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EDITORIAL

Additive Manufacturing

Additive Manufacturing (AM) is an appropriate name to describe the technologies that build 3D objects by adding layer-upon-layer of material, whether the material is plastic, metal, concrete or one day…..human tissue.

Common to AM technologies is the use of a computer, 3D modeling software (Computer Aided Design or CAD), machine equipment and layering material. Once a CAD sketch is produced, the AM equipment reads in data from the CAD file and lays downs or adds successive layers of liquid, powder, sheet material or other, in a layer-upon-layer fashion to fabricate a 3D object.

The term AM encompasses many technologies including subsets like 3D Printing, Rapid Prototyping (RP), Direct Digital Manufacturing (DDM), layered manufacturing and additive fabrication.

AM application is limitless. Early use of AM in the form of Rapid Prototyping focused on preproduction visualization models. More recently, AM is being used to fabricate end-use products in aircraft, dental restorations, medical implants, automobiles, and even fashion products.

While the adding of layer-upon-layer approach is simple, there are many applications of AM technology with degrees of sophistication to meet diverse needs including:

- a visualization tool in design
- a means to create highly customized products for consumers and professionals alike
- as industrial tooling
- to produce small lots of production parts
- one day….production of human organs

At MIT, where the technology was invented, projects abound supporting a range of forward-thinking applications from multi-structure concrete to machines that can build machines; while work at Contour Crafting supports structures for people to live and work in.

Some envision AM as a complement to foundational subtractive manufacturing (removing material like drilling out material) and to lesser degree forming (like forging). Regardless, AM may offer consumers and professionals alike, the accessibility to create, customize and/or repair product, and in the process, redefine current production technology.

Whether simple or sophisticated, AM is indeed AMazing and best described in the "adding of layer-upon-layer, whether in plastic, metal, concrete or one day…human tissue".

Examples of Additive Manufacturing (AM)

SLA

Very high end technology utilizing laser technology to cure layer-upon-layer of photopolymer resin (polymer that changes properties when exposed to light). The build occurs in a pool of resin. A laser beam, directed into the pool of resin, traces the cross-section pattern of the model for that particular layer and cures it. During the build cycle, the platform on which the build is repositioned, lowering by a single layer thickness. The process repeats until the build or model is completed and fascinating to watch. Specialized material may be needed to add support to some model features. Models can be machined and used as patterns for injection molding, thermoforming or other casting processes.

FDM

Process oriented involving use of thermoplastic (polymer that changes to a liquid upon the application of heat and solidifies to a solid when cooled) materials injected through indexing nozzles onto a platform. The nozzles trace the cross-section pattern for each particular layer with the thermoplastic material hardening prior to the application of the next layer. The process repeats until the build or model is completed and fascinating to watch. Specialized material may be need to add support to some model features. Similar to SLA, the models can be machined or used as patterns. Very easy-to-use and cool.

MJM

Multi-Jet Modeling is similar to an inkjet printer in that a head, capable of shuttling back and forth (3 dimensions-x, y, z)) incorporates hundreds of small jets to apply a layer of thermopolymer material, layer-by-layer.

3DP

This involves building a model in a container filled with powder of either starch or plaster based material. An inkjet printer head shuttles applies a small amount of binder to form a layer. Upon application of the binder, a new layer of powder is swept over the prior layer with the application of more binder. The process repeats until the model is complete. As the model is supported by loose powder there is no need for support. Additionally, this is the only process that builds in colours.

SLS

Somewhat like SLA technology Selective Laser Sintering (SLS) utilizes a high powered laser to fuse small particles of plastic, metal, ceramic or glass. During the build cycle, the platform on which the build is repositioned, lowering by a single layer thickness. The process repeats until the build or model is completed. Unlike SLA technology, support material is not needed as the build is supported by unsintered material.

http://additivemanufacturing.com/basics/

Science and Technology of Clean Coal

Ahindra Ghosh

Introduction

Clean coal literally means coal with very low ash. However, in this paper, volatile matters generated during manufacture of coke from coal such as tar etc., as well as oil and gas manufactured from coal, shall also be included.

Coal is a major fossil fuel that meets about 60% of World's commercial energy demand. Known resources of coal and other solid carbonaceous fuels in the World are far greater than the known resources of petroleum and natural gas. Despite this abundance, reliance on coal as primary source of energy has been discouraged mostly because petroleum and natural gas are cleaner burning fuels and are easy to transport.

There are many books on coal. Hence, I do not have plans to write much on it. To be very brief, coal is formed from trees and other vegetal matters by geological processes over millions of years in the following stages by deposition of sedimentary rocks and consequent heat and pressure.

Wood → peat → lignite → bituminous coal → anthracite coal → graphite. The volatile matter progressively decreases in these stages.

Basically coals are amorphous mixtures containing carbon and carbon compounds, especially hydrocarbons, carbon – hydrogen – oxygen compounds, and some organic sulphur and nitrogen compounds. The inorganic matters embodied in coal is the source of uncleanness, i.e. ash.

In India, coal is mined in open pits at depths less than 600m. The coal has high ash. To reduce ash content of coking coal several 'washeries' have been set up to yield cleaner coal with 15 -18 % ash. But the problem is that the ash is finely disseminated. Hence, Indian coal is difficult to wash because large quantities of carbonaceous matter is rejected as middlings and tailings in washeries.

Table 1 [2] is data for coal reserves of India as of the year 2007. It shows that the total reserves of each coal type are somewhat more than reserves down to 600 m depth.

Table 1:Total coal reserves in India, billion tonnes [2]

Coal type	Total reserves	Reserves down to 600 m depth
Coking coal	30	24
Non-coking superior grade	47	43
Non-coking inferior grade	124	112
Total non-coking coal	171	156
Total coal available	**201**	**180**

The coal at depth more than 600 m from surface is cleaner with lower ash content. Some coal fields such as Deocha Pachami in Birbhum district of West Bengal have resources of coal at large depths. Suitable technology to extract coal from such depth is not currently available in India. It has to be obtained from abroad such as Germany by collaboration.

Panigrahy et al [3] have reviewed clean coal technologies: current status, priorities and implementation. They have provided estimates of total coal resources in India as over 300 billion tonnes. About 70 % mined coal goes for power generation, rest for ironmaking etc. 90 % coal comes from public sector undertakings Coal India Ltd. (CIL) and Singereni Collieries Co. Ltd. (SCCL). Indian coal has high ash (25 – 55 %), and as stated earlier, is difficult to wash due to fine dissemination of ash.

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Currently 93 % coal is mined in open –cast mines [3] near the surface. The advent of surface miner technology is saving energy use in mining, generation of smaller percentage fines and reduction of greenhouse gas emissions (GHG) etc. It consists of several blast holes by drilling and blasting, then blasting of the entire depth by powerful dynamite. Figure 1 shows it schematically.

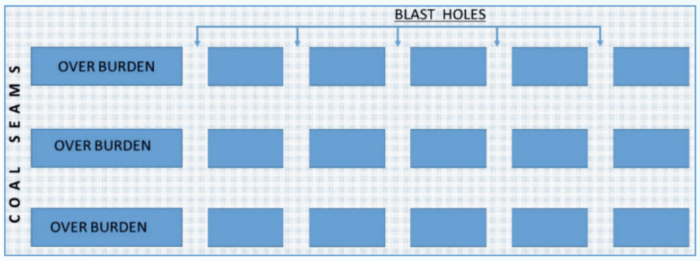

Fig. 1: Drilling in multiple layers of coal seam [3]

Dutta and Ghosh [4] carried out some experimental investigations on devolatilization of Bachra and Hutar coals in connection with their studies on ore-coal composite pellets. Cold –bonded pellets were prepared by steam curing in an autoclave at high pressure employing inorganic binders. In composite pellets the mixture was iron ore and coal. In devolatilization studies, it was alumina powder (an inert material) and coal.

The pellets were heated from room temperature to 1000^{0}C under flowing purified argon at two heating rates. Hence, these were non-isothermal experiments. Rates of evolution of product gases were determined by gas chromatograph and temperature of sample measured by thermocouple embedded in pellet.

Figure 2 [4] shows variation of exit gas composition and W□$_o$ for devolatilization of coal as function of temperature at lower heating rates for low percentage Bachra and Hutar coals. Rate of oxygen loss from pellet (W□$_o$, in gs^{-1}) was computed from rate of evolution of CO and CO_2. H_2 evolved was sum total of both H_2 obtained by pyrolysis of coal as well as H_2 formed by reaction of H_2O of binder with C, CO etc. These two were separated by calculation and it was found that hydrogen evolved due to pyrolysis was about 25 % of total hydrogen evolved.

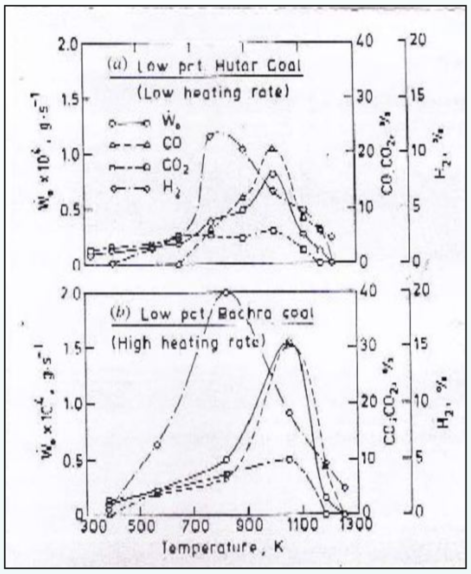

Figure 2: Variation of exit gas composition and W^xo with temperature in non-isothermal devolatilization studies [4]

Environmental Concern

21st conference on environment was held at Paris in 2015. India participated in it, and announce the following action for the year 2030:

- Reduction of emissions intensity by 33 – 35 % from the 2005 level.
- Achievement of 40 % power from renewable energy sources.
- Creation of additional CO_2 sink of 2.5 -3 billion tonnes of CO_2 by additional tree and forest cover.

The Government of India has already announced action plan for the above. All programs on clean coal technology are to ensure not to violate the above. In the following write-ups I shall occasionally mention some environmental aspects.

Coal Beneficiation

Biswal et al [5] have listed coal washing techniques in several countries. In India, the problems are:

- Washeries are mostly old having been set up in 1960s, and they require modernization.
- Coal has high content of mineral matter (MM) which leads to high ash.
- Indian coal is difficult to wash due to fine dissemination of MM in coal substance.

Only few washeries are able to lower ash content properly, for lowering ash further, there would be lots of rejects. Some of the mines , especially in Mahanadi coal fields of Orissa, the coal deposit is banded type and the coal layers are thick and contain 20 -25 % ash. These can be beneficiated to produce coal with 10 % ash by heavy media cyclone, spiral concentrator and flotation process.

Methane can be extracted by drilling wells into the coal seam. The goal is to decrease the pressure of water by pumping out water from the well. The decrease in pressure allows methane to get desorbed from the coal and flow as a gas up the well to the surface. Methane is then compressed and piped to market.

Tens of thousands of methane wells have been drilled, and extensive support facilities such as roads, pipelines and compressors have been installed for CBM extraction in the Powder River Basin of north east Wyoming in the USA. CBM is also an important source of methane in Canada, Australia etc. 7% of natural gas produced in the US comes from CBM. In west Bengal, natural gas is extracted from CBM in coal fields of Ranigunj, Panagarh etc. and piped to nearby localities.

Disposal of water is a problem. At greater depth water is less but salty. There are techniques of laboratory measurement of methane content of coal. Empirical equations also have been proposed.

Coal and Cokemaking

Ghosh and Chatterjee [2] have discussions on:

- Chemical characterization of coal – proximate and ultimate analyses
- Petrographic characteristics – macerals and mineral matters; macerals are the microscopically recognisable organic constituents of any coal, and have three main groups - vitrinite, exinite and inertinite.
- Crucible swelling number (CSN) is an easy test for ascertaining coking characteristics. It ranges from 0 to 9. CSN = 0 indicates no coking characteristics at all. CSN = 9 means excellent coking characteristics. CSN should be at least 3.5 for coke making.

In a typical by-products oven, one tonne of coal (ash free basis) yields approximately

- 750 - 800 kg coke , 45 - 90 kg coke breeze
- 285 - 345 m^3 coke oven gas
- 27 - 34 litres tar
- 55 - 135 litres ammonia liquor
- 8 - 12.5 litres of light oil.

The gas, tar and oil are clean fuels. But by-product ovens are not environment friendly because of emissions. Hence, there have been Worldwide efforts to eliminate them and go for non – recovery ovens, where the by – products are burnt inside the oven chamber. The hot combustion products are employed for raising steam for generation of electricity. However, to the best of my information, by – product ovens are still there in integrated steel plant of India.

Coal to Liquid Technologies (CTL)

Share of coal used for CTL is less than 50 % in the World [9]. Technologies fall into two categories:

- Direct (DCL) : carbonization and hydrogenation
- Indirect (ICL): coal gasification → synthetic gas ($CO + H_2$) → Fisher Tropsch (FT) synthesis (liquid hydrocarbons).

CTL processes require high temperature / pressure with significant energy consumption. Indirect CTL based on gasification followed by FT and methanol to gasoline technologies are now commercially viable. Lots of applied research is required in India.

Figure 3 [10] shows traditional steam reforming reactor for coal. It shows various zones and reactions. The output product gas is a mixture of CO and H_2. Figure 4 shows [10] mols of H_2, CO and CO_2 in the product gas as function of % of H_2O decomposed in the coke bed.

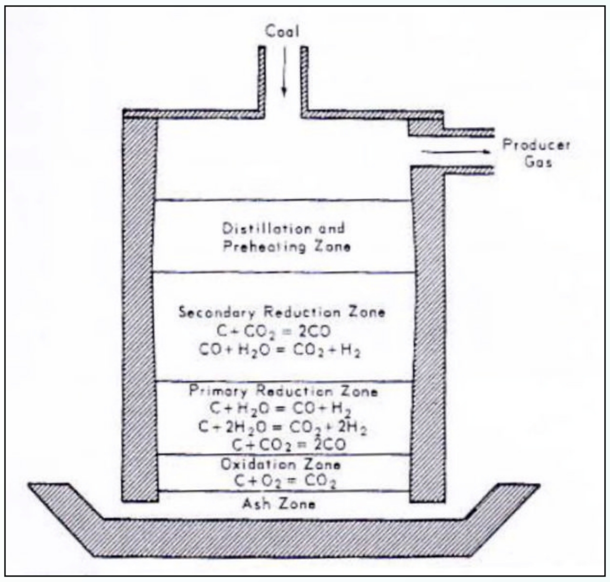

Figure 3: Reaction zones in a gas producer [10]

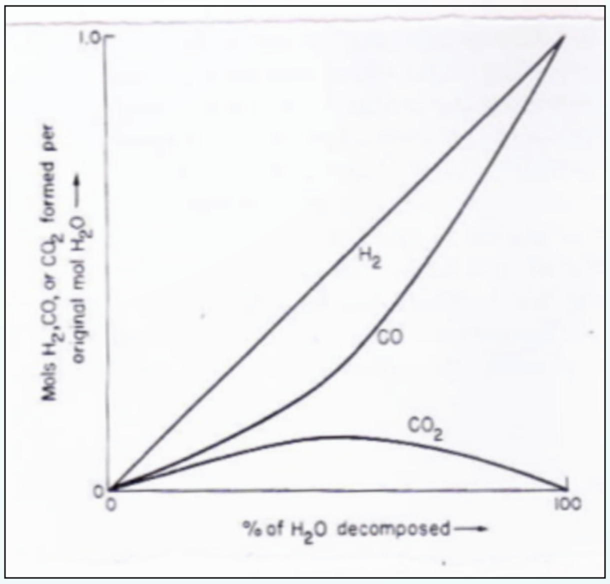

Figure 4: Decomposition of steam in coke beds [10]

The Fischer Tropsch was invented by Franz Fischer and Hans Tropsch while working at the Kasiser Wilhelm Institute in 1920s [11]. Since then many improvements have been made. The term "Fischer Tropsch" is used now for several similar processes. Fischer and Tropsch made many patents and gave the process to factories in Germany in 1936. Germany has very little petroleum but abundance of coal. By FT the coal was being converted into petroleum. Gasification into CO and H_2 by steam reforming is the first step. For FT, Cobalt catalyst is best. But sulphur damages the catalyst. So it should be removed from the gas first.

The largest FT factories in the World are owned and operated by Sasol in South Africa, which has large reserves of coal and not enough oil to meet its demand. The company makes several liquids. The diesel caters to most of the diesel requirements of the country. There are some other plants in the World which employ some kind of carbonaceous materials as starting feed. Now –a-days gasification is done in fluidized bed. Lots of studies are available in literature as to mechanisms of reactions in FT process.

Underground Coal Gasification (UCG)

UCG involves injecting steam and air or oxygen into a coal seam from a surface well. The injected gases react with coal to form a combustible gas which is brought to surface in a production well, cleaned and used as fuel or chemical feedstock. A cavity forms as the coal burns. So the roof is allowed to collapse. This gas is known as synthetic gas (syngas) and is a mixture of CO, CH_4, CO_2, H_2 and higher hydrocarbons. It has a calorific value of $3.56 \times 10^3 – 4.6 \times 10^3$ kJ / m^3. It is mostly employed for generation of power in thermal power station.

In India, UCG was taken up by ONGC and CIL with technical assistance from the then USSR. 13 coal / lignite blocks were tried, but only one block (Merba Road Lignite deposit) was found suitable. In 2015, Government of India approved its UCG policy and identified 8 coal blocks for development of UCG. But lot of R&D efforts would be required for future success.

Circulating Fluidized Bed Gasifier (CFBG)

Sonde et al [12] and Dalvi et al [13] have discussed about CFBG. Earlier I have presented old type gas producer [10] where gasification occurs by passing a mixture of steam and air / oxygen through coke bed in vertical shaft furnace (Fig. 3). However, for the last several decades, CFBG technology has gained popularity. It is very promising and is being advocated [12].

In coal – to – liquid (CTL) processes, CFBG is the modern reactor for coal gasification and methanol production. Thermax Corporation has developed and is operating a CTL gasifier where CFBG reactor is operated at 4 bar pressure using high ash Indian coal, lignite and Pet Coke. A 1 MW power plant of Ruchi Soya Industry Ltd. at Washim in Maharashtra is under commissioning stage [12].

Dalvi et al [13] have discussed injection of solar thermal heat into coal fired power plants for clean coal technology. Already some plants are operational around the World. Price would be competitive with coal fired power plants if the cost of solar power drops to 25 % of existing cost.

Currently temperature of heat transfer fluid from solar to thermal is 400^0C saving as much as 57% coal. All coal can be eliminated if fluid temperature reaches 600^0C.

For development of this technology in India multidisciplinary team efforts would be required consisting of power plant operators, engineers of several disciplines, software developers economists etc. NTPC may be the nodal agency. Solar thermal energy is to be stored for use at night. This is yet to be developed. Molten salt device is being considered.

Raghavan et al [9] have reviewed advanced coal combustion technologies. First supercritical boiler was commissioned by Babcock and Wilcox in the US in 1953. First supercritical power plant was commissioned in India 60 years later in 2012 at Sipat.

Fluidized bed gasifier for coal was pioneered in Germany in 1920. It is known as Winkler generator, and is currently operating in many countries. Indian power industry has successfully migrated from moving grate to circulating fluidized bed combustion (CFBC) in its early days. Considerable technological advances have been made through R&D efforts. CFBC can handle poor quality of coal with even 60 % ash and thus is important for clean coal technology. Cycle efficiency increases as the temperature of CFBC increases. This will be primarily limited by materials problem. For going to 700^0 C, changeover from carbon steel to alloy steel of proper quality is desired.

Currently coal is pulverised to 70 micron. This adds to cost. Raghavan et al [9] have proposed that use of 3 to 8 mm coal would cut down cost. Some experiments have been carried out at IISc Bangalore in laboratory scale unit. R&D has been carried out on catalyst development for production of synthetic gas.

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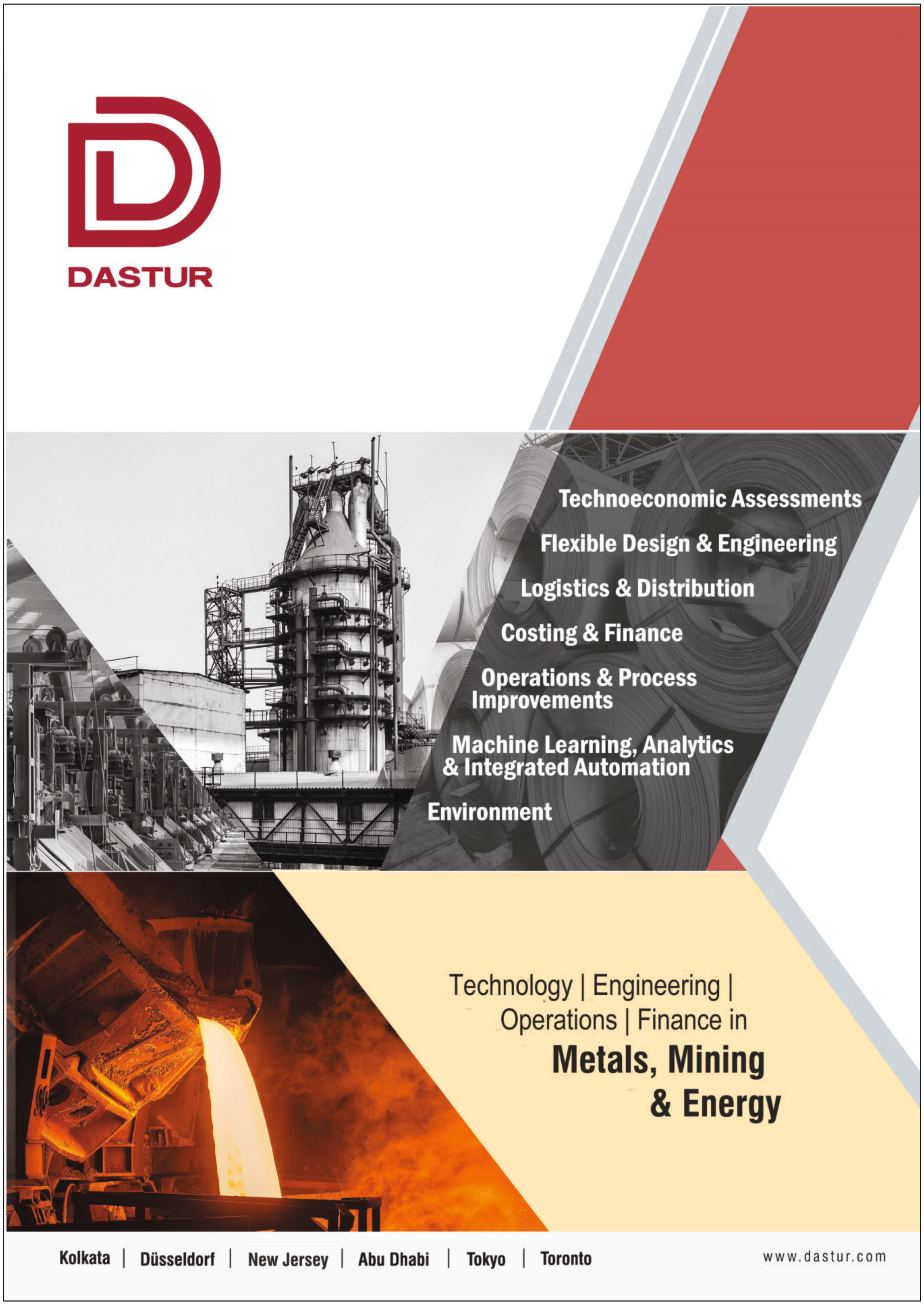
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Introduction

The basic features by which a group of inhabitants are recognized as a distinct community are: movement, activity, culture and their way of living. Each tribe has its own rules which govern their life. There are subdivisions or classes in a tribe according to work they do to sustain themselves. A tribe is thus identified on these characteristics and based upon the measurement yardsticks of these characteristics the first basic category they are put to, is whether they are civilized or uncivilized.

Metals and alloys exhibit all these characteristics: they have their own set of laws and subdivisions, though not externally perceptible with naked eyes, there is movement, purpose of activity and distinctly noticeable behaviour. Even each metal or alloy has its own constitution. In the following paragraphs each such characteristics of metals and alloys have been examined as case studies.

Case study 1: Constitution

Each human community across the world small, big or very big has its own set of laws or precedence, which govern their lives. Bigger groups have written constitution, Governments and law enforcing agencies to regulate and monitor their lives. Any metal or alloy has its own configuration which is the imprint of its norm of life. In a particular block or sheet of metal innumerable numbers of positively charged mass are arranged in periodic and systematic manner surrounded by sea of electrons. Each metal has its own atomic configuration owing to its position in the periodic table and has a fixed crystalline structure, and this governs how it reacts to other elements or environment around it. However, in some metals at different combination of temperature and pressure, i.e., under changed premises, its crystal structure changes, as a consequence of which there are subtle change in their reactivity and behaviour. An alloy, depending upon the elements it comprises of, and at a particular combination of temperature and pressure may manifest in a unique crystal structure or in a combination of more than one crystal structures. Alloying as a separate case study is discussed later. So unlike human societies where laws governing lives are externally imposed, laws governing the activity and behaviour of metals and alloys are imprinted in their structure, i.e. self-imposed and need no external agency to monitor and regulate their activity. No wonder peace and harmony is the order of life in metals and alloys.

Case study 2: Movement

Movement of individuals or groups in human society can be broadly categorized into two types. Routine Movements, like doing the daily choirs of life which in turn varies from age to age, group to group; and Purposeful Movements. Preparing for higher study or a particular career, varies from individual to individual where as political movement and war like movement are group movements. It is needless to mention here that there are inexhaustible number of movements, but here only a few general types are cited to highlight the movements in human society. In metals and alloys there are atomic movements; grain boundary and subgrain boundary movements; twinning and martensitic transformations which are like military movement; and pile up, climb and locking of dislocations which in turn are dependent on conditions of metal working.

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Council Member, IIM.

Case study 3: Motivation and inspiration

Movement especially purposeful movement is directly related to motivation or inspiration. For progress, prosperity and for pursuit of knowledge people, especially those who are young inspire themselves, set goals for themselves to accomplish what they desire. Similarly another group of persons may derive motivation from teachers, coaches and leaders for group activities. What is motivation or inspiration to us, it is driving force for metals and alloys. Atomic movements in metals and alloys occur by diffusion, and lowering of chemical potential is its driving force. Depending on chemical potential atoms can move down the concentration or up the concentration gradients and mostly it is the vacancy mechanism which helps it attaining it. At higher temperatures number of vacant sites in metals or alloys increase, facilitating faster movement of alloys by hopping through the vacant sites. At lower temperatures vacancies decrease, so atoms within the matrix can move only by squeezing past the oscillating atoms just like the movement of pedestrians on a crowded space. Movement of atoms within the metals and alloys discussed above is known as diffusion. Galvanizing, a surface protection process in which zinc is coated on steel is a classic example of diffusion. A close look across the crystals structures moving from zinc to steel reveals a very interesting situation. Zinc and steel has distinctly different crystal structures but the crystal structures of the layers separating them changes gradually from that of zinc to steel in such a systematic manner that there is a complete harmony in the system. Compare this with a national border say between Bengal and Odisha. The culture and spoken language of the people from Bengal to Odisha and vice versa change so gradually but distinctly that there is complete harmony across the border unless external agencies disturb them. Same is true for all borders. The similarities between the alloy system and human society are indeed remarkable.

Phase transformation or transformation of crystal structure is an important aspect of alloys which enables it to attain suitable property to be used for specific purpose. Lowering of free energy is the driving force for phase transformation. For an example at lower temperatures free energy of solid phase is lower than liquid phase so solidification occurs on cooling a metal or an alloy to lower temperature.

With life becoming faster everyday image makeover has become an order of the day, especially with the young generation. Sometimes because of fancy and sometimes because of necessity they like to mould themselves in a completely different avatar. In metals and alloys it is even more frequent. However, the equivalent term for this in metals and alloys is deformation. The only difference between the two is while in human society it is superficial, in metals and alloys it is its physical appearance. Under the application of external force atoms in metals and alloys undergo massive movement causing physical change of shape. If the transformation occurs at very low a temperature that is by cold working the physical and mechanical properties of the metal or alloy undergoing transformation depart from their inherent properties. However, it reverts to original properties if the metal or alloy is subjected to a heat treatment called annealing which is done at higher temperature. It is interesting to note here that the changed properties due to cold deformation are unstable and tend to revert to the original properties. Annealing just hastens the process. The image makeover is also due to external influence and more often doesn't last long. Over working that is excessive manual labour leads to exhaustion and fatigue. But a good night's rest clears all the exhaustion. Annealing of metals and alloys is thus similar to physical rest after a hard day's work.

Case study 4: Cultural exchange

Each human community can be identified by its own cultural heritage which it develops over the ages and pass it on to next generation in a subtle but systematic manner. However, when a community comes in contact with another community perceptible changes occur in both the communities. More often migration of people in small or large numbers across international as well as national borders exposes different communities to each other. If a close look is taken to a migrating communities a few interesting things are noticed. Long time after migration some of them adjust so naturally to the adopted ambience that it becomes very difficult to separate them from the inherent people of the soil. Conversely it also happens that some of the migrant people refrain from the change and cling to their regional cultural identity even after ages. More often gradually but perceptibly both the communities change with time and a cultural transformation occurs in them. The nature of such changes compare very well with alloy formation or alloying in metallic systems.

When a few atoms of a solute metal say ‘B’ cross into a solvent metal ‘A’, generally in liquid state, B atoms dissolve into solution of A. When it solidifies, depending on the thermodynamic properties of A and B, solute atoms B may remain in solid solution of A or it may be rejected from A. Even if solute atoms get into a solid solution of a solvent, except a few systems, solid solubility of a solute in a solid solution is limited. What happens when the solid solubility is exceeded? Along with solid solution of A, B atoms takes into its fold some A atoms and forms it's own solid solution. B atoms alongwith A atoms may also form intermediate phase, which has a different crystal structure than that of either A or B. Obviously the properties of the intermediate phase or compound (when formed at a fixed ratio of A and B) are quite different compared to the terminal A or B crystal forms. An alloy, thus depending upon the composition may comprise of mixture of solid solution of A and intermediate phase/intermetallic compound or mixture of solid solution of B and intermediate phase/intermetallic compound. In complex alloy systems at the intermediate composition range more than one intermediate phases may coexist.

If pure terminal solids are considered as distinct preexisting societies, solid solutions as a dominant society accepting generous modifications from the solutes, the intermediate phases or intermetallic compounds can be considered as formation of inspired multicultural entity.

Contradictions

Though the community of metals and alloys exhibit all the activities that human beings show, on a quick check it fails to show the usual sign of life that living things show like food habits, expressions of joy, love and disagreement, attire and habitats. But all the living things do not possess or exhibit the sign of life as listed above. Nomads have no fixed habitats, oriental expression is famous for lack of perceptible expression, for that matter true saints or hermits portray no emotions that is they are neither amused nor sad nor angry, animals and trees don't dress. In this regards the close resemblance metals and alloys have, are with the trees which till about 100 years ago were considered nonliving things. However, a few things can still be said in defence of metals and alloys. Metals and alloys may not seem to take or derive substances to sustain themselves but it is a fact that they survive only in good environment. Iron and steel exposed in the open moist corroding environment gradually degrades back to the minerals from which it is recovered. Metals and alloys when happy are shiny. By constituting crystals of different metals in an alloy can coexist even when atoms of these are not soluble in each other, a situation like this is perhaps the main cause of disagreement in human society. Consider two metals A and B which do not have any solid solubility in each other, but still then these may form eutectic alloy of suitable and useful application. A mineral from which a metal is extracted is found only in specific locations. Finally coatings, paintings or oxidised layers can be considered attires of metals and alloys.

Conclusion

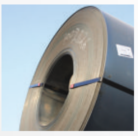
Metals and alloys need genius of likes of Sir Jagadish Chandra Bose to discover a very advanced instrument to demonstrate to the world that there is life in them as well. Till such a genius comes along metals and alloys will continued to be called non-living thing.

Acknowledgement: My years with students at Jadavpur University

MAKING INDIA STRONGER FROM WITHIN

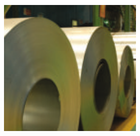
The flagship company of US$ 13 billion JSW Group, JSW Steel is one of India's leading integrated steel manufacturer. It adds to India's strength with an entire gamut of steel products - Hot Rolled, Cold Rolled, Electrical Steel, Galvanised, Galvalume, Colour Coated Sheets & Profiles, TMT Bars, Wire Rods, Special Steel Bars, Rounds, Blooms, Spring Steel Flats and Billets & Blooms.

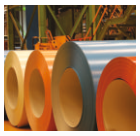
O&M 5346


Hot Rolled


Cold Rolled


Electrical Steel


Galvanised/ Galvalume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JSW Steel

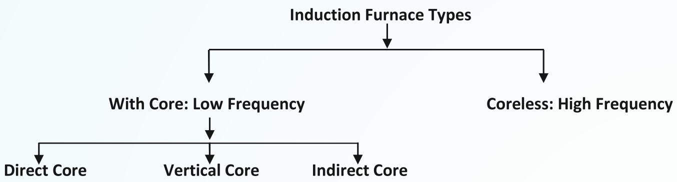
Intra Disciplinary Technology Transplantation for Improving Induction Melting of Steel

Suhrid Kumar Roy *

Introduction

The article proposes a process configuration for secondary steel making by Induction Melting (IM) with technologies transplanted from related areas and introduction of new ideas to save costs by lowering specific energy requirement, utilizing and reducing pollutants with improved steel quality. Currently, IM furnaces have efficiencies well over 90% but the process route has remained unchanged. India is one of the first countries to adopt IM route to produce stainless steel for utensil making and then pencil ingots for rebar. About 4.5 mill tons of steel of various grades was made by this route in 2001-02 and the production has increased since then [1].

Types of Induction Melting Furnaces



What is Induction Melting?

IM furnace is a coreless one where the metal charge is the core. Alternating electric current conducted through a coil of water cooled copper or aluminum tubing creates a high frequency reversal of magnetic polarity resulting in rapid heating/melting of the charge but not the furnace body. The depth of penetration of the heat of the melt is inversely proportional to the frequency of the AC applied. Smaller the volume of the melt, higher can be the frequency with greater power that is quicker melting with reduced stirring homogenizing the bath chemistry and the temperature [2] Excessive stirring increases gas pick up, lining wear and oxidation of alloys. The degree of stirring is also influenced by the size and shape of the induction coil and density/viscosity of the molten metal. In IM, the magnetic field produces stirring action of the molten metal like that of a rotor of a motor as shown in the following diagram (Figure-1).

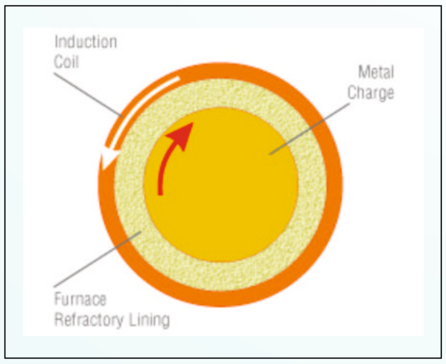


Figure 1. Electrical current flowing in opposite direction to flow of the induced current as per Fleming's rule

*Member IIM

Why Induction Melting?

1. It has lower capital and operating cost than a similar EAF; so suitable for MSMEs.
2. No consumable graphite electrodes as in EAF.
3. Consumption of refractory is lower than EAF.
4. The specific energy consumption hovers around 540/550 kWh/ton [3].
5. Has lower load requirement on the electric grid with less of spikes.
6. Provides higher yields with lower losses of Ferro-alloys added.
7. Comparatively cleaner i.e. less polluting with lower noise level than EAF.
8. Improved temperature control than EAF

The Table -1 shows comparative values for EAF and IM:

Table -1 : Comparative values for EAF and IM

Sl. No.	Item	EAF	IM
1	Energy Consumption (kWh/t)	510-650	520-550
2	Refractory Consumption (kg/t)	4.1 -4.2	3.4-3.6
3	Electrode Consumption (kg/t)	2.4-2.6	Nil
4	Oxygen (N Cum/t)	15-25	Nil/Forging scale
5	Flux (kg/t)	25-28	Nil/Optional
6	Dust Generation (kg/t)	6-12	1-2
7	Noise Level dB (A)	95-120	82-86
8	Slag (kg/t)	65-72	11-15

The disadvantages of IM are:

- The low thickness of refractory wall poses the risk of cracking.
- Needs better quality of scrap than that for EAF.
- Limited decarburizing, desulphurizing and dephosphorizing in comparison to EAF.
- Relatively lower capacity of furnaces unlike EAF.

Furnace capacities and specific energy requirement.

Metal holding capacity of an IM furnace varies from few grams to as high as 65 tons. A preheated, one-ton furnace can melt a cold charge to tapping readiness within 90 minutes or less. AC power with frequencies varying from 50 Hz to 10,000 Hz is used. Power supplies range from 10 kW to 42 MW for melt sizes of 20 kg to 65 tons respectively [4]. The following gives a general idea about gradual tapering of specific power demand for steel making spanning three decades (Figure-2).

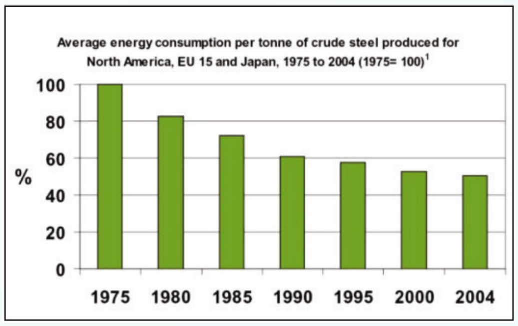


Figure 2. Chart showing decreasing rate of energy usage in steel making over the years.

For the purpose of general information, route-wise specific energy requirement in GJ/ton of crude steel [5] is given below for comparison:

- Ore/Coke/BF/BOF: 19.8-31.2
- DRI/Scrap/EAF: 28.3-30.9
- Scrap/EAF/IM: 9.1-12.5

Demand for ingots

Presently continuous cast sections predominate. However continuously cast sections do not cater to odd sizes in low tonnages. So ingots are still needed to fill in the demand gaps in these sizes particularly in air hardening grades. Typical applications involve forged products like large turn tables, ring gears for wind power generators, turrets for mounting guns in tanks/armoured vehicles/ships, rockets/missiles launchers, earth moving/mining/material handling equipment, construction industries, forged valves etc.

Eccentric bottom tapping

Eccentric bottom tapping (EBT) [6] is well established in EAF but not so for IM. EBT with liquid metal heel of about one third of the furnace metal capacity expedites melting increasing production rate. Charging of preheated scrap expedites melting further. Refractory for EBT and use of slide gates for tapping management can be implemented for an IM furnace to accrue the benefits. A typical arrangement for EBT as applicable for EAF is given for reference in Figure-3.

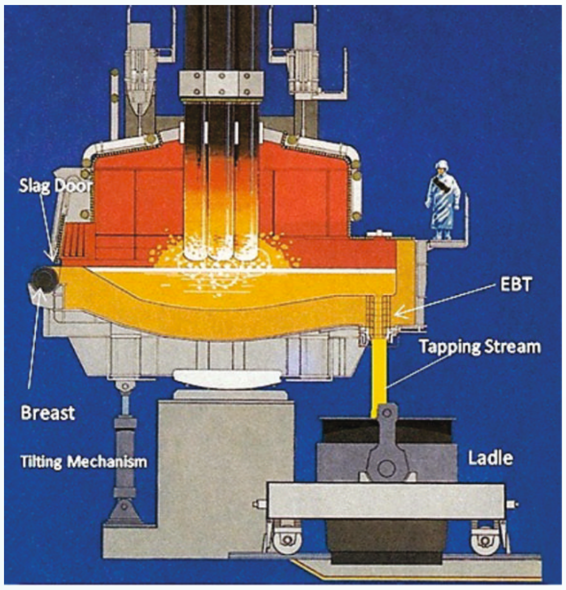


Figure 3. Schematic diagram for Eccentric Bottom Tapping (EBT) for EAF.

Preheating scrap and cleaning of exhaust gases

Exhaust gases with pollutants from IM furnaces [7] is led into a scrap bucket with a clamshell type bottom to preheat the scrap [8]. Preheating scrap reduces specific energy consumption for steel making and also removes moisture, oil, grease, plastics and rubber, as these are the sources for increasing dissolved hydrogen in the metal. After pre-heating the scrap, the gases are sucked/led through baffles/bag house to collect the accompanying dust. The gases are finally pushed through a water sprinkler/scrubber to arrest the majority of the CO_2 and Respirable Particulate Matter (RPM) [9]. A schematic diagram for the above as used in EAF is as shown (Figure -4).

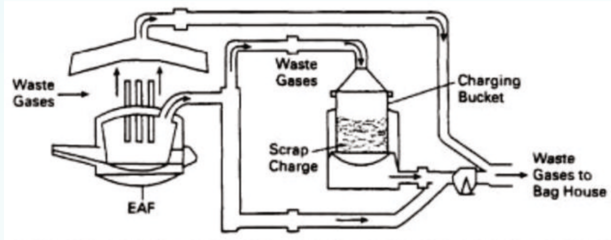


Figure 4. Schematic diagram for a conventional scrap preheating system for an EAF.

Dual furnace IM route

The proposed route utilizes a pair of induction melting furnaces, one for melting and the other for refining (LRF).This will enable the system to be versatile increasing quality of metal and productivity. For producing commercial grades both the furnaces can be used on melting mode. The functions of an IM furnace as a refining unit are stated below:

- IM while refining holds the temperature of metal without electrodes as in LRF.
- Homogenization of steel temperature and chemistry through stirring is inherent for IM so Argon purging is not essential as in LRF.
- Additions of ferroalloys oxidants etc. can be done as in conventional LRF.
- Cored wire addition of CaSi for morphology control of inclusions/desulphurization can be done.
- Act as a buffer for downstream equipment and process (if any) allowing time in case of a break down.

Aluminium killed steels have less than 5 ppm of dissolved oxygen. Steel produced by IM have low nitrogen and hydrogen content. Sulphur content of 20 ppm or less can be achieved by using calcium aluminate or by injecting flux of 70%CaO and 30%CaF_2 [10]. Recirculating bag house dust and forging scales comprising oxides of iron can provide both oxygen and add iron to the bath utilizing what is termed as pollutants.

Argon rinsing

Conventional LRF have argon purging in the ladle from tapping onwards for stirring and scavenging of inclusions. In case an IM is doubled up as a refining unit, the stirring action is inherent. Dehumidified Argon purging @ less than 0.6 N cum/min [10] can be done after transferring the metal to the ladle and continued through vacuum degassing till end of teeming [11].

Degassing by bell type vacuum degasser

Low/high carbon or alloyed/non alloyed type steels, all need vacuum degassing to remove dissolved gases. A bell type vacuum degasser with a four bar linkages, avoiding crane handling, can be used [11]. Due to ferro-static pressure, effectiveness of degassing decreases from the top to the bottom of the steel bath i.e. the depth of molten steel. So a wide mouthed ladle with lower depth is preferred.

Unconventional yet proven method for hydrogen removal:

Use of tablets of Hexa Chloro Ethane used extensively in degassing of Aluminium have been successfully used in ladles of molten steel to bring down dissolved hydrogen level to 2.5 ppm or so on a number of occasion. The method though is not readily acceptable to the industry, but has been proved successfully in secondary steel making units for quite a few casts when the degasser broke down. In absence of Hexa Chloro Ethane tablets, commonly available of CaOCl in powdered and dehumidified form can also be used. Chlorine has strong affinity as a highly electro negative element to Hydrogen as per common knowledge of chemistry and is used in Aluminium degassing for decades [13].

Direct Teeming from Furnace

For commercial grades of plain carbon type for rebars etc., not needing argon rinsing or degassing, direct teeming into the trumpets to feed the ingots can be done by tilting the furnaces. This eliminates the cost for maintaining elaborate ladle preparation arrangements and the floor area required for the same with associated systems. This is a system widely used in the unorganized sectors and can always be looked into by the qualified metallurgists and researchers for further improvement if needed.

Arrested/Slow Cooling of Alloy Ingots

Bottom teemed broad end up hot topped ingots is a standard way of producing low and medium alloy steels which need to be cooled in a controlled fashion. A concept of fabricated reusable split type insulated cover can be slid/rolled into position covering the teemed ingot to resist rapid cooling [12] (Figure-5).

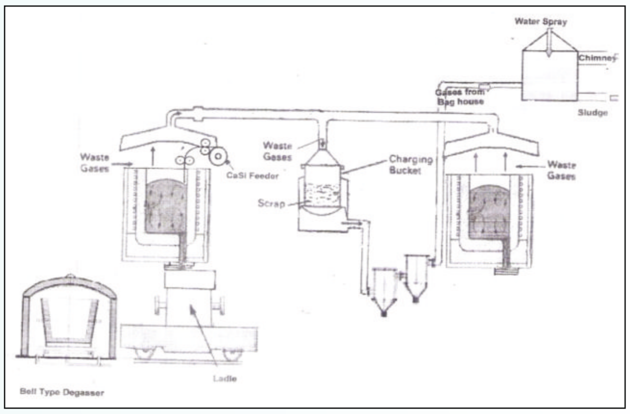


Figure 5. A schematic diagram shows major components of the proposed new IM route. The furnace on the left is on refining mode and the one on the right is on melting mode.

Observation

1. The proposed route of scrap preheating is expected to lower energy requirement at least by 10%.
2. Twin IM for melting/refining with the use of bell type degasser and a split type insulation cover are expected to increase productivity with reduced hydrogen content of metal at a low cost.
3. Water/alkaline solution spray on waste gases will reduce RPM and CO_2 emissions.
4. Recycling of forging scales and bag-house dust may provide process oxygen and add metal, reducing cost and pollutants.
5. Observations made showed dissolved hydrogen content of about 2.5 ppm thro' the above routes at a lower cost.
6. Facilities can be set up in multi-tier form to save on land and in a phased fashion to spread out the capital requirement.

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12. Suhrid Kr.Roy; Unpublished Information/work for portable reusable split type heat insulating covers for arrested cooling of ingots.
13. Suhrid Kr.Roy; Unpublished Information/work on use of CCl6 and CaOCl in ladle with a capacity of about 35 tons for over 10 casts of various grades.

Plant Visit to Star Wire India Ltd, Ballabgarh*

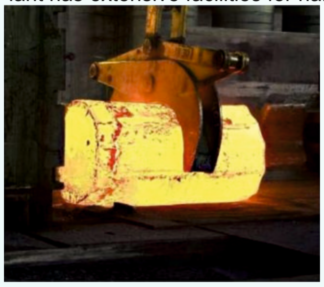
SWIL, one of the leading Mini Steel Plants, is engaged in the manufacturing of Alloy Steels, Stainless Steel and Special Steels for diversified engineering applications in shape of castings, forging and rolled products. The plant is fully equipped with modern equipment and testing facilities which have created confidence and ability for manufacturing various sophisticated grades of steel conforming to international and National standards. Various kinds of Special steels cater to requirements of Indian consumers, and the products are also exported to ~ 20 countries. SWIL has its own research and development centre to facilitate the manufacturing activities and is also catering to engineering and manufacturing industries for failure analysis and other analytical activities.

Manufacturing Processes

The major Manufacturing facilities at different units/locations are:

- Steel Melting, Refining and Casting Ingots using Electric Arc Furnaces, Induction Furnaces, Ladle Refining Furnaces, AOD Convertor, VD/ VOD processes for Heat Sizes which can go up to 25/ 28 MT
- Electro Slag Refining Process using State of the Art Technology from ALD, Germany to produce ESR Ingots for very special applications.
- Casting Liquid Steel into Heavy Castings (Foundry Operations) weighing up to 100 MT single piece, for Power Sector & other Engineering Applications.
- Hot Forging of High Quality Ingots into Forged products, Semis through a 2000 MT Press as well as a pneumatic Hammer.
- Hot Rolling of Ingots/ Semis on various Mills: 20 Inch Mill, 18 + 14 + 10 Inches Mills, and 18 + 12 Inch Mills.
- Extensive facilities for Ingot/ Forged Product/ Rolled Product Conditioning & Finishing are available, e.g. Swing frame grinders for Surface Conditioning, Hydraulic Presses for Straightening, Roller Straightening Machines, High Speed Band Saw machines for Cutting using HSS & Carbide blades, etc.
- Heat Treatment of Forged and Rolled Products (hardening, tempering, solutionising, annealing, spherodising etc.) in Batch type Bogey Hearth furnaces to do heat treatment of 10 meter long rolled product, as well as Continuous Hardening and Tempering Operations.
- Bright bar finishing operations including Straightening, Centreless Grinding, Peeling (more than 100 Centreless Grinders and Peeling machines) to produce Engine Valve Steels and other Bright Bar Grades of steel
- Advanced Research & Development facilities where Steels and Materials can be tested for Mechanical, Physical, Chemical and Metallurgical properties. The laboratory is NABL approved.

Plant has extensive facilities for handling large ingots as shown below



Boiler Quality Ingot

Boiler Quality Ingot

Report received from IIM Delhi Chapter

Products

Products manufactured by SWIL cater to the demands of a wide spectrum of industries viz. Automobile Industries, Power Equipment Manufactures, General Engineering Industries, Steel Plants, Cement Industry, Sugar Industry, Mining & Mineral Industries, Petro-Chemical Industry, Thermal Power Stations, Engine valve manufacturers, Railways, Ordnance factories, Defence, Aerospace, Para Military Forces and other Engineering Industries.

Product Segments are:

Energy Sector Steels

- Complex Alloys for extreme applications such as
  - Super & Ultra Super Critical Parameter stream & Gas Turbines
  - High Corrosion & wear conditions for Hydro turbines (Nitonic Steel)
  - Low temperature (cryogenic) conditions for valves
- Steel Castings for Power Sector (upto 65 MT single piece)
  - Steam turbine castings & valves for sub & super critical parameter applications
  - Hydro turbine & pump castings for medium & large projects
- Blade Steel & Rolled/Forged materials (ESR & non-ESR process)

Special Steels for Defence Nuclear & Aerospace

- PINAKA Pre-forms
- End Fitting Billets
- Critical Forgings for Nuclear power projects
- Weld consumables
- Forgings for fuel handling machines
- Plates & Sheets
- Bulb bars for Navy

High Speed Steels

- AISI Specs. M2 for Milling Cutters, drills, reamers, taps, broaches etc.
- AISI Specs. M3-2 for Dies, punches, hacksaws, taps etc.
- AISI Specs. M35 for Hobs, Milling cutters, hacksaws, broaches, reamers, etc.
- AISI Specs. M42 for Bi-metallic bandsaw blades, milling cutters, drills etc.
- AISI Specs. T1 for Knives, taps, drills, cutters, wood quality tools etc.

Die Steels

- AISI Specs. D2 for Cutting, punching stamping tools; Shear blades, thread rolling dies, etc.
- AISI Specs. H11 for Punches, Mandrels, Die Inserts, Hot shear blades, Moulds for plastic materials, etc.
- AISI Specs. H12 for Die casting dies, Forgings dies, hot shear blades, extrusion tooling, etc.
- AISI Specs. H13 for Mandrels, pressure pads, bolsters, die cases, die holders and adaptor rings, etc.
- AISI Specs. L6 for Rams, bolsters, mandrels, plunger sleeves, chipping beds, press & hammer dies, etc.
- AISI Specs. P20 for Die holders, zinc die casting dies, backers, bolsters and injection moulds, etc.
- AISI Specs. P20S for Die holders, zinc die casting dies, bolsters and injection moulds, etc.

Engine Valve Steels

- These high Alloyed (Mn-Ni-Cr-Mo-N) magnetic and non-magnetic steels are used for Inlet & Exhaust Valves for

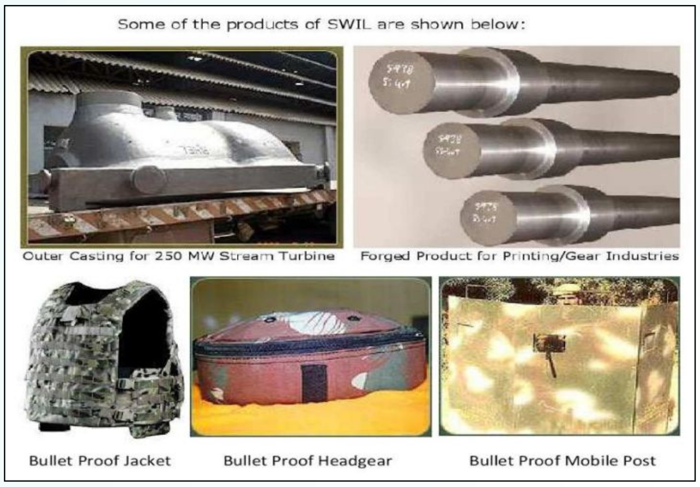
cont. to page 18

cont. from page 16

- for IC engines, which work under extreme conditions of severe heat & corrosion stress. These steels retain their properties at elevated temperatures. Specific Customer requirements are met as per India/International (IS/DIN/DS/SAE/JIS) standards

Bullet-proof Steel patented as `Phantom Steel'

- Bullet proof Jackets
- Bullet proof Cars/ Personnel Carrier
- Bullet proof Helmets/Patka
- Bullet Proof Mobile Posts
- Bullet proof Election Podium
- Bullet proof Sentry Post
- Steel for Cartridge Case & Gun Barrel



Some of domestic clients of SWIL are – Valve Steel (Rane Engine Valve; Sriram Piston Rings; Eaton Industrial Systems; Varroc Engineering; AVR valves; Automotive Valves; SSV valves; Toshiba; Nextech Engineering; etc.), Forged Quality Ingots (Bay Forge; Bharat Forge; Rajkumar Forge; Choudhry Hammer; Eschjay Forgings, Pushpman Forgings; Achme Forgings; etc.), Forged products (Manugraph India; Printer House; Triveni Engineering; Fender; Eleon etc.)

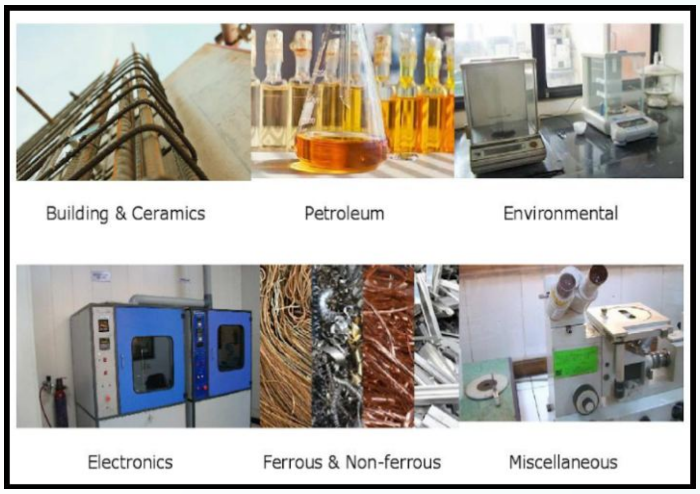
Some of Global Customers of SWIL are – FM Global, Technostar SRL Italy, Mahle Global; Eaton Global; Shinhan Valves, Supar Supap Ve Parca Sanayi Ticaret A.S., Turkey;Federal Mogul Valves (Pty) Ltd, South Africa;Supsan Motor, Turkey; Siemens Germany, Alstom Germany, Skoda Czech Republic, Technistar S.r.l.Italy, Ivam S.r.l.Italy, Paradowsay AMP S.J.Poland, Goons Motor; Nittan Italy etc.

Total Productive Maintenance (TPM)

SWIL has extensively adopted TPM practices to adhere to strict process/product quality of International standards. An Interactive presentation on TPM was made to IIM-DC members by Mr S K Sinha, Advisor (TPM) focussing on various related activities.

Testing Division

SWIL Testing Division was established in the year 1994 to undertake testing the quality in the fields of Ferrous & Non-ferrous Alloys, Water and Building materials. Over the decades, it has expanded into further fields such as Air, Oil and other testings. "Quality Centered" team (approach accompanied by NABL Accreditation) ensures testing of the finest quality. Keeping in mind the growing markets, they have now expanded into Electronic Testing which is NABL and BIS Certified. A number of Outside agencies avail the facilities of Testing Division.



The Visiting Team went around modern facilities of the Unit and had extensive deliberations with the senior officials.

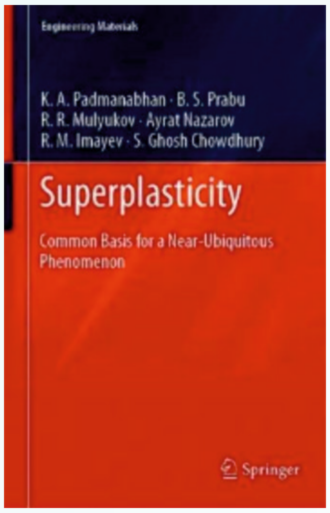
"Intellectual growth should commence at birth and cease only at death."

—Albert Einstein

BOOK REVIEW

"Superplasticity: Common Basis for a near Uniqitous Phenomenon"
by K A Padmanabhan,
S Balasivanandha Prabhu,
R R Mulyukov,
AyratNazarov,
R M Imayev and
S GhoshChowdhury

Springer Nature, 2018
Pages: 428, Price: € 118.99



Superplasticity is a well-known phenomenon in which materials under certain conditions exhibit phenomenal elongations (> 200% and usually during tensile loading). However, this definition is rather technically incorrect as elongation is not a property of state. Originally this phenomenon was observed in metals, intermetallics and ceramics. However, in recent times this phenomenon has been observed in very wide class of materials such as bulk metallic glasses, poly-glasses, geological materials, ice and exotic materials such as carbon nano-tubes. This begs the question, is there a common physical origin for such a near-universal phenomenon?

The book, 'Superplasticity – common basis for near-ubiquitous phenomenon', by Prof. K.A. Padmanabhan and co-authors and published by Springer-Verlag in 2018 (ISSN: 1868-1212) in the series on Engineering Materials, precisely addresses this aspect. This is a third expert level book from the same group, all published by Springer. The book has 9 chapters and presents a combined perspective of materials science and design, mechanics and performance of this phenomenon and its applications. In the introduction chapter, the historical origins are traced, and superplasticity is classified into structural and environmental superplasticity. Chapter 2 deals with the mechanics of superplastic deformation and discusses the constitutive equations for superplastic flow. Chapters 3 to 7 present exhaustive experimental results on all classes of materials exhibiting structural and environmental superplasticity. Chapter 8 presents phenomenological and physics based modeling approaches and discusses their advantages and limitations. Chapter 9 presents analysis of superplastic forming from continuum, mechanics and numerical simulations as well as successful industrial applications of the phenomenon. The appendix presents a wealth of experimental data (a treasure for engineers and scientists alike!!).

This is a very lucidly written book in simple language, and makes reading a pleasure. I have had the privilege to have taken a course on Superplasticity offered by Prof. K.A. Padmanabhan during my post-graduation at IIT Madras (more than 25 years ago) and we referred to the first book in this series. It is amazing to see enormous strides made in this field since then with significant contributions being made by Prof. K.A. Padmanabhan and his group. The present book captures all these developments and is highly recommended to those practicing engineers and scientists dealing with materials forming in general and superplasticity in particular. This is an advanced level text book for post-graduate and research students for courses on superplasticity / materials processing / manufacturing / high temperature deformation.

V Subramanya Sarma
Professor, Indian Institute of Technology Madras
Chennai

ADVERTISERS' INDEX

Deep-sea mining opens mineral opportunities on the seabeds

Maritime exploration programmes around 150 years ago identified the existence of minerals on the seabed. Since then, one could say the arguments for and against mining seabed minerals have ebbed and flowed. Seafloor massive sulphides (SMS) and cobalt-rich crusts have garnered economic interest in deep-ocean mineral deposits. But the debate is sometimes clouded by the term manganese nodules being applied to deposits comprising several minerals, for instance, nickel and copper. In fact, manganese has a much higher concentration than nickel plus copper. Another, more appropriate term, is polymetallic nodules.

By the mid-1970s, consortia had formed to exploit nodules in the north-eastern Pacific Ocean between the Clarion and Clipperton Fracture Zones (CCFZ). However, the intended commencement of mining never happened as metals prices dropped worldwide. In the years since, 16 exploration contracts in the CCFZ have been agreed or are pending with the International Seabed Authority.

To some extent, this increased interest in seabed minerals follows the increased demand for minerals as a whole, with existing mineral resources facing the dual challenges of decreasing resources because of current extraction rates and a lower mineral quality.

US Geological Survey Pacific Coastal & Marine Science Center's Research Geologist, Dr James R Hein, commented on the quality of land-based minerals to Materials World. 'The deposits that can be mined at a profit on land have to be large deposits and may not be of the highest grade because the amount of infrastructure and investment required at a mine site prohibits mining small, high-grade deposits', he said.

'So, the new generation of land-based mines will be deeper, open-pit mines will become much larger due to lower metal grades, and underground mines will be deeper and also huge in size. Small, high-grade ores on land do exist, but may not be mined, except perhaps by artisanal mining in places.'

So why seabed mining?

The case for seabed extraction is sometimes deemed acceptable because it does not have other disadvantages of on-land mining – there are no people at the mine site to experience the disruption to their health, the breakup of their community or the need to move entire villages.

In the case of SMS against nodules and crusts, seabed minerals generate a smaller footprint in terms of size of operation, but in all cases there are lower emissions from mining machinery, little over-burden and no need for surface roads, ore transport systems and substantial construction costs.

Mining techniques, too, are straightforward even if this form of mining is in its infancy. Extraction has been delayed because the development of highly specialised and hitherto unknown technology has held up advancement. Exploration offers its own challenges, as marine-oriented scientific sampling, photography and research must be factored in.

In short, actual mining of deep-ocean seabed mineral resources is still some years away. However, for decades now, seabed mining has been happening in coastal waters in depths of up to 150m.

If sea mining is allowed

'Different methods are required for the different SMS, nodules and crusts,' Hein said. 'Four or five methods have been developed for mining SMS, but none is favoured because mining has not yet started and testing has not been completed. For nodules, several methods have been developed, with none favoured for the same reason. For crusts, methods as far as I know have not been developed although much of that work has been kept proprietary and may exist.'

Various potential methods for mining the seabed have been put forward. They include the use of remotely operated vehicles (ROVs) which would operate on the seabed itself, and would scoop up the nodules. The latter would be conveyed from the ROVs via a pipeline or a continuous-bucket dredging system, both ending with a platform or ship on the surface.

At this point the platform or vessel would separate the water from the nodules, which would be released back into the sea, with the nodules taken onshore for processing and sale.

The right quality

Considerable time has been devoted to discussing whether minerals on the seabed are of the quality demanded by the organisations likely to purchase them. Hein suggested that the grades in question were excellent, and there are good tonnages available in terms of crusts and nodules. When it comes to the SMS, small deposits with very high grades can be mined because the mining ship – the infrastructure – can be moved from one small deposit to another.

However, Hein sounds a note of caution. 'The profitability will not be known until mining actually takes place,' he said. 'There are many unknowns, such as the longevity of the mining equipment working continuously in extreme environments, which will be critical, and of course global metal markets cannot be predicted, although this may be somewhat lessened by the fact that more than one metal will be extracted from the marine mineral deposits. Right now, the many critical factors that must come together for profitable deep-sea mining look promising for the companies. This requires that the operations will take place in the most environmentally sound ways possible.'

Cook Islands case study

Manganese nodules are identified within the Pacific Ocean, with an abundance in territories such as Kiribati and the Cook Islands. An estimate six years ago determined the Cook Islands' Exclusive Economic Zone (EEZ) hosts 10 billion tonnes (Bt) of manganese nodules – the second largest deposit after the CCFZ's 27Bt. The CCFZ nodules are lower in cobalt but higher in nickel and copper.

One technical term relevant here is the seabed of the Cook Islands' – the Cook Islands' EEZ, ocean floor and subsoil, which extends for 200 nautical miles, as defined by the United Nations Convention on the Law of the Sea (UNCLOS). In reality this means the Cook Islands can explore and exploit a total marine area of 1,830,999 sq. km.

Numerous surveys since the mid-1970s have provided a resource database that enables marine scientists to gain a reasonable indication of the location, size and content of the seabed minerals resources within the Cook Islands' EEZ. Much more resource definition, as well as environmental studies of the ecology of the seabed where the manganese nodules are identified, need to be carried out before the feasibility of mining the nodules can be determined. This will be done under exploration licences granted to mining companies that can demonstrate that they have inter alia the necessary technical and financial resources.

Mining and the environment

As with any mineral activity, there are always environmental considerations. On 8 November 2018, The Economist article Mining the deep ocean will soon begin asked, 'what will it mean for existing denizens of the abyss?'.

The article reported that in 2013, Natural History Museum, London, Research Fellow, Dr Diva Amon, recorded seeing a whale skull on an expedition to the CCFZ. It lay on beige silt, 4,000 m beneath the surface and was covered in a black coating. This latter meant the skull was millions of years old with a coating. The Economist said was 'made of the same slowly accumulating metallic oxides as the potato-like ore nodules that are drawing miners to the area'. It continued that would-be seabed miners visualise seabed mining as a multi-billion dollar industry. One additional factor is seabed minerals are not just abundant but are also found in combinations of two or more such minerals – something rare in terrestrial mines. The publication cites Global Sea Mineral Resources General Manager, Kris Van Nijen, as saying the company is interested in exploiting the nodules, 'for the same amount of effort, you get the same metals as two or three mines on land'.

Amon's discovery reinforces how little is known of the seabed. The consideration that arises is weighing up the economic gains of mining the seabed against the environmental consequences of mining activity. A further factor is the benefits for countries in the immediate vicinity of the mining operations. If nodules are mined in the Cook Islands' EEZ, the islands will reap economic benefits. In the case of the CCFZ, some part of the profits will be distributed to countries as per ISA regulations.

Seabed sustainability

The manganese nodules off the Cook Islands are no exception to the rules governing all nodules – they have developed over millions of years and are not a renewable resource. In other words, once the nodules are gone, they are gone for millions of years so successful and careful management is vital, whether the criterion is profitable operations, conservation or the revenue to benefit the local community such as the Cook Islands.

So are there plans for recycling sea-based minerals? 'Two companies proclaim that they can process manganese nodules with zero waste – if so, there would be nothing to recycle,' said Hein. 'Crusts should be able to be processed in those same plants, while SMS will be processed by the same processing plants that process volcanogenic massive sulphides produced from land-based mines. The waste produced will be handled as usual for those plants.

'Products made from metals mined in the deep ocean will be recycled along with those from land-based mining. Recycling needs much greater education worldwide to help fill demand gaps for metals and, of course, that will depend on the profitability of the recycling, unless it is subsidised.'

It is likely that some seabed mining will be carried out in the near future, as substantial research and evaluation will have taken place. Exactly how one can reconcile the quantities that would need to be mined to make the project viable with the environmental considerations and benefits for local communities will make this a subject of much debate, and argument, for a long time to come.

Michael Schwartz in Materials World

EVENTS CALENDAR 2019-2020

October'19
5
11th Dr. Placid Rodriguez Memorial lecture (PRML) organized by IIM Kalpakkam Chapter at Kalpakkam

November'19
13-16
International Symposium on "Advanced Materials for Industrial and Societal Applications" , 57th National Metallurgists' Day (Under the aegis of Government of India,Ministry of Steel) and 73rdAnnual Technical Meeting of IIM, organized by IIM Trivandrum Chapter in association with Kalpakkam, Chennai, Trichy & Coimbatore Chapters at Hotel Samudra & Hotel Uda Samudra, Thiruvananthapuram.
Convener : Dr P Ramesh Narayanan, convener@iimnmdatm2019.org

February'20
21-23
10th International Conference on Materials Processing and Characterization organized by IIM Mathura Chapter.
Website: www.icmpc.com

JSPL bags Rs 665 crore rail contract from RVNL

Jindal Steel and Power Limited (JSPL) said it has bagged an order from Rail Vikas Nigam Limited (RVNL) to supply 89,042 tonnes of rails at a cost of Rs 665 crore. India's only private manufacturer of rails will supply UIC 60 kg IRS T-12 880 grade 13-metre rails for RVNL's upcoming projects. RVNL functions as an extended arm of the Ministry of Railways.

JSPL said the required rails will be manufactured and supplied from its Raigarh facility, which has a capacity to supply over 50,000 tonnes of rails per month.It is the company's second big rail order in less than a year. The first-ever rail order for supplying close to one lakh tonnes rails to Indian Railways was completed in April, four months ahead of time.

Business Standard

SAIL supplies steel for Indian Army's 'Dhanush'

Domestic steel giant SAIL said it has supplied special quality steel for India's indigenous artillery gun 'Dhanush'. Special quality forging steel was supplied from the PSU's Durgapur-based Alloy Steels Plant. "Steel Authority of India supplied steel for India's first indigenous and biggest artillery gun Dhanush, which was inducted into Indian Army on April 8, 2019," the company said in a statement.

With this, SAIL has once again established its commitment to fulfilling the country's requirement and strengthening India's defence systems, it said. Dhanushhas been designed and developed by the Gun Factory in Jabalpur where it was handed over to the Indian Army.SAIL steel has been used in the country's various defence programmes, including INS Vikrant, INS Kiltan, INS Kamorta, MBT Arjuetc, it added.

"SAIL is ready to meet and supply special grade steels for technical requirement of Indian's defence programmes," Chairman Anil Kumar Chaudhary said. The government owns about 75 per cent stake in SAIL. Its crude steel output grew over 8 per cent to 16.3 million tonne (MT) in the just concluded fiscal.

Business Standard

NMDC Q4 profit rises 31% to Rs.1,453 crore

State-owned miner NMDC reported an over 31 per cent rise in standalone profit at Rs 1,453.77 crore for quarter ended March 2019. The company had posted a standalone profit of Rs 1,105.85 crore in the year-ago quarter, NMDC said in a filing to the BSE. Total income during the March quarter declined to Rs 3,839.40 crore from Rs 4,053.16 crore in January-March 2018, the statement said. Total expenses for the latest quarter also fell to Rs 1,641.65 crore from Rs 2,059.84 crore in the year-ago period. The National Mineral Development Corporation (NMDC) is country's single largest iron ore producer, presently producing about 30 million tonnes of iron ore from three fully mechanised mines.

Financial Express

Hindustan Zinc becomes ninth-largest silver producer in the world

India's zinc and lead major Hindustan Zinc (HZL), from Anil Agarwal-led Vedanta group, has become the world's ninth largest silver producer in calendar year 2018 (CY18). The firm improved its ranking from last year's 11th spot, according to the data provided by Washington-based Silver Institute, a global body of all silver stakeholders, from mines to consumers.

Also, India has become the 12th largest silver producer in the world, from last year's position of 13.

In its World Silver Survey 2019, the institute said, "Silver output in Asia in 2018 increased to 5,809 tonne and the biggest growth was posted in India's HZL. The company's underground operations increased its mining output, while better silver grades boosted silver production by 16 per cent in relation to 2017, to a record level of 19.6 Moz (610 tonne) in CY18."

HZL Chief Executive Officer Sunil Duggal told Business Standard, "The company has increased its production of silver manifold in the past 15 years from 41 mt in FY02 to 679 mt in Fy19." "The company has plans to produce 1,000 tonne of silver in the next two years and quite eager to produce 1,500 tonne in the next 5-6 years."

TOP SILVER PRODUCING COMPANIES

Rank 2017	Rank 2018		Output 2017	Output 2018
1	1	Fresnillo	1,686	**1,807**
2	2	Glencore	1,173	**1,086**
3	3	KGHM Polska Miedz SA Group	1,135	**1,054**
6	4	Cia De Minas Buenaventura SAA	821	**815**
5	5	Polymetal International	834	**787**
7	6	Pan American Silver	778	**771**
4	7	Goldcorp	890	**762**
9	8	Hochschild Mining	594	**613**
11	9	Hindustan Zinc	526	**610**
13	10	Southern Copper	495	**538**

Source: GFMS, Refinitiv; figures in tonnes

Business Standard

NINL to supply steel billet to PGCIL

Public sector steel producer Neelachal Ispat Nigam (NINL) has struck a deal with Power Grid Corporation of India (PGCIL) for supply of steel billets. Initially, NINL will provide billets to PGCIL for one year. PGCIL will use the MS channels and angles produced from NINL steel billets for electrical transmission towers across the country.

NINL, jointly promoted by MMTC and two Odisha government PSUs, operates a 1.1 million tonnes per annum (mtpa) steel plant at Duburi within the Kalinganagar Industrial Complex touted as the steel hub. NINL has branched into steel billets production to shore up margins. The public sector steel manufacturer is eyeing a major share in the special grade steel billet supply for the power transmission and distribution segment, which is growing in accelerated pace in the country. NINL is also going to market its own brand of TMT, wire rods and structures through conversion agents. Billets produced by NINL has already been widely accepted and has immense value.

Business Standard

NMDC iron ore output jumps 20% to 2.90 MT

State-owned miner NMDC said its iron ore output rose over 20 per cent to 2.90 million tonne (MT) in April. The company produced 2.21 MT iron ore from its mines in Chhattisgarh, while its production from Karnataka mines stood at 0.69 MT, NMDC said in a filing to the BSE.

NMDC's output had stood at 2.41 MT during the corresponding month in 2018. The company sold 2.70 MT of iron ore -- 2.18 MT from Chhattisgarh and 0.52 MT from Karnataka -- during April 2019, NMDC said. Sales in April 2018 had stood at 2.22 MT.

Production and sales figures of iron ore are provisional, NMDC added. According to its website, NMDC is the country's single largest iron ore producer, currently producing about 35 million tonne of iron ore from three fully mechanised mines.

Besides iron ore, NMDC is also involved in the exploration of wide range of minerals such as copper, lime stone and gypsum.

The Hindu Business line

Iron ore powers above $100 as supply crisis roils global market

Iron ore rallied above $100 a ton, surging to the highest since 2014, as investors bet that a global supply crunch will spur a scramble for cargoes just as China's mills push out record volumes of steel.

Benchmark spot ore climbed 2.5% to $100.35, according to Mysteel Global. Earlier, most-active futures in Singapore as much as 3.8%, while miners' shares powered ahead, with Fortescue Metals Group Ltd. hitting the highest since 2008.

Iron ore has staged a stunning rally in 2019 as supply disruptions in Brazil and Australia, the top shippers, spurred forecasts the seaborne market will swing to a deficit. At the same time, mainland mills have been producing record quantities of steel, underpinning expectations for strong import demand.

Business Standard

India's crude steel production remains almost flat at 8.662 MT in April

India's crude steel output remained almost flat at 8.662 million tonne (MT) during April 2019, according to official data. The domestic crude steel production stood at 8.653 MT during April 2018, according to a report by the Joint Plant Committee (JPC), which comes under the Ministry of Steel.

"Crude steel production stood at 8.662 MT in April 2019, up by 0.1 per cent over April 2018," the report said. State-run Steel Authority of India Ltd, Rashtriya Ispat Nigam Ltd along with private firms Tata Steel, Essar Steel, JSW Steel, and Jindal Steel and Power produced 5.082 MT and the remaining 3.58 MT came from other producers, it added.

During April this year, the production of hot metal was 1.4 per cent down at 5.825 MT, against 5.907 MT in April 2018. The output of pig iron grew 3.9 per cent to 0.537 MT in April, compared with about 0.517 MT in the same month a year ago. The JPC is the only institution in the country that collects data on the domestic iron and steel sector. India has set an ambitious target of increasing its crude steel production capacity to 300 million tonne by 2030-31.

Business Standard

Steel firms may go for price hike in June

A cost push might lead to a rise in prices of flat steel products next month, say companies in the sector. "Iron ore prices are up by Rs 450 a tonne and coking coal by about 5 per cent over the last couple of months. There will be some impact on pricing," said a primary steel producer.

Mining companies raised ore prices by Rs 400-600 a tonne in February. Seaborne prices have been rallying due to a supply disruption in Brazil, a major producer. In the past two months, global iron ore prices have moved up by around $20 a tonne to $108 a tonne.

Coking coal cost for domestic blast furnaces in the fourth quarter of 2018-19 had seen increases of Rs 800 a tonne, compared to the earlier quarter, ratings agency Icra said in its April report. This had increased steel making cost by around Rs 630 a tonne. Jayant Acharya, director, commercial and marketing, at JSW Steel, said: "There is cost pressure due to increased prices of and already elevated coal prices. We are reviewing the situation."

If an increase does happen, it would be the second one in this calendar year. In February, there was a rise of around Rs 500 a tonne. Though small, the hike had stemmed the downtrend in prices since since November. "Prices fell in November, December and January, with the total reduction in prices from November and January being Rs 5,500 a tonne. The first increase was in February and since then prices were rolled over," said a producer. A secondary producer, however, wondered if the market could absorb a price hike. The automobile and white goods sectors have been slowing. "Automobile has been in the slow lane but this time of the year is typically so for the sector. The coated steel business is also a little off-demand during the monsoon but the construction and infrastructure segments are steady. There are a lot of projects in the pipeline that are expected to take off, now that the elections are over," a producer said. Around 60 per cent of steel consumption is accounted for by the infrastructure and construction segments. The growth in steel consumption has therefore largely been supported by these segments, despite the slowing of automobile sales.

Business Standard

Hindustan Copper bid to invest Rs 600crore

Hindustan Copper has set a target to raise production by 25 per cent in 2019-20 and planned a capital expenditure of Rs 600 crore on expansion projects.The government-owned copper miner plans to produce 51.5 lakh tonnes ore in the current fiscal against last year's 41.22 lakh tonnes. The target is in line with plans to ramp up production to 200 lakh tonnes.

"My strategy of growth is based on three areas —capacity expansion of the operating mines, reopening of some of the closed mines and acquisition of new mining lease from the state government," said Santosh Sharma, chairman and managing director, Hindustan Copper.All the three areas have been taken into consideration to meet the target of 51.5 lakh tonnes, Sharma added.The company said the Malanjkhand underground mine project in Madhya Pradesh is progressing according to schedule and production is expected in 2019-20. The company also plans to re-open the Rakha mine and start the ChapriSideshwar mines at Ghatsila, Jharkhand.

Moreover, Sharma said the company was expecting mining lease for the Dhobhani Pathargora mine from the Jharkhand state government in 2-3 months. "Since that was an operating mine, there is not much work," said Sharma.The company, which recorded a revenue of Rs 1,816.25 crore in 2018-19, has set its sight on a revenue of Rs 2,000 crore in 2019-20. The company may also spend more than its planned capital expenditure during the year with investments up to Rs 1,200 crore.

"My actual capital expenditure commitment is Rs 600 crore but considering that I am planning to reopen one mine, ensuring expansion of another mine, the expenditure may go up to Rs 1,200 crore," Sharma said.HCL also plans to zero in on its first overseas acquisition in six months.

The Telegraph

Experts say steel demand may grow 6-8% in Fy20

Amid concerns about sluggish steel demand and dumping threat from China, domestic steel may register a growth of 6-8 per cent in the current financial year, experts said on May 28.

The sector remained bullish on domestic demand for the current financial year amid short term concerns on sluggishness and dumping threat from China, JSW Steel president (Operations) Partha Sengupta said. "We expect a demand growth of 6-7 per cent in FY'20," he said on the sidelines of The Metals Conclave organised by the Bengal Chamber of Commerce and Industry. The Institute for Steel Development & Growth (INSDAG) was also of the view that the sector will script a growth of 7-8 per cent during the fiscal. "The central government has been focusing on infrastructural projects like Sagarmala, Smart Cities and the new government would stick to its focus. I think steel demand is expected to grow by 7- 8 per cent in 2019-20," INSDAG Director General Sushim Banerjee said.

NMDC's former chief Rana Somsaid the steel companies should expand with equity capital rather on debt fund. He also said the PSU land bank should be made available for expansion of the private sector. The government should also take a view on long term contracts for iron-ore if it wants to achieve the steel production target of 300 million by 2030, he said.

Financial Express

Delhi Chapter

A technical talk on "Nature and Role of R & D in Defence Preparedness" was organised by IIM Delhi Chapter on 29 April 2019 at the chapter premises. At the outset Shri B D Jethra, Chairman, IIM Delhi Chapter welcomed Dr. Arvind Bharti and all who were present in the technical talk. ShriNirmalKakkar, Hony. Secretary, IIM Delhi Chapter, introduced Dr Arvind Bharti, formerly in DRDO HQ, Ministry of Defence, highlighting his academic and professional achievements. Shri S C Suri, former Chairman and Head, Technical Committee IIM Delhi Chapter also spoke about the association of Dr. Bharti with IIM Delhi Chapter. After introductory session, the stage was handed over to Dr Arvind Bharti.

Dr Bharti outlined Global Perspective in `Technological Leadership' emphasising that any sovereign nation need to be independent in its technological needs. In order to prevent economic exploitation by leveraging technology by powers that be, focus has to be on development of industrial capacities and in-house expertise by systematic enhancing the potentialities of R & D Institutes and Academic Institutions. This issue becomes much more critical in Defence sector.

The talk was attended by IIM members. Shri Pankaj Bajaj Vice-Chairman, IIM Delhi Chapter, proposed a vote of thanks to Dr Arvind Bharti and all the participants. As a token of appreciation, a Memento was presented to Dr Bharti by Chairman.The programme concluded with lunch.

- Report from IIM Delhi Chapter

Vijayanagar Chapter

IIM Vijayanagar chapter organised a lecture on 25th May 2019 at J-Max Vidyanagar, JSW Steel Toranagallu, Karnataka. Topic of the lecture was "Opportunities for Energy Conservation using Heat and Mass Exchangers". The lecture was delivered by Dr. Milind Rane, Professor and Energy Technology Consultant from Department of Mechanical Engineering, IIT Bombay. The event started with welcome address and with emphasis on Energy Conservation and heat recovery in integrated steel plants by the Secretary, IIM Vijayanagar chapter, Mr. L R Singh. Event was chaired by Mr. Rajashekhar Pattanasetty, President, JSW Steel Vijayanagar works. In his address he highlighted the initiatives being taken for Energy Conservation and heat recovery in steel sector by JSW steel. Prof Rane showed his work on HVAC&R - Heating, Ventilation, Air Conditioning and Refrigeration and his developed technologies on Engine Exhaust Heat recovery, Super Heat Recovery, Water Heater and Heat Pumps. It was an interactive session with participants from all areas of steel plant. Many innovative ideas were discussed for heat recovery at various locations in a steel plant.

Glimpses of the event

SPECIAL REPORTS

A Brief Report on First Dr. Baldev Raj Memorial Lecture

The First Dr. Baldev Raj Memorial Lecture was organized by the Indian Institute of Metals, Kolkata, IIM Human Resources Development Centre, Kalpakkam-Chennai & IIM Bengaluru Chapter in association with National Institute of Advanced Studies (NIAS), Bengaluru on 9th April 2019 in JRD Tata Auditorium at NIAS, Bengaluru. The program started with a welcome address by Prof. Satyam Suwas, Hon. Chairman, IIM Bangalore Chapter. A floral tribute was paid by the dignitaries to Dr. Baldev Raj.

Dr. U. Kamachi Mudali, Vice President, IIM & Chairman, IIM HRDC-KC introduced the profile of Dr. Baldev Raj and detailed about the initiation of "Dr. Baldev Raj Memorial Lecture" in memory of Dr. Baldev Raj, a renowned metallurgist and eminent scientist and technologist. The lecture was initiated to perpetuate his significant contributions towards energy policy, advanced materials, manufacturing processes, and characterization of materials. Dr. Kamachi Mudali described Dr. Baldev Raj as a man of passion, known for providing solutions to many unsolved problems in strategic sectors in the country. He further added that Dr. Baldev Raj mentored hundreds of children, students, scientists and technologists, inspiring them to pursue high levels of professionalism in the pursuit of science and technology without losing sight of the need for exemplary ethical practices.

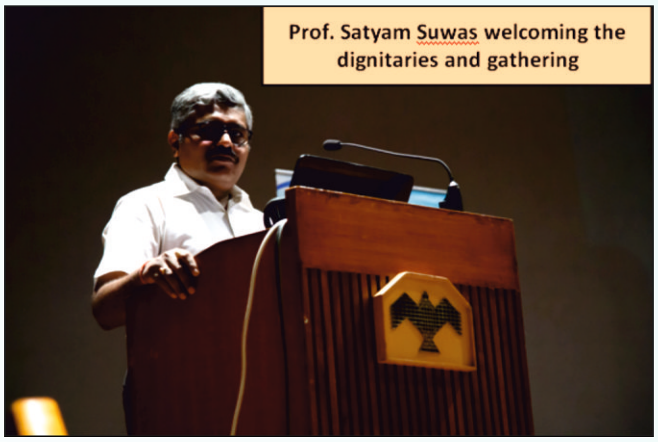
The presidential address of Shri Anand Sen IIM, Kolkata was presented by Sri. Kushal Saha, Secretary General, IIM from Head Office of IIM. The presidential address clearly outlined the work of Dr. Baldev Raj in interdisciplinary domains of energy, cultural heritage, medical technologies, nano science and technology and education. He was portrayed as a bridge between academia and industry, and was known for overcoming the barriers of academic, research and industry with acumens of leadership and experience. He also explained how Dr. Baldev Raj played a very decisive role in shaping the activities of the Indian Institute of Metals, at the national level.

A special remark was made by the director of NIAS, Dr. Shailesh Nayak, sharing his views and experiences working with Dr. Baldev Raj. Later Prof. B. S. Murty, Co-Chairman, IIM HRDC-KC introduced the speaker, Prof. P. Rama Rao, ARCI, Hyderabad & Former President, IIM.

Prof. P. Rama Rao recalled his very long association with Dr. Baldev Raj, and that he has always admired his multifaceted personality contributing towards leadership, management, technology and policy making. Later he delivered the first Dr. Baldev Raj Memorial Lecture on the topic "**Plutonium (Pu) - The man-made wonder element**". Prof. Rao pedagogically introduced the discovery of elements and periodic table outlining the inherent beauty of the approach, with special emphasis on Plutonium. He has also brought out the special and unique properties of Plutonium which is the most desired element for nuclear energy development. The lecture was very well received by the 80+ scientists and young academic scholars who had participated in the event. The lecture was also attended by Mrs. Aruna Baldev Raj and his son Mr. Kunal Pachnanda.

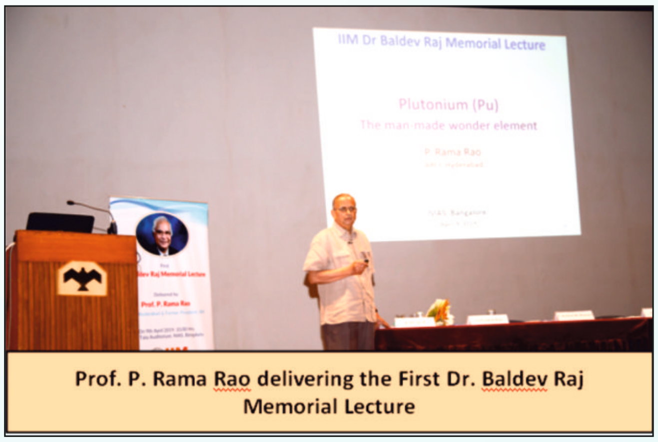
Dr. U. Kamachi Mudali presented the memento to Prof. P. Rama Rao, and a Certificate from M/s Springer Publishers to avail books and publications worth of 1000 Euro online. The program ended with a vote of thanks by Dr. Divakar Ramachandran, Chairman, IIM Kalpakkam Chapter.

A few snapshots.....


Prof. Satyam Suwas welcoming the dignitaries and gathering


Prof. P. Rama Rao paying floral tribute to Dr. Baldev Raj


Dr. U. Kamachi Mudali speaking about Dr. Baldev Raj and the Lecture series



Prof. P. Rama Rao delivering the First Dr. Baldev Raj Memorial Lecture

Symposium on "Critical Non Ferrous Metals: Establishing the Value Chains", under Indian Institute of Metals held at Indian Institute of Technology Bombay, Mumbai during 15-16 April, 2019

Critical metals are generally identified based on their high impact on product performance, poor substitution potential and poorly established supply chains. As India's high technology sectors encompassing Defence, Space, Atomic Energy, Mobility and Energy are poised for growth, there is concern that their prospects may be hindered unless supply chains for critical materials are under control. As supply chains are closely dependent on value chains, which are scientific and technological in nature, it is necessary to identify the gaps in value chains, make strategies for their early closure and involve industry and government bodies to enable and accelerate the efforts.

In view of the above, The Indian Institute of Metals, Mumbai Chapter in association with the Indian Institute of Technology, Bombay conducted a two day symposium on 'Critical Non Ferrous Metals: Establishing the Value Chains' at IIT Bombay, Mumbai during 15-16 April, 2019. A total of 19 invited lectures on subjects encompassing global supply chains, indigenous capacity creation, science and technology of few critical non ferrous metals were delivered by leaders from Chamber of Commerce, industry, R&D and academia. The talks covered value chain aspects related to Rare Earths, Titanium, Zirconium, Hafnium, Tungsten, Niobium, Tantalum, Lithium, their alloys and products for industrial, defence, atomic energy and space applications.

Prof Amol Gokhale, Chairman of the Symposium and Vice President of the Indian Institute of Metals said that the purpose of the symposium was to understand current capabilities and technology gaps in critical nonferrous metals in the country and suggest ways to close the gaps to strengthen the supply chains so that the security and economy of the country do not suffer.

In his inaugural address, Prof BK Mishra, Director, IIT Goa and a specialist in the subject, said that an early revival of ore exploration and subsequent exploitation efforts is necessary. He further said that wherever primary sources are not available or too lean, recovery of critical and precious materials from secondary sources should be attempted, citing the examples of precious metals like silver, gold, tellurium and platinum. Private parties interested in such activities need to be sensitised, encouraged and possibly given soft loans as the commercial prospects for such metals are often poor. He finally emphasised the importance of synchronising the supply chain components to improve commercial viability. Prior to him, Dr U Kamachi Mudali, Vice President of the Indian Institute of Metals and Chairman Heavy Water Board had informed that many small industries were identified by a NITI Aayog committee, headed by him, to separate rare earth elements from electronic waste.

Shri G Chandrashekhar, from the IMC Chamber of Commerce and a well- known metals commodity market analyst, predicts a clear growth for critical non- ferrous metals in the coming years. Electric vehicles and clean energy production will drive further growth during the coming decade. However, he cited the examples of lithium and cobalt whose demand has been growing, due to the growth in lithium ion battery industry, but its prices have been sliding since the second half of 2018 due to oversupply. Certain producer countries of critical metals are moving toward economic nationalism in which domestic compulsions are overriding international obligations, resulting in increased uncertainties of supply. He cited several examples involving the US, China, Russia and Europe vis-à-vis supply of steel, aluminium and certain edibles. In the evolving uncertainties of the global markets, countries which have protected economies will suffer less than those with open economies, he said. He concluded by saying that, India should diversify its supply base for critical metals to reduce risks, and invest in exploration, recycle, re-use, environmental impact and finding of substitutes for critical metals much ahead of the expected rise in demand. Dr PV Venkitakrishnan is the Director of ISRO's Capacity Building Program Office which, as the name says, is mandated to create capacities in Indian industries where technology exists, to cater to future needs of ISRO. Their experience, of 'forced backward integration', has led to a model which worked very well in the past, in which they created capacities at Bharat Aluminium Company and Ordnance Factory Ambajhari for advanced aluminium alloys, Kerala Minerals and Metals Limited for titanium sponge, Centre for Materials for Electronics Technology for hafnium, HAL for special mill forms etc. They have recently created capacities in niobium alloys and copper alloys to name a few. In order to overcome high local price vis-à-vis international prices, he suggests the country to adopt 'best in India' as the criterion for price comparison for the same technical specifications, till the capacities grow to become commercially competitive.

Dr I Chattoraj, the Director of CSIR-National Metallurgical Laboratory talked about their recent work on tungsten recovery from secondary sources as well as by scrap recycling. Tungsten is an armament material, whose supply is mainly controlled by China. They have also developed a process for recovery of rare earth metals from their halides which, with further effort, can integrate with the existing capability at IREL to produce rare earth halides and oxides. Rare earth metals are used extensively in high energy permanent magnets which find use in high speed brushless DC motors to be used in Electric Vehicles, wind mills and medical diagnostic equipment, among others.

They regularly work with industries to transfer their laboratory scale technologies for commercial use.

Dr SK Jha, Director (Production and Marketing) showcased the capabilities and past work of Mishra Dhatu Nigam, a DPSU in producing various critical nonferrous alloys for defence, energy and space sectors. In most cases, they are the only industry which produces nickel base superalloy forgings and sheets, titanium alloys and special steels. They recently launched electron beam refining process of niobium for aerospace alloy development. He mentioned about their plan to enter niche aluminium alloy production at a newly planned campus.

The Director General of the Centre for Materials for Electronics Dr N R Munirathnam spoke about production and refining of high purity nonferrous metals like tellurium, cadmium etc. They recently start operating a new facility to extract hafnium metal. They plan to recover critical nonferrous metals from e-waste and to use artificial intelligence techniques to cover the entire value chain from ideation to manufacturing in the field of critical metals. He said that a national facility for Glow Discharge Mass Spectroscopy is needed for accurate analysis of high purity metals.

Dr Nikhil Dhawan, a young Assistant Professor from IIT Roorkee spoke about his work on recovery of rare earths from RE magnets used in computer hard discs, CFLs etc. He projected future work on separation of dysprosium, a heavy rare earth required in high performance high temperature stable magnets and the technology of grain boundary diffusion dysprosium to produce magnets with high coercivity. Interestingly, he envisaged future work on dysprosium replacement by cheaper elements like lanthanum and cerium to gain pace in the country to reduce dysprosium consumption.

Dr R Gopalan of the Advanced Research Centre for Powder Metallurgy and Advanced Materials, Chennai Centre for Automotive and Energy Materials talked about the lead his Centre has taken in lithium-ion cells fabrication at the pilot plant scale for electric vehicle (EV) application. Processing the conventional as well as newer electrode materials indigenously was a priority goal. He also highlighted the importance of developing motor technology requiring high coercivity hard magnets based on Nd-Fe-B and also cost effective soft magnets. Resource risks for neodymium and dysprosium metals are high, according to him. Dysprosium metal, a heavy rare earth difficult to separate, is used in magnets for hybrid cars, plug-in hybrid vehicles, and electric cars, in which the motors are exposed to a high-temperature environment.

In his scientifically oriented talk, Dr T K Nandy, who currently leads the tungsten alloy development program for long rod anti-tank penetrator, presented recent improvements in the properties of these powder metallurgy processed alloys. The technology for making the long rod penetrator was transferred to the then newly created Ordnance factory called the Heavy Alloy Penetrator Project at Trichy in the early 1990's. He said that, while the goals of achieving higher tensile strength combined with higher impact energy were regularly being achieved, it was only recently that they were able to control the number of samples showing lower-than-accepted impact energy values. The importance of this achievement is to be understood based on the knowledge that penetrators made from such low impact energy rods can potentially shatter during launch of the armament and render the gun barrel unusable during battlefield operations.

Dr Madangopal of the Bhabha Atomic Research Centre gave a fascinating account of the journey from science to product which his group led in establishing nickel-titanium- copper base, iron base and ferromagnetic shape memory alloys and couplings on a commercial scale for the Light Combat Aircraft programme.

G Das of the Nuclear Fuel Complex presented the work done on development and production of zirconium based alloys known as Zircalloy as seamless tubes to contain natural as well as enriched uranium based fuels by processes known as extrusion and pilgering He emphasized the importance of choosing the correct source of zircon sand from which zirconium metal is extracted. Certain zircon sands are rich in titanium minerals, which introduce titanium as impurity in zirconium increasing its neutron cross section. By selecting the correct source of zircon sand, the titanium impurity content in zircalloy was brought down from 0.7% to 0.2%.

This was followed by a talk by Dr T Raghu who elaborated the current production of titanium alloy compressor discs for Adour aeroengines which propel Mirage aircraft. A technology called near isothermal forging, which requires lower forging loads and enables producing more contoured features is adopted by using the country's only isothermal forging facility in the Defence Metallurgical Research Laboratory at Hyderabad. He felt that the basic technology can be scaled up to sizes required by the current fighter aircraft engine programmes of the country, provided a 50,000 MT forge press was available in the country. Another new concept called multi-axial forging was described by him, which allows working at lower temperatures and higher strain rates without compromising with the soundness of the forging for higher throughput.

Dr Dinesh Srivastava, the Chairman and Chief Executive of the Nuclear Fuel Complex gave an overview of all the nonferrous metals activities at his Complex. In particular, he elaborated on the zirconium sponge facility of NFC which has come up at Tamil Nadu to produce 1.5 MT per batch of zirconium. This batch capacity was unique, he said, and exceeds the typical batch capacity of 900 kg elsewhere in the world.

K V Mirji of the Nuclear Fuel Complex presented global trends in special metals, including tantalum and niobium, and also noting the steadily increasing indigenous demand. He made the point that for the exotic metal like tantalum for which the ore prices have increased manifold in recent years, recycling is a cheaper option than extracting from minerals. He also presented the work on niobium extraction starting from ore. His group has done pioneering work on niobium refining using electron beam melting. He mentioned that the small scale of indigenous operation in niobium and tantalum extraction is a matter of concern for competing with leading producers in the world. He strongly recommended recycling of tantalum and niobium from used products.

Dr V V Satyaprasad, said that niobium alloys are candidate materials for future scramjet engines, which requires niobium to be refined to aerospace grade to reduce oxygen interstitial impurity. His group is developing a higher strength niobium-tungsten-zirconium alloy for the purpose. Dissolution of high melting point metal tungsten is a major challenge, which was overcome by adopting a route in which tungsten is used in powder form during electron beam melting. Having established the basic processes, he is aiming to establish larger infrastructure to be able to satisfy user size requirements.

Dr R K Gupta from ISRO's Vikram Sarabhai Space Centre spoke about product development from niobium and cobalt alloys for nozzles and other components in satellite launch vehicles, especially for the liquid rocket engines for higher thrust vehicles. He too felt that niobium recycling will play an important role in future, but emphasized that processing challenges need to be understood and controlled, as the metals are highly prone to oxidation at high temperature. He also mentioned that all technologies needed to make high strength and weldable aluminium alloys for space vehicles exist in the country, except for sheet products of 2.5 m and higher width, for which facilities need to be augmented.

Dr S Basu, Director of CSIR-Institute for Minerals and Materials Technology, Bhubaneswar presented his laboratory's work in recycling of spent lithium ion battery. Recently, he said, several newly developed methods have been tested from laboratory to bench/pilot scale, demonstrating potentially commercially successful recovery of the cathode components from the batteries to produce lithium, cobalt, nickel, manganese, aluminium and copper products, as either alloys or compounds. However, he said that methods which are environmentally friendlier and more economically viable need to be developed. He talked about a recently launched program at his laboratory to establish a novel process for simultaneous recovery of lithium and reactivation of carbon content from the spent batteries in a greener way.

Dr Ch R V S Nagesh of the Defence Metallurgical Research Laboratory described the long journey for titanium extraction technology to transit from DMRL to KMML in Chavara, Kerala where a 500 tpy ISRO facility is running closing a long existing gap in the ore-to-product technology for titanium alloys. However, he said commercial success will depend on being able to bring down production costs and finding markets for non-aerospace grade titanium sponge which is co-produced along with aerospace grade. He touched the newly launched area of tungsten recovery from Hutti Gold Mines gold ore tailings, saying that recent efforts have been successful in recovering tungsten powder from tungsten heavy alloy scrap as well as from the gold ore tailings.

Dr Alok Awasthi highlighted the importance of understanding and applying metallurgical thermodynamics for choosing between alternate extraction routes and optimising the processes, an expertise fast dwindling in academic institutions. He illustrated his point by showing examples from the work on refractory and reactive metals carried out at Bhabha Atomic Research Centre. His views carry importance given the fact that BARC has been the pioneer in extracting a wide range of metals from a variety of ores to satisfy the needs of several strategic programmes.

A Panel Discussion was organized to identify the technology gaps in the value chains for critical nonferrous metals and the way forward. It was moderated by the former Chairman cum Managing Director of Indian Rare Earth Limited, Dr R.N. Patra, and participated by Dr Venkitakrishnan of ISRO, G Kirupakaran of Brahmos, Dr Shankar Venugopal of Mahindra and Mahindra, R. A. Khale of Indian Rare Earths Limited, Prof G N Jadhav of IIT Bombay and Dr T. Sreenivas of BARC.

Dr Patra said that ISRO had set a shining example for creating an ecosystem for the development and commercial production of several critical metals and related technologies at existing plants and laboratories within the country. Dr Venkitakrishnan said that ISRO's strategies in indigenisation included consolidation of requirements, investments at the right time and recycling/reuse. G Kirupakaran of Brahmos Aerospace, which indigenized several critical nonferrous metals and alloys said that new processes need to be established to produce and process such critical metals; major investments may be needed to produce high strength weldable aluminium alloys in sheet and plate forms to the required sizes and agreed with Dr Venkitakrishnan's suggestion that consolidation of requirements of niche metals and alloys is needed to satisfy minimum order quantity (MOQ) requirements of producers. Dr Shankar told that his company has gone ahead in putting three electric vehicles in operation in autonomous tractors. He said that the technologies for mobility and energy were interdependent, clarifying that eventually solar energy as a means of energy generation has to be coupled with lithium ion battery as a means of energy storage. He felt that redesign (of batteries and other source components) was necessary for recycling to succeed. Dr Sreenivas of the Bhabha Atomic Research Centre said that geological mapping of the country is once again needed to identify all ore deposits of critical metals. Documentation of available information is equally important if repetition of past work is to be avoided. He felt that we should not work in a reactive way but move forward proactively when it comes to critical metals, due to long lead times in realising them. He said that Geometallurgy as a discipline was coming up where a holistic view of exploration, mining and mineral processing is emphasised. Prof GN Jadhav emphasised that minerals were a non-renewable source and vulnerable to geopolitical situations. He felt that a re-look at recovery of critical metals from non-traditional sources was needed, citing several examples. Finally, R A Khale said that IREL was planning to establish a rare earth and titanium theme park within the country where pilot scale production of these metals will be carried out.

Valedictory Session and few takeaways from the Symposium

Dr Pradeep, Vice President, Indian National Academy of Engineers and former Vice President of TCS Pune summarized the findings of the Symposium based on brief presentations made by Co-Chairs of various sessions. Overall, the following realisation and directions emerge regarding establishing value chains for critical nonferrous metals.

The supply chains for critical nonferrous metals are complex and make price predictions challenging. Based on the experience of the strategic departments, Government support is necessary to invest in establishing technologies and capacities, irrespective of costs and uncertainties to insulate indigenous programmes.

Continuous identification of future requirements is necessary to be able to strategize in advance.

Recovery efforts need to take into its fold primary as well as secondary sources of critical metals. Recycling technologies are different for different products, and need to be recognised as such. There are opportunities to establish processes for recovery of critical metals from electronic waste.

Computational development of alloys is needed to accelerate new alloy development.

Academia-Government collaborative efforts are needed to shorten the development cycle in electronic materials.

Indigenously produced lithium ion batteries may cost 50% of imported ones if supply chains for critical materials are established.

New developments in higher penetration long rod penetrators based on tungsten are attractive. There is already production capability at HAPP Trichy, although the facilities need modernisation.

Development of shape memory alloys is extendable to biomedical devices, which will improve their commercial feasibility. Zr alloy tube manufacture is completely established in the country. Titanium alloy aeroengine discs of small engines like Adour are being manufactured using isothermal forging facility. However, for Kaveri class engines and beyond, larger capacity forge presses and isothermal capability are needed.

In nuclear core and clad materials, the vision should be ore-to-core. Zirconium sponge plant is now operational, which completes most of the links of Zircalloy value chain.

Indigenous development of exotic materials like Nb and Ta has led to fall in import price. Hence indigenous development programmes need to be encouraged in spite of import option to reduce costs. Purification of Nb for aerospace has been demonstrated. Alloy development route is also established. However, investments are required in scaling up downstream processing and vacuum heat treatment facilities. Also, for large size nozzle products made on Nb and Co alloys, 1m x 1m vacuum heat treatment facilities are required.

Innovative process techniques which can reduce dependence on expensive large scale facilities is to be encouraged.

Li ion batteries, currently being imported, can serve as a good resource of Li metal in future.

Area wise exploration of minerals of critical nonferrous metals needs to be re-launched in the country.

Ti sponge plant at KMML is running well. The sponge product has been airworthiness cleared. Orders are coming. However, the sponge does not meet international prices. One reason for higher price of the indigenous sponge is that the B and further grades of the sponge has no takers, which adds to overall product cost. Development of low cost titanium alloys will create demand for B to E grade sponge.

Behind all technologies of metal extraction lies the solid foundation of thermodynamics. It helps to rule out possibilities and concentrate on fewer process variables to be optimised.

Academic community is not active in nonferrous metals related research, specially extraction and recovery from secondary sources.

There is hardly any development of related facilities indigenously.

Vendor development is required, since the commercial feasibility for most metals is poor and hand holding by user industries/departments is necessary.

Since most metal extraction activities are based on availability of ores, involvement of earth sciences to identify and explore necessary ore deposits and characterisation of minerals should be encouraged.

There is a general feeling that such events need to be held annually at different locations in India to create and spread awareness of this important segment of economy, with participation of many young to middle level scientists and academicians. More participation of policy makers is needed to deliberate the subject in the overall context of national security and economy, and to take further steps towards supporting efforts to establish complete value chains for critical nonferrous metals in the country.

- Report by

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Past Event

TRAERF's Four – Day National Seminar on
ADVANCED MATERIALS AND MATERIALS TECHNOLOGIES FOR PROTOTYPES AND SYSTEMS (AMMTPS-2019)

TR Anantharaman Education and Research Foundation (TRAERF), Hyderabad and Defence Materials and Stores R&D Establishment of DRDO, Kanpur jointly organized a four-day National Seminar on Advanced Materials and Materials Technologies for Prototypes and Systems (AMMTPS-2019). Thus commenced the Decennial Celebrations of TRAERF during April 03 – 06, 2019 at DMSRDE, DRDO, Kanpur in association with JATC of IIT, New Delhi and SFA Kanpur Chapter, Kanpur with active participation of a total of 160 engineers from industry (OFs, HAL, PSUs, MSMEs, UP Corridor Industries), scientists from DRDO and other organizations (ATVP, DMSRDE, ADRDE, CEMILAC, DMRL, DRDL, ASL, SSPL, NSTL, NPOL, NMRL, TBRL, CVRDE, DEBEL, IRDE, ADE, ADA, DLJ, CSIR-CGCRI, NML, NIIST, ISRO Units) and faculty members from various academic institutions(IIT-BHU, IIT-Kanpur, IIT-Delhi, JATC/IIT-D, NIT-Nagpur, NIT-Jamshedpur, AU-Visakhapatnam, PSG College-Coimbatore, UPTTI-Kanpur).Apart from these participants, 75 meritorious students and research scholars of various laboratories and engineering colleges of Kanpur have also been supported to attend this national seminar. A technical exhibition, entitled ADVANCED DEFENCE PRODUCTS EXHIBITION was also organized in which 12 large industrial pavilions have showcased their recent products and software capabilities directed towards defence production. As many as 2000 students and learned citizens of Kanpur have visited this technical exhibition and the same was extensively covered in the local media.

The principal aims of AMMTPS-2019 were two-fold: (i) To evolve roadmaps for the development and deployment of advanced materials; and (ii) To develop materials technologies and materials systems, capable of addressing the requirements of futuristic Indian national prototypes and systems, in general and in particular, those for Indian Defence in the areas of Missile, Aero and Naval applications. A keynote lecture on Materials for Future Defence Systems, by Dr. SV Kamat, DS & DG (NSM), DRDO and 12 invited lectures by leading Systems / Programme / Laboratory directors of DRDO, 5 detailed technical interaction sessions and a special brainstorming session on RE-ESTABLISHING INNOVATIVE RESEARCH IN DRDO, Chaired by Professor Shrikant Lele, Former Director, IIT-BHU& Chairman, LRC, DMSRDE were the key components of the Seminar, which were well appreciated by all the participants, including 12 service officers and Radm. R Viswanathan, VSM, PDSC, ATVP. Professor P Rama Rao, President, TRAERF, Dr. G Malakondiah, Treasurer, TRAERF, Dr. K BhanuSankara Rao, Trustee, TRAERF, Professors D Banerjee, LM Manocha, V Ramaswamy, Vakil Singh, RK Mandal, NK Mukhopadhyay, P Venkitnarayanan, Anish Upadhyay, Drs. V Bhujanga Rao, KU Bhasker Rao, MZ Siddique, Vikas Kumar, N Eswara Prasad, AK Ghosh, Manoranjan Patri, Air Comdr. DB Murali, VSM, chaired the various technical sessions. A special report prepared based on the proceedings of AMMTPS-2019 will be submitted to NITI Aayog and DRDO with recommended roadmaps and the salient pointers for future initiatives for advanced materials and materials technologies for Indian Defence.

N Eswara Prasad
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In association with
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IIM Chennai Chapter
IIM Trichy Chapter
IIM Coimbatore Chapter
Venue: Hotel Samudra, Kerala Tourism Development Corporation (KTDC) &
Hotel Uday Samudra, Kovalam, Thiruvananthapuram

Non - Ferrous Metal Prices in India

Product	13-June-2019
Rs./Kg (Mumbai Local Prices)	
Copper Armature	*420*
Copper cathod LME ++	*435*
CC Rod LME ++	*439*
Copper Cable scrap	*433*
Copper shell 40mm	*461*
Electrolytic Copper strip 25mm	*456*
ACR Copper Coil 3/8	*520*
Brass Sheet scrap	*345*
Brass Pales scrap	*345*
Brass Pallu scrap	*345*
Brass Honey scrap	*305*
Brass Shell 40mm	*384.04*
Aluminium 6063 scrap	*128*
Aluminium scrap Taint/Tabor	*115*
Aluminium Cable scrap	*138*
Aluminium Ingot	*143*
Aluminium utensil scrap	*121*
Zinc Slab	*209*
Lead ingot	*152*
Tin Slab	*1420*
Nickel Cathod	*870*

Source : http://www.mtlexs.com/todays-metal-prices

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