THE INDIAN INSTITUTE OF METALS
DELHI CHAPTER

"MET-INFO"

INHOUSE PUBLICATION

ISSUE NO. 19 E-VERSION JANUARY 2021

K K Mehrotra-Chairman, Delhi Chapter
S C Suri-Editor-in-Chief (IIM-DC Newsletter)

For Private Circulation only

Contents of E-Version of this Issue

E - Version

Published By
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ISSUE NO. 19 E-VERSION JANUARY 2021

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Dear Esteemed Member,

This is the first issue of New Year e-version of Met-Info.

I on my behalf and on behalf of Executive Committee of Delhi Chapter extend New Year greetings to you and members of your family.

I am glad to inform you that IIM will enter 75th year of its existence on 24th February 2021. IIM will be celebrating Platinum Jubilee from 24th February 2021 to 23rd February 2022. On this occasion Delhi Chapter plans to bring out a directory of its members giving members' contact details and professional profile along with their photographs.

I am attaching a list of all the IIM DC members giving their contact details. I would request you to go through your details and indicate change, if any, relating to your details. I would also request you to give your brief professional profile along with soft copy of your photograph.

We plan to collate the contact details and professional profile of our members along with their photographs.

After collating the contact details and professional profile, the same along with members' photograph will be sent to your fellow members to facilitate them to interact with other members.

As you are aware, the year gone by witnessed unprecedented situation arising out of Covid-19 thereby impacting the technical activities of our Chapter. Things have started improving in 2021. Let us hope that technical activities of our Chapter will start in full stream soon.

Request for your prompt reply.

With Regards,

K K Mehrotra
Chairman

MANAGEMENT OF LOGISTICS FOR INDIAN STEEL INDUSTRY

Introduction

Today, the steel industry contributes slightly more than 2% to the GDP of the country. This percentage accounts for direct contribution. The indirect contribution of steel is much larger, owing to the dependence of other sectors. The steel industry employs nearly half a million people directly and two million people indirectly. India is currently the world's second largest producer of crude steel, with 109.2 million tonnes (Mt) produced in 2019-20. The export was 8.35 Mt, an increase by 31.4% as compared to the previous year and India was a net exporter of steel.

As per National Steel Policy the steel-making capacity is to reach 300 Mt per annum by 2030-31. Crude steel production is expected to reach 255 Mt by 2030-31 at 85% capacity utilisation. Production of finished steel to reach 230 Mt, assuming a yield loss of 10% for conversion of crude steel to finished steel. With 24 Mt of net exports, consumption is expected to reach 206 Mt by 2030-31.

The growth trajectory of the steel industry has its own set of challenges. The Indian steel industry is often regarded as uncompetitive globally and one of the main reasons of higher cost is the logistics cost in India.

Importance of Logistics to Remain Competitive

For most Indian steel makers, managing logistics requirements is arduous, challenging and costly. The primary raw materials for steel making are iron ore, coal and fluxes. These are bulk minerals, and steel is also a bulk commodity. So, whether it is physical transportation of raw materials for steelmaking to the steel mills or physical transportation of finished steel to demand centres, transportation of bulk materials is always arduous. Moreover, most Indian steel plants are located inland, unlike in China, Japan or Korea, where they are located close to the sea. This increases the challenge of managing logistics requirements for most steel plants in India.

Access to infrastructure is an issue in India. For every 1 tonne of steel produced, roughly 3 tonnes of raw material needs to be transported. To produce 300 Mt of steel, the total transportation need of the steel sector is expected to be about 1,200 Mt. As most new steel plants are likely to be situated in resource-rich states such as Odisha, Chhattisgarh, Jharkhand and Karnataka, these areas will become steel hubs needing access to infrastructure. The target of reaching 300 Mtpa cannot be achieved unless proper infrastructure to handle such large volume of materials is developed. Because of high transportation cost in India, the steel plants are becoming uncompetitive globally.

The Mode of Transport for Steelmaking Raw Materials and Finished Product

Railways

Railways are naturally the preferred mode of transportation for steel makers. More than 80% of the total logistics requirements of the steel industry are met through the railway network, as the sea route can be partially leveraged for only three steel plants. Moreover, transportation through roadways for bulk materials is economically unviable. The railways face huge infrastructure constraints, which makes managing logistics challenging for Indian steel makers. Moreover, for a long time now, the overwhelming dependence of the Indian Railways on revenue from freight traffic, especially from bulk commodities, is well documented. In other words, the freight cost of moving materials through the railways, both raw materials and finished steel, is artificially much higher as passenger traffic is subsidised from freight earnings by the Indian Railways. NITI Aayog estimates a relative cost disadvantage for Indian steelmakers are USD 20-25 per tonne of finished steel. The study estimates that the freight cost from Jamshedpur to Mumbai can be as high as USD 50/ tonne in comparison with USD 34/tonne from Rotterdam to Mumbai.

In view of the importance of moving materials by railways, the Government need to plan for future rail network capacity and mobilize funds accordingly. In addition, the timely execution of railway projects in key mining areas will be critical to ensure availability of raw material in a cost-effective manner. For example, the rakes available for transportation of coal by rail are fewer than required – Coal India needs 16% more railway rakes to ensure efficient dispatch of coal. Railways need source-to-destination pairs for integrated network, which needs visualizing and planning long-term economic activity around those regions. Specialized wagons are also necessary for certain input and new products to be efficient. The dedicated freight corridors (DFC) need to be executed in a time bound manner. The average payloads also lag behind countries such as China, which has increasingly separated passenger and freight movements.
The following steps can help in this direction:

- Lowering the freight class for iron ore to 145, uniform with the freight class for raw material such as coal and limestone. Currently it is 165 same as that of steel which is a finished good.
- Inclusion of iron ore, coal in Long Term Tariff Contract (LTTC) Policy
- Removal of route rationalisation policy (Charging of iron ore and Limestone by a longer route)
- Abolition of long-term policy on freight structure for short lead traffic up to a distance of 100 km.

An infrastructure bottleneck, especially in railway connectivity, is a challenge that can outweigh future growth considerations. Unless there is a significant effort by the Indian Railways to rationalise costs as well as to improve railway connectivity, capacity additions will remain limited.

Road Transportation

In terms of infrastructure, road is the dominant mode of transport which accounts for 68% of freight movement in India. Trucks are the most widely used mode of transportation in India. At present, around 1.5 million trucks operate on the Indian roads and the number of trucks increases around 10% a year.

Road transport is preferred in many cases over railways for movement of finished steels as it if flexible, supplies door to door delivery and useful for shorter load for customers. Tracking trucks has also vastly improved and introduction of GST has helped the sector in speedy delivery.

Despite having one of the extensive road networks in the world, India has long suffered a capacity shortage due to poor road quality. More than 25% of national highways and 50% of state highways are in poor surface conditions and are congested. The major economic centres are not linked by expressways. Most national highways are double-lane or single-lane, with a mere 2% being four-lane or higher standard. According to the World Bank Group Report, the poor condition of roads is exacerbated by an outdated freight vehicle fleet. Very limited modern multi-axle trucks are used, while the extensive overloading by rigid two-axle trucks has resulted in serious damage of road pavement and structure. The overall poor road condition leads to low vehicle speed, and thus less coverage. To illustrate, trucks move on the national highway with an average speed of 30 to 40 km with the distance covered by only about 250 to 300 km, where as in developed countries, the speed and distance covered average twice of that in India.

Ports, Shipping and Inland Waterways

Indian ports are currently suffering from low productivity. Slow unloading of cargos are leading to increased transaction costs and a loss of competitiveness for Indian steelmakers. New policies will be required to increase the seamless connectivity of railways and roads to ports and to provide the required technical and financial assistance in building deep-draft ports to handle large vessels. Port capacities need to be significantly enhanced in terms of ability to handle large cap size vessels, space to manage increasing cargo volumes and mechanization for improved turnaround times. Coastal shipping and inland waterways need to be encouraged and leveraged for reducing costs and managing bottlenecks. Frameworks need to be strengthened to streamline multimodal transportation. The potential to flag shipping vessels in foreign countries to reduce cost of funding is to be explored.

Slurry Pipelines

Transportation of fines mixed with water through Slurry pipelines is becoming popular among Indian steel plants. The erstwhile Essar Steel used this mode very effectively in Odisha and Andhra Pradesh. JSW Steel was also considering this mode for transportation of imported iron ore from port to their Bellary plant. It avoids use of road which normally is congested and prone to delays, accidents and creates pollution. It is faster and can be installed parallel to highways. However it is not free from disturbances by those opposed to the industry.

It is thus apparent from the above that movement of goods in bulk for long distance is the most preferred mode for transportation. Dedicated freight corridors need to be used for speedier movement. New rail lines should come up for connecting mines and steel plants to the consumption points and ports. Infrastructure spend need to go up significantly to build highways and between smaller towns. Multi-axle trucks are to be used for carrying greater loads. The various present constraints at ports including poor work ethics need to be addressed to make the system attractive. Digitisation is key to success for port handling More Slurry pipe lines to be built to replace movement by roads/ railways.

Challenges for Implementation and Reduction of Costs to Customers

Land

Land acquisition has been an extremely cumbersome process, with mixed success in the Indian steel sector. While a new acquisition policy was unveiled, it still needs further improvements to address uncertainty of land acquisition for the entrepreneur. The industry, in general, feels that the Government should still play a facilitator role in identifying special steel zones and create a land bank for potential steel projects, as well as afforestation as mandated under environmental guidelines.

Tax, Duties and Cess

While the government has recently lowered corporate tax rates to 25%, there are certain non creditable taxes, duties and cesses, specifically paid by the steel sector, which reduce the competitiveness of Indian steel products in the global market.

NITI Aayog estimates that Indian steel makers pay an additional amount, varying between USD 15 and 23 by way of taxes, duties and cesses compared to their global peers. Our own calculations estimate the figure to be around USD 35-40, as elaborated in Table 1.

Abolition of these taxes, cesses and duties or making them creditable would only increase India's competitiveness and, in turn, add value to both upstream and downstream steel producing and steel-using units. The National Steel Policy has laid down certain goals. For these to be realised, Indian steel needs to be globally competitive. Otherwise, India will never be able to increase steel exports beyond a certain limit and will continue to be threatened by cheaper imports. To prevent this, the government needs to ensure that the additional burden of USD 80-100 that Indian steel makers are saddled with is removed. Removal of non-creditable taxes, duties and cesses is the easiest to achieve. Otherwise we foresee this to be a big challenge going forward.

Table 1: Type of taxes and rates

Input	Type of Taxes	Amount - Rs/t
Iron ore	Royalty, Clean Energy Cess, District Mineral Foundation, National Mineral Exploration Trust and a few others	1100
Electricity	Electricity duty	500
Freight	Taxes on fuel	500
Customs duty	Customs duty on imports of raw materials	650
Total		**2750**

Source: ISA analysis

Supply Chain Maturity in Steel Performance

The Indian steel industry faces challenges in lower performance attributes as compared to the developed countries as shown in Table 2.

Table 2: Supply Chain Maturity in Steel Performance

Performance Attribute	Metrics	India	Best In Class
Reliability	Forecast Accuracy	50-70%	Over 85%
	Delivery Performance to Customer Request Date	40-65%	97.7%
Responsiveness	Total Order Fulfilment Lead Time	20-30 days	14 days
	Response Time to Inquires	1 day-1 month	Less than 3 sec
Flexibility	Re-plan cycle time	1 to 3 months	15 days
Assets	Inventory Turns	3 to 5	Over 7

Customer Perspective

The present form of logistics industry in India is still in its infancy and is highly fragmented. There are thousands of logistics companies, ranging from the international giants to the highly localised small players in the country. As the logistics industry in India is in nascent stage, there are a lot of logistics issues to be improved. For example, the Indian companies continued to perceive cost as the major consideration in selecting their service providers. With increased competition and global trade, and greater thrust on customer-centricities, the companies are now realizing the value of high quality "customer-responsive" factor. Traditional transporters, freight forwarders and courier companies are rapidly transforming themselves into integrated logistics service providers by incorporating other activities like inventory management, order processing, collection of bills, sales and excise duty documentation in order to effectively utilize their existing assets and experience. The gradual deregulations over the 1990s, which includes the opening up of sectors to foreign MNC investments, full liberalization of current account transactions and the largely permissible of capital account transactions, have further boosted the logistics industry. However, when compared with developed countries, the Indian logistics industry is still considered to be underdeveloped. The major restrictions hindering the growth of logistics industry in India include the poor conditions of infrastructures and transport vehicles, complex tax laws, complexity of international trade documentation process and lack of IT infrastructure, shortage of professionally competent logisticians and insufficient technological aids and the lack of industry readiness. Due to these restrictions, the logistics costs in India are still higher than in the developed markets. It is also forecast that the potential savings for India is about $4.8 billion per year if logistics cost decreases by 1%. At the other end, the average inventory level of grocery stores is recorded to be 45 days of sales in India compared 11-22 days in developed countries. Such inefficiencies indicate that there is much to be done with the current situation in order to boost the Indian logistics industry.

Long Term Perspective to Reduce Logistic Cost for Indian Steel Plants

The Indian Steel Plants except RINL and AMNS (erstwhile Essar Steel) are not located near the coasts like in Japan, S. Korea, etc. Plants like SAIL, Tata Steel, JSPL, JSW Steel were set up close to iron ore mines. This increases freight costs for imported raw material like coking coal, lime stone and sometimes iron ore too. Freight cost for export of finished goods also goes up. AMNS takes iron ore from Odisha through their own shipping vessels and these are transported all the way to Surat.

Another problem area is the market for the finished products. Most of the integrated steel plants are in the eastern region whereas the market is at other regions because of which finished steels travel about 1500 to 2000 km incurring transport cost of approx. Rs 3,500 per tonne.

The measures needed to reduce logistic costs are:

- The location of new Greenfield steel plants needs to be coastal-based as far as possible.
- For iron ore based steel plants, these need to be closer to iron ore mines as 1.6 tonnes of iron ore is needed for production of 1 tonne of finished steel. For scrap-based plants, these can be located where scraps are available and power cost is reasonable.
- Downstream facilities for steel processing need to be set up near the steel plants to reduce transportation cost. The government has already advised for setting up such facilities in the eastern region.
- Steel service centre to be set up next to the steel plant site so that steels are cut to the required lengths, shape, etc. to reduce transportation of unnecessary products at the users' end. Small scale industries can use the cut/ rejected materials locally for production of useful products. For example round blanks can be made out of LPG quality coils and then be despatched. Similar thing can be done for supply to automotive

industry.

- Digitization at every point is required to make the system more effective for speedier movement of goods and easier tracking. Support from both central and State governments are required to avoid delays in inter-state movement of goods and delays on paper work.

Government's Assurance to Reduce Logistics Cost for Steel Players

The Government in a recent FICCI-organised webinar assured steel makers that it will take appropriate measures to reduce the logistics cost of products that currently reaches as high as 28%. Minister of State for Steel Faggan Singh Kulaste told the participants that high cost of logistics is also a matter of concern for the ministry. He sought suggestions from the stakeholders on how to reduce the logistics cost of raw materials and assured them that the ministry will take steps accordingly.

Since India has a target to produce 255 Mt of steel by 2030 for which about 800-850 Mt of raw material would require logistics, the country need huge infrastructure for this. Anticipating the needs of the future, the government has already started working on mega projects in the area of logistics like Sagarmala, Bharatmala and Dedicated Freight Corridor.

The Minister added that currently, for every 250 kilometre, transportation cost of iron ore, a key steel-making raw material, is Rs 800-Rs 1,000 tonne through rail. He added that it comes between Rs 2,000 and Rs 2,500 through road; while via waterways, it comes around Rs 450-550 and through slurry pipelines, it costs in the range of Rs 80-100. He said that once the said projects are completed, these would help reduce both transportation cost and time for materials.

V R Sharma, Managing Director of Jindal Steel and Power Ltd (JSPL), requested the Minister for his intervention to bring down the logistic cost for the industry which works out to about Rs 8,000 per tonne for movement of raw materials and finished goods. It adds about 28% to the factory cost and finally customer has to bear it. In addition there is another 10% cost as Port-handling charges. He requested the minister to take measures to bring it down to about Rs 4,000 per tonne.

Alok Sahay, Executive Director (Commercial) of Steel Authority of India Ltd., suggested for a long-term service agreement with the railways for providing suitable rakes within specified time. This will help customers plan his supply chain in a better way. He also suggested a uniform rate for transportation of materials up to 100 km by railways. "There is a need for rail freight concession on the long-distance movement of iron ore. He also highlighted the challenges faced by the industry in rail transportation & suggested remedial measures for the same.

Pankaj Satija, Chief Regulatory Affairs of Tata Steel Ltd., said logistics is an important part for the industry. He suggested dedicated road corridors for transportation of materials and doubling of railway lines besides setting up slurry pipeline facilities. “It is important for the government to expedite the process of road and railway expansion to meet the future demands. As we are moving towards lower-grade ore, the slurry pipeline is the only viable option.”

Cluster-based industry approach

India’s Ministry of Steel has prepared a draft framework policy for development of steel clusters in the country. This would also generate employment, especially in the Eastern part of the Country covering the States of Chhattisgarh, Jharkhand, West Bengal, Odisha and Andhra Pradesh as part of the Purvodaya initiative of the Ministry of Steel.

Kulaste said that more and more down-stream companies should come up near the steel plant like DRI, pellet and sponge iron plant. This will also help in reducing the logistics cost. “We must emphasize on cluster-based industry approach, adopt newer technologies along with reducing inventory and other costs. The industry must come forward in ensuring these.

Steel and Iron under Dedicated Freight Corridor

Rasika Chaube, Additional Secretary, Ministry of Steel said that the government is aware of the challenges faced by the steel industry and is taking appropriate steps to overcome these. “The ministry is working with all concerned ministries to ensure that the industry and sector get the benefit. Steel and iron ore are important components under the Dedicated Freight Corridor project. The government has already announced the national waterways project and we have mapped the state-wise industry requirement for logistics & are working towards the same,” she added.

Rail freight concession for iron ore

R K Pandey, Member (Projects), NHAI said that the government is coming up with new dedicated Greenfield corridors under the Bharatmala project which will help reduce the logistics cost.

S K Ahirwar, Joint Secretary, Ministry of Commerce & Industry said that the ministry is already in the process of introducing the new logistics policy along with a dedicated National Logistics Portal.

Conclusion

The Government is aware of the need to develop suitable infrastructure for catering to the need of the steel industry. Dedicated freight corridors are presently under construction. The allocation for development of infrastructure including roads, waterways etc. has been vastly increased. New Greenfield steel plants are being planned near the coasts like Paradeep, Andhra Pradesh. Scrap based plants using EAF route are coming up near the point of generation of scrap like Delhi area. Downstream facilities have now been encouraged to set up in the eastern region.

It is expected that with all the initiatives taken by the government, logistic problems will be eased and Indian steel plants will be in a better position to compete globally.

Source: Steel Tech

REFRACTORY DEMAND AND USAGE IN INDIA

Introduction

Refractory consumption in India is primarily driven by the steel sector. The steel industries contributes around 72% of our country's refractory consumption, while the remaining 28% caters to cement, non-ferrous, power & petrochemical, glass and ceramic industries (Table 1). The different types of refractory used in terms of volume, consumption pattern, price and total value during 2019-20 are shown in Table 2. As can be seen, the estimated consumption of refractory material in India is to the tune of 1.6 Mt with a sales turnover in excess of INR 9116 crores. The refractory demand is projected to increase to 2.3 Mt by 2026 with a CAGR of 5.2%. In terms of turnover, the refractory market is expected to increase from 1.2 billion USD presently to 1.74 billion USD by 2026.

Table 1: Consumption of refractory in India by different sectors

S. No.	Industry segment	Consumption level (%)
1	Iron & Steel	72
2	Cement	11
3	Non-Ferrous	5
4	Power & Petrochemical	4
5	Glass	3
6	Ceramics	2
7	Chemical, Fertilizer & others	3

Table 2: Estimation of Indian refractory market in 2019–20

S. No.	Type of refractories	Demand (Tonnage)	Average price (USD/t)	Total value INR (Cr)
1	Basic shaped	279,000	850	1779
2	Basic non-shaped	144,000	700	756
3	Non-basic shaped	645,700	860	4165
4	Non-basic, non-shaped	537,000	600	2417
	Total	16,05,700		9116

Refractory raw materials

The steel industry uses a variety of refractory materials in the coke ovens, blast furnaces, steelmaking facilities and reheating furnaces. Refractories can be broadly classified under three heads, non-basic (acidic) refractories, basic (alkaline) refractories and additives, binders & sintering materials, as shown in Table 3. Non-basic refractory includes silica, alumina, zirconium oxide, SiC and carbon. Basic refractory mainly comprise different types of magnesia (SWM, DBM, FM), dolomite, olivine (dunite) and chromite. Additives and binders consist organic and inorganic based compounds. The estimated volume of binders/ additives required is to the tune of 92,000 tons annually.

India is largely dependent on China for its raw materials, mainly calcined bauxite, tabular alumina, magnesia and graphite. Around 30% of India's refractory materials are sourced from China and other countries resulting in an outflow of 300 million USD annually. The demand and foreign exchange outflow is expected to double with the ramping up of steelmaking capacity to 300 Mt by 2030, as per NSP 17.

Table 3: Raw materials used in the manufacture of Refractories

S. No.	Item	Materials
1	Non-basic (acidic)	Silica, alumina, Zirconium oxide, Silicon carbide and Carbon (graphite)
2	Basic (alkaline)	Magnesia, dolomite, Cao, Olivine & Chromite
3	Additives, Binders, Sintering aids	Additives: Organic & inorganic compounds, accelerator, retarders etc. Binders: Organic & inorganic compounds Sintering aids: Micro silica, rutile, Zirconia

Table 4: Import figures for calcined bauxite

S. No.	Exporters	2016 (tons)	2017 (tons)	2018 (tons)
1	World	90818	98567	70276
2	China	90372	98266	61074
3	Singapore	–	–	3500
4	Hongkong	–	–	3196

Source: ITC Trade Map

Table 5 : Import figures for magnesia (SWM, DBM, FM)-tons

S. No.	Exporter	2017	2018	2019
1	World	143837	327581	301065
2	China	54732	153249	211048
3	Australia	2575	19188	27373
4	Turkey	33501	26506	23698
5	Ireland	28428	29640	15494

Source: ITC Trade Map

Raw material availability and pricing has been a major issue for domestic refractory producers since August 2017. Imposition of environmental regulations in China has led to a substantial increase in cost of refractories by 23% since April 2018 and compelled raw material producers to scale down production. Pollution control measures have resulted in the shutting down of bauxite mines in Shanxi and Guizou province. Thus, there is an urgent need to enhance domestic raw material production and use of alternate sources of raw materials.

Production and Import

India imports large quantity of calcined bauxite, magnesia, tabular alumina and graphite. Table 4 shows the import figures for calcined bauxite during 2016, 2017 and 2018. During 2016 and 2017, the entire requirement was imported from China. In 2018, around 70276 tons were imported worth 26 million USD, with 90% of the total imports sourced from China.

Table 5 shows the import figures of magnesia (DBM), FM) during 2017, 2018 and 2019. It may be seen that the import of magnesia doubled in 2018 to 327581 tons from 143837 tons in 2017. In 2019, 301065 tons of magnesia was imported worth 141 million USD with more than 70% sourced from China.

Refractory manufacture in India is done by major players such as TRL Krosaki, RHI, Calderys, OCL, VIL and IFGL. Apart from the above, a sizeable tonnage is sourced from foreign suppliers such as TRL China, RHI China, OCL China, Minteq USA, NDK Japan, Metamin Turkey, Nedmag Netherland and Queensland Australia. Magnesite obtained from China and Australia have a high purity of 96-97% as compared to 85-92% from domestic sources at Almora and Tanmag. A small quantity of graphite is sourced indigenously from Palamou and Sambalpur, while the rest is imported from China. Dunite which is rich in olivine was earlier available from Salem, but the mines have since closed down due to environmental reasons. Similarly, though we have abundant reserves of bauxite, availability of refractory grade bauxite is fast dwindling and we are dependent on China for the material.

Table 6: Refractory production in India

S. No.	Item	2014-15 (tons)	2015-16 (tons)	2016-17 (tons)
1	Fireclay bricks & shapes	265,335	235,801	229,195
2	High alumina bricks & shapes	218,710	216,917	224,115
3	Silica bricks & shapes	49,595	45,900	45,860
4	Basic bricks & shapes	198,715	191,875	190,020
5	Monolithic castables & precast blocks	318,187	329,933	324,651
6	Special products	60,667	56,792	58,191
7	Others	88,651	61,184	63,636
	Total	**11,99871**	**11,38401**	**11,35668**

Source: IRMA

Table 6 shows production data of different types of refractories produced in India. Out of total production of 11.35 lakh tons in 2016-17, 5.11 lakh tons (~45%) constitutes basic bricks, monolithics and castables, which are extensively used for lining of BOF converters, EAF and ladles. Fireclay bricks and high alumina bricks constitute another ~40% of the production, while the remaining 15% comprise silica bricks and certain special products. The sales turnover of domestic producers together was around INIR 6671 crores in 2016-17, which is around 73% of the market turnover.

Refractory usage in Steel Industry

Steel plants are the largest consumer of refractories, contributing to around 72% of India's annual demand. Refractories are used in the coke ovens, blast furnaces, torpedo ladles for transportation of the hot metal to the converter, BOF converter/EAF, steel ladles, secondary refining units, reheating furnaces etc. For integrated steel plants, the consumption of refractory is around 10-12 kg/tcs, while that of mini steel plants it is higher at around 15-20 kg/tcs, resulting in an average cost of INR 800/tcs.

Coke Ovens

The heating walls of a coke oven battery are traditionally constructed of silica refractory. Silica refractory is material of choice due to its good creep resistance. It also exhibits high resistance to thermal fluctuations and mechanical loads experienced during operation of a coke oven. The lining life of a coke oven battery with proper maintenance is expected to last 15-20 years. Thus, refractory lining cost of a coke oven does not contribute significantly to the overall cost of refractory/ tcs.

Blast Furnace

Selection of appropriate material is important for smooth and efficient operation of a blast furnace. Since different regions of a blast furnace are subjected to different thermal, mechanical and corrosive environments, the type of refractories used varies accordingly. To ensure a consistent and long lining life under stringent operating conditions, it is necessary to have the right type of refractories along with a highly efficient cooling system. Fig. 1 Shows the cross-sectional view of the blast furnace with the different types of refractories used.

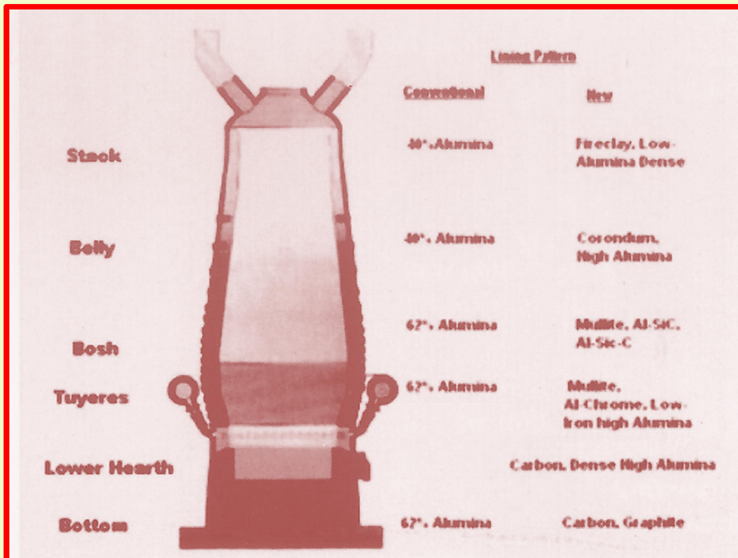

Fig.1: Different type of refractory used in a blast furnace

The bottom part of the hearth of a BF is subjected to corrosive environment and is usually made of dense alumina bricks or conventional carbon blocks. Recent trend is to use super porus graphite blocks. The stack of a blast furnace is subjected to high abrasion and erosion due to the combined effect of descent of charge material and upward movement of hot blast gases. Super duty fireclay refractory brick or dense Al_2O_3 WITH 39-42% Al_2O_3 are used for stack application. In the critical areas of BF such as tuyere, belly and lower stack, SiC, SiC-Si3N4 and corundum refractories are used. Bosh linings, considering the severity of temperature and chemical attack, are made of high duty fire bricks with 45-65% Al_2O_3. Carbon blocks are also used in the bosh region and it gives better life than fire bricks. The hot blast stoves are made of 42-82% alumina bricks and more recently, 70-82% alumina, 91% SiO_2 checker bricks are used. A freshly lined BF is expected to have a campaign life of 15 years with intermediate minor zonal maintenance.

BOF and Ladles

The purpose of refractory lining in BOF converter is to ensure maximum furnace availability and achieve low specific refractory consumption. Typical refractory lining is shown in the cross-section of a BOF in Fig.2. BOF converters are subjected to oxidizing atmosphere, mechanical and thermal stresses and high temperatures. Earlier, converters were lined with tar dolomite bricks and pitch bonded dolomite bricks. Dolomite is available in India, but only a small fraction is suitable for sintering and use as refractory material. The steel industry shifted from dolomite Mag-C refractories in the 70's due to certain inherent limitations of dolomite bricks such as poor refractoriness, higher heat losses and susceptibility to hydration. The Mag-C bricks have superior refractoriness of ~2800 C as compared to 1540-1630C for dolomite and negligible hygroscopic susceptibility. Recent developments include advanced refractories made with resin bonds, metallics, graphite and fused MgO of ~99% purity. The major factors contributing to the quality of magnesia refractory are purity, crystal size, bonding agent and type, quality of graphite used and type and amount of anti-oxidants used. Magnesia refractories are of various types obtained from different sources such as sea water magnesia (SWM), dead burnt magnesia (DBM) and fused magnesia.

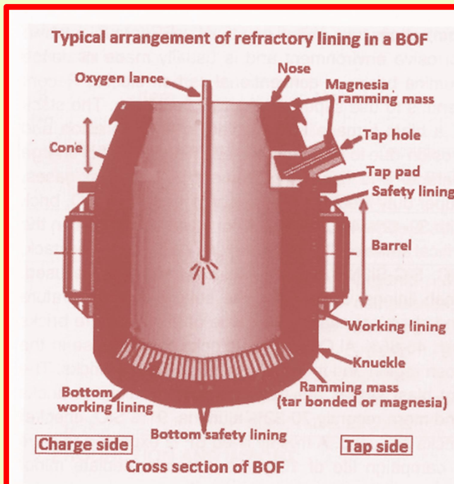

Fig.2: Cross sectional view of a BOF converter

The refractories lining of steel ladles have undergone a lot of changes from high alumina bricks to alumina-magnesia, aluminium-magnesium spinel castable, aluminium MgO-C bricks and many others. Fig.3 shows the cross section of a ladle. The different types of refractories used in the ladle are as follows:

Slag line: MgO-C bricks with 10-12% C.

Sidewall: Magnesia, Anti-oxidants & graphite (AMG), Magnesia, alumina, carbon (MAC), MgO-C

Bottom: AMG or MgO-C brick

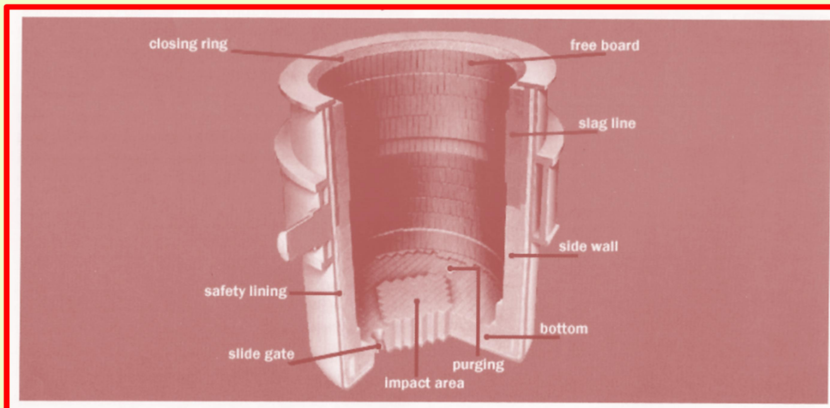

Fig.3: Cross sectional view of a steel ladle

The lining life of a BOF varies from 3000-10,000 heats, depending on the refractory used and frequency of intermediate repairs and maintenance. Usually, a converter is taken down once a year for capital repair, when the lining material is replaced. Intermediate slag splashing technology is used where residual slag from the steelmaking process is used to coat the inner surface of the converter and improves the lining life. A ladle however, has an average lining life of 100-140 heats and requires relining every month.

Another area where refractory is used are the reheating furnaces used for heating the slabs, blooms and billets before rolling them to finished products. For reheating furnaces Al-Si refractory materials are used containing 36-75% alumina.

Electric Arc Furnace (EAF)

Fig. 4 shows the view of an EAF. Depending on the operating conditions, a variety of refractory materials are used in the different parts of the EAF. The roof of the arc furnace uses high alumina bricks containing 75-85% Al203 which is characterized by high refractories, thermal shock resistance, good slag resistance and high compressive strength. The furnace wall is divided into general furnace wall, slag line area and hot spot near the arc. The main furnace wall uses MgO-C bricks. Arc furnace walls with ultra-high power or smelting special steel requires magnesia-chrome bricks. Slag line area and hot spot requires refractory lining made from 10% graphite or high quality fused LC magnesia. The hearth of an EAF comprise tar pitch bonded magnesia brick as working lining, dead burnt magnesia brick as permanent lining and a protective ramming mass of high CaO/FeO dry MgO. The tap hole is usually lined with resin bonded MgO-C bricks.

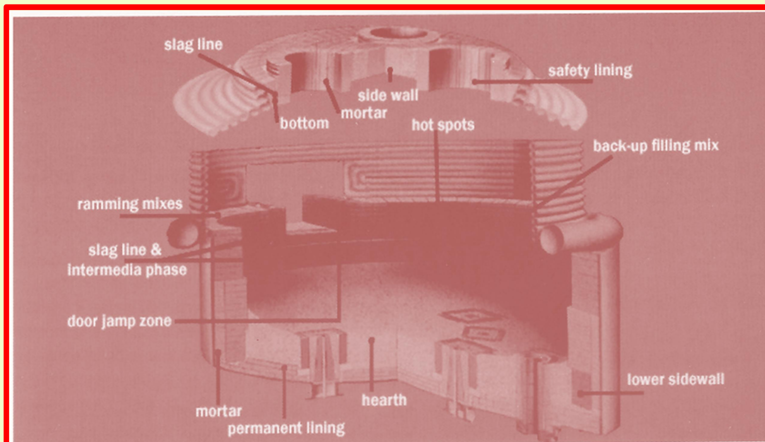

Fig.4: Cross sectional view of an electric arc furnace (EAF)

Concluding Remarks

- The refractory consumption in India is estimated to be around 1.6 Mt annually with a sales turnover in excess of INR 9000 crores.
- Steel industry consumes more than 72% of the total refractory demand in India, while the remaining 28% caters to the needs of cement, non-ferrous, petrochemical, glass and ceramic industries.
- India is overly dependent on China for its raw materials, mainly calcined bauxite, tabular alumina, magnesia in the form of dead burnt magnesia (DBM) and fused magnesia (FM) and graphite. Around 25% of country’s refractory requirement is imported from China with

the remaining 5% from other countries.

- Around 5 lakh tons of raw material/ finished products are imported annually resulting in an outflow of 300 million used annually.
- Environmental regulations imposed by China has led to a shortage of raw materials and a 23% surge in price since April 2018. There is an urgent need to scale- up domestic production and identify alternate sources of raw materials.
- India imported around 90% of its calcined bauxite requirement (61074 tons) during 2018 from China. Similarly, 70% (211048 tons) of DBM and FM were imported from China during 2019. The remaining 30% was sourced from Australia, Turkey and Ireland.
- India produced around 11.35 lakh tons of refractory during 2016-17, out of which 5.11 lakhs (~45%) comprise basic bricks, castables and monolithics, which are used in steelmaking vessels. Fireclay bricks and high alumina bricks used in BF lining constitute around 40% of the production while the remaining 15% essentially silica and Ai-Si bricks used in coke ovens and reheating furnaces of rolling mills in addition to other special refractories for special alloy steel and stainless steel production.
- The annual turnover of domestic refractory producers is around 6670 crores, which is roughly 73% of the refractory market.
- The consumption of refractories is around 10-12 kg/tcs for the integrated steel plants and 15-20 kg/tcs for the mini steel plants. Average cost of refractory to the steel producers is around INR 800/tcs.
- Coke oven batteries are traditionally lined with silica refractories. A freshly lined battery is expected to last 15-20 years with minor preventive maintenance.
- The BF uses different types of refractory materials such as dense alumina bricks, super porus graphite blocks in the hearth. Super duty fireclay bricks, SiC and corundum refractories are used in the critical zones. A freshly lined BF has a campaign life of 15 years with minor intermediate repairs.
- BOF converters are lined with Mag-C bricks. The lining life varies from 3000-10000 heats, depending on the type and quality of refractory used. The relining of a BOF converter is usually scheduled with the capital repairs and the lining life is accordingly designed.
- Refractory material used in steel ladles are Mag-C, AMC and MAC bricks. The lining life of a ladle is typically 100-140 heats, after which it is taken out of circulation for relining.
- Reheating furnaces are lined with Al-Si refractories containing 36-75% alumina.
- EAF uses high alumina bricks for the roof and Mag-C bricks for the furnace wall. The hot spots and slag line are made of 105 graphite or fused LC magnesia.

Future Outlook

India has moderate reserves of raw materials used for the manufacture of refractories such as bauxite, dunite, silica, magnesia, graphite. Some of these mines are closed due to environmental regulations while the others need beneficiation to improve their quality and purity level. There is a need for concerted R&D activities supported by the Government in order to make the country Atmanirbhar and reduce our dependence on other countries. In step with this initiative, SAIL, one of the largest steel producer in the country, has recently organized a webinar with domestic refractory manufacturers from different regions to explore possibilities to enhance usage of domestically manufactured refractory in SAIL plants. Opportunity will be provided to the domestic manufacturers to invest in R&D and develop alternate products for which SAIL will provide necessary support and platform for trials. The following suggestions are put forward for consideration.

- Explore and develop alternative sources of raw material and mines in India. Focus on development of substitute materials/ products based on raw materials available in India.
- Increase the domestic refractory industries capacity utilization, which is presently around 60%, through technology driven innovation, price competitiveness and development of value added products.
- IRMA to initiate engagement with GOI and major refractory producers for scouting alternative supplies of refractory material from Brazil and Europe.
- Creation of a "Centre of Excellence" for carrying out cutting edge research on the development of alternative raw materials and products specifically for the Indian steel industry at competitive cost. MOS and steel industry should join together and fund such programs on a national mission mode.
- CGCRI, CSIR and academic institutes should take up research projects which are industry specific and addresses real issues faced by the industry.
- Rationalise the duty structure since the present system makes imported finished goods cheaper than those made in India with raw material sourced from overseas. GOI should encourage and provide incentives to local manufacturers to boost domestic production of raw materials and finished products as part of "Make in India" and PM's Atmanirbhar initiative.

Source: Steel Tech

CAST METAL MATRIX COMPOSITES OVER LAST 50 YEARS AND FUTURE OPPORTUNITIES IN INDIA

Abstract

Research in Cast Metal Matrix Composites in India was started in 1968 at IIT Kanpur and now India is considered as one of the world leaders in Cast MMC Research according to a recent Business Report. Metal matrix composites (MMCs) have received increased attention worldwide due to their potential applications in aerospace, automobile, railways motorcycles, computer hardware and recreational equipment and the total volume of MMC industry is now 400 million per year. This paper reviews the progress in Cast MMCs over 50 years in India in relation to the developments worldwide and discusses future of next generation cast metal matrix composites. The information on MMC industry worldwide including major producers and users of cast MMCs will be presented. Some cast MMCs discussed will include Aluminium-Graphite, Aluminium- Silicon Carbide, Aluminium-Alumina and Aluminium-Fly Ash. Current and future directions in Cast MMCs, including manufacture of foundry produced Nano-Composites, functionally gradient materials, syntactic foams; self-healing and self-lubricating composites will be presented. Solidification issues in casting

metal matrix composites, the major challenges in casting metal matrix composites will be outlined. Recent progress in manufacture of lightweight self-lubricating cylinder liners for compressors, piston and rotary engines in Al-Graphite and Al-Graphite-SiC composites are discussed. The opportunities of manufacturing cast metal matrix composite in foundries in India for internal consumption and exports will be presented.

Keywords

Metal Matrix composites, hybrid composites, functionally graded materials, stir casting, nanocomposites, self-healing and self-lubricating composites, lightweight.

Introduction

The increased demand for lightweight materials with high specific strength, stiffness and better tribological properties in the automotive, aerospace and defence sectors have accelerated the development and use of MMCs[1-4]. Automotive manufacturers strive to reduce vehicle weight in order to improve performance, lower fuel consumption and reduce emissions. Many automotive components made of steel and cast iron could be replaced by components made from less dense metals or metal matrix composites. In recent years, aluminium metal matrix composites (MMCs) used for tribological components have attracted more and more interests. They are widely used as high-speed rotating or reciprocating mass items such as pistons, connecting rods, drive shafts, brake rotors and cylinder liners. Aluminium and its alloys are widely used for the fabrication of MMC because they are light in weight, economically viable, amenable for product by various processing techniques and possess high specific strength and good corrosion resistance properties. India has had a leadership in research on cast MMCs over the last 50 years and there is a very large opportunity for manufacturing these composites in Indian foundries for internal consumption and exports. There is an exponential growth in paper publication on cast metal matrix composites from Indian Institutions like IITs, NITs, IISc, DMRL, and CSIR.

Aluminium matrix composites have been developed to meet very high-performance defence and aerospace needs[1-7]. As material cost became a more significant consideration, the emphasis shifted toward particulate-reinforced materials, with the goal of a lower cost, high volume product that could be used in automotive and commercial aerospace applications. Many of the major aluminium companies had MMC development programmes in the 1980's and early 1990's. Alcan, through its Duralcan subsidiary, established a 25 million pound per year production capability for particulate-reinforced aluminium composites.

The conventional cast MMC developed and used contains mainly one type of discontinuous reinforcement[6-7]. However, in order to introduce the multifunctional property requirement, more than one type of reinforcements are introduced within a single component leading to hybrid MMC with enhanced and synergistic properties. Similarly, in recent times, newer functionally graded/ gradient MMC with selective and graded reinforcement are processed to obtain location specific properties within a component. Nano MMC is synthesised with large enhancement in mechanical and physical properties, with minimum reinforcement addition. In recent years, metal matrix composites have been extended to produce self-healing, self-cleaning and self-lubricating castings.

Processing of cast metal matrix composites

The evolution of different metal matrix composite systems has led to the development of newer processing techniques, in addition to conventional metal processing techniques. The major criteria for the selection of a process rely on the type of composite system to be fabricated, the properties required and the component to be produced. Apart from the adoption of conventional foundry processing methods for making MMC, newer solidification and casting process were developed suiting to the shape and property requirements of engineering components.

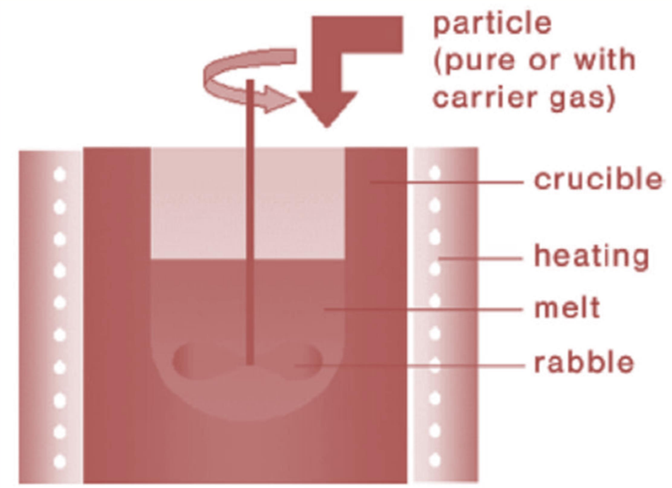

Fig 1: Schematic diagram of liquid metal stir casting process

The processing methods of MMC are widely classified into primary and secondary processes. The primary processing techniques combining matrix and reinforcements to produce the basic composite systems are classified into liquid and solid state processes. The important primary liquid state processes are stir casting or vortex method, infiltration, in-situ and spray deposition processes. The important solid state processes are powder metallurgy and diffusion bonding. The developments in liquid state processing methods used in foundries for making cast MMC are described here. Stir casting or vortex method is the simplest and economical process available for the manufacture of MMC in large quantities in foundries. In the process, the molten metal is stirred and dispersoids are added through the vortex. Figure 1 shows the schematic diagram of liquid metal stir casting process. Surface treatments and

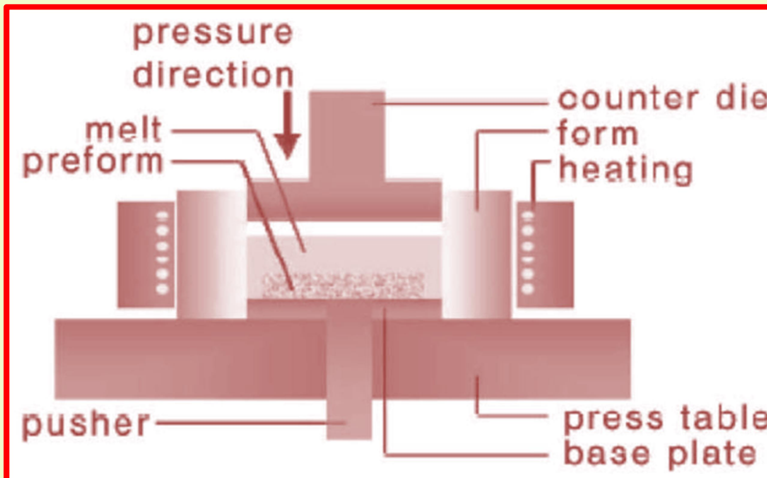

Fig 2: schematic diagram of squeeze cast infiltration process

addition of wetting promoters into the melt can enhance the particle distribution and its bonding in the matrix. This method is commonly used for fabricating discontinuous dispersoids reinforced MMC. The hybridisation can be carried out by either melting a composite and introducing the second reinforcement or introducing both the dispersoids in the matrix alloy simultaneously.

Infiltration process involves infiltrating the liquid metal through the interspaces in a porous preform made out of reinforcements, with or without the application of an external force. The infiltration of liquid metal could be made with or without the application of an external force. Figure 2 shows the schematic diagram of squeeze infiltration process. Synthesis of porous ceramic/ fibre preforms with sufficient strength to withstand the squeeze pressure is a crucial step in processing. The infiltration processes are classified depending on the nature and type of force applied as pressure, pressureless, vacuum, combination of pressure and vacuum, etc. Infiltration process is very effective for synthesising fibre-fibre, fibre-particle, functionally gradient and selectively reinforced hybrid composite systems, with high volume percentages of reinforcements. Similarly, hybrid composites with high volume fraction of reinforcements could also be successfully fabricated. In-situ composites are lower in cost as it involves synthesis of reinforcements within the melt itself using chemical reactions or pyrolysis of polymers.

In-situ process involves generating the reinforcement material by chemical reactions from the matrix alloy within the melt with the introduction of selective additives and the composites thus produced are known as in-situ composites. In-situ hybridisation of reinforcements could be made by the reaction between the various components of the system to produce two or more dispersoids, which contribute to the properties of the composites. In situ hybridisation can also be made by the reaction between the surface coatings of reinforcement with the matrix to produce a second type dispersoids. The advantage of in-situ method is the development of composites dispersoids both in micro and nano size range and stable metal-reinforcement interface.

Hybrid metal matrix composites

Hybrid metal matrix composites (HMMC) are the second generation composites, wherein more than one type, shape or size of reinforcements are used to obtain the synergistic properties of the reinforcements and the matrix. Al-SiC-Graphite Composites are one of the potential hybrid systems for automotive application with lighter weight, better wear resistance and antifriction behaviour. Cast Al-SiC-Graphite Composites have been developed for cylinder liner applications[6]. The addition of graphite to aluminium-SiC provides three unique benefits viz greater stability of particle distribution during casting process, improved machinability and increased resistance to wear. Graphite provides seizure resistance while the hard particulate provides abrasion resistance, resulting in a material with excellent dry sliding wear performance.

In order to produce a lighter engine compared to cast iron liners, an aluminium block and a hypereutectic aluminium silicon alloy has been developed as an alternative to cast-iron blocks and liners. To replace the cast iron liners, a new engine block has been developed in which the cylinder liners of aluminium based composite reinforced with short hybrid fibres of alumina and carbon are used. The self-lubricating effect of carbon fibre contributes to improvements in antiseizure when there is no continuous oil film in the cylinder bore surfaces. The engine blocks and the cylinder liners developed using Al-1.5Cu-9.6Si (ADC12)-12% Al_2O_3 (sf)-9%C (sf). HMMC are light in weight and have lower wear than conventional engine block. These engine blocks can be efficiently mass produced through preform production and casting process and possess better wear resistance due to Al_2O_3, improved lubrication by carbon fibre, 50% the weight of cast iron and improved cooling efficiency. MMC engine blocks manufactured using Saffil-carbon fiber hybrid preforms reinforced with aluminium have been used by Honda in the Accord, Ascot, Innova (two-wheeler) and the S2000 models.

Functionally graded metal matrix composites (FGMMC)

Functionally Gradient / Graded Materials (FGM) are emerging as a new class of materials, exhibit gradual transitions in the microstructure and/or the composition in a specific direction, the presence of which leads to variation in the functional performance within a part. The presence of gradual transitions in material composition in FGM can reduce or eliminate the deleterious stress concentrations and result in a wide gradation of physical and/ or chemical properties within the material. FGMs are in their early stages of evolution and expected to have a strong impact on the design and development of new components and structures with better performance.

A wide variety of processing methods are available for the fabrication of functionally graded metal-ceramic composites, hence it is difficult to group them. Mortensen and Suresh have classified the processing methods of FGM broadly as constructive and transport-based processes. In the constructive processes, the FGM or the precursors such as preforms are constructed layer by layer with appropriate gradients in the distribution of constituent phases. On the other hand, the transport based processes create the gradients in local microstructure and/ or composition in a component by the natural transport phenomena such as the flow of fluid, the diffusion of atomic species or by heat conduction. In liquid state processes, the matrix is either fully or partially molten during the formation of FGMMC. The important liquid state processing methods are infiltration, gravity aided settling, centrifugal casting, sequential casting and spray forming. Among the various fabrication techniques mentioned above, important solidification processing methods are infiltration, settling, centrifugal casting, spray casting and laser melt processing, which are described below.

Infiltration process involves the preparation of graded ceramic preform containing graded porosity and its infiltration with the liquid metal with or without the application of pressure or vacuum. Al FGMMC for automotive applications has been successfully fabricated, featuring graded transition from aluminium to ceramic reinforced aluminium at surfaces. One of the critical steps involved in this process is the fabrication of the preform with the required concentration of the particles. In the case of higher volume fraction, preform should not experience excessive deformation during pressure assisted infiltration of metal. Figure 3 shows the aluminium-SiC composites prepared using a graded porous SiC preform and by squeeze infiltration technique. Aluminium pistons locally reinforced along their crown surface have been produced using preforms containing four layers of distinct volume fraction of 21, 25, 40 and 51% of hybrid reinforcements of alumina short fibres and aluminium titanate particles, which are created by conventional slurry and binder methods. These graded composites have shown superior thermal crack resisting performance, compared with corresponding unreinforced and ungraded MMC pistons.

Metal matrix nano composites

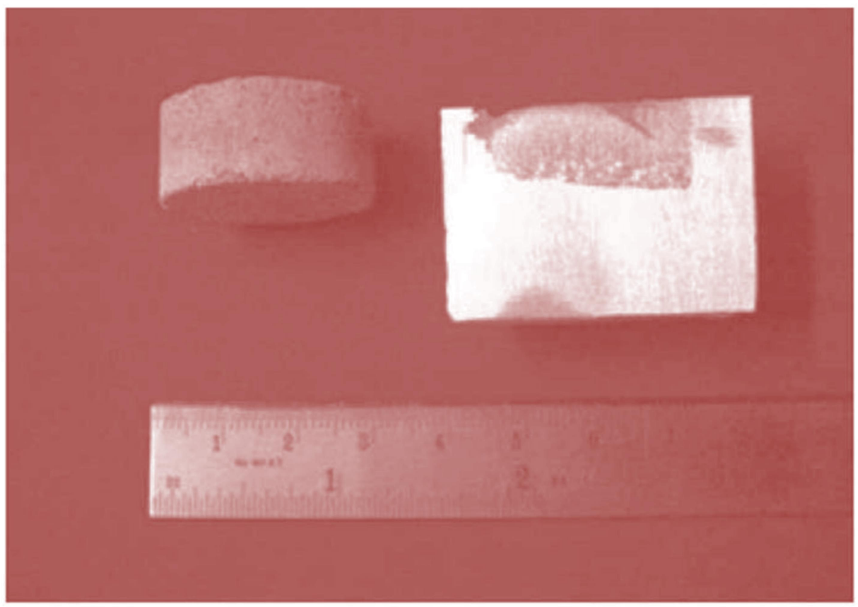
Fig 3: Graded SiC perform and aluminium–SiC infiltrated specimen

Nanostructured and ultrafine grained materials offer exotic ranges of physical, chemical, electronic and engineering properties over the conventional bulk microstructured materials. The greatest challenges in the development of nano and ultra-fine grained MMC for wider applications are the cost and complexity in processing these MMC as well as the cost of nano-scale reinforcements. The improvement in properties of nano and ultra-fine grained MMC greatly depends on size, distribution, volume fraction and properties of the reinforcements and the interfacial behavior between matrix and reinforcements. The high surface area of nano size reinforcements tends to agglomerate and generates problem in uniform distribution in the matrix when processed through conventional methods. Nano MMCs are processed by liquid metal dispersion of nano size reinforcements, infiltration of liquid into a nano-dispersoids preform and rapid solidification techniques.

Liquid Metal Dispersion involves production of nano or ultrafine grained MMC by dispersing the fine reinforcements into the molten metallic matrices by some form of agitation. Liquid metal stir casting, ultrasonic dispersion and electromagnetic dispersion are some of the variants of liquid metal dispersion processes. Aluminium Alloy-Al_2O_3 nano MMC have been fabricated by combination of stir mixing and ultrasonic mixing processes with the addition of wetting agent to the molten alloy.

Cast metal matrix syntactic foams

Syntactic foams are made in foundries by pressure infiltration and stir casting process[11-13]. Hollow ceramic particulates including fly ash cenospheres are infiltrated by aluminium alloy, to create aluminium fly ash syntactic foam as shown in Fig 4. The density of this Cast Aluminium Hollow cenospheres foam is 1.4 gm/cc and demonstrates the potential of reducing the weight of aluminium by the incorporation of fly ash cenospheres. This opens up the possibility of producing syntactic foams with other cenospheres, not just fly ash, in foundries. These foam materials have high damping capacity and energy absorbing characteristics of interest to automotive industries. In addition to fly ash other hollow micro balloons of alumina have also been incorporated in the matrix of metal to synthesize syntactic foams.

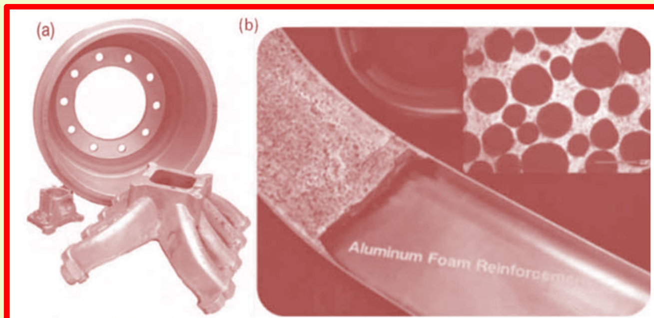

Fig 4: (a) Automotive components made of aluminium- and magnesium-fly ash composites developed at UWM11 (b) Aluminium-fly ash cenosphere syntactic foam (micrographinset) within a steel frame. (Courtesy of Bob Purgert)

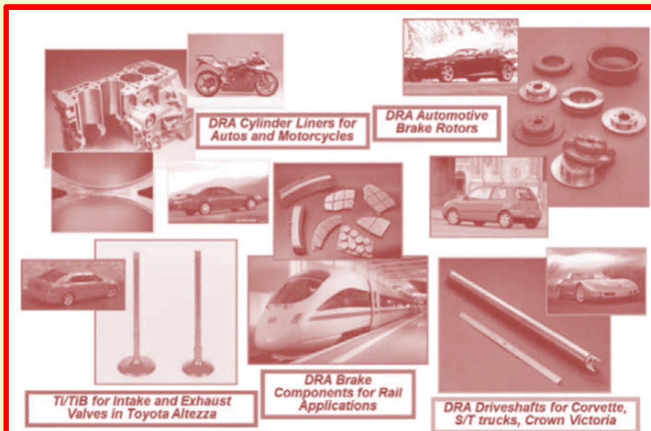

Fig 5: MMC uses in automotive applications as cylinder liners, brake rotors, intake and exhaust valves, and driveshaft etc

Applications

Metal Matrix composites have emerged as one of the advanced engineering materials having potential application in the areas of aerospace, automotive, defence, electronics, general engineering and other advanced structures. They can be tailored to have the required superior properties such as high specific strength and stiffness, increased wear resistance,

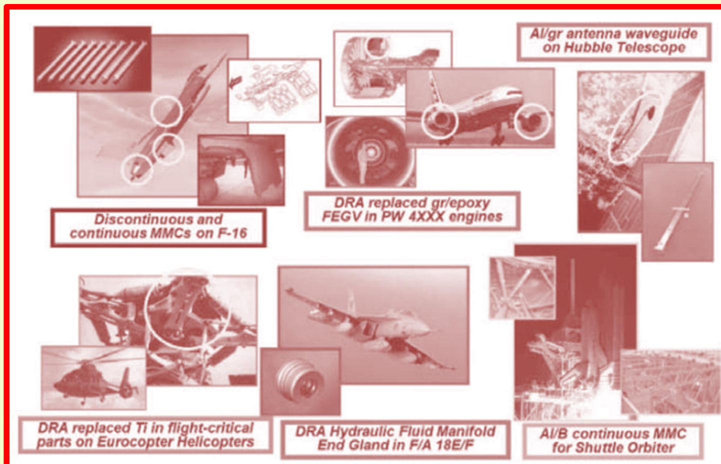

Fig 6: MMC uses in space industries

enhanced high temperature performance, and improved thermal conductivity, low coefficient of thermal expansion, high damping capacity and better thermal and mechanical fatigue and creep resistance, than those of monolithic material. This has led to their widespread use in automotive, aerospace, thermal management and heat sink, and recreational equipment applications.

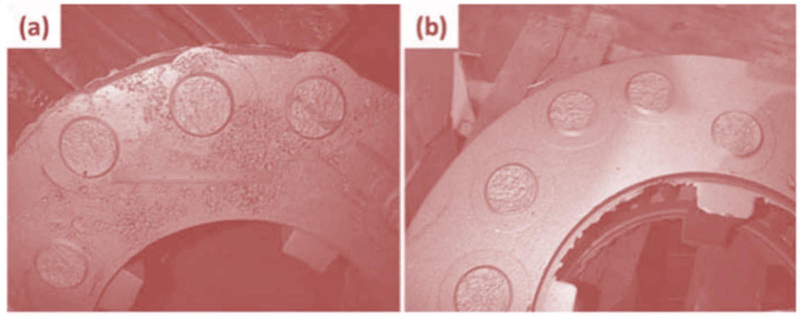

Fig 7: Train rotor made from Duralcan

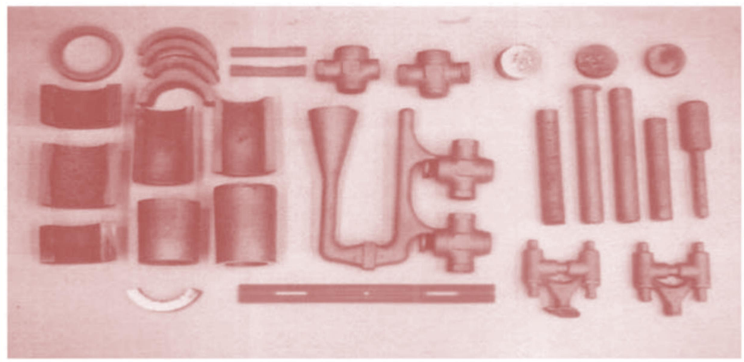
Fig 8: Montage of lead-free copper-graphite composite castings

Several automotive components including pistons, cylinder liners, brake rotors and connecting rods have been made out of aluminium composites as shown in Fig 5. Table-1 shows the development of metal matrix composites by different industries [Metal-Matrix Composites in Industry: A Database of Companies, Materials, and Products 2011]. Continuous fibre reinforced aluminium was used in the Space Shuttle and Hubble Space Telescope. The metal matrix composites used for aerospace components are shown in Fig 6 and brake rotors for trains made out of Al-SiC composites in foundries are shown Fig 7.

Table-1: Aluminium MMC Components developed and used in automobiles

Composite System	Production Method	Automotive Component	Manufacturer
Al-Graphite(p)	Gravity casting	Cylinder liners	AEC, Ferrari, Hiromotors and Alfa Romeo
Al -$SiC_{(p)}$	Gravity Casting	Piston	Lanxide, Dural
Al-$SiC_{(w)}$	Squeeze Casting	Connecting Rod	Nissan
Al-SiC_{P}	Compocasting Squeeze Casting Extrusion	Shock Absorber Cylinder	Mitsubishi
Al-$SiC_{(W)}$	Squeeze Casting	Diesel Engine Piston	Niigata
Al-$SiC_{(p)}$	Squeeze Casting Extrusion	Drive Shaft	Dural, GKN
Al-Alumina, $C_{(f)}$	Low Pressure Forming	Cylinder liner	Honda
Al-$Alumina_{(p)}$	Gravity Casting	Brake Rotor	Dural
Al-$Alumina_{(f)}$	Squeeze Casting	Piston Crown	Toyota
Al-Alumina $_{(f)}$	Squeeze Casting	Piston Ring Grove	Toyota
Al-$SUS_{(CF)}$	Squeeze Casting	Con Rod for Petrol Engine	Honda
Al -$FP_{(CF)}$	Squeeze Casting	Connecting Rod	Du-pont
Al-$Al_2O_{3(sf)}$ -$C_{(sf)}$	Squeeze Casting	Engine	Honda

Since Lead is being banned in a number of copper alloys for bearing and plumbing applications, lead-free copper graphite composites have been developed at UWM USA as a substitute for lead containing copper alloys for plumbing and bearing applications. Graphite particles have been shown to impart machinability and lubricity similar to lead at much lower costs without the associated toxicity. Graphite is also much cheaper and abundantly available compared to Bismuth and Selenium which are being proposed as alternatives to lead. Figure 8 shows a large number of plumbing fixtures and bearings cast in lead-free copper-graphite alloys at UWM. By centrifugally cast copper alloy- graphite composite, one can concentrate the graphite particles on the inner periphery, where they selectively reinforce and provide solid lubrication for bearing applications. Instead of using lead, one can in a single step, produce selectively reinforced, self-lubricating copper graphite alloy, by centrifugal casting of copper alloy-graphite melts for bearings.

Table-2: Components which can be manufactured by Centrifugal Casting

Bearings, bearing bushings and cages	Heat exchanger tubes	Railroad car wheels and bearings
Brackets	Hoist drums	Retorts
Brake drum liners	Hollow extrusion billets	Rocket and missile fins
Cylinder liners	Hydraulic and pneumatic cylinder tubes	Sewage pipe
Dental prosthetics	Impellers and blades	Shells for canned motor pumps
Ductile iron pressure pipe	Paper and textile mill rolls and drums	Sleeves
Electric motor rotors	Piston rings and piston inserts	Stator shells for atomic power
Electronic module cases and covers	Pressure vessels	Steel mill rolls
Gas turbine rings	Pulleys and sheaves	Submarine masts
Gears, gear blanks, including bi-metallic	Pump rotors and liners	Thin-wall aerospace components

For more than a decade, Kolben Schmidt, Mahle, AE and Toyota have pioneered the use of Saffil fibre reinforced pistons for diesel engines, while Honda Motor Company focused on the reinforcement of engine blocks. Cast aluminium matrix composite brake drums and rotors have been used for the Prowler and EV-1, driveshaft for the Corvette and GM S/T truck, and tire studs in Scandinavia. In 1990, Honda launched a new generation of aluminium engine blocks with fibre reinforced cylinder walls replacing traditional cast iron liners. The first model selected for production was the Prelude Si, a 16-valve in-line 4-cylinder engine, using a new casting process to incorporate the Saffil-carbon fibre hybrid preforms discussed earlier, Elimination of the cast iron liner using MMC technology allows a reduction in material thickness between the adjacent bores. Tightening the cylinder spacing in this way results in reduction in the overall length of the engine and a weight saving on the block of around 4.5 kg. Honda has since expanded the use of MMC engine blocks in their vehicles like Accord, Ascot, Innova and the S2000

Table-3: Use of Metal Matrix Composites in Automotive Applications Developed at UWM

METAL-MATRIX COMPOSITE (MMC) MATERIALS BEING DEVELOPED AT UNIVERSITY OF WISCONSIN–MILWAUKEE FOR USE IN AUTOMOTIVE APPLICATIONS

Property	Materials	Application
Wear resistance	SiC-, Al_2O_3-, and/or graphite-reinforced micro and nano MMCs	Bearing surfaces, cylinder liners, pistons, cam shafts, tappets, lifters, rockers, brake components
Light weight, energy absorption	Fly ash cenosphere- and low-density ceramic microballoon-reinforced syntactic foam MMCs	Crumple zones, frame members and reinforcements, pedestrian impact zones, batteries
Self-cleaning	MMCs with hydrophobic reinforcements, biomimetic coatings, and surface finishes	Water pumps, water jackets, exposed metallic components
Self-lubricating	Micro and nano MMCs incorporating graphite, MoS_2, TiB_2, hexagonal BN, or other solid lubricants	Bearing journals, cylinder liners, pistons, cv joints, gear surfaces
Self-healing	MMCs incorporating shape memory alloys or hollow reinforcements filled with low-melting healing agents	Difficult-to-access, fatigue prone, and critical components, such as driveshafts, wheels, steering knuckles and columns, and connecting rods
High thermal conductivity	Micro and nano MMCs reinforced with high conductivity carbon, diamond, or cubic boron nitride (cBN) powder	Cylinder liners, water passages, brake components, turbo/supercharger components, catalytic converters, electronics packaging
High strength	Micro and nano MMCs reinforced with SiC or Al_2O_3 particles, carbon nanotubes (CNT), carbon or Nextel fibers, and in-situ ceramics	Connecting rods, brake calipers, brake rotors, brake calipers
Low cost	MMCs containing fly ash or waste sand as fillers	Intake manifolds, accessory brackets, low-load brackets, oil pans, valve covers, alternator covers, water pumps

Table-4: Selected companies who have produced and used discontinuously reinforced cast MMC components[5]

3M Company, Specialty Fibers and Composites, USA	Ford Motor Company, USA
Advanced Refractory Technologies, Inc., USA	Foster-Miller Inc, USA
Alcan, USA	General Motors, USA
Alcoa, USA	Gibbs Die Casting Corporation, USA
Ametek, Inc, USA	High Performance Materials Group (HPMG), USA)
Bell Helicopter Textron, Inc, USA	Hitchiner Manufacturing Company, Inc, USA
Boeing, USA (www.boeing.com)	Honda Motor Company, Ltd,
Chesapeake Composites Corporation, USA	KolbenschmidtPierburg AG, Germany (www.kolbenschmidt.de)
Composite Metal Technologies Plc, UK	London & Scandinavian Metallurgical Co Ltd (LSM), UK
Cycotech Pty Ltd, Australia)	M-Cubed Technologies, Inc, USA (www.mmmt.com)
Cymat Corporation, Canada	Mahle GmbH, Germany (www.mahle.com)
DaimlerChrysler AG, Germany	Mazda Motor Corporation, Japan
Delphi Automotive Systems, USA	Metal Matrix Cast Composites (MMCC), USA
Dynamet Technology, Inc, USA	(MC-21), USA (http://www.mc21inc.com)
Motorola, Inc, USA (www.motorola.com)	Porsche, Germany (www.porsche.com)
PCC Advanced Forming Technology, USA (www.pcc-aft.com)	Siemens AG, Germany (www.siemens.com)
Sandvik AB	Toyota Motor Corporation, Japan (http://www.toyota.com/)
GKN Sinter Metals Engineering GmbH.	Hitachi Metals, Ltd.
Plansee SE	CPS Technologies Corporation, USA
Sumitomo Electric Industries Ltd.	Deutsche Edelstahlwerke GmbH
3A Composites	Santier
Materion Corporation, USA	Ceradyne, Inc.
Metal Matrix Cast Composites LLC	TISICS Ltd.
Daewha Alloytic Co. Ltd.	Thermal Transfer Composites LLC
ADMA Products, Inc.	Inco Ltd, USA

models. Honda has also developed a high pressure die casting (HPDC) process for manufacturing the MMC engine blocks which reduces process costs and enables widely available equipment to be employed. Hence, discontinuously reinforced MMCs based on particulates, short fibres and whiskers have become the potential composite systems for automotive sector. The potential components, which can be fabricated using metal matrix composites by Centrifugal Casting, are given in Table-2, Table-3 summarises the use of metal matrix composites in automotive applications developed at UWM[5]. Table-4 shows the major companies producing discontinuously reinforced cast MMC and their engineering components.

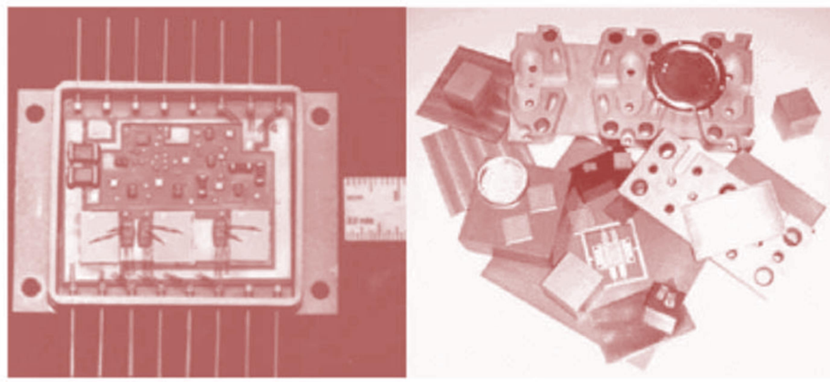

Fig 9: Discontinuously reinforced aluminium MMCs for electronic packaging applications: (a-left) SiCp/Al electronic package for a remote power controller (photo courtesy of Lockheed Martin Corporation), and (b-right) cast Grp/Al components (photo courtesy of MMCC, Inc.)

Al-SiC (Aluminium Silicon Carbide), a metal-matrix composite, provide highly reliable and cost-effective thermal management solutions for electronic packaging. It offers high thermal conductivity (~200 W/mK) and a tailored, low Coefficient of Thermal Expansion (CTE). The low density and high strength and stiffness values give AlSiC added advantages over more dense, traditional materials in applications where weight savings or shock and vibration tolerance are required. Several SiCp/Al and Grp/Al (Fig. 9) electronic packages have been space-qualified and are now flown on communication satellites and Global Positioning System satellites. These components are not only significantly lighter than those produced from previous metal alloys, but they provide

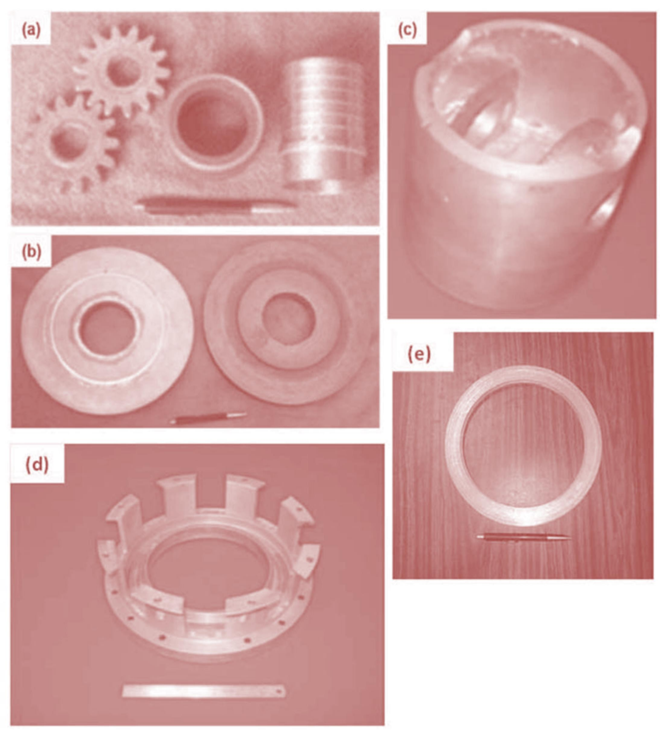

Fig 10: Functionally graded aluminium matrix composite prototype components at CSIR-NIIST(a) cylinder liners and gears (b) brake rotor disc (c) piston for engineering application (d) Al (356)-15%SiC metal matrix composite first gear housing and (e) piston ring processed by liquid metal stir casting and shaped by sand casting

significant cost savings through net-shape manufacturing.

NIIST CSIR Trivandrum in India has developed functionally graded aluminium matrix composite prototype components fabricated by centrifugal casting for engineering application at National Institute for Interdisciplinary Science and Technology, Trivandrum. Various prototype FGM components such as (a) cylinder liners and gears (b) brake rotor disc and (c) piston had been fabricated by centrifugal casting technique (Fig 10(a-c)). Al-SiC FGM fishing boat cable pulleys are reported to be fabricated successfully by centrifugal casting method[19]. They have also developed prototype of light weight Al (356)-15% SiC metal matrix composite first gear housing and piston ring for application in engines of battle tanks (Fig 10(d-e)). These components possess enhanced wear resistance and heat dissipation behavior coupled with light weight. Fabrication of functionally graded components by centrifugal casting method has wide scope for different engineering applications.

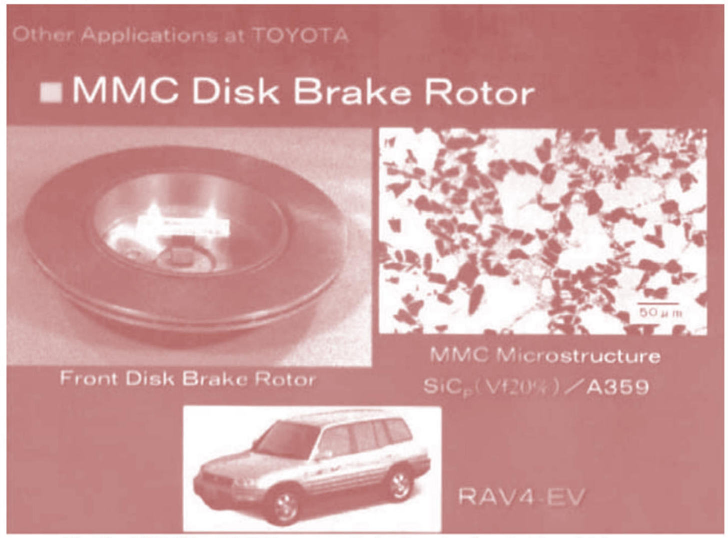

Fig 11: A359/20 vol% SiCp composite brake rotor for electric vehicle

Major use of Al-SiCp composite has been for the brake rotor and heat sink applications. Composite brake rotors are as effective as cast-iron rotors in braking applications, in addition to the weight savings which is around 50-60% of the weight of cast iron. Toyota has also used A359/20 vol% SiCp composite brake rotors in their electric vehicle (the RAV4-EV) (Fig 11). Lotus Elise was also released with Al-SiCp composite brake rotors.

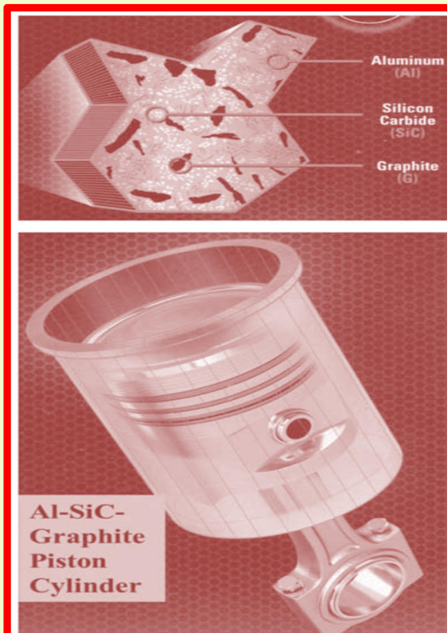

Fig 12: Al-SiC Graphite piston cylinder made by Intelligent Composites including hybrid Al-SiC-Gr

Intelligent Composites has developed hybrid Al-SiC Graphite cylinders for internal combustion and rotary engines (Fig 12) and compressors.

Advanced Materials Processing Research Institute (AMPRI) CSIR at Bhopal has developed high strength aluminium matrix composites with greater formability through liquid metallurgy route for automobile and structural applications. Pressure die cast Al-SiC composite brake drums have been produced with 66% weight reduction in comparison to cast iron brake drum (fig 13 (a-b)). Al-SiC composite Torpedo's nose cone was developed for defence applications which exhibited around 40 to 50% higher damping capacity and noise attenuations shown in Fig 13c. 35 million cars are running in India. Even 10% of its requirement being met with cast composites could lead to market in excess of Rs 1000 crore. Prototype components such as forged connecting rod, light weight high performance helicopter blade sleeve have also been developed at AMPRI Bhopal.

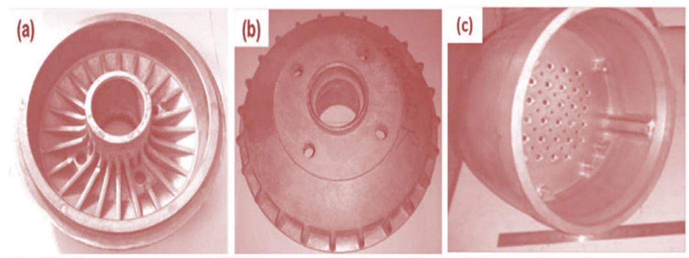

Fig 13: Pressure die cast Al-SiC composite brake drums (a) inner (b) outer view, 66% weight reduction in comparison to cast iron brake drum and (c) LM13-10wt% SiCp Composite Nose cone with higher damping capacity and higher strength

Next generation self-lubricating, self-cleaning and self-healing metal matrix composites

The technology to manufacture cast Metal Matrix Composites is being extended to smart composites including self-lubricating, self-cleaning, and self-healing and shape-restoring composite materials. Incorporation of solid lubricants like graphite and mica in the matrices of metals like aluminium reduces friction coefficient and wear rate, and provide ability of components to run in boundry lubrication, suggesting the possibility of oil-less engines. In recent years hydrophobic reinforcements have been incorporated in metals which are hydrophilic, to impart hydrophobicity and self-cleaning capabilities to metals and enhance their corrosion resistance property. Cast Metal Matrix Composites have been synthesized which have capabilities of self-healing cracks, similar to biological materials like bone and skin which self-heal after being damaged. Self-healing metal matrix composites have been synthesized by incorporating shape memory alloys in the matrix of solders, aluminium, magnesium and zinc; selected cracks in the matrix are closed when the shape memory alloy shrinks remembering its original shape; if the temperature of healing is high for some liquid to form on crack surface, the crack is welded. Alternately hollow micro balloons or micro tubes containing a low melting healing liquid within it, are incorporated in the matrix of metals to form a composite; selected cracks fracture the micro balloons and upon heating the low melting healing agent within micro balloons or micro tubes can melt and flow into the crack sealing the crack.

Research imperatives

- To date, fibres or particles have been incorporated mainly in conventional monolithic alloy matrices commonly used by foundries, and it has not been able to get the best advantage of Cast Metal Matrix Composites.

- There is a need to develop special reinforcements including surface treated reinforcements for cast MMCs.
- There is a need to develop techniques for rapid infiltration of preforms, including techniques for rapid pressure-less infiltration.
- Need of using reinforcements that are much smaller, nanometer instead for micron size and disperse them in the matrix uniformly with good interface bonding. These particles act like artificial precipitates and impart high strength that makes the metal composites more desirable.
- There is a need to produce machinable composite that allows parts to be more affordable.
- Need to develop pathways to recycle cast metal matrix components at the end of life.
- There is a need to develop low cost filled castings with low embodied energy reinforcements.

Conclusions

The potential of next generation metal matrix composites as an advanced material for the automotive, aerospace and electronic engineering applications has been demonstrated by the development of various composite systems and their components. The replacement of high density conventional materials based on ferrous alloys by Al MMC has been observed. The light weight, high specific strength and modulus, better high temperature performance and wear and antifriction behavior are the attractive characteristics. However, the cost of production has to be reduced by development of suitable mass production techniques for near-net shape components with consistent properties Squeeze casting technique has established its importance for the fabrication of Al MMC for automotive applications. Hybrid and functionally graded Al matrix composites are some of the recent developments and have demonstrated their potential as futuristic materials.

There is a great potential for manufacture and use of next generation metal matrix composite castings in India in view of strong research base in India and very large markets within India and for export abroad. Foundry produced metal matrix composites will have large market for scooters, cars (both IC Engine and electric cars), trucks, trains and motorcycles in India especially in view of high price of petroleum-based fuels and lubricants and increasing pollution levels in several cities). Several million cars are produced in India each year and even if 10% of these cars having 30 kg of metal matrix composites is used in each car, it would lead to very large markets in India, significant amount of energy can be saved and emission reduced through the use of metal matrix composites for brake rotors, cylinder liners, pistons, plumbing fixtures, and other components in transport systems including railways, cars, trucks motorcycles, scooters, and aerospace components. In addition, there are significant opportunities to manufacture heat sinks made out of cast metal matrix composites in computer hardware and space applications.

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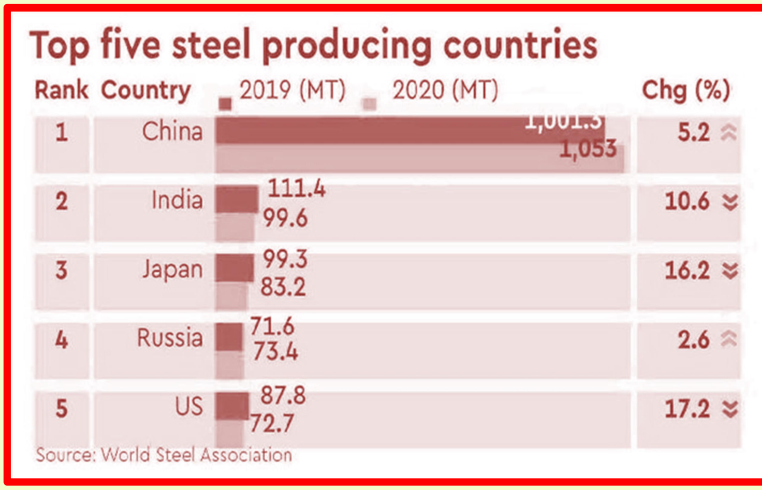
INDIA'S STEEL PRODUCTION FALLS BY MORE THAN 10%

Bucking the global trend, China and Russia produced more steel in 2020 than in 2019. Among the top five nations, production declined in India, Japan and the United States by up to 17.2%.



According to World Steel Association (WSA), crude steel production fell globally by 0.9% in 2020 to 1,864 million tonne (MT) over the previous year; but China bettered its production to 1,053 MT, up by 5.2% over 2019. China's share of global crude steel production increased from 53.3% in 2019 to 56.5% in 2020.

Russia's production also improved by 2.6% to 70.4 MT. Toppling the US, Russia also managed to improve its ranking by one notch to the fourth position among world's top five steel production nations.

Though India retained its second spot, its production fell by 10.6% in 2020 to 99.6 MT from 111.4 MT a year earlier.

India's share in the global output shrunk to 5.3% in 2020 from 5.9% a year ago. Japan also retained its third spot, but its production fell by 16.2% to 83.2 MT.

The US, the worst hit in the pandemic, produced 72.7 MT crude steel in 2020, down 17.2% over 2019. Overall, Asia produced 1,374.9 MT crude steel in 2020, an increase of 1.5% compared to 2019; but production declined 11.8% in the European Union to 138.8 MT. production in North America was also down 15.5% to 101.1 MT; the decline in South America was milder at 8.4%. Production in Africa remained unchanged at 17.2 MT.

Source: Financial Express

FIGURES RELEASED BY THE WORLD STEEL ASSOCIATION SHOW THAT GLOBAL CRUDE STEEL PRODUCTION REACHED 1.86 BILLION TONNES FOR THE YEAR 2020, DOWN 0.9% WHEN COMPARED TO 2019

Asia produced 1.37 billion tonnes of crude steel in 2020, an increase of 1.5% compared to 2019. China's crude steel production in 2020 reached 1.03 billion tonnes, up 5.2% on 2019. China's share of global crude steel production increased from 53.3% in 2019 to 56.5% in 2020. India's crude steel production for 2020 was 99.6 Mt, down 10.6% on the previous year. Japan produced 83.2 Mt in 2020, down 16.2%, and South Korea produced 67.1 Mt, down 6% on 2019.

The European Union produced 138.8 Mt of crude steel in 2020, down 11.8% compared to 2019. Germany produced 35.7 Mt of crude steel in 2020, down 10.0% on the previous year.

In the CIS, production was 102.0 Mt in 2020, up 1.5% on 2019. Russia is estimated to have produced 73.4 Mt in 2020, up 2.6% on 2019. Ukraine produced 20.6 Mt, down 1.1% on 2019.

Crude steel production in North America was 101.1 Mt in 2020, down 15.5% on 2019. The United States produced 72.7 Mt in 2020, down 17.2% on the previous year.

45.4 Mt of crude steel was produced in the Middle East in 2020, an increase of 2.5%on 2019, Iran is estimated to have produced 29 Mt in 2020, up 13.4%.

Annual crude steel production for South America was 38.2 Mt in 2020, a decrease of 8.4% on 2019. Brazil produced 31 Mt in 2020, down 4.9% compared to 2019.

Turkey's crude steel production for 2020 was 35.8 Mt, up by 6% on 2019.

Africa produced 17.2 Mt of crude steel in 2020, the same as in 2019.

Oceania produced 6.1 Mt of crude steel in 2020, down 1.4% on 2019.

SUMMARY / REVIEW OF "SANAK MISHRA: AN AUTOBIOGRAPHY"

I have gone through Autobiography of Dr. Sanak Mishra with a lot of interest. The book indicates his journey from his childhood till date. Dr Sanak Mishra has taken a lot pains to pen down every small details happening in his life.

It is heartening to note that Dr. Mishra was ranked first in the whole state of Odisha in his matriculation examination.

His academic career was very brilliant. He graduated from Ravenshaw College Odisha in 1965 with first class honours in Physics and distinction in Mathematics and Chemistry.

It is a matter of pride for Indian Institute of Science (IISc) Bangalore to admit Dr Mishra in Engineering Course in Metallurgy in 1965. He graduated from IISc in 1968 with distinction. It is a coincidence that his summer training was at Rourkela Steel Plant (RSP) in 1968. On the occasion of centenary celebrations of IISc in 2008, he was conferred Distinguished Alumni Awards. Dr. Sanak Mishra did his MS in 1970 and PhD in 1973 from University of Illinois USA. The title of his MS Thesis and PhD was "Paramagnetism in Copper-Nickel Solid Solutions: Effect of Small Iron Additions" and "Magnetic Clusters in Dilute Alloys Iron in Copper-Nickel Solid Solutions" respectively. His work was of much fundamental significance. In the year 2010 he received the Distinguished Merit Alumnus Award from the University of Illinois.

He joined SAIL RDCIS at Ranchi as Research Metallurgist in 1973. The First Technical report prepared by him at RDCIS was "State of Art of Technology of CRGO Steel".

He became a member of IM in 1976. I was then the Secretary of IIM Ranchi Chapter and had the pleasure of introducing him to the fold of IIM.

In 1979, Dr Mishra was awarded Humboldt Fellowship in Germany. Duration of this Fellowship was two years, at the Aachen Technical University. During this two years period Dr. Mishra published seven technical papers. After availing two years fellowship he joined back RDCIS in 1981. He made immense technical contributions to the R&D activities of RDCIS Ranchi. Dr Mishra was transferred to SAIL CO in February 1998 as ED i/c of Corporate Planning. During his stay at CO, he prepared a strategy document "Path to Turnaround and Transformation of SAIL" in June 1998.

Rourkela steel Plant (RSP) was fortunate to have Dr. Sanak Mishra at its helm as MD in May 2001. At that time RSP was incurring huge financial losses. During his stay at RSP a lot of technological and administrative interventions were introduced by hm. This resulted into turn-around of RSP from loss making plant to profit making plant. His efforts to turn-around RSP are referred to at different forums. After his superannuation from RSP he joined ArcelorMittal as Vice President in June 2006.

IIM was privileged to have him as its President in 2009-10.

After leaving ArcelorMittal in July 2013, he was inducted as Independent Director of the Asset Boards of Essar Steel in 2013-14.

He also had the privilege to head newly created India Steel Association in September 2014. His contribution in the formation of Steel and Technology Mission of India is well known to the stakeholders of Steel Industry.

He also contributed a lot to MIDHANI as its Sr. Adviser in 2018-19.

Dr. Sanak Mishra is a recipient of various National Metallurgists Day (NMD) Awards instituted by Ministry of Steel, Govt. of India. The most important NMD Award is Lifetime Achievement Award which is given to individuals to recognize outstanding Lifetime achievements and original contributions in the fields of metallurgical and industrial profession having significant impact on National Scenario. Dr. Sanak Mishra had the privilege to receive this coveted Award in 2018.

He was appointed as President of the Indian National Academy of Engineering (INAE) in January 2019. During the same time he was inducted as a member of the Executive Board of the world body CAETS (Council of the Academics of Engineering & Technological Sciences). It is learnt that our former President APJ Abdul Kalam was a former President of INAE.

This book indicates Dr. Sanak Mishra's tall standing in academic, technical, research and administrative areas. Needless to say that today he stands out as one of the tallest luminary in metallurgical field and steel fraternity.

Summarized by
S C Suri