in Material Processing, Modelling and Characterization 2020" (RDMPMC-2020), on 27th August 2020, NIT, Jamshedpur.

	**Dr. Arvind Sinha,** Chief Scientist
	• "**Biomaterials :** An ongoing journey from biomimetics to biodegradable alloys" 8th December 2020 at ICBMI 2020 ; Society for Biomaterials & Artificial Organs, India and Bharathiar University, Coimbatore • "Science Education for Aatm-Nirbharta" on 18th December 2020, PIB, Patna • "Biomimetic Material Science : Inspiration from Nature (In Hindi)" on 17th September 2020 on Hindi Diwas, CSIR-CGCRI, Kolkata • "Biomimetic Materials: Learning from nature" on 08th August 2020; Recent Advances in Chemstry & Materials Science 2020 (RACMS 2020); Indian Chemical Society in collaboration with American Chemical Society • "Biomimetic Nanomaterials: Science coupled with Innovations" on 22nd May 2020, Kolhan University
	**Dr. Sandip Ghosh Chowdhury,** Chief Scientist
	• "High-Temperature Performance (HTPAA) of Aluminium Alloys" MANIT Bhopal during December 2020
	**Dr. Sanjay Kumar,** Sr. Pr. Scientist
	• "Geopolymer" Center of Excellence on Geopolymer and Green Technology, Malaysia. • "This geoplolymer Cement Is Good, Let Us Make It Better"; Sathyabama Institute of Science & Technology on 30th July 2020. • "Recycling For Self-Reliant India"; on 11th March 2021.
	**Dr. Kamla Kant Sahu,** Sr. Pr. Scientist
	• "Production of potash fertiliser from low grade indigenous resources" in NMD-ATM 2020 of the Indian Institute of Metals, during 23rd -26th February 2021. • "Metal extraction principles – An overview" in Continuing Education Program (CEP) on 'Metal Extraction & Recycling Technologies" Defence Metallurgical Research Laboratory (DMRL), Hyderabad during 15th -17th March 2021.
	**Dr. Sanchita Chakravarty,** Sr. Pr. Scientist
	• Keynote talk on topic "Oil Agglomeration: An Effective Tool For Generation of Clean Coal" in National Conference on "Advancement in Materials Processing Technology (AMPT-2020)" during 31st October -1st November 2020; Department of Materials and Metallurgical Engineering, National Institute of Technology (NIT) Jamshedpur.
	**Dr. L. Sarmistha Sagar,** Sr. Pr. Scientist
	• Keynote speaker at National Conference on Electronics, Communication and Computation-2020 during 5-6 September, 2020, NIT Jamshedpur • Keynote Speaker at Virtual Conference & Exhibition on Non-destructive Evaluation during 10-12 December, 2020

Dr. V. C. Srivastava, Sr. Pr. Scientist

- "New Scientific Knowledge: Writing and Publishing" SERB sponsored workshop on 'Research Methodologies', on 19th September 2020, NIT-Jamshedpur.
- "Paradigms of Materials and Process Design" National Conference on Materials, Mechanics and Modelling (NCMMM 2020) during 29th-30th August 2020, NIT-Jamshedpur.
- "Advanced Materials Processing' in Faculty Development programme; Department of Mechanical Engineering, Narasaraopeta Engineering College, Guntur, Andhra Pradesh, on 04th June 2020.
- "Product development and metallurgical issues in metal additive manufacturing" in summer program for B. Tech. students on Additive Manufacturing, CET, IILM Academy of Higher Learning, Noida on 06th June 2020.
- "An Introduction to Materials for Structural Applications" in TEQIP programme, Rajkiya Engineering College, Bijnor, Uttar Pradesh on 14th December 2020.
- Keynote Talk titled "Materials design and processing: A perspective" in webinar for young researchers in Metallurgy & Material Science Organized by CSIR – National Metallurgical Laboratory during 12th – 14th August 2020.

Dr. D. Mishra, Sr. Pr. Scientist

- "Recycling of Tungsten Heavy Alloy Scraps" in 58th National Metallurgist Day and 74th Annual Technical Meeting (NMD-ATM 2020) of the Indian Institute of Metals, during 23rd -26th February 2021.
- "Extraction of Strategic & Critical Metals from Secondary Resources" in Continuing Education Program (CEP) on 'Metal Extraction & Recycling Technologies" Defence Metallurgical Research Laboratory (DMRL), Hyderabad, during 15th -17th March 2021.

Dr. Sital Kumar Pal, Sr. Pr. Scientist

- "Role of NML-IPFC in leveraging IP and generating business intelligence for MSME" – Webinar on Role of IPRs in Innovation Management for on October 12, 2020, NML-IPFC, Jamshedpur
- Talks delivered in the Webinar series on Intellectual Property Rights under the scheme of "Building awareness on IPR for MSMEs" organized by MSME-DI, Ranchi and NML-IPFC, Jamshedpur
- "Relevance of Trademark and branding for MSMEs", on 16 December, 2020,
- "Relevance of Industrial Design and Trademark for the development of MSMEs" on 22 December, 2020
- "Importance of IPRs for the development of MSMEs" on 20 January, 2021
- "Importance of IP tools for the development of MSMEs" on 15 February, 2021
- "Patent as IP Tools for the development of MSMEs" on 5 March, 2021
- "Relevance of Patent, Copyrights, Industrial Design, Trademark and GI for MSME development", on 8 March 2021

	• "IPRs and its importance" on 12 March 2021 • "Importance of IPR and its challenges in Academia/Research Institute"- Training programme on Intellectual Property Rights held on 18 March, 2021, CSIR Integrated Skill Initiative & NML-IPFC, Jamshedpur • "Importance of IPRs and challenges faced in Academia / Research Institutions in India" - Faculty Development programme on 28 December, 2020, MIT Moradabad
	**Dr. Ashish Kumar Panda,** Sr. Pr. Scientist • "Development of rapidly solidified magnetic materials for sensor applications" on 18th January 2021, Workshop on "Advances in Applied Physics (AAP-2021)", Sardar Vallabhbhai National Institute of Technology (SVNIT), Surat, during 18th -22nd January 2021.
	**Dr. Abhilash,** Pr. Scientist • "Waste recycling for metals and materials-a sustainability pathway", 57th Annual Convention of Chemists (ACC) of the Indian Chemical Society (ICS), on 29th December 2020.
	**Dr. Pratima Meshram,** Pr. Scientist • National Workshop on the theme of "New Horizons in Metallurgy, Materials and Manufacturing" organized by Indian Institute of Metals (IIM) during 14th-16th December 2020. • "Indigenous technological developments in portable spent rechargeable battery recycling", Recommerce – Global Battery Recycling Conference, during 4th-5th March 2021.
	**Mr. V. Rajinikanth,** Pr. Scientist • "Advances in Materials Manufacturing Processes and Properties" TEQIP short-term course, MNIT Jaipur, during 6th-10th July 2020.
	**Dr. Ashok Kamraj,** Sr. Scientist • "Recent trends in process metallurgy", FDP programme, O. P Jindal University, Raigarh and IIM Raigarh chapter and ASM International, on 15th July 2020
	**Mr. Amit Prakash,** Sr. Tech. Officer (2) • "Non Destructive Testing : Basics & Applications" organised by Lok Nayak Jai Prakash Institute of Technology on 12th July 2020

CSIR-NML Foundation Day Awards (26th November 2020)

B.R. Nijhawan Award for the Best paper published in 2019

 **Mr. G.K. Bansal** Scientist	 **Dr. V.C. Srivastava** Sr. Pr. Scientist	 **Dr. S. Ghosh Chowdhury** Chief Scientist	For the article *"Role of solute Nb in altering phase transformations during continuous cooling of a low-carbon steel"*, published in Materials Science and Engineering, A

V.A. Altekar Award for Best technology developed or transferred in 2019

 **Dr. S.K. Maity** Principal Scientist	 **Mr. M. Chandrasekhar** Sr. Tech. Officer (3)	 **Mr. S. Choudhary,** Sr. Tech. Officer (3)	For *"Technology development for commercial production of sodium"*
 **Mr. M.K. Runda** Sr. Tech. Officer (3)	 **Mr. P.K. Dhawan** Chief Scientist	 **Mr. Krishna Kumar** Sr. Scientist	

Dr. S. Banerjee Award for Best in-house project completed in 2018

 **Dr. Sanjay Agarwal** Principal Scientist	 **Mr. S. Sinha** Sr. Scientist	 **Mr. S. Shekhar** Sr. Scientist	 **Mr. R.K. Choudhari** Tech. Assistant	 **Mr. D.R. Mahato** Technician (2)

For the project "Production of Fe-Ni/Co-Mo metallic alloy and alumina rich slag from Ni-Mo/Co-Mo spent catalysts in electric arc furnace"

P.R. Rao Award for Best employee

Technical Cadre

Mr. Saban Purty
Sr. Tech.

Mr. R.R. Srivastava
Sr. Tech. Officer (1)

Non-Technical Cadre

Mr. Ved Prakash
Asst. Sect. Officer (G)

Mr. Sarthi
MTS

S.P. Mehrotra Award for Best Colloquium speaker in 2019-2020

Mr. Gaurav Kumar Bansal
Sr. Scientist

Special Award for Excellence in Social Responsibility

Mr. Parmarth Suman
Asst. Sect. Officer (G)

Mr. Ramashray Ram
Sr. Tech.

Mr. Biswanath Mukhi

Mr. Rimil Mardi
Mr. Dablu Behera

Mr. Aboni Pradhan
Lab. Assistant

Mrs. Panmai
MTS

Special appreciation award for providing exemplary lifetime services to the laboratory

Mr. Ved Prakash,
Asst. Sect. Officer (G)

Special Award for designing the Logo for the NML @ 70

Best Paper/ Poster/ Presentation Awards

Best Oral Presentation Award in National Conference on Electronics, Communication, and Computation, Department of Electronics and Communication Engineering, National Institute of Technology, Jamshedpur

Mr. Chandan Dutta
Project Assistant

Dr. Tarun Kr Das
Principal Scientist

Mr. Alok Kumar
Project Assistant

Mr. Avinow Raj

Dr. Jayendra Kumar

Dr. Sarmishtha Palit Sagar
Sr. Pr. Scientist

Dr. Abhilash,
Principal Scientist

First Prize in Oral Presentation in the Theme of Engineering Sciences in the young scientist's conference (YSC-2020, New Delhi) at IISF 2020.

Dr. Anjan Pradhan,
Principal Scientist

Best Technical Paper in Indian Foundry Journal during the calendar year 2019 by Institute of Indian Foundryman

Mr. Lalit K. Meena
Scientist

Mr. Ravada Seshagiri
Technical Assistant

Dr. Raghuvir Singh
Sr. Pr. Scientist

Anney K. Sinha

Best Paper Award in the "National Symposium on Electrochemical Science and Technology 2020 (NSEST-2020)" held via online mode at IISc campus Bengaluru, 21–22 January 2021.

Meritorious Children of CSIR-NML Staff

Securing Admission in High Repute Institute of Country 2020

Mr. Ankur Mehta
at
IIM, Bangalore

Mr. Srikar Verma
at
IIT-BHU, Varanasi

Mr. Aditya Upadhyay
at
IIT-ISM, Dhanbad

Securing 100% marks in a subject

Miss Stuti Dash
(X - 4 subjects)

Miss Diya Chakravarty
(XII - 2 subjects)

Mr. Deepanshu Sau
(XII - 2 subjects)

Miss S. Trisha
(XII – 1 subject)

Securing 90% marks or above in each of the minimum three science subjects in the Senior Secondary Examination (12th Class) in 2020

Miss S. Trisha

Mr. Srikar Verma

Mr. Ivan Jacob Thomas

Mr. Dibyaranjan Mishra

Securing 85% marks or above in in ICSE/ CBSE in class 10th and 12th

Miss S. Trisha

Mr. Srikar Verma

Mr. Ari Jatin

Miss Sanjana Sahu

Mr. Ivan Jacob

Mr. Dibyaranjan Mishra

Mr. K. Venkat Anirudh

Miss Alishma Rath

Mr. K. Shiva Abhishek

Mr. Bojja Jonathan

Mr. Aditya Upadhyay

New Facilities

Motorized 4-Axes (X, Y, Z, θ) Ultrasonic Immersion Scanning System

Make: **NDTT, Mumbai /Mistras, USA**

Technical Details : The Motorized 4-Axes (X, Y, Z, θ) Ultrasonic Immersion Scanning System along with UTwin software, is an equipment to examine defects inside a material in a non-destructive manner through ultrasonic imaging. The system has greater accuracy than other non-destructive methods in determining the position of internal flaws and the thickness of parts with parallel surfaces and estimating the size, orientation, shape and nature of defects. In addition to ultrasonic imaging of plates and block specimens which are flat parallel, this 4-axes ultrasonic scanning system is also capable of scanning and defect detection in cylindrical rod and pipe samples of uniform dimension.

NITROGEN & OXYGEN DETERMINATOR

Model : LECO ON 836

Use : simultaneous wide-range measurement of Oxygen & Nitrogen content of inorganic materials, ferrous and nonferrous alloys, and refractory materials using the inert gas fusion technique. The ON 836 is ideal for inorganic materials, ferrous and nonferrous alloys, copper, aluminum, titanium, and refractory materials.

Specifications **:**

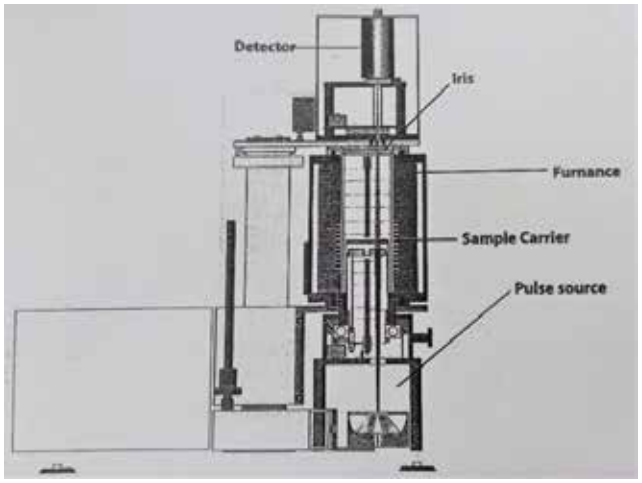
Instrument Range at 1 g sample wt.: Oxygen: 0.00005 to 50 mg; Nitrogen: He Carrier Gas: 0.00005 to 30 mg

Precision : Oxygen: 0.000025 mg or 0.3% RSD; Nitrogen: He Carrier Gas: 0.000025 mg or 0.3% RSD

Features : Drift correction, blank calibration, multipoint calibration as well as gas dose calibration

Terminal Velocity Separator

The separator is fabricated with indigenous technology. This separator is being used for fine size iron ore beneficiation and later shall be used for the beneficiation of other materials like chromite, coal etc.



Thermal Conductivity Measurement System

Make : Linseis Messgerate GmbH, Germany

Technical Details : The instrument (LFA unit) measures the thermophysical properties of the bulk and the thin film materials. It uses the flash (up to 15-joule pulse energy) method to measure the thermal diffusivity and thermal conductivity of various kinds of solids like metals, ceramics, and composites. It can measure the thermal diffusivity 0.01 to 2000 mm^2/s and thermal conductivity 0.1 to 4000 w^2/s. The LFA unit is equipped with a high-speed infrared furnace which enables high-speed heating (up to 50ºC/sec) from RT 1000ºC to in vacuum (~10^{-2}mbar), inert (Ar or N_2) and air environments. It can handle various shapes of samples like round, square, and rectangle.

Usages : To measure the thermal conductivity, thermal diffusivity, and specific heat capacity of the bulk, thin films, and liquid samples for development of thermoelectric materials.

Advanscan AS - 414 Ultrasonic flaw detector

Make : **Electronic and Engineering Company India (EECI)**

Technical details **:** a portable Ultrasonic Flaw Detector which is customized as per requirements. The customization has been done for the evaluation of binder percentage and homogeneity in Tungsten -Carbide Rings (TC Rings). The evaluation is done using propagation of ultrasonic wave through TC Rings.

Indian Metal Crafts

The Ladakh region has its own traditional vessels made from brass and iron, whereas, the Kashmir region is popular for the naquashi work. Here the designs and patterns that are embossed on silver and copper items are oxidized.

Kamrupi metal craft is practiced in Kamrup, Assam. Made from brass and bell metal the items produced by this metal craft are pots or kalah, the sarai, lota (water pot), bati (bowl), cymbals and more. The craft also uses copper, silver and gold to create objects.

Sources:

https://blog.aboutamazon.in/supporting-small-business/earth-to-chisel-magnificent-metal-crafts-of-india

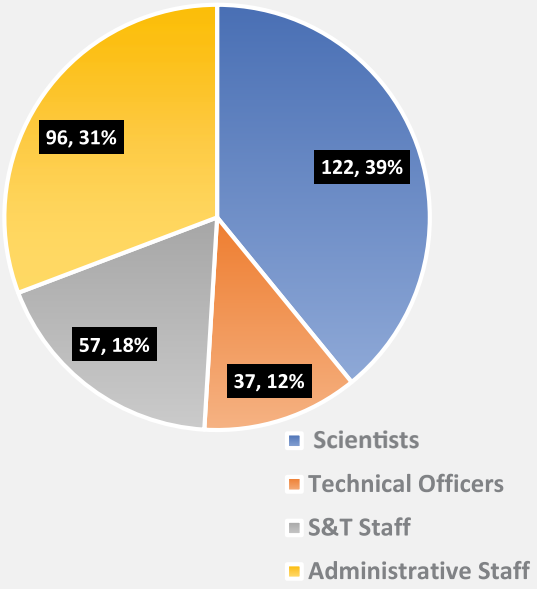
https://www.ancient.eu/image/11429/mehrauli-iron-pillar/

https://www.indianmirror.com/culture/indian-specialties/Bonecarving.html

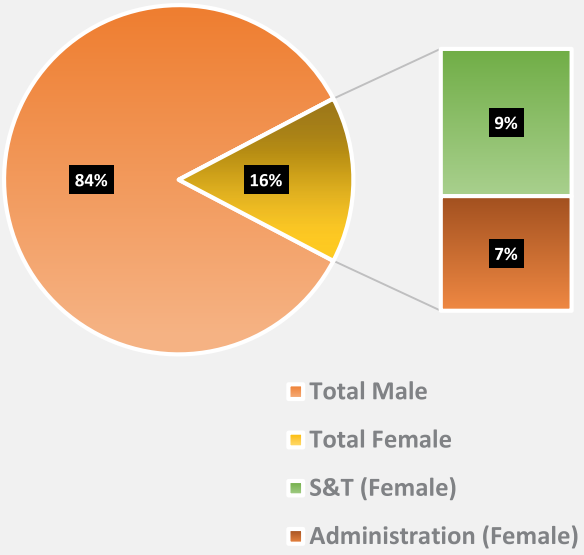
https://www.thebetterindia.com/86046/training-new-generation-keep-art-bone-carving-alive/

Human Resources Status (as on 31st March 2021)

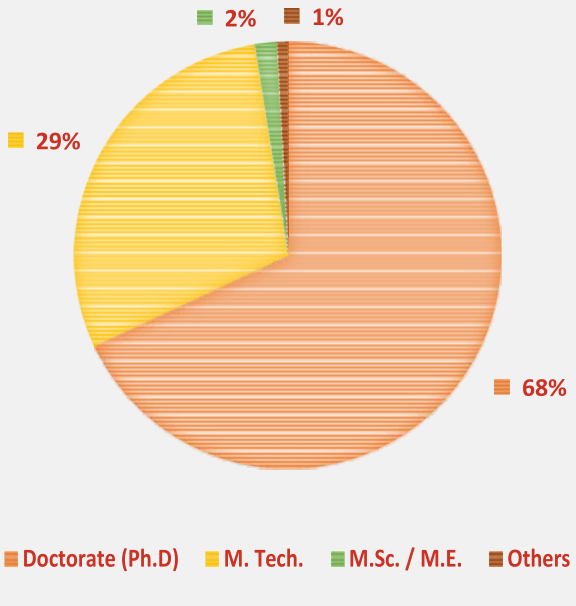
Distribution of Staff



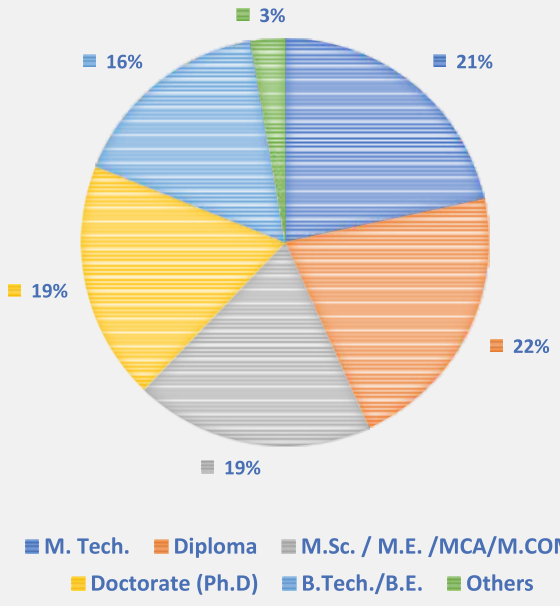
Gender Wise Staff Distribution (%age)



Qualification of Scientists



Qualification of Technical Officers



Staff News

Superannuated : *"Wishing our superannuated colleagues a happy retired life."*

Dr. Gautam Das,
Chief Scientist
30th April 2020

Mr. Mahendra Kr. Mahato,
Principal Technical Officer
30th April 2020

Dr. Nilima Roy.
Chief Scientist
30th September 2020

Mr. K Bhaskar Rao,
Multi-Tasking Staff
30th September 2020

Mr. Premjeet Singh,
Assistant Section Officer (S&P)
31st October 2020

Mr. Mona Bhattacharjee,
Multi-Tasking Staff
31st October 2020

Mr. Shankar,
NML Madras Centre
31st October 2020

Dr. Ratnakar Singh,
Chief Scientist
28th February 2021

Shri Mukh Lal,
Manager Grade II
28th February 2021

Mr. Narayan Chandra Das,
Multi-Tasking Staff
31st March 2021

New Joinees:

Dr. G. Sudhakar Rao,
Senior Scientist
18th June 2020

Dr. Partiosh Dubey,
Senior Scientist
09th July 2020

Transfers from Sister Laboratories

Dr. Asit Baran Panda,
Principal Scientist
27th January 2021

Md Arif,
Technical Assistant
08th February 2021

New Entrants:

"We welcome the new entrants to the laboratory and wish them success in their endeavours.

Transfers to Sister Laboratories/Headquarter :

Joined CSIR-CGCRI, Kolkata as Director

Congratulations!

Dr. (Mrs.) Suman Kumari Mishra,
Chief Scientist & Head,
Human Resource Group
16th January 2021

Joined CIMFR, Dhanbad

Mr. Divakar Aloke Srivastava,
Assistant Section Officer (S&P)
July, 2020

Joined CSIR HQ, New Delhi

Dr. Mamta Sharma,
Senior Scientist
October, 2020

Joined CSIR HQ, New Delhi

Dr. Rajneesh Kr. Gupta,
Principal Scientist
October, 2020

Joined IICB, Kolkata

Mr. Manas Samanta,
Technical Officer
January, 2021

Demise of Staff:

"We will remember them fondly and miss them"

Dr. Shyamal Kumar Maity,
Sr. Principal Scientist
17th August 2020

Mr. Rajendra Kumar Mukhi,
Multi-Tasking Staff
23rd December 2020

Mr. Motilal Mukhi,
Multi-Tasking Staff
20th February 2021

Distinguished Speakers

Speaker		Date Delivered & Topic of Webinar
Dr. Anurag Agrawal CSIR-Institute of Genomics and Integrative Biology		27th April 2020 *"COVID-19"*
Mr. Deependra Singh CMD, IREL		16th June 2020 *"Indian rare earth elements and its extraction"*
Dr. Jagdish Lohia Consultant, Brahmananda Narayana Multispecialty Hospital, Jamshedpur		24th September 2020 *"Bronchial Asthma & COVID 19"*
Dr. Rajiv Maharshi Consultant, Brahmananda Narayana Multispeciality Hospital, Jamshedpur		16th October 2020 *"Spine & Back Pain"*
Prof. AK Pandey Faculty of Law, BHU, Varanasi		02nd November 2020 *"Probity in Public Life & The Role of Law"*
Prof. Indranil Manna VC-BIT Mesra, Ranchi		26th November 2020 *"Perspectives and Prospects of Additive Manufacturing (AM)"*
Mr. TV Narendran MD-Tata Steel		26th November 2020 *"Creating an Ecosystem for Innovation in Materials and Manufacturing"*

Speaker		Date Delivered & Topic of Webinar
Dr. Sekhar C Mande DG- CSIR & Secretary DSIR		26th November 2020 *"CSIR: Past, Present and Future"*
Dr. E. Zachariah Chacko Sr. Technologist, Tata Steel Limited, Jamshedpur		10th February 2021 *"Continuous Billet Casting: Issues and solutions using Fibre Bragg Grating Sensors"*
Dr. BN Mohapatra Director General, National Council for Cement and Building Materials (NCCBM), Ballabgarh, Haryana		12th February 2021 *"Utilisation of Steel Slag in Cement and Construction Industry"*
Dr. Ananya Kar Consultant Gynaecologist, NHS, UK		05th March 2021 *"Awareness of Cervical Cancer"*

Indian Metal Crafts

A blacksmith shapes the iron to create objects including sculptures, weapons, gates etc. A tinsmith creates utensils out of metal, whereas, a silversmith makes fine items from the silver metal. Where a coppersmith creates objects out of copper and brass, a goldsmith forms valuable designs and objects with gold.

Sources:

https://blog.aboutamazon.in/supporting-small-business/earth-to-chisel-magnificent-metal-crafts-of-india

https://www.ancient.eu/image/11429/mehrauli-iron-pillar/

https://www.indianmirror.com/culture/indian-specialties/Bonecarving.html

https://www.thebetterindia.com/86046/training-new-generation-keep-art-bone-carving-alive/

CELEBRATIONS

Independence Day Celebrations - (15th August, 2020)

The national flag was hoisted at laboratory and residential complexes. Staff-Children participated in a series of cultural events through virtual platforms.



Hindi Week Celebrations (08th -14th September 2020)

The program was organized on virtual platform. As part of the celebrations, various events like poetry and song recitations, and discussion on social issues, were organized.

79th CSIR Foundation Day Celebrations (26th September 2020)

The foundation day lecture was delivered by the chief guest, Ms. Soma Mondal, Director (Commercial), SAIL. On this day, as customary, the laboratory recognized the services of the staff who had superannuated recently as well as those who had completed 25 years of continuous service at CSIR. The meritorious wards of laboratory staff were awarded.


JHARKHAND'S OWN ENGLISH DAILY

THE AVENUE MAIL

CSIR 79th Foundation Day: NML wins Best Technology Award 2020

Mail News Service


The Researchers'

HOME | TOP STORIES | FEATURES | NATIONAL | INTERNATIONAL | STATE | LIFESTYLE

NML Celebrates 79th CSIR Foundation Day on virtual platform

CSIR-NML Foundation day Celebrations (26th November 2020)

Dr Shekhar Mande, Secretary-DSIR & DG-CSIR, Mr. TV Narendran, CEO & MD- Tata Steel and Prof. I Manna, VC, BIT Mishra graced the occasion with their presence and lectures. Two special issues of the e-Journal "Journal of Metallurgy and Materials Science" were released on the occasion.


Morning India

NEED NEW TECHNOLOGIES FOR CAR-BON DIOXIDE CAPTURE: NARENDRAN


उदित वाणी

300 मिलियन टन उत्पादन लक्ष्य में पर्यावरण कानून बड़ी चुनौतीः नरेन्द्रन

सीएसआईआर की कोविड से जंग में बड़ी भूमिकाः मांडे

Republic Day Celebration 2021

The occasion was celebrated at the laboratory and the residential complexes. The national flag was hoisted at all campuses. A number of events were organized for the families of the staff.

National Science Day Celebrations (26th February 2021)

CSIR - NML in association with Jharkhand Chapter of The National Academy of Sciences, India (NASI) celebrated National Science Day. Dr. Rajendra Joshi, Founder and CEO, RI Instruments & Innovation, and Managing Director of RINZTECH, New Zealand, was the Chief Guest of the function.

Women's Day Celebration (8th March 2021)

Dr. Ananya Kar, Consultant Gynecologist, NHS, UK, delivered a talk on "Awareness of Cervical Cancer" preceding the Woman's day. A number of programs were organized. Mrs. Debarati Chattoraj graced the occasion as the Chief Guest. Mrs. Rima Dey delivered a talk on "Discover your personal style".

Other Official Events

Research Council (RC) meetings

The 75th RC meeting was held on 8th June, 2020 and the 76th RC meeting was held on 31st March, 2021. The 75th Meeting was chaired by Professor Amol Gokhale, and marked the last meeting of that RC. The 76th Meeting was chaired by Professor Indranil Manna, and a new RC attended the meeting.

Vigilance Awareness Week (27th October to 2nd November 2020)

The theme of Vigilance Awareness Week was "Satark Bharat, Samriddh Bharat" (Vigilant India, Prosperous India)". Prof. A. K. Pandey, Faculty of Law, BHU Varanasi was the Chief Guest of the programme.

India International Science Festival - Curtain Raiser (2nd November 2020)

A curtain raiser event was held by CSIR-NML for the IISF. Professor KK Shukla, Director, NIT Jamshedpur, was the chief guest and Dr. Shubra Diwedi, Chairperson, SEEDs, was the guest of honour.


Morning India

NML holds curtain raiser of IISF on virtual platform


न्यू इस्पात मेल

इंडिया इंटरनेशनल साइंस फेस्टिवल 22 से

Visit of Secretary, DSIR, Govt. of India & Director General of CSIR (19th January 2021)

Dr. Shekhar C. Mande, DG-CSIR visited the laboratory and addressed the staff. During his address, Dr. Mande discussed about the initiatives of CSIR in fighting COVID-19. During his motivating interaction with the young researchers of the laboratory, he emphasized upon using science and technology for the benefit of the common man.


दैनिक जागरण

एसी से नहीं होगा कोरोना का संक्रमण, खुल सकेंगे सिनेमा हॉल : डा. मांडे


सीएसआइआर की अग्रिम रणनीति से समय पर बना वैक्सीन टीका

एनएमएल ग्लोबल लैब बनने की ओर अग्रसर है : डॉ शेखर सी मांडे


हिन्दुस्तान

देश की 10 % आबादी में एंटीबॉडी विकसित

Conferences & Seminars

Conference on Low-Grade Resources: Opportunities for Indian Iron & Steel Industry (28th May 2020)	CSIR-NML in partnership with the Confederation of Indian Industry (CII) organized a Digital Conference on the subject. This digital conference garnered huge interest across India.
TDB-CII digital conference (11th May 2020)	Ministry of Science and Technology (TDB) jointly with CII organized a digital Conference on "Reboot the Economy through Science, Technology and Research Translations (RE-START)" on the occasion of the National Technology Day, 2020. CSIR-NML showcased its technologies, R&D services and Facilities, in a digital stall in CII HIVE.
e-BTTD-2020 (28th August 2020)	e-Behind The Teachers Desk (e-BTTD) program, an international student seminar on materials and metallurgical engineering was organized by the Indian Institute of Metals (IIM), Jamshedpur in association with CSIR-NML, NIT-Jamshedpur, and TATA steel.  THE AVENUE MAIL Students connect on 'Behind The Teacher's Desk' More than 75 students from 25 different organizations took part in the event. For the finale, the Chief Guest was Dr. Namburi Eswara Prasad (Outstanding Scientist & Director, DMSRDE, DRDO), and the Guest of Honor was Dr. Shantanu Chakrabarti (formerly Head-Research Application, TATA Steel & Visiting Professor of IIT-Kharagpur)

Webinars

Structural Integrity Assessment: Tool for Prediction and Prevention of Failures (2nd July 2020)	Organized jointly with CII, the webinar presented the available strategies to ensure structural safety and ascertain the extent of degradation of materials, and extend their usage if possible.
Webinar on Metallurgy and Materials Science (WMMS) (12th-14th August 2020)	A series of webinars for young researchers in Metallurgy & Material Science was organized. The webinars, over three days, disseminated knowledge in all areas of metallurgy and materials engineering. Experts from CSIR-NML and other reputed institutes and industries shared their expertise.
Webinar on "Role of Intellectual Property Rights in Innovation Management for MSMEs"	In order to compete with global standards and technological challenges, MSMEs are now focusing on the management of their IP assets to achieve competitive advantage. This webinar emphasized that and provided means and methods for innovation management.
CSIR-NML and CII webinar (13th October 2020)	A webinar was organized jointly with CII on - "Extraction of Strategic Metals: Opportunity and Business Prospects". This was widely attended by industrial participants.
Scientists-Science Teachers Conclave (17th December 2020 and 29th January 2021)	More than 180 science teachers participated in the first and around 100 in the second conclave, from all across India.

Intellectual Property Rights (IPR) Webinar (16th December and 22nd December 2020)	NML-IPFC hosted two webinars on Intellectual Property Rights, organized jointly by MSME-DI, Ranchi, Ministry of MSME, Govt. of India, and Indo Danish Tool Room (IDTR), Jamshedpur.
CSIR Integrated Skill Training Initiative : Online Faculty Development Program (11th-15th January 2021)	A one-week training program was organized through virtual medium for faculty members of diploma and graduate engineering colleges on "Materials Processing and Heat Treatment Processes of Metals and Alloys".

SN Sinha Memorial Materials and Metallurgy (SNS3Q) Event (07th November 2020)

CSIR-NML and Indian Institute of Metals -Jamshedpur Chapter, jointly organized an elocution contest in memory of Prof. SN Sinha, an eminent teacher in the field of metallurgy, on virtual platform for the students of XI and XII. Students from various schools participated in the event.

Industrial Training under CSIR Integrated Skill Initiative (7th - 11th December 2020)

CSIR-NML, Jamshedpur organized Industrial Training on Metallurgical Furnaces for Diploma students under CSIR Integrated Skill Initiative.

Social and Cultural Activities

Blood Donation Camp (05th June 2020)

More than 78 donors came forward voluntarily to be a part of this noble cause. The camp received huge support and response from all staff.

CSIR-NML Staff Picnic (31st January 2021)

Annual Badminton tournament- (6th-7th February 2021)

Deputations for Participation in Webinars (Training/ Seminar/ Workshop/ Conference)

- **Mr. Chandra Veer Singh,** Scientist, attended a web-based training on "Metals, Materials Modelling: Plasticity" organized by the International Association for Engineering Modelling, Analysis and Simulation (NAFEMS) Community Ltd., U.K., during 20th May, 2020 to 03rd June, 2020.

- **Mr. C Soupramanien,** Senior Technical Officer, participated as a speaker in the 1st virtual European Conference on "Fracture", on 29th June, 2020.

- **Dr. Sanchita Chakravarthy,** Chief Scientist, Dr. Arvind Kumar Upadhyay, Principal Technical Officer, and Mr. Jay Narayan Patel, Senior Technical Officer, took part in the online training program on "General requirements for the competence of reference material products based on ISO 17034:2016", during 17th - 19th June, 2020.

- **Dr. Ashok Kamaraj,** Senior Scientist, delivered a talk on "Recent trends in process metallurgy" in an online FDP program organized by O.P. Jindal University, Raigarh, in association with IIM Raigarh Chapter and ASM International, on 15th July, 2020.

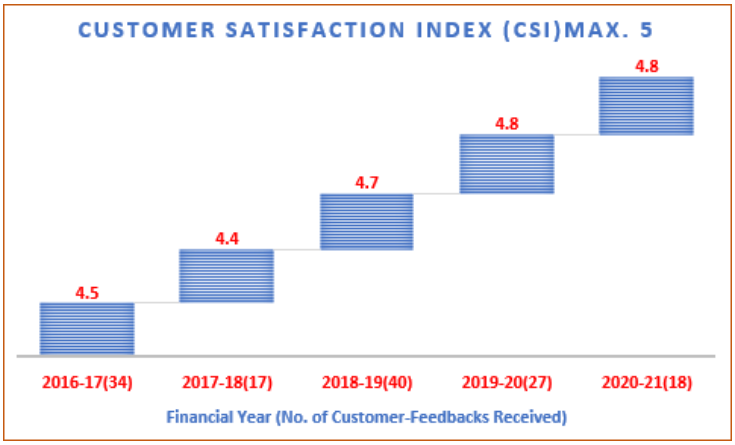
- **Mr. Chandra Veer Singh, Scientist,** attended an e-learning course on "Metals Material Modeling : Creep" (Online) organized by NAFEMS, U.K., during 04th to 18th March, 2021.

- **Mr. Rohit B. Meshram,** Scientist, participated as a speaker in the 28th CIRP Conference on "Life Cycle Engineering" (Online); organized by BIT's Pilani and Technische Universitat Braunschweig, Germany, during 10th to 12th March, 2021.

- **Mr. Biraj Kumar Sahoo,** Scientist participated in an online workshop on "Learning Crystallographic Texture Analysis with MTEX'2021" organized by Technische Universitat Chemnitz, Dresden, Germany, during 08th to 17th March 2021.

Customer Satisfaction Index (CSI) and Feedbacks

100% of our customers recommended us for providing R&D Services



Completed project as per their commitment NML, Jamshedpur should submit more project proposals needed for Coal industry like Assessment of futuristic elements like Lithium, Cobalt and Aluminium being used in battery industries in India. *—Central Mine Planning Design Institute (CMPDI), Ranchi—CLP 0191*
Very good*—M/s The Ramco Cements Ltd.—SSP 1090*
Good work*—Tata Steel—CLP 0208* Project execution is excellent. Project costs are increasing very high*—Tata Steel Limited—CLP 0190* Very good analysis with knowledge sharing to understand the exact corrosion environment in Tata Steel Kalinganagar. *—Tata Steel Limited Kalinganagar—SSP 1045* Very good*—M/s. Tata Steel Limited—SSP 1190*
We are very much satisfied towards the R&D collaboration with NML and we hope for more project interaction in future. *—Weir Minerals India Pvt Ltd—SSP 1233*
The capability of scientist, Experience in his field Successful completion of project report. *—NTPC Limited, Telangana—SSP 1049*
Formulization of MoU, Agreements, Technology documents and demo made were outstanding. The technology is very relevant in present era. Hopefully technology will be commercialized soon. Director NML and Team Members were very co-operative. Excellent demo and strong desire to have long term co-operation with NML. *—UNQ IND PVT. LTD, Firozabad—SSP 1235*
Competent and knowledgeable members. *—Kharkai Canal Division, Jamshedpur—CNP 0172*
Well executed. *—Institute of Minerals & Materials Tech, BBSR-SSP 1174*
We had an interactive discussion from time to time and outcome of the study is going to benefit ONGC *—ONGC, Mumbai—SSP 1055*
Full utilization of laboratory for industry new grade development. *—Jamshedpur Continuous Annealing & Processing Company Pvt. Ltd.—SSP 1153*
The technology is very relevant at an industrial scale and the support of the team at NML lab made it possible to implement and scale it up at our plants. *—EXIGO Recycling Pvt. Ltd.—SSP 1215*

Indian Metal Crafts

Indian Metallurgy on Postal Stamp

Spouted Lota made of Silver

Paandaan made of copper

Issued by Indian Postal Department on 26th August 2016.

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Patents Filed

S. No.	Title
1.	**A process for production of directly reduced Iron briquettes from LD sludge, mill scale and CDQ**
	Inventors (CSIR) : Dr. Dayanand Paswan and Dr. M. Malathi; Ref: NML/PAT 0585/2020/IN; Assignee: TSL & CSIR
2.	**A process for producing low carbon cold rolled continuous annealed steel with high plastic anisotropy**
	Inventors (CSIR-NML): Mr. Biraj Kumar Sahoo and Dr. Sandip Ghosh Chowdhury; Ref: NML/PAT 0586/2020/IN; Assignee: SAIL & CSIR
3.	**A sensing device for real-time Zinc weight measurement in commercial pad wiping galvanizing line**
	Inventors: Dr. Tarun Kumar Das, Mr. Chandan Dutta, Mr. Alok Kumar, and Dr. Sarmishtha Palit Sagar; Ref: NML/PAT 0587/2020/IN; Assignee: CSIR
4.	**A novel design for preheating of clay mould and resin recovery for melting furnace used in artifacts manufacturing**
	Inventors: Mr. Nimai Halder, Mr. R B Meshram, Mrs. Y Usha, Dr. Palash Poddar, and Dr. K L Sahoo; Ref: NML/PAT 0588/2020/IN; Assignee: CSIR
5.	**Organic/Inorganic composite self-healing anticorrosive coating and a process for preparation thereof**
	Inventors: Dr. Ashok Kumar Mohanty, Dr. Suman Kumari Mishra, and Mr. Shankar Kumar; Ref: NML/PAT 0589/2020/IN; Assignee: CSIR
6.	**An improved process to produce ceramic tiles using overburden as raw material**
	Inventors: Dr. S. K. Nath, Dr. Sanjay Kumar, Dr. T. C. Alex, and Mr. D. P. Sahoo; Ref: NML/PAT 0590/2020/IN; Assignee: CSIR
7.	**A process for the production of Neodymium metal by molten salt electrolysis of Neodymium chloride prepared from Neodymium oxide**
	Inventors: Dr. Shyamal Kumar Maity, Dr. Mallarouth Chandra Shekhar, Mr. Manoj Kumar Runda and Dr. Jayant Konar; Ref: NML/PAT 0591/2020/IN; Assignee: CSIR
8.	**A new electrolysis set up for the production of zinc powder from zinc-containing wastes**
	Inventors: Dr. Sanjay Prasad and Mr. Deo Prakash Singh; Ref: NML/PAT 0592/2020/IN; Assignee: CSIR
9.	**A novel method for the preparation of inorganic-organic hybrid geopolymers**
	Inventors: Ms. Rashmi Singla, Dr. Sanjay Kumar, and Dr. T. Mishra; Ref: NML/PAT 0593/2020/IN; Assignee: CSIR
10.	**Development of hot-dip coating of Al-Si-X (X=Mg, Cu, Sc and Sr) on steel substrate with excellent high-temperature formability for hot forming application**
	Inventors: Mr. Biraj K. Sahoo, Mr. M. G. Walunj, Mr. A. Chakraborty, Dr. V. C. Srivastava, Mr. R. Pais, Dr. L. C. Pathak, and Dr. Gopi K. Mandal; Ref: NML/PAT 0594/2020/IN; Assignee: CSIR & TSL
11.	**Temperature and strain measurement in a tube mould by fiber-optic measurement method**
	Inventors: Dr. Tarun Kumar Das, Mr. Chandan Dutta, Mr. Alok Kumar, Dr. Sarmishtha Palit Sagar; Ref. No: NML/PAT 0596/2021/IN; Assignee: TSL and CSIR

12.	**A process for simultaneous recovery of ammonium metavanadate, vanadium pentaoxide and derivatives from spent catalysts**
	Inventors: Dr. Pratima Meshram, Dr. Abhilash, Mr. Rohit Buddham Meshram, Mr. Jai Narayan Patel, Mr. Akhilesh Shukla, Mr. Sheeba Mashruwala, and Ms. Kiran Rokkam; Ref. No: NML/PAT 0558/2019/IN; Assignee: CSIR
13.	**Ultra-low Si-Al added medium manganese hot rolled steel having strength-ductility product greater than 35GPa% and process for preparation thereof**
	Inventors: Mr. Avanish Kumar Chandan, Mr. Gaurav Kumar Bansal, Mr. Biraj Kumar Sahoo, and Dr. Sandip Ghosh Chowdhury; Ref: NML/PAT 0597/2020/IN; Assignee: CSIR
14.	**Evaluation of high-temperature magnetic phase transition by a non-contact magneto-impedance sensing device**
	Inventors: Dr. Rajat K. Roy, Mr. Nimai Haldar, Mr. Prem Kumar M, Dr. B. Ravi Kumar, Dr. Ashis K. Panda; Ref: NML/PAT 0598/2020/IN; Assignee: CSIR
15.	**A novel warm rolling process for improving strength without compromising ductility in cold-rolled medium manganese steel**
	Inventors: Mr. Avanish Kumar Chandan, Mr. Gaurav Kumar Bansal, Dr. Jay Chakraborty; Ref: NML/PAT 0604/2021/IN; Assignee: TSL and CSIR
16.	**Quenching and non-isothermal partitioning process for strong, tough and ductile low carbon medium manganese steel**
	Inventors: Mr. Gaurav Kumar Bansal, Mr. Avanish Kumar Chandan, Mr. Biraj Kumar Sahoo, and Dr. S. Ghosh Chowdhury; Ref: NML/PAT 0603/2021/IN; Assignee: CSIR
17.	**A bainite-based quenching and non-isothermal partitioning process for the preparation of tough and ductile high strength hot-rolled steel**
	Inventors: Mr. Gaurav Kumar Bansal, Mr. Snehashish Tripathy, Mr. Avanish Kumar Chandan, Dr. V. Rajinikanth, Dr. Vikas Chandra Srivastava and Dr. S. Ghosh Chowdhury; Ref: NML/PAT 0602/2021/IN; Assignee: TSL and CSIR
18.	**A process for oxidative dissolution of copper from sulphides using surfactant assisted chlorine leaching**
	Inventors: Mr. R. Choudhari, Mr. S. Sinha, Dr. D. Mishra, Dr. K.K. Sahu, Mr. J.K. Singh, Mr. S. Shekhar, and Dr. A. Agrawal; Ref: NML/PAT 0601/2021/IN; Assignee: CSIR
19.	**A preparation of post functionalized metal organic framework and its composite polymer beads for separation of rare earth metal**
	Inventors: Mr. Shivendra Sinha, Dr. S. De, Dr. D. Mishra, Dr. K.K. Sahu, Mr. S. Shekhar, and Dr. A. Agrawal; Ref: NML/PAT 0600/2021/IN; Assignee: CSIR
20.	**Strong and ductile non-equiatomic medium entropy alloy and preparation method thereof**
	Inventors: Mr. Avanish Kumar Chandan, Dr. Mainak Ghosh, and Dr. Sandip Ghosh Chowdhury; Ref: NML/PAT 0599/2021/IN; Assignee: CSIR
21.	**CSIR-NML_IPFC - A website for management of activities of Intellectual Property Facilitation Centre at CSIR-NML (Copyright)**
	Authors: Dr. Beena Kumari, Dr. SK Pal, Mr. Santosh Tiwary, Mr. Sudhakara Rao Kogapu, Mr. Ashish Upadhyay; Ref: NML/CR 0100/2021/IN; Assignee: CSIR

Fortune 1000 and ET 500 Clients 2020-2021

HINDUSTAN ZINC LIMITED

AcSIR – NML Activities

In 2020-21, two students have been admitted in the IDDP programme and another two students in the Ph.D. programme (Industry Sponsored). After enrollment in the current session, the total enrollment of Ph.D. students, till date (including those awarded Ph.D), in AcSIR-NML is 45.

All the IDDP students have been awarded CSIR-GATE-JRF.

The students who completed their doctoral degree in the Academic Session 2020-2021 were-

1. Dr. Charu Singh (September, 2020)
2. Dr. Vikas Singh (November, 2020)
3. Dr. Minal Shah (December, 2020)
4. Dr. Aarti Kumari (February 2021)

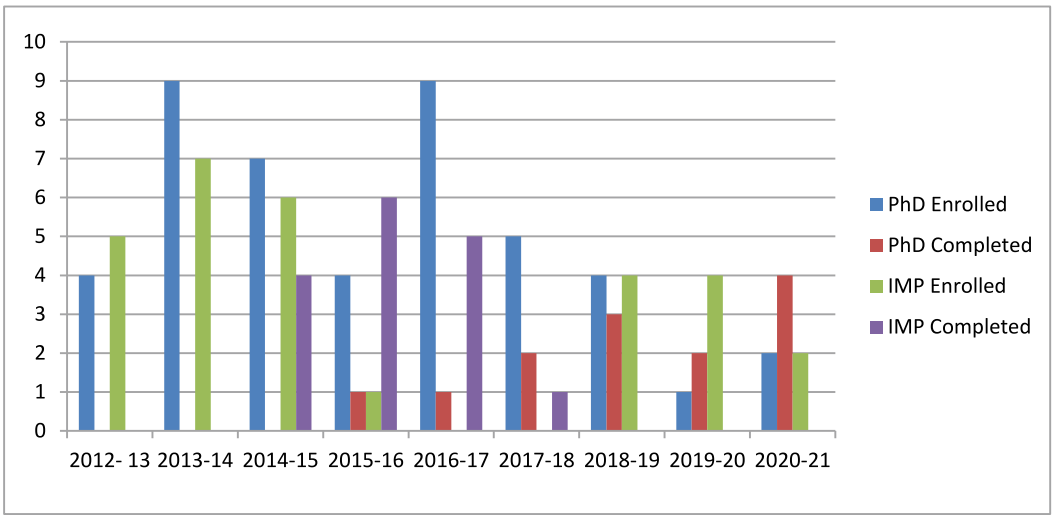

Figure -1 : Student enrollment and completion of Degree

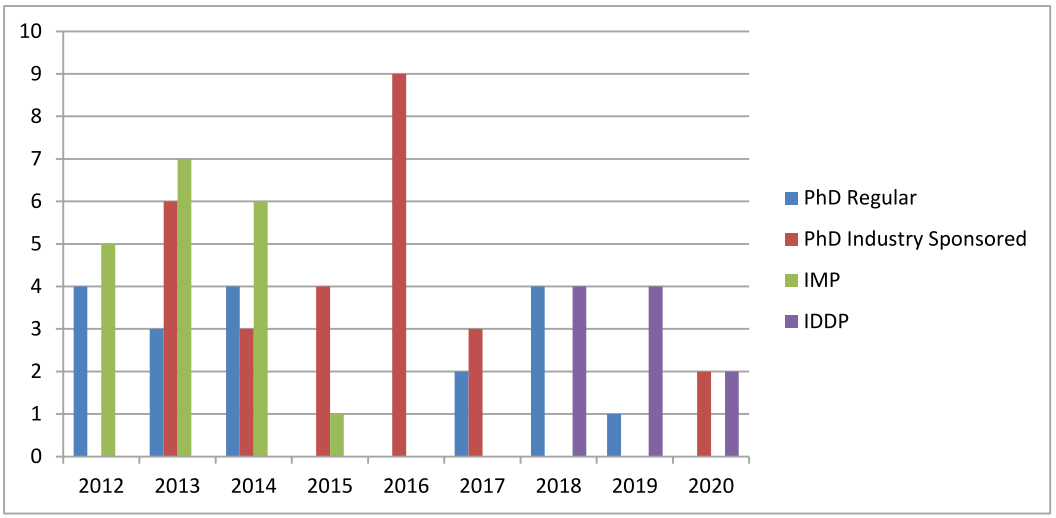

Figure -2 : Student Strength in different academic sessions at AcSIR-NML

Indian Metal Crafts

Indian Metallurgy on Postal Stamp

Nataraja made of Bronze

Iron Surahi

Issued by Indian Postal Department on 26th August 2016.

Sources:

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https://exclusivecoins.blogspot.com/2016/08/371-indian-metal-crafts-set-of-six.html
http://postagestamps.gov.in/Stampsofyear.aspx?uid=2016
http://philamirror.info/2016/08/27/india-post-issued-stampsms-and-sheetlet-on-indian-metal-crafts/

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Giving us feedback, keeping in touch :

We want to hear from you, whether it is a constructive suggestion or a critical observation or any other feedback that you have about this Report.

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