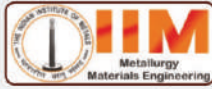


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THE INDIAN INSTITUTE OF METALS
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14th November, 2019

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						2015-18	*Mr Sadhan Kumar Roy

LOW COST UTILITY STAINLESS STEEL 409M

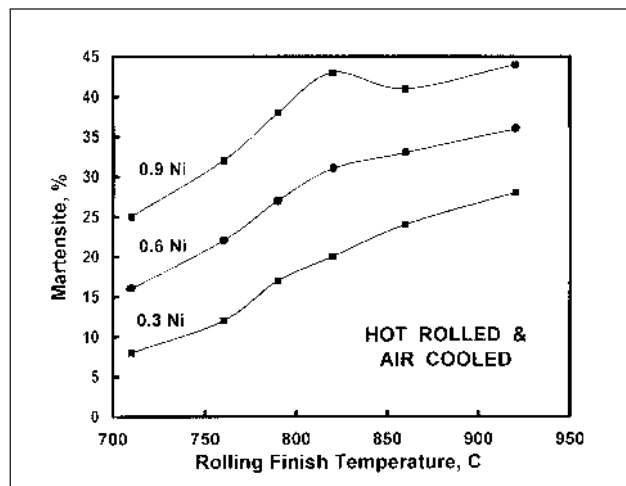
A fine-grained ferrite-martensitic utility stainless steel, designated as 409M, is ideally suited for application as liner plate of coal and material handling plants because of its superior wet-abrasion resistance. It has been observed that nickel content, finish rolling temperature and rate of cooling of the hot rolled sheet / plate are critical factors. The chemistry and the processing parameters influence the requisite martensite content, which is key to the final mechanical properties. Comparative evaluation of the commercial hot rolled product with respect to other grades has also been established, specifically for corrosion, wet abrasion and slideability.

Ferrite-martensitic stainless steel sheet having 11-12% chromium and with fine grains is being used in many countries for applications requiring resistance to corrosion as well as wet abrasion. Four or five of these equivalent grades with minor variation in composition constitute the lean-alloy dual-phase (LADP) utility stainless steels. These are less expensive than the common stainless steel grades, like AISI-304, 430 etc. They offer considerable advantage with respect to life cycle cost, as compared to mild steel or the very expensive normal stainless steels. Good combination of strength, formability, slideability and resistance to wet abrasion has made these grades the candidate material for storage and handling systems of bulk solids, like coal, minerals etc.

Small but significant composition deviation from the standard ferritic AISI-409 grade, makes the new 409M grade ferrite-martensitic at room temperature. Chemistry, hot rolling and annealing parameters play important roles in obtaining the optimum martensite content, and its influence on the final mechanical properties.

Suitable addition of nickel, manganese and titanium controls the extent of transformation of δ -ferrite to austenite at elevated temperature (1300 - 750 C). Hence, coarsening of the ferrite grains during continuous casting of slab, or reheating of slab can be arrested by selecting the right chemistry. The second important factor is the temperature at which the hot rolling is finished. This controls the relative amount of δ -ferrite and austenite at the completion of the rolling operation. The third important factor is the rate at which the product is cooled to the ambient temperature. This would control the extent of transformation of austenite to martensite. Hardenability of course would be a function of chemistry. Since the amounts of carbon, chromium and titanium are decided based on other considerations, mainly nickel, and to a certain extent manganese, would influence the extent of martensite transformation.

Control of martensite can result in the desirable combination of strength and elongation. It has been observed that if martensite content in the as rolled plate is maintained in the range of 10-15%, the optimum combination of 300-360 MPa YS and 30-33 % elongation can be achieved. The important issue is to achieve the desirable martensite content by manipulating nickel content and the processing parameters, like rolling finish temperature and the cooling rate of the hot rolled plate. The effects of nickel and rolling finish temperature on the martensite content in as rolled and air cooled plate is shown in the following figure. It is observed that 10 - 15% martensite can be obtained for 0.3 % Nickel and rolling finish temperature in the range of 750-780 C. Higher levels of nickel or rolling finish temperature are needed for getting increased amount of martensite. Cooling of as rolled sheets at a rate slower than that for air cooling obviously generates less martensite and more ferrite.



Effect of nickel and rolling finish temperature on martensite content

Broad guidelines obtained from laboratory investigation have been used in formulating nickel content and processing parameters for the commercial heats. Different stages of processing have been evaluated :

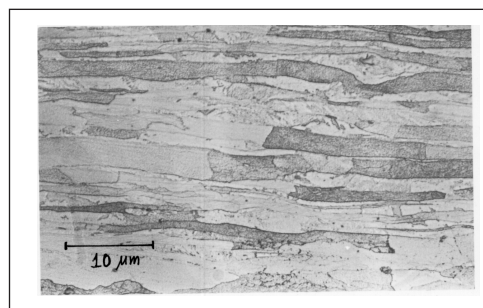
- Hot rolled & air cooled (HRAC)
- Hot rolled & slow cooled (HRSC)
- Hot rolled, air cooled, and tempered at 750 C for 30 minutes (HRACT)

Mechanical Properties under different conditions are given below :

Nickel %	Thickness (mm)	Condition	Hardness (BHN)	YS (MPa)	UTS (MPa)	Elong %	Bend 180°	Martensite %
0.4	5	HRAC	165	470	580	23	2T	35
0.4	5	HRACT	140	375	510	30	2T	15
0.4	10	HRAC	160	440	580	25	2T	30
0.4	10	HRACT	140	380	515	29	2T	15
0.6	6	HRAC	225	560	660	18	1T	60
0.6	6	HRSC	180	460	600	26	2T	35
0.6	6	HRACT	150	415	530	30	2T	15
0.6	12	HRAC	210	540	645	20	1T	55

Typical **microstructure** consists of elongated bands of ferrite and martensite. Martensite content varies depending on specific conditions. The final microstructure is a result of the structural evolution during cooling from slab reheating temperature, hot rolling and subsequent cooling to room temperature. The final annealing temperature further modifies the microstructure.

δ -ferrite grains partially transform to austenite via Widmanstatten growth to produce lath like structure during reheating and soaking of slab. Elemental partitioning between δ -ferrite and austenite has been found to take place. δ -ferrite bands become more rich in Cr, which is a ferrite stabiliser. Austenite-stabilising elements like nickel and manganese on the other hand, get preferentially partitioned to the transformed austenite phase. The elemental partitioning of Cr, Mn and Ni between ferrite and austenite grains has been detected by EDS microanalysis



Elongated bands of ferrite and martensite in as rolled and air cooled plate

The incomplete $\delta \rightarrow \gamma$ transformation till rolling temperature produces a duplex microstructure with compositional variation between ferrite and austenite. Subsequent hot rolling results in a banded δ -ferrite - austenite structure. Partial transformation of austenite to martensite and ferrite takes place during cooling subsequent to hot rolling. The final annealing treatment leads to recovery of martensite and grain boundary coalescence in ferrite. The original impression of compositional banding of ferrite and austenite persists even after the annealing treatment, with the ferrite grains retaining the original elongated shape.

409M grade has immense potential in applications requiring **resistance to wet abrasion**. Liners of material handling equipment like wagon, coach, chute, slurry tank, silo, bin, conveyor, trough, launder etc. offer a wide ranging applications for this product. **Comparative evaluation** of corrosion in industrial environment and resistance to wet abrasion has been conducted with mild steel and the common stainless steel grade AISI 304. The relative values of corrosion rate, wet abrasion and angle of friction are shown in the following Table. Good surface quality of corrosion-resistant hot rolled sheet of 409M ensures low friction, and enhances faster mass flow of solid materials during handling and storage in hopper, bin, bunker, silo lined with this product. The angle of friction for this grade is quite low, as compared to mild steel.

Comparative Corrosion Performance			
Grade	Mild Steel	409 M	AISI 304
Corrosion rate ($\mu\text{m} / \text{yr}$)	34.0	0.11	0.001
Relative Wet abrasion	1.0	3.0	3.5
Angle of friction (degree)	40 – 58	16 - 18	18

It is thus evident that 409M is much superior to mild steel with regard to wet abrasion resistance, and is almost similar to the expensive stainless steel grade AISI 304. The cost of hot rolled sheet of 409M is about half that of AISI-304. Hence, this grade has the advantage of life cycle in comparison to mild steel, and is more cost-effective with respect to AISI-304 for applications requiring resistance to wet abrasion.

Delhi Iron Pillar

Ahindra Ghosh

Late Dr. R. Balasubramaniam, Ex- Professor, Materials and Metallurgical Engineering, IIT Kanpur, wrote a monograph entitled “DELHI IRON PILLAR – New Insights”. It was published by INDIAN INSTITUTE OF ADVANCED STUDY, Shimla in 2002 in association with Aryan Books International, New Delhi. It has 168 pages, 33 figures, 42 photographs, large number of references and some tables.

Dr. Balasubramaniam was also the convenor of an International Conference, code named “METALLO”, held in 2007 at IIT Kanpur to felicitate Prof. T. R. Anantharaman on his 80th birthday. Prof. Anantharaman could not attend due to illness, and sadly passed away after a short while. But large number of his renowned ex-students and ex-colleagues participated from India and abroad. I also attended it as an invitee.

Prof. Balasubramaniam also organised installation of a fibre glass replica of Delhi iron pillar in front of the Students Union Building of IIT Kanpur.

Sadly, a few years after the conference, Prof. Balasubramaniam expired due to cancer at a young age. I was very close to him and carried out several pieces of research jointly with him and had published the same. So I had great sorrow at his demise.

In the present paper I shall pick and choose a few topics from the monograph for conciseness. I shall also not follow seriality of contents of the monograph. I shall first concentrate on the APPENDIX of the monograph and note few items from there. It has been established that the good corrosion resistance of 1 ancient Indian objects in general and the Delhi iron pillar in particular, is due to the unusually high percentage phosphorus in them.

Phosphorus in the metal aids formation of a protective amorphous δ - FeOOH layer and / or protective phosphate layer on the metal – scale interface. Modern steels contain less than 0.02 % phosphorus in order to avoid intergranular embrittlement. Therefore phosphorus is removed from liquid steel at steelmaking stage by transferring it to a highly basic CaO –containing slag.

Ancient iron was reduced from iron ore in bloomer furnaces where air used to be blown through the tuyere by bellows at temperature range of 900°C to 1300°C. The ancient smelters added SiO₂ or lean siliceous ore as flux to generate molten Fayalitic (Fe₂SiO₄) slags at 1250°C to 1300°C. Melting point of Fayalite is 1205°C and the eutectic FeO - Fe₂SiO₄ melts at 1177°C. The red hot sponge iron with low carbon was obtained in solid state with entrapped slag. Research done by Balasubramaniam et al on this has been published [1].

Slag compositions in ancient and modern ironmaking processes are required to estimate the equilibrium distribution of phosphorus between the slag and metal phases by empirical and thermodynamic methods. Elvin [2] has reported in detail the ironmaking process by the Agarias, a group of tribal people of Madhya Pradesh, who were primarily involved in ironmaking by heredity. Prakash [3] has reported in details about the process. Several others have also reported about these furnaces.

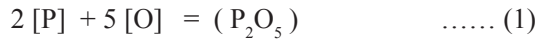
Elvin [2] has provided the slag composition from one such Agaria furnace and has also recorded the chemical analysis of the iron extracted from the same furnace. Table 1 contains the slag composition of ancient and modern ironmaking. Elvin also reported that the iron from Agaria furnace after smelting had 0.780 % C, 0.025 % Si, 0.140 % P, 0.1 % Mn and traces of S.

Table 1 : Typical composition (weight percent) of an ancient and a modern iron making slag

Slag Component	Ancient Slag	Modern Slag
Silicon Dioxide (SiO ₂)	18	16
Wustite (FeO)	53.4	20
Hematite (Fe ₂ O ₃)	10	0
Manganese Oxide (MnO)	9.75	5
Magnesium Oxide (MgO)	2	4
Alumina (Al ₂ O ₃)	9.02	0
Carbon (C)	0.28	0
Titanium Dioxide (TiO ₂)	0.3	0
Calcium Oxide (CaO)	0.4	52
Phosphorus Pentoxide (P ₂ O ₅)	0.45	3

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The metal-slag phosphorus reaction can be written as :



Where [] is symbol for metallic solution and () is symbol for slag solution.

Thermodynamic analysis has been reported by Turkdogan [4] and Banya et al [5] who have also reported Healy's method. Balasubramaniam et al carried out calculations based on the above as well as data of Table 1.

The results are presented in Figure 1. The figure shows phosphorus content as a function of temperature in ancient and modern iron, as calculated by methods of various investigators.

Phosphorus content is shown in the vertical axis in logarithmic scale. It may be noted that the values of phosphorus in metallic solution are more than 2 orders of magnitude higher in ancient iron than in modern iron. As shown in Table 1, this is because the slag in modern ironmaking is highly basic and is capable of removing bulk of phosphorus from iron.

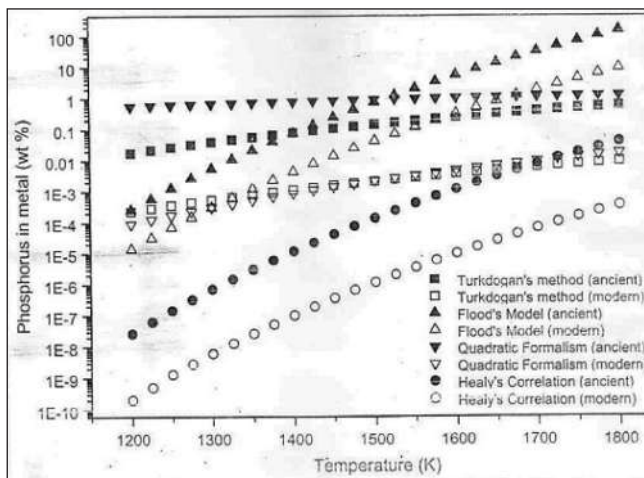


Fig. 1 : Phosphorus content as a function of temperature in ancient and modern iron

The monograph has extensive discussions on history of the pillar. It has large number of references of persons who worked on the topic. The authors of the papers have different views on the subject. I shall not get into these, but try to present the most likely history.

It has been generally agreed by the historians that the pillar was constructed during the Gupta Period by King Chandragupta (abbreviated as Chandra). It seems most likely that he was Chandragupta II Vikramaditya.

Vikramaditya was a mighty king. In the east he conquered upto Kamrup (now Assam) and also Kalinga (present Orissa). In the north his army crossed Sindhu river and conquered Vahlikas (present Punjab). Some Southern kings also were subjugated. But he did not annex their territories. He also reined for a long time.

The book has several photographs of gold, silver and copper coins of the Gupta period. The inscriptions on the

pillar were in Sanskrit but written with Brahmi script. Figure 2 presents palaeography comparing Brahmi characters of Kushan period, Iron pillar and Gupta period.

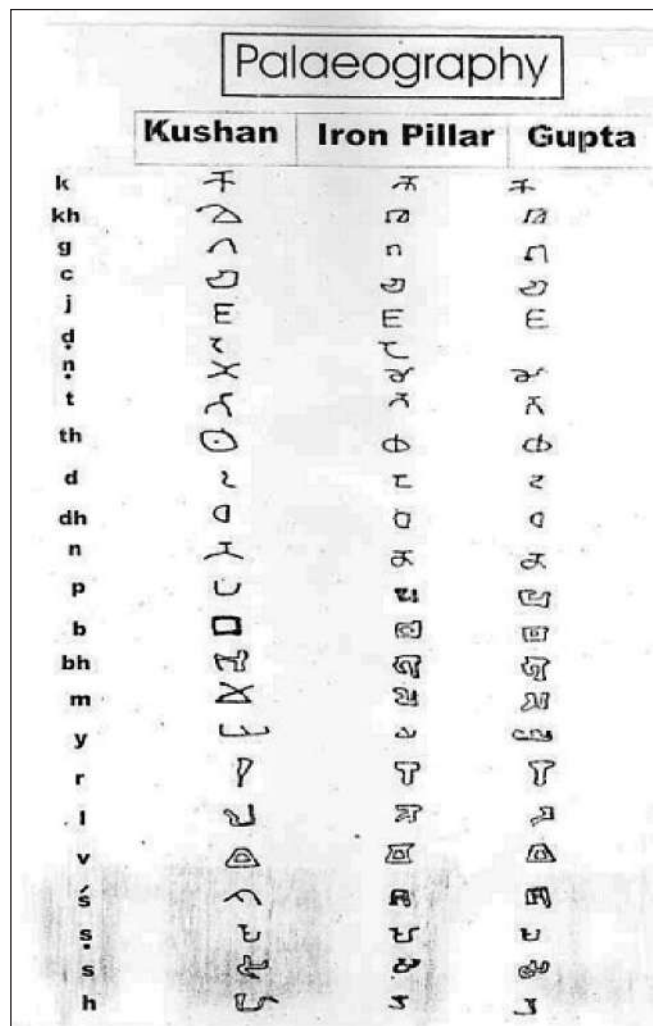


Fig. 2 : Comparison of Brahmi characters in the Delhi iron pillar inscription with those of the Kushan and Gupta characters

The pillar was constructed most likely in early 5th century. It has been well established that the inscription on the pillar was in the year AD 410. According to some historians the pillar was originally located at Vishnupadagiri, which was near Mathura. Mathura is eighty miles away from Delhi. It is an ancient city and has been the site of famous Vishnu temples and Vaishnava worship from time immemorial.

The Guptas were ardent devotees of Vishnu as attested by the legends inscribed on their coins and temples, and inscriptions of Chandragupta II and Kumaragupta. The magnificent temple was burnt to the ground by Mahmud of Ghazni when he plundered Mathura in his seventeenth raid on 2nd December, AD 1018.

The major power that ruled North India just before the ascent of the Guptas were the Kushanas who were Buddhists and Shaivaites with their capital at Mathura. These worships also continued even in the Gupta period.

Some other historians identified Udaigiri in the Vidisha region as Vishnupadagiri. This region had a long tradition of ironmaking as evident from wedges at Sanchi, Heliodorous iron pillar, iron slags and remains of ironmaking furnaces.

The pillar was moved to Dhilli (Delhi) around AD 1050 by the Tomar king Anangapala, who also founded the fortress called Lal Kot. The fortress city changed hands after the defeat of Prithviraj Chouhan by Qutbudin Aibak who built a mosque to commemorate his victory.

The dimension of the pillar, as given by historians differed to some extent (not much). I am herewith noting the dimensions as measured by Beglar and quoted by Hadfield [6].

Total length	23'8"
Height above the ground	22'
Height below the ground	1'8"
The upper diameter (below the decorative capital)	12'5"
The lower diameter	16'5"
Total weight	6 ton

Figure 3 shows dimensions of the Delhi iron pillar. Unit u = 1".

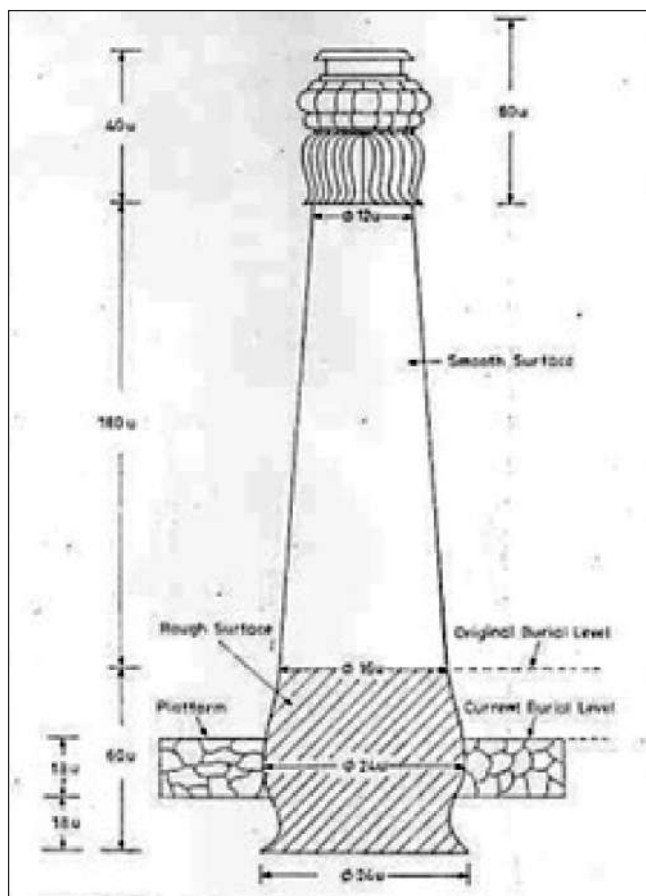


Fig. 3 : Dimensions of the Delhi iron pillar. The unit U measures 1"

The pillar had been assembled piece by piece by forge welding. It involved heating of solid iron in a bed of charcoal to a high temperature to make it soft. Then one lump was placed above another and they were joined by hammering with heavy hammers by various techniques. Of course iron used to have entrapped slag particles. Metal inserts and dies of various designs were employed as required.

Molten lead or lead – based soldering alloy was found at the base of the decorative bell capital and base the pillar also in order to fill the crevices. Since Pb is nobler than Fe, it caused galvanic corrosion at the base of the decorative bell capital. Figure 4 presents X-ray diffraction pattern obtained from the white corrosion product identifying it as lead carbonate hydroxide hydrate and Pb_2CO_4 . It seems that molten Pb was poured at the base of the pillar by the Archeological Survey of India later.

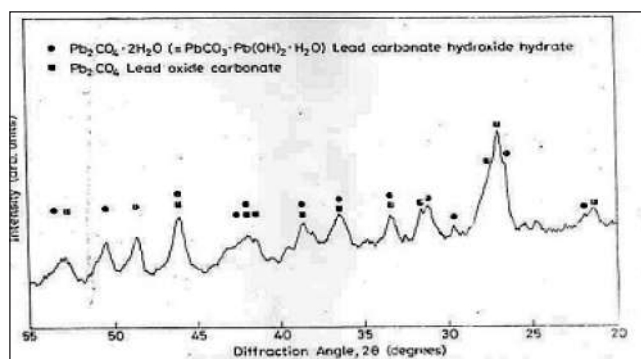


Fig. 4 : X ray diffraction pattern obtained from the white corrosion product identifying it as lead carbonate hydroxide hydrate

Figure 5 shows atmospheric conditions at Delhi averaged over 30 years (1930– 60) (Wrangle [7]). It also shows well - known effect of atmospheric humidity on the corrosion of iron as measured by the weight of a sample of iron.

The nature of the protective passive layer on the corrosion –resistant Delhi iron pillar has been addressed based on detailed characterization of its rust. The rust is composed of iron hydrogen phosphate hydrate ($FePO_4 \cdot H_3PO_4 \cdot 4H_2O$) in crystalline form in addition to α -, β -, γ - $FeOOH$ and magnetite in amorphous form. It has been established that the corrosion resistance of Delhi iron pillar is due to :

- (i) iron with its high phosphorus content conferring protection by the formation of crystalline iron hydrogen phosphate, and
- (ii) the environment providing alternate wetting and drying conditions.

The Pb coating at the base was cleaned and fresh Pb coating was applied by the Archeological Survey of India (ASI) much against the wishes of the chief chemist of ASI. The ASI also erected a metallic fencing around to prevent visitors to touch the pillar.

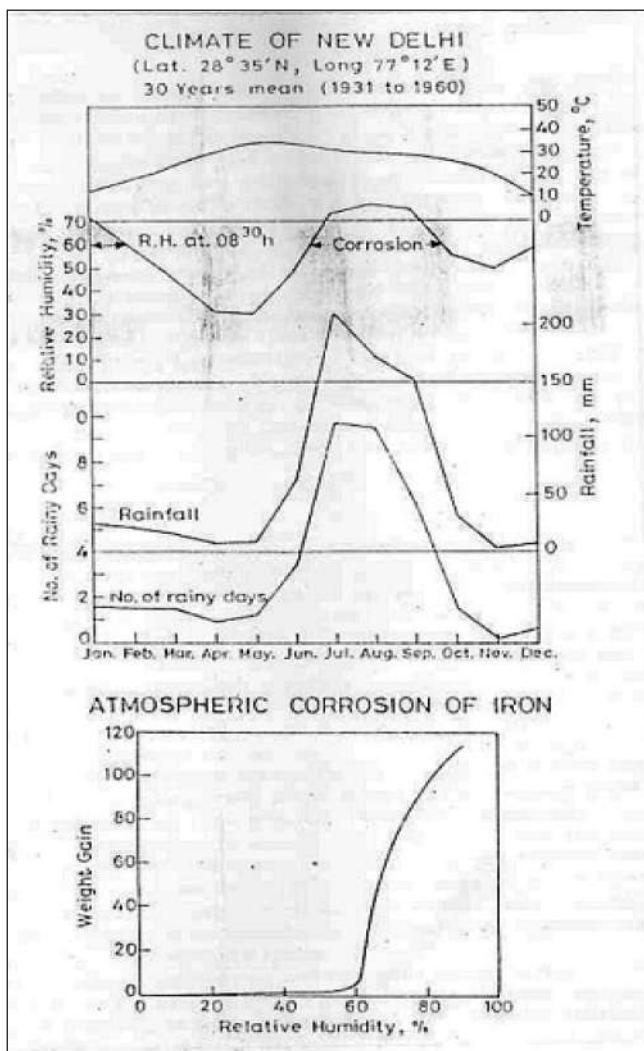


Fig. 5 : Atmospheric conditions at Delhi averaged over 30 years (1930 – 1960) showing the well known effect of atmospheric humidity on the corrosion of iron

Scientists from the Indira Gandhi Centre for Atomic Research (IGCAR) conducted several scientific investigations on the pillar (such as insitu metallography, radiography, sonography etc.).

There are several other ancient iron objects in India, some of which are reasonably rust --free and some others are rusted. Few examples are Ashokan pillar at Sanchi, Garuda pillar at Eran, Udaigiri in M.P., large iron beams at Konarak Sun Temple, Dhar iron pillar, Dalmadal Cannon

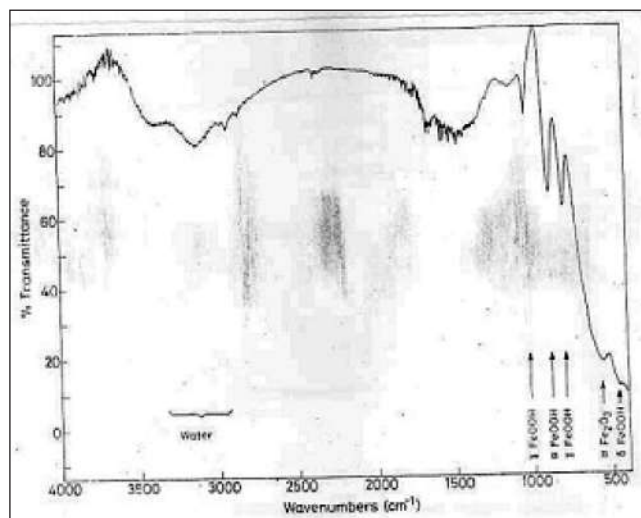


Fig. 6 : FTIR spectrum of rust from Dhar iron pillar

at Bishnupur, Dt. Bamkura in West Bengal, iron pillar at Mandu, iron pillar at Mount Abu, iron pillar at Kodachasri hills, large iron cannon at Thanjavur.

Balasubramaniam spent some time at Dhar and obtained a sample from the pillar with permission of the ASI. He then carried out several scientific studies on the sample (optical metallography, scanning electron microscopy, Fourier Transform Infrared Spectroscopy (FTIR) etc.). Figure 6 shows FTIR spectra of rust.

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Phosphorus in Steel

U K Chatterjee

Small amounts of phosphorus have long had an ill reputation for rendering iron brittle when worked cold, or 'cold short'. Because of this embrittling effect, in the majority of steels its amount does not exceed 0.05%. That phosphorus embrittles iron has been known since at least 1860 : “a very small amount of phosphorus will make bar iron brittle, so small a proportion as 0.5 per cent.” [1]. In 1864, John Percy wrote that "There is no fact relating to the metallurgy of iron which seems to be better established than this, and certainly there is not one which is more generally received as correct" [2]. In 1918, Stead reported that "prominent metallurgists refer to phosphorus as treacherous" [3]. Specifically, phosphorus embrittles grain boundaries, and its interactions with boundaries led to the creation of segregation models as early as 1948 [4], with the subject of temper embrittlement reviewed in 1953 [5] and on many occasions since then [6–11]. That phosphorus reduces grain boundary cohesion, thus promoting intergranular failure, and the embrittling effect of phosphorus is reduced by the presence very small amounts of carbon was reported by Allen back in 1963 [12]. The boundaries at which the segregation of phosphorus occurs were indicated to be between ferrite grains or austenite grains [13]. In cast and wrought metallurgy, use of phosphorus remained restricted owing to its tendency to segregate along grain boundaries causing cold shortness [14, 15]. However, unlike sulphur, phosphorus does not cause hot shortness and as such poses no problem in hot fabrication of steel.

Considerable work has been done on the mechanism of embrittlement. A useful concept is that if a solute in iron has a greater reduction in energy (Δg_s) when transferred from solid solution to a free surface, than when it is similarly transferred to a grain boundary (Δg_b), then it embrittles the boundary because it becomes favourable to separate the grains [16]. Noting that both these energies

would be negative for any solute that tends spontaneously to segregate, the potency to embrittle scales with the positive $\Delta g_b - \Delta g_s$. Table 1 shows in this context that phosphorus has a strong tendency to embrittle grain boundaries. Another interpretation quite effectively correlates the size misfit of the segregating atom relative to iron, against the energy required for boundary fracture [17].

These studies do not establish whether any embrittlement is sufficient to induce brittle fracture. It is well known that slip and separation at grain boundaries are competing mechanisms, so that anything which makes slip more difficult will in general tend to lead to grain boundary failure [18]. Whether such failure occurs depends on the ability of the material within the grains to accommodate strain. Factors that should enhance grain boundary failure can be listed as follows:

- a) matrix that is so strong that boundaries become the weak links;
- b) low testing temperatures where the matrix is strengthened by the reduced mobility of dislocations;
- c) large grain size [19] since a fixed impurity content is then distributed over a smaller boundary area per unit volume.
- d) a large fraction of high energy boundaries where impurity segregation is favoured [20, 21].

It follows that strong steels will necessarily be more susceptible to phosphorus embrittlement. The vast majority of steel that is produced in the world has an ultimate tensile strength less than 600 MPa with ductility in excess of 25%. Such steels should be tolerant to phosphorus concentrations that would lead to severe difficulties in the case of very strong steels with strengths in excess of 1500 MPa [22].

A second important consideration is the role of other

Table 1: Selected segregation free energies for solutes in iron [16]

Segregant	$-\Delta g_b$, kJmol ⁻¹	$-\Delta g_s$, kJmol ⁻¹
Carbon	50-75	73-85
Phosphorus	32-41	76-80
Hydrogen	65-68	71-109

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solutes. It is known, for example, that carbon segregates to ferrite-ferrite boundaries to an extent that is two orders of magnitude greater than phosphorus [23]. This is because of its low solubility in ferrite with the atom fitting better at the more loosely packed grain boundaries. By doing so, the carbon can displace the phosphorus or limit its uptake to the boundary, thereby mitigating phosphorus embrittlement, and permitting greater quantities of phosphorus to be tolerated. Almost all structural steels contain in excess of 0.008wt% of carbon in which case carbon will occupy at least half of the boundary sites available. The tolerable level of phosphorus then doubles. Any element such as chromium that does not itself segregate or is prevented by low diffusivity from doing so, and which decreases the activity of carbon in ferrite will reduce the tendency for carbon to segregate and hence free up boundary sites where phosphorus can reside [24].

Some alloying additions that are in solid solution have been shown to reduce the segregation of phosphorus to grain boundaries [25]. It is speculated that this is because the alloying element has a strong chemical interaction with phosphorus, in effect pinning the phosphorus atoms within the matrix. Both niobium and titanium reduce the phosphorus concentration at the grain boundary when ternary alloys are tempered. Titanium itself has been shown to segregate to grain boundaries and this may add to the blocking of grain-boundary sites where phosphorus might deposit. It is also possible, but not established, that titanium or niobium phosphides form, thus reducing the concentration of phosphorus available for segregation. Whatever the mechanism, it is possible to achieve a four-fold decrease in the concentration of phosphorus at the grain boundaries using appropriate concentrations of niobium and phosphorus. In these circumstances, the tolerable level of phosphorus becomes much greater.

Molybdenum undoubtedly helps mitigate the embrittling effect of phosphorus and it is argued that there is an optimum concentration that is effective in doing so. It is used routinely in commercial steels for the specific purpose of eliminating grain boundary embrittlement [26]. Dissolved molybdenum is said to inhibit the segregation of phosphorus (scavenging), and that which segregates to boundaries acts by an unknown mechanism to improve the strength of the boundary in the presence of phosphorus [27]. Large concentrations of molybdenum become ineffective in steels due to the ready formation of molybdenum-rich carbides. The optimum concentration of Mo in the steel is about 0.7wt%, but this obviously must vary with the overall composition of the steel since the tendency to form carbides depends on the detailed constituents of the alloy [28].

In steels, P exists exclusively as a solid solution in ferrite. Although an iron phosphide (Fe_3P) is known to exist, it is never present at the P contents encountered in commercial steels. Fe_3P is common in cast irons as steadite phase ($\text{Fe}/\text{Fe}_3\text{P}$) which is a hard structural constituent consisting of the eutectic of ferrite and Fe_3P . The composition of the eutectic is 10.2 % P and 89.8 % Fe.

Phosphorus is one of the most potent solid solution strengtheners of ferrite. Figure 1 compares the change in lower yield strength of carbon steel as a function of alloy addition for several common elements. Among the elements considered, only carbon and nitrogen produce a greater strengthening effect than phosphorus. This is related to the fact that phosphorus enters the crystal lattice as a substitution solute, whereas carbon and nitrogen are interstitial solutes. Nevertheless, the addition of only 0.1 wt% of phosphorus raises the yield strength by about 62 MPa (9 ksi). A similar effect of phosphorus is observed on ultimate tensile strength. The decrease in ductility in terms of % elongation and % reduction in area is more in case of carbon than with phosphorus. (Table 2) [29]. Hence, small additions of phosphorus are used to inexpensively increase the strength of low carbon sheet steel.

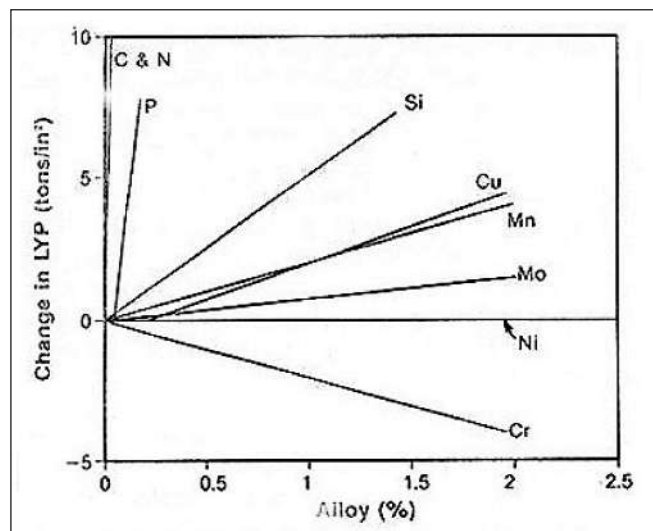


Figure 1: Change in the lower yield strength of carbon steel as a function of the alloy content for several common elements (1ton/inch² = 13.8 MPa)

Phosphorus has a tendency to reduce the work-hardening rate of ferrite. But only a minor decrease in the strain-hardening exponent, n , with increasing phosphorus up to 0.12 % was observed by Hu in laboratory processed low carbon, Al-killed steel [30]. The detrimental effect of P on n is greater in Ti-stabilized ULC steel. But the n -value of this steel still maintained high levels, in excess of 0.27 even at 0.1 % phosphorus. Thus it appears that the work-hardening capacity of ferrite is not seriously impaired by dilute additions of phosphorus.

Table 2: Change in tensile properties of steel with addition of 0.1% C and 0.1%P [29]				
		With 0.1% C	With 0.1% P	
			Stead's data	Amico's data
Yield stress, tons/sq in	Raised	1.78	2.5	2.3
Maximum stress, tons/sq in	Raised	4.18	2.4	4.1
Elongation %	Reduced	4.35	0.7	1.36
Reduction in area %	Reduced	7.40	1.5	3.8

The addition of phosphorus also improves the bake hardening response and deep drawability. Because of these properties, rephosphorised high strength steels are widely used for cold forming applications. Phosphorus at levels around 0.1 wt. % is known to improve the strength and deep drawability of sheet steel used for automotive applications. The carbon contents are maintained at < 0.01 wt. % to obtain high formability in this application [31, 32]. P is added along with sulphur (S) to enhance the machinability of steels. Higher P is specified in low C free machining steels to improve machinability. Such steels have limits on P content as 0.07 % to 0.12 %. P can be present in some of high strength low alloy (HSLA) steels up to 0.15 % for increased strength. Whereas P is usually considered to be an embrittling element in steel, substantial amounts can be tolerated when C is less than 0.15 %. P also improves atmospheric corrosion resistance in mild and low alloy steels, especially when copper is also present [33].

Carbon imparts strength to steels, but it impairs ductility and weldability. Maintenance of the desired strength level with less deleterious effect on ductility can be achieved by lowering carbon and increasing phosphorus within tolerable limits [29]. Improvement of corrosion resistance of steels in atmospheric exposures and those embedded in concrete structures is also desirable in view of corrosion losses to the tune of 5% of world GDP. BIS specification for reinforcing bars [34] has prescribed enhancement of phosphorus level to 0.12% with the statement: "Low alloy steel may be produced by adding alloying elements like Cr, Cu, Ni, Mo and P either individually or in combination, to improve corrosion properties. However the total content of these elements shall not be less than 0.40 per cent... In such low alloy steels, when phosphorus is used, it shall not exceed 0.12 per cent, and carbon shall be restricted to 0.15 per cent, and in such case the restriction to maximum content of sulphur and phosphorus (0.040 – 0.060%) and the condition of minimum alloy content 0.40 per cent shall not apply". In this context it is worth mentioning that the Delhi Iron Pillar made of wrought iron having a composition 0.15 % C, 0.25 % P, 0.005 % S, 0.05 % Si, 0.02 % N, 0.05 % Mn, 0.03 % Cu, 0.05 % Ni, balance Fe, [35] has withstood atmospheric corrosion

for 1600 years and the excellent corrosion resistance of such a heterogeneous structure has been attributed to the presence of high phosphorous in its chemistry. [36].

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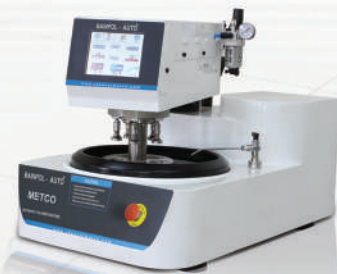
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RECENT DEVELOPMENTS

Maraging Steel Produces World's Finest Fencing Blades

Due to its strength, flexibility and extreme toughness, professional fencers will compete using swords made from maraging steel. With roots in aviation, maraging steel is a high-strength alloy made with around 18% nickel and lesser amounts of cobalt, molybdenum, titanium and aluminium. This combination of alloying elements stops titanium carbide precipitates from forming during heat-treatments as part of the manufacturing process. This in turn preserves the alloy's amazing impact strength, ductility and toughness.

US two-time Olympian fencer Ms Lee Kiefer has, what is known in fencing circles as a 'killing flicking riposte'. From the French for 'retort', the riposte is an offensive fencing action made to hit your opponent after blocking an attack. But what makes Kiefer's riposte special is her spectacular flick, in which she whips her fencing blade to drastically bend it, so she can hit opponents in hard-to-reach places. The diminutive fencer has used her killer riposte again and again to win medal after medal, and it wouldn't be possible without her maraging steel blade.

Mr Eric Mallet, fencing master and former member of France's Junior National team, now running the Austin Fencing Club in Texas said that "Thirty years ago we didn't really have this flicking action it was just so rare to see, as the quality of the blade wouldn't permit this. But now we have flashy fencers that carry out actions that are so physically impressive. The reason they can do this is down to the blade they use."

Source : World Steel Association

IIT Kharagpur gets India's 12th supercomputer

IIT Kharagpur on Thursday got India's 12th supercomputer with India gradually moving to install four others in Pune, Hyderabad, Bangalore and Kanpur by November. All the new ones of the year 2019, including the first one installed at IIT-BHU Varanasi in February, are indigenously built supercomputers.

These are part of 70 highperformance computing facilities which are being installed in India under the National Supercomputing Mission (NSM), launched in 2015 with allocation of Rs 4,500 crore. The supercomputers under the NSM will foster research in medicine, gene-editing, weather prediction, climate modelling, seismic analysis, atomic energy simulations, space exploration and big data analytics among others.

India is expected to install all the supercomputers by 2022 — the year when India would celebrate 75 years of its independence. The country's first supercomputer

— called PARAM 8000 — was launched in 1991. After IIT Kharagpur, the next in line is the Indian Institute of Science Education and Research, Pune. The other three in queue under first phase of the NSM are IIT Hyderabad, Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) Bangalore and IIT Kanpur.

The Centre for Development of Advanced Computing (C-DAC) will eventually connect all 70 supercomputers to a common national supercomputing grid under the National Knowledge Network (NKN) which aims to connect academic institutions and R&D labs over a high speed network.

Source : The Times of India

Nitrex Metal improves nitriding process for Aluminum extrusion company in Poland

Nitrex Metal Inc., Montreal, Quebec, has supplied a nitriding system to Hydro Extrusion Solutions, an aluminum extrusion company in Poland, to address the need for improved process performance and more accurate control of nitriding. The Nitrex N-EXT 812 nitriding system replaces a decommissioned nitriders that was phased out several years ago due to extrusion die failures and inconsistent metallurgical results.

The delivered solution includes Nitrex technology, which consists of potential-controlled gas nitriding and Nitrex-C potential-controlled gas nitrocarburising (ferritic nitrocarburising: FNC). This technology helps to optimise parameters for maximum efficiency and quality, increasing die strength and extrusion throughput, while reducing the possibility of potential die failures.

Moreover, Nitrex contributes to cost savings from reduced consumption of process gases and energy savings from shorter process times. The N-EXT type furnace has chamber diameter of 31.5 inches and height of 47.25 inches, with a capacity to nitride a 2200-pound load.

Since the start of operations with the new nitriding installation, treated samples have been periodically assessed by an external QA service to validate the nitride quality, specification compliance, and reliability of the Nitrex process. As part of this testing program, Nitrex results have been consistently in compliance with Hydro's quality standard.

Source: ASM International

Wear resistance of stainless steel increases by high-intensity implantation of ions

Scientists from Tomsk Polytechnic University in Russia have announced that they have developed a new method of ion implantation that improves the wear resistance of stainless steel by more than a hundred times through

highly intensive implantation of ions with low energy.

TPU scientists have experimentally confirmed the possibility of creating a doped surface layer with a depth of several hundred micrometers, compared to a depth only several tens or hundreds of nanometers for conventional methods. In addition, this technology reportedly makes it possible to manufacture details and products with specific surface properties. For example, a barrier layer is formed by ion doping of zirconium with titanium, thus preventing oxygen penetration. This can be used to increase the service life and safety of nuclear fuel cells.

According to Alexander Ryabchikov, the head of the Laboratory for Highly Intensive Ion Implantation, "We proposed to increase the ion penetration depth into the material by enhancing the radiation-induced diffusion with high-density ion beams that are two to three orders of magnitude superior to those used in traditional ion implantation."

Source: ASM International

Binghamton University to acquire \$1.75M HAXPES X-ray system for materials research

Binghamton University, New York, have announced that the school will acquire a HArD X-ray Photoelectron Spectroscopy system (or HAXPES), which allows researchers to get detailed information about a device or material without taking it apart. The \$1.75M system — the third of its kind in the world and the first outside of Europe — will be funded by \$1.23M from the National Science Foundation's Major Research Instrumentation program and additional money from the campus.

HAXPES relies on the photoelectric effect, one of the most important tools in condensed matter physics and in materials science. The instrument sends hard X-rays into the target material. The material absorbs the energy and momentum, and emits electrons. Conservation of energy and momentum allows researchers to determine the chemical and electronic structure of the material.

Compared to similar instruments, HAXPES offers more kinetic energy, which means excited electrons have a greater chance of escaping from deeper within the solid. That increases the instrument's sensitivity. HAXPES may go 60 nanometer deep into a material versus 5 nanometer with other tools. Scientists will be able to access interfaces at a depth of real devices such as transistors. It will be possible to measure energy levels and chemical composition of buried interfaces without tearing them apart.

The HAXPES, made by European company Scienta-Omicron, should be ready for use within two years at Binghamton's Smart Energy Building, part of the Innovative Technologies Complex.

Source: ASM International

Digital Metal launches two binder-jet additively manufactured superalloys

Digital Metal AB, Sweden, a Högan's Group company, announces that it is launching two binder-jet 3D-printed superalloys for applications in extreme environments: DM 247, a nickel-base superalloy, and DM 625, a nickel-chromium superalloy. The unique properties of Digital Metal's binder jetting technology make it highly suitable for printing superalloys with near full density, including non-weldable grades.

Superalloys exhibit great strength and corrosion resistance even when subjected to high heat and stress. These properties make them especially suitable challenging applications such as aerospace, automotive, and chemical. However, so far it has been difficult to use non-weldable materials such as MAR M247 in 3D printing, where high solidification rates and thermal gradients are inherent.

Digital Metal's unique binder jetting technology helps avoid most of these problems by printing in an ambient temperature without applying any heat, followed by a separate sintering step. During sintering densification takes place without melting and with minimal thermal gradients during cooling from sintering temperature.

The DM 247 is based on the non-weldable MAR M247, which is widely used as material for turbine blades and in other applications with elevated temperatures. The DM 625 is an Inconel 625-grade. Its application areas range from seawater applications and chemical processing equipment, to nuclear industry and aerospace.

"We have been receiving qualified requests for these materials from various large companies," says Ralf Carlström, General Manager at Digital Metal. "Many producers within the aerospace and automotive business have long been anticipating high-quality superalloys that are suitable for 3D printing. Now we can offer them the perfect combination – our unique binder jetting technology and superalloys that are specially developed for our printers."

Source: ASM International

Northern Minerals signs rare earths supply agreement with Thyssenkrupp

Northern Minerals Ltd., Australia, announces that it has signed a rare earths supply agreement with Germany's Thyssenkrupp Materials Trading for 100% offtake from the Western Australia Browns Range pilot plant, which has already begun producing heavy rare earth carbonates.

Under the terms of the agreement, Thyssenkrupp will purchase all heavy rare earth carbonates from the pilot plant and will serve as the exclusive sales partner of Northern Minerals. The two companies will jointly work on the implementation of separating technologies and future expansion of the Browns Range project.



Wolfgang Schnittker, CEO of Thyssenkrupp Materials Trading, commented, "Northern Minerals Limited is one of the few suppliers of rare earths outside China, so we

are really looking forward to a successful collaboration between the companies. As the exclusive marketer of these high-quality products, we have the opportunity to strengthen our customer relationships long-term and expand our positioning in this field."

Northern Minerals Chief Executive Officer George Bauk says the company will benefit from the lack of price caps in the agreement, noting that dysprosium and terbium prices are up 60 percent and 35 percent respectively over the year to date, as electric vehicles become more popular. Prices of rare earths elements have jumped this year on speculation that China, which controls about 80 percent of the supply, could cut shipments to the United States due to the ongoing trade war.

The agreement replaces the recently terminated offtake agreement Northern Minerals had with China's Lianyungang Zeyu New Materials Sales. Northern Minerals cited a contract breach when it canceled its two-year agreement with Lianyungang Zeyu on August 6, but did not give further details.

Source: ASM International

NEWS UPDATE

India mandates extension to mining leases to secure iron ore supply

India has made it mandatory for mining leases granted to state-run companies to be renewed for up to 20 years, the steel ministry said, thereby ensuring iron ore production will be secure as several leases were due to expire in March 2020. The ministry of mines has amended legislation to allow the leases to be extended before they are due to expire, "ensuring raw material security and seamless renewal of mining leases allocated to the government companies," the steel ministry said. Under "Minerals (Mining) by Government Companies) Rules, 2015", the mines ministry said it substituted "may, for reasons to be recorded" with "shall, for reasons to be recorded." The lease extension will be granted after an application has been made by the state-run company at least 12 months before the lease is due to expire.

However, the amendment does not apply to private sector companies seeking to extend mining leases due to expire in March 2020. There are at least 31 iron ore mining leases due to run out on March 13, 2020. The upcoming expiry has caused market concerns about "probable disruptions," the ministry said. "This will also ensure price stabilization of raw materials and will have positive effect on the secondary steel industry," said Shri Dharmendra Pradhan, minister of petroleum and natural gas and steel.

Metal Junction

RSP's capacity to be increased to over 10 MT: Pradhan

Union Steel Minister Dharmendra Pradhan announced the Centre's plan to raise the capacity of Rourkela Steel Plant (RSP) to over 10 million tonne from 4.2 million tonne. The minister asserted that further expansion and modernisation at RSP, a unit of SAIL, will play a major role in transforming the western Odisha town of Rourkela into a manufacturing hub.

"RSP presently has the capacity to produce 4.5 million tonnes of hot metal and 4.2 million tonnes of crude steel per annum. Its capacity is planned to be increased over 10 million tonne per annum," Pradhan told. He asserted that raising RSP's capacity is important as crude steel production in the country is sought to be increased from 140 MT to 300 MT by 2030 which will benefit the country in a big way.

Pradhan, during his meeting with RSP officials, emphasised the need for fast-tracking projects and greater contribution towards regional development. Noting that RSP is located in the heart of the mineral rich belt of Odisha, he said it can be a leader in steel production in India and can contribute significantly towards achieving the target of producing 300 million tonne of steel. RSP officials need to explore options for localisation of consumption of primary steel produced at the plant. This will ensure growth of the downstream steel industry in Rourkela, he said.

Business Standard

India aims to turn net steel exporter

Government has set a target to become a net exporter of steel in the next two-three years, banking on a strategy to sell more of the product to the Gulf countries. "Currently we are importing 2 or 3 million tonnes of steel, in the coming two to three years, India will be a net exporter of steel for a long time to come," steel minister Dharmendra Pradhan said.

"India has been purchasing crude oil and gas from so many countries but there is hardly any role of Indian exports in developing the infrastructure there. Now we have started asking them to give a preference to Indian steel companies for meeting their needs," he said. Pradhan was speaking at a ministry meet that discussed ways to make the industry globally competitive. "I recently went to the Gulf countries. I gave them an estimate about the amount of oil and gas we buy from them, and their consumption of steel, and mentioned we don't have a share in it," the minister said.

The country has the capacity of 140 mt and produces about 100 mt annually. "The outcome of this Steel Meet will be felt within the next two-three years, India will remain a net exporter of steel for years," he said. There is a need to find new ways of trade protection and trade negotiation, he added.

However, exports of finished steel have observed an increasing trend since July. Pradhan said there was a need to bring down the export of iron ore to zero. His comments were in light of demands to lower the export duty on high grade iron ore.

The Telegraph

World's longest zipline built on steel

A new tourist site in the UAE relies on the enduring properties of steel for the longest zipline in the world, resulting in a unique and thrilling experience. The UAE's remote Ras Al Khaimah mountain range is perhaps the last place you would expect to find the world's longest zipline. But by harnessing the power of steel, Toroverde Ecological Park overcame incredible logistical challenges to open the Jebel Jais Flight zipline in January 2018 and – thanks to its single unbroken span of 2,831.88m – was awarded with the accolade of being the longest on the planet by Guinness World Records.

Jebel Jais is the UAE's highest mountain, and the zipline begins an impressive 1,680 m from the ground. Even at its lowest point visitors will find themselves 400 m above sea level. The conditions that go hand-in-hand with constructing a zipline in such a challenging environment presented a tough set of challenges for the engineering and installation teams.

[https:// worldsteel.org/](https://worldsteel.org/)

South Korea's Posco continues exploring joint venture possibility with RINL

Having stumbled earlier on its plans to set up a plant in

India due to a struggle against land acquisition, South Korean steel giant POSCO is again turning to the country's growing steel market. But this time through a joint venture with RINL in Visakhapatnam, according to sources. POSCO is looking to set up a joint venture with RINL in Visakhapatnam for manufacturing of value-added special grade of steel. POSCO officials have visited the RINL facility three times since January 2019, the sources said.

In July this year, senior POSCO officials also met Steel Secretary Binoy Kumar and submitted an investment proposal, sources in the steel ministry said. The 7.3 million tonnes RINL plant in Visakhapatnam is a shore-based integrated steel plant. It has a land of over approximately 22,000 acre of its own and enjoys access to Gangavaram Port, where raw materials such as coking coal etc arrive. An expert said, since RINL is located on the eastern coast of India, a JV plant will give access to the South East Asian markets besides catering to the domestic needs of special steel through rail and road.

Business Standard

SAIL looks at hiving off manufacturing units to take advantage of new tax rates

Steel Authority of India Ltd (SAIL) is looking at means to lower its overall tax incidence by hiving in-house manufacturing and project expansions into separate companies. "Industry has to take full advantage of the fiscal measures. The government has come out with quite a few measures and one very important measure is that new manufacturing companies are going to pay corporate tax at the rate of 15 per cent. Steel industry should take full advantage of this while keeping within the legal framework," SAIL Chairman, Anil Kumar Chaudhary said at the Chintan Shivir organised by Federation of Indian Chambers of Commerce and Industry (FICCI) and the Ministry of Steel. Earlier, Finance Minister Nirmala Sitharaman announced a slew of tax measures including reducing the effective tax rate for domestic companies to 25.17, provided they do not take any incentives. For new manufacturing firms, the effective tax rate will be 17.01 per cent inclusive of surcharge and cess.

Business Line

Vizag Steel Employees win Viswakarma Rashtriya Puskar

Vizag Steel employees brought national level recognition by receiving prestigious Viswakarma Rashtriya Puskar for their innovative work. S Eswara Rao, D Trinadha Rao, B Dharma Rao, A Satti Babu, B Appala Raju led by D Devadanam of Steel Structural Shop of Engineering Shops & Foundry have undertaken a critical job of repairing, renovating a Torpedo Ladle in a short time of 56 days, thereby saving huge amount to the Company.

Tarpedo Ladle Cars transport 300 T of Hot Metal from Blast Furnace to LD Converters of SMS. The overall length of the vessel is 19.60 meter. During usage vessel got deformed and damaged. The dedicated and committed team of Steel Structural Shop renovated using in-house resources and inherent skills. The award was bestowed on them by Mr Santosh Gangwar, Honorable Union Minister for Labor & Employment.

Steel Guru

Mandatory registration of steel import contracts is a sound move; but time limit, fees can be eased

The government's move towards mandatory registration of steel import contracts under the Steel Import Monitoring System has raised the hackles of the user industry. The decision is intended to check, if not eliminate, invoice manipulation, the government has argued. Until now, New Delhi has had no clue about the details of import contracts entered into including the origin of goods, contract prices and period of arrival. In the absence of this vital information, policy-making was reactive rather than proactive. So, any expression of grievance against contract registration deserves to be ignored.

But two issues merit reconsideration by the government. First, the time limit specified for the registration of import contracts. The timelines make little sense and are unlikely to serve any useful purpose. Second, the registration fee. Why should the fee for mandatory registration of contracts depend on the value of the imported cargo? After all, the government, in its own interest and to advance transparency, has mandated registration. It cannot become a revenue generating measure. A nominal registration fee on a per-tonne basis should be levied primarily to cover administrative costs.

Mere registration of import contracts is unlikely to solve the menace of invoice manipulation — over-invoicing or under-invoicing — although the registration authority will have advance information of the contracted prices. In order to address the issue of invoice manipulation, the tariff value can be specified. When it is specified for an imported commodity, the customs duty will be charged on the specified tariff value and not on the basis of the invoice price. The tariff value can be reviewed every fortnight or month depending on global market conditions. This way revenue will not be lost and importers of identical or similar goods will end up paying the same amount of customs duty. The exchequer will stand to benefit.

Business Line

Odisha Government seeks Support for 100 Million Tonne Steel Output

Odisha state government sought Union government's support to meet the 100 million tonne steel production target by 2030 and to become a major contributor in national steel production target of 300 million tonne.

Taking part in Chintan Shivir organised by the Ministry of Steel, Odisha Chief Secretary Mr Asit Tripathi raised four issues and sought the Centre's support towards enhancing steel production in the state. He said that the Union government should consider developing waterways in Brahmani river for better transportation of goods and also introduce goods trains. He also said there is a need to develop the skills of people living in mining areas so that they can get gainful employment opportunities at the steel plants. Mr Tripathi further said that the Centre should consider expediting the process of environment clearance for the projects.

Steel Guru

SAIL move likely to cheer steel makers

The Centre has allowed SAIL to sell a quarter of its captive annual iron-ore output, a move that will increase input-supplies security for domestic steel makers, as the state-run company is the country's second-biggest miner of the key raw material.

The ministry of mines order, valid for two years, will allow SAIL to offload 7 million tonnes of iron ore (60-65 per cent iron content) produced at its different mines — Jharkhand, Odisha and Chhattisgarh — to be sold in the domestic market after getting the necessary clearances from the respective state governments.

The Economic Times

Indian steel mills hope to invest in upcoming Saudi Arabian steel, iron ore projects

Indian steel manufacturers plan to strengthen their relationship with the Middle East market, especially Saudi Arabia, according to remarks made during the second day of the First International Saudi Iron and Steel Conference. "India is a natural supplier for Middle East given its position on the Indian Sea," V.R. Sharma, Managing Director of India's Jindal Steel and Power, said. "The industry will definitely grow and more investments will come from India to Saudi Arabia," Sharma added, highlighting that the iron ore hubs identified in Saudi Arabia as potential opportunities. In addition, the company is hoping to seek partnerships for railway structures in the Middle East. Sharma also said that the casting industry is the future in Saudi Arabia and expressed interest in possible investments. "Indian companies are very keen to participate as investors in the Middle East and Africa. Our appetite is for 2 to 3 mt capacity, nothing big like China," he added.

Bhaskar Chatterjee, secretary general and executive head of Indian Steel Association, said that the association would like to play a vital role towards achieving Saudi vision 2030. "Where industrialisation goes, steel follows. We have seen that before as well" Chatterjee said. "We believe that Saudi and Indian 2030 strategies will generate synergies for both countries" he added.

Metal Junction

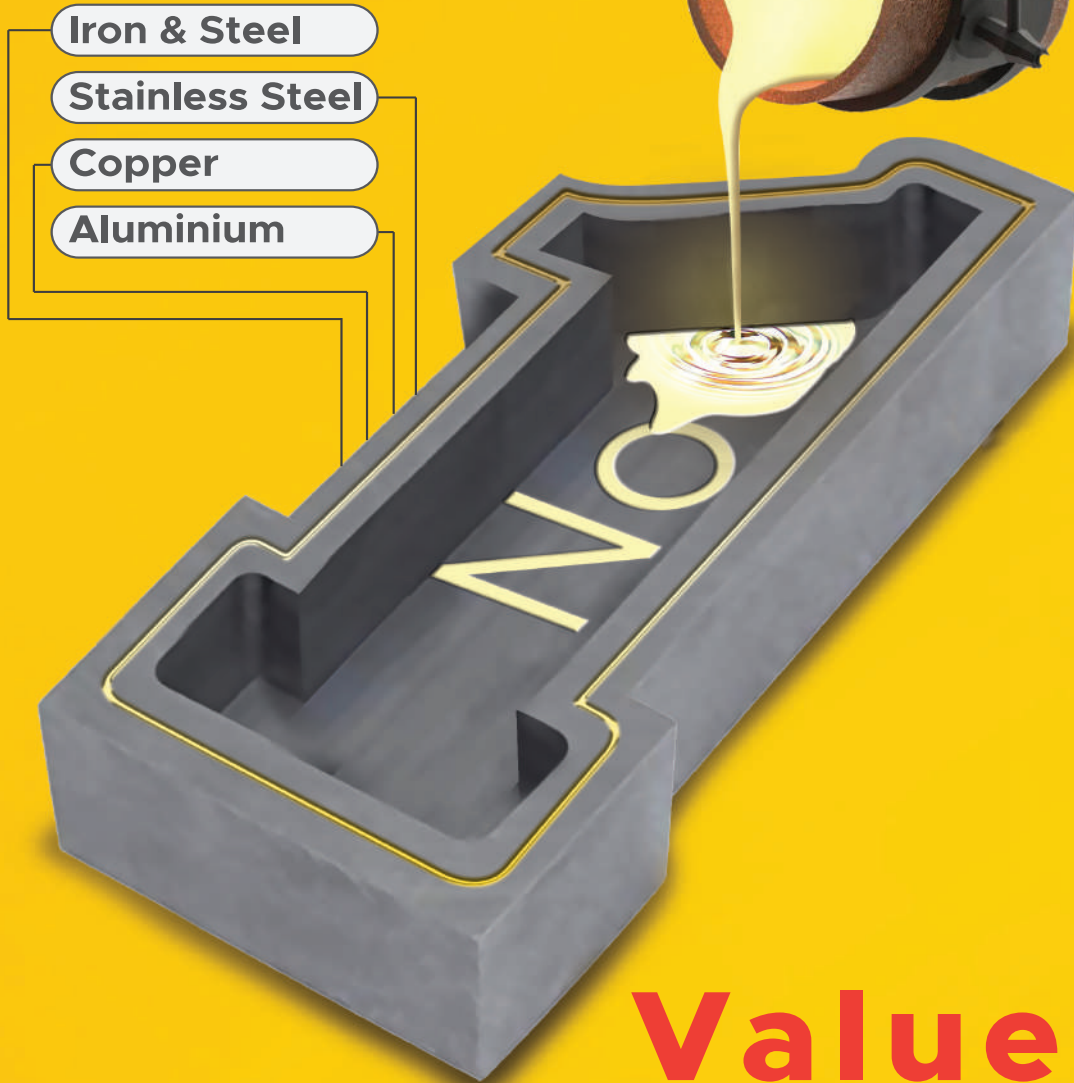
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IIM CHAPTER ACTIVITIES

Pune Chapter

- 1) Four Technical Talks were organised by IIM Pune Chapter during June'19 to September'19.
 - i) "High Strength and Corrosion Resistant Aluminum Alloys" by Dr. Rajeev Kumar Gupta on 21st June, 2019. Around 50 participants from industry and academia attended this talk.
 - ii) "Ion Beams: A Materials Perspective" by Dr. Saumitra K Vajandar on 4th July, 2019. Around 35 participants from industry and academia attended this talk.
 - iii) "Electric Vehicle: Novel Approach & Technological Trend" by Dr. Dhananjay Kumar on 21st August, 2019. Around 150 participants from industry and academia attended this talk.
 - iv) "Importance of Failure Analysis and its Role in Fabrication Industries" by Dr. R. Vaideeswaran held on 13th September, 2019. Around 45 participants from industry and academia attended this talk.
- 2) The EC Meeting of IIM Pune Chapter was held on 17th September, 2019. The following Chapter Bearers were elected for the year 2019-20:

	Position in IIM PC	Name
1	Chairman	Sandeep P. Butee
2	Secretary	Rishabh Shukla
3	Treasurer	K.R. Kambale



A snap of HQ visit to IIM Pune chapter held on 17-9-19 at Pune

- 3) **13th Dr. Dara P. Antia lecture on 'A Discourse on the Art of Leadership Practice' by Dr. Sanak Mishra** : "Leadership is contextual and there is no such thing as universal leadership", said Dr. Sanak Mishra while delivering the discourse on the 'Art of Leadership Practice' at the annual national event of the IIM, at College of Engineering, Pune on September 17, 2019.

Citing many examples of leaders like Yudhisthir, Moses, Adi Shankaracharya, Lincoln, Gandhi and Einstein, he pointed out that the context of their leadership was very clear and sharp at different times. Leadership is about influencing the mindset, behavior and actions, in that order, of people that come across in our lives or the people at our workplace and even the people who are our next-door neighbours.

The 'Metaphysical Powerhouse', the novel concept developed by the speaker detailed the different types of powers and their hierarchy, to influence people. One by one, unfolding the petals of different inner power centers like the power of mind, the power of communication, power of relationships with intrinsic abilities, based on the foundation of tradition, heritage, culture and values were explained in detail with their order of importance and hierarchy.

The transformational change in an organisation will mean that all its members act collectively and in unison and for a common purpose. Only leaders are capable of unifying the collective energy of their followers in one direction. An organization is also like a powerhouse. It deals not only with human resources, but also simultaneously with financial, technological and natural resources for the purpose of materialistic gains such as productivity and profitability.

The leader is able to leverage his powers as an individual, namely the power of the mind, the power of communication, the power of relationships and the power of intrinsic ability along with all the powers of the organisation streamlining various processes, systems, assets and structures in their right proportions leading to a perfectly balanced organisation.

'Every leader has a Mission, the one that his followers should be able to subscribe', Dr. Sanak Mishra concluded. He explained that life seems to have five dimensions. These are physical space (length, breadth and height), mind space (mental space), time and matter (mass, or substance). The true leaders impact all dimensions of life along with the fifth dimension of 'Samskar'. This is a way of living, of say a human being or a group of human beings, as they anticipate and cope with the changes that occur around them. We have to add Samskar as the fifth dimension of life. Institutions, Societies and Civilisations which survive are those whose leaders carry out a continuous Samskar.

At the end of the discourse, the speaker discussed the qualities of responsibility and courage of a good leader. The responsibility is something that is never handed over;

what can be handed over is accountability. It is a reflection of one's own inner urge to respond to the call of the inner self. However to be responsible one has to have courage. It takes courageous approach to uphold principles, to invoke and uphold values. The leader should have courage to do the right things and also the courage not to do things which are not right.

Finally, Dr. Sanak Mishra mentioned that taking responsibility is the ultimate essence of personal courage. 'Leadership lies in taking up responsibility, in facilitating others, and in letting people make a significant contribution to a befitting cause - with full freedom, dignity and without fear. Be a Leader!!'

The Memorial Lecture function started with the welcome address by Professor B. B. Ahuja, Director, College of Engineering Pune, followed by a welcome address by Dr. U. Kamachi Mudali, currently the President of IIM and the Chief Executive of the Heavy Power Board, DAE, and by Mr. Hemant Nerurkar, Chairman of the Dr. Dara Antia Memorial Lecture Committee. Dr. Kamachi Mudali recalled the pioneering contributions made by Dr. Dara Antia in building the IIM on extremely sound foundations and that is the reason it has withstood the test of time. It is today the premier professional body for the minerals, metals and materials engineering fraternity in the country, with more than 10,000 members drawn from industry, academia and the research institutions. Mr. Nerurkar introduced the distinguished speaker and felicitated Dr. Sanak Mishra.



From Left to Right : Dr. Pradip, Professor S Banerjee, Professor BB Ahuja, Mr. Jehangir Ardeshir, Mr. Hemant Nerurkar, Dr. Sanak Mishra, Dr. Kamachi Mudali, Mr. Kushal Saha, Dr. Satyam Sahay and Professor NB Dhokey

Jamshedpur Chapter: BTTD-2019

The 9th edition of "Behind The Teacher's Desk" (BTTD-2019), two-day students' seminar on Metallurgical engineering, was jointly organised by the Jamshedpur Chapter of Indian Institute of Metals (IIM), Tata Steel Limited and CSIR-National Metallurgical Laboratory (NML) during 5-6 September, 2019 at CSIR-NML. The seminar was formally inaugurated with the release of seminar souvenir by the Chief Guest Dr. Tridibesh Mukherjee, Chairman, TechnoPlus Consultants Pvt. Ltd., Jamshedpur.

The aim of the seminar was to provide a common platform for promising and aspiring metallurgists to interact with the pool of experts from industries, R&D centres and academia. The student participants of this event got an opportunity to update their current knowledgebase, and share their academic achievements, innovative thoughts and new ideas in the field of metallurgy and materials technology. This students' seminar is being held at the CSIR-NML for the past eight years and has been a great success. Like previous years, this year also more than 150 students from various engineering colleges/institutes from different parts of the country were participated. Around 45 technical papers and 18 e-posters were presented in three parallel sessions in the area of metallurgy and materials sciences.

During inauguration Dr. Indranil Chattoraj, Director of CSIR-NML motivated all metallurgy graduates to work and contribute in core profession and to come up with noble and newer ideas for the advancement of the metallurgy and materials engineering. Chief Guest, Dr. Tridibesh Mukherjee appreciated the involvement of huge number of student participants from metallurgical fraternity in this historical event. He advised the students to apply the first principle theory to solve any problem.

Industrial tours were organised to TATA Steel Ltd, Tinplate and Usha Martin Ltd. to familiarise students with a first-hand exposure. A cultural programme was organised where BTTD delegates actively participated. An interactive session was held on "Industrial Problem Statement" that included two rounds. The first round comprised of technical group discussion moderated by two R&D and industrial experts; and the second one contained stage round which was judged by a seven members panel.



- Report from IIM Jamshedpur Chapter

Baroda Chapter: FAHT-2019

A one day seminar on Fundamentals & Applications of Heat Treatment (FAHT-2019) was organised by Mechatronic Dept. of G H Patel College of Engineering and Technology and The Indian Institute of Metals, Baroda Chapter on September 9, 2019 at Seminar Hall GCET. Dr. Sunil Kahar, Chairman of IIM Baroda Chapter spoke about various activities of IIM Baroda Chapter in his address. Prof. Shashank Joshi, Asso. Professor, BVM college shared his views on Fundamentals of Heat Treatment. Mr. D. R. Lodhari, Asst. Professor, MSU talked about Induction, Flame Hardening Treatment for gears, crankshafts, turbine blades etc. Mr. Rajan Kaduskar, Head, TUV aerospace certification, gave an expert talk on Case hardening through nitriding, carburising & its applications. Entire program was co-ordinated by Dr. Ketan Tamboli, Convener & Asso. Professor, GCET. Around 100 students participated in this seminar.



-Report from IIM Baroda Chapter

Delhi Chapter

1) A Technical talk on “Standardisation and Quality Control Framework in Indian Steel Sector” was organised on 14th September, 2019. The talk was delivered by Shri A C R Das, Vice Chairman, Delhi Chapter and Iron and Steel Consultant.

He informed that India’s steel production is on the growth path. During 2018-19 crude steel production was 110.8 Mt and the consumption of finished steel was 97.5 Mt, an increase of 7.5% over the previous year. Today there are more than 3500 types / grades of steel having different physical, chemical and metallurgical properties.

He mentioned that standards are key to quality and quality control. Bureau of Indian Standards (BIS) the national standards body in India is responsible for development of standards, as well as conformity assessment of goods and services and process and systems etc. It has published 1650 Indian Standards on various metals and metals products, of which about 180 relate to iron and steel products, and 66 have been notified under the mandatory quality certification marks of BIS. These constitute about 80-85 % of total steel consumption in India.

The genesis of quality control order of steel products dates back to 2000 and from time to time more and more steel products are getting added in the standardisation list. Implementation of steel control order is mandatory, both indigenous and imported products must conform to the relevant Indian standards and bear standard mark of BIS. Contravention of these orders entail penalty under the relevant provisions of BIS Act.



2) **One day Programme** : The Indian Institute of Metals Delhi Chapter along with IIT Delhi, Material Science & Engineering Department organised a one day program on “Development of Physical Simulation Using Gleeble System and its Application in Steel Processing” on September 28, 2019 at IIT Delhi Campus. The welcome address was given by Dr. Jayant Jain, Associate Professor, Dept. of Material Science Engineering, IIT Delhi. He welcomed the IIM Members and Chairman of Delhi chapter Mr. K K Mehrotra and expressed his desire to conduct such interactions between IIM and IIT Delhi which will be beneficial for both the organisations.

A presentation was given by Dr. Wayne Chen, Managing Director, Asia Pacific Operations, Dynamic Systems Inc. of USA. They are the pioneer in Gleeble Simulation technology and its application in metal processing. The system is widely used for fundamental studies such as phase transformation, dilatometry, weldability, recovery and recrystallization along with simulation of industrial processing such as continuous casting, multi-pass hot rolling, heat treatment, continuous annealing and product development. Samples of material are heated and mechanically worked while various performance

parameters of interest are measured and recorded for analysis. After the simulation or test is done, the microstructure of the material may also be examined. A visit to various facilities of Material Science & Engineering Dept., IIT Delhi was undertaken before the lecture session.



- Report from IIM Delhi Chapter

Kalpakkam Chapter: 27th Prof. Brahm Prakash Memorial Materials Quiz

IIM Kalpakkam Chapter conducted the 27th Prof. Brahm Prakash Memorial Materials Quiz (BPMMQ) at Indira Gandhi Centre for Atomic Research, Kalpakkam during September 20-21, 2019. A total of 33 teams comprising 66 students of class XI and XII accompanied by escorts and office bearers from 19 chapters across India participated in this flagship programme.

On September 20, 2019, the Metal Camp programme commenced with welcome by Dr. Divakar R., Chairman, IIM Kalpakkam and special address by Dr. G. Amarendra, Chairman – BPMMQ 2019. A video film “Kalpakkam on Course” highlighting the various reactor facilities and research laboratories at Kalpakkam was screened. This was followed by Prof. Brahm Prakash Memorial Lecture 2019, delivered by Dr. G. Amarendra, Distinguished Scientist and Director, Metallurgy and Materials Group, IGCAR, on the topic “Effects of Radiation on Materials”. The speaker presented an overview of the structural materials used in nuclear reactors and the type of radiations they are exposed to. He lucidly explained how materials behave differently and their properties alter under irradiation. He presented the results of materials irradiated in FBTR and charged particle accelerators. This was followed with visit to the facilities at Kalpakkam, namely Fast Breeder Test Reactor (FBTR), Madras Atomic Power Station – (MAPS) and the Nuclear Desalination Demonstration Plant (NDDP). A souvenir BPMMQ 2019 Digest containing the details of all BPMMQ events held in previous years, essay articles

selected for elocution contest and special messages from dignitaries was released on this occasion.

On September 21, 2019, the quiz programme commenced with drawal of lots for the preliminary rounds held in six parallel sessions. The winner and runner of each session contested in semifinal round held in two parallel sessions. The teams included Jamshedpur – A & B, Bhilai - B, Sunabeda - B, Trichy - A & B, Chennai- A & B, Bhubaneswar - B, Hyderabad, Mumbai and Bangalore - A. Six teams (three from each semi-final round) were selected for the Grand Finale. The teams included Trichy – A & B, Chennai - A & B, Bangalore - A and Mumbai.

Dr. Sumanth C. Raman, a renowned sports quiz master from Chennai conducted the Grand finale of BPMMQ 2019. The Finale comprised of eight rounds with audio, video, dumb charades and rapid fire rounds. The winner was IIM Bangalore Team–A comprising Ashutosh M. Bharadwaj and Bharath Shankar of National Public School, Rajaji Nagar, Bangalore. IIM Trichy Team-B comprising P. Harshavarthini and V. Srideiva Prasanna of Sri Jayendra Swamigal Silver Jubilee MHSS, Tirunelveli won the second place.

The essay cum elocution contest for the quiz participants also was well received this year. The topics were (i) “Evolution of the Periodic Table of Elements – Is it complete?” (ii) “Destination Moon – A materials Perspective” and (iii) “Ocean Bed – Store House of Rare Metals and Minerals. A total of 19 essays (7 in Periodic Table; 6 in Materials - Moon; and 6 in Rare Metals) were received. Six best essays were selected for elocution contest. The selected participants rendered excellent and flawless elocution and was judged by a three member jury of eminent experts from IGCAR, Kalpakkam. Ms. Arpita Mahapatra, D.A.V. Public School, Kalinga, Angul Chapter, was the winner of Essay/Elocution contest for the topic “Evolution of the Periodic Table of Elements – Is it complete?” and Agnidh Ghosh, Loyola School, Bistupur, Jamshedpur Chapter, was the runner of this contest for the topic “Destination Moon – A Materials Perspective”.

The Winner and Runner teams of the Quiz and the elocution contest were awarded by Dr A.K. Bhaduri, Director IGCAR, Kalpakkam. The event was successfully conducted with generous financial supports from several well-wishers and promoters of science, including Department of Atomic Energy, The Indian Institute of Metals, Indira Gandhi Centre for Atomic Research, JSW Centre, Mumbai, ARCI, Hyderabad, NFC, Hyderabad, MIDHANI, Hyderabad, Madras Atomic Power Station, BHAVINI, Heavy Water Board, Mumbai, and several leading firms dealing with metallurgical equipment and services. Dr. B. Anandkumar, Convener BPMMQ 2019 proposed a vote of thanks.



Dr. G. Amarendra delivering Special Address



Dr. A.K. Bhaduri, Director, IGCAR, distributing the prizes to the winners of BPMMQ 2019



The Metal Camp Programme

- Report from IIM Kalpakkam Chapter



340th IIM Council Meeting on 2nd October, 2019 at BARC Training School Hostel, Anushakti Nagar, Mumbai

MEMBER NEWS



Dr. (Prof.) Ram Pravesh Bhagat, previously with CSIR- NML Jamshedpur, and IIT (ISM) Dhanbad has authored a book titled, 'Agglomeration of Iron Ores' published in August 2019 by the CRC Press, Taylor & Francis. The book has 16 (sixteen) Chapters, spread over 438 pages, and covers the topics of Raw Material Preparation, BF Iron Making, as well as Sintering (Chapters 5 to 10) and Pelletisation (Chapters 11 to 16). Prof. Bhagat has previously contributed an article titled, 'Agglomeration' in the Encyclopedia of Iron, Steel and their Alloys (in 5 Volumes) published by the same Group in January 2016.

EVENTS CALENDAR 2019-2020

November'19

13th-16th

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 73rd Annual 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

6th – 7th

Tata Steel and CSIR-NML, in association with the Jamshedpur Chapter of Indian Institute of Metals, is organising an International Conference on "Steelmaking and Casting – Sustainable Technology and Practices" (SMCSTP 2020) at Jamshedpur.

Website : www.smcstp2020.com

21st-23rd

10th International Conference on Materials Processing and Characterization organized by IIM Mathura Chapter.

Website: www.icmpc.com

ADVERTISERS' INDEX

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SEMINARS & CONFERENCES

Past Events

Workshop on “Science and Technology in Ironmaking and Steelmaking”

The First India-Japan workshop on “Science and Technology in Ironmaking and Steelmaking” held at Okayama, Japan on 10th September, 2019. India has emerged as the second largest steel producer surpassing Japan in 2018. The growth in steel production, in India, during the last 10 years (2008-2018) has been the highest and productivity increased nearly 1.6 times. Steel production is expected to increase further during the next decade, the planned annual target in 2030 being 300 MMT. The growth in iron and steel sector as well as challenges in the market place warrants that mineral, iron and steel education and research in the country is strengthened further. Quality technical manpower is a precursor to innovation, the production of high quality steel and development of environmental friendly, energy efficient future mineral, iron and steelmaking processing routes.

Mineral, iron and steel centric research and development activities are currently predominantly carried out in the Asian countries (viz., China, India, Japan and Korea) where nearly 70% of global steel is produced. Japan has been and is a leader in iron and steel manufacturing arena and contributed immensely to the science and technology of iron and steelmaking through world class R&D activities. Although Nordic countries, USA, China, Australia as well as many other countries have taken advantage of this unique position of Japan through bilateral educational exchange programme and collaborative academic research, such programmes remained yet to be worked out between India and Japan. It is to encourage and strengthen academic research and interactions and to exchange thoughts and views on mineral, iron and steel education and research, an annual workshop with Indian and Japanese researchers have been contemplated. Prof. Shin Kitamura (Chairperson of the 1st workshop) of Tohoku University spearheaded the activity and the first India-Japan workshop in this area was successfully organised at Okayama City in Japan, in collaboration with IMRAM (Institute of Multidisciplinary Research for Advanced Materials, Tohoku University) and ISIJ, on 10th of September, 2019.

The workshop was attended by forty-five academicians, researchers from industries as well as students from both the countries. Thirty delegates participated from the Japanese Universities and industries, and fifteen participants from India presented their work. The Indian

delegates were from academic institutions (IITs and IISc) and comprised of eight professors and seven graduate students mostly working in the area of mineral, iron and steelmaking. Profs. Govind S. Gupta (Co-chair of the workshop, IISc), Amarendra Singh (IITK), N.N. Viswanathan (IITB), G.G.Roy (IITKgp), Sabita Sarkar (IITM), Ajay Shukla (IITM), Nikhil Dhawan (IITR) and D.Mazumdar (Co-chair of the workshop, IITK) delivered lectures on diverse research problems. Presentations were made in the workshop, as well as, in the parallelly ongoing 178th meeting of the ISIJ (in the international session titled contribution of steelmaking technology for the sustainable development in Asia). Graduate students from India presented their research work in poster session of the ISIJ meeting.

The workshop was generously supported by ISIJ. To celebrate the successful completion of the first India-Japan workshop, a dinner get-together was organised on 10th evening by the workshop chair, Prof. Kitamura at a well-known Indian restaurant “Namaste Ganesha” in Okayama City. Informal discussions were made to workout future plans and paths for formulating definitive academic collaboration and exchange programmes between the two countries. The success of the workshop and interest among both Indian and Japanese researchers provided enough indication that the effort must continue and concrete plans worked out to strengthen academic ties among Universities and researchers, publicly and privately, in these two countries. It has been generally agreed to organise the workshop on a yearly basis, alternating between the two countries. Accordingly, it is planned to host the 2nd India-Japan workshop in India. A mutually convenient time and date is planned to be worked out soon.



-Report by Prof. D Mazumdar

‘GIMII 2019’

The national seminar on “Green Initiatives for Metallurgical Industries in India” organised by Department of Metallurgy and Materials Engineering, IEST Shibpur and Corporate Monitor in association with the Indian Institute of Metals, B E College Chapter was held on 11th September, 2019 at IEST Shibpur. GIMII 2019 highlights the “GO GREEN” initiatives of Indian metallurgical industries during 2018-19, with special sessions on Iron & Steel, Aluminium and Copper sectors.

The Chief Guest of the seminar was Shri A K Shukla, Director (Operations), Hindustan Copper Limited. Dr. Debashish Bhattacharjee, Vice President, Technology & New Materials Business, Tata Steel, Dr. Susmita Dasgupta, Joint Chief Economist, ERU, Joint Plant Committee, Shri R N Parbat, Former President, Indian Institute of Metals, Shri Shobhit Tiwari, Chief HSEQ Officer, Cairn Oil and Gas, Vedanta Limited were the Guest of Honours.

Theme Paper and Technical Papers were presented.



Coming Event

International Conference on Steelmaking and Casting– Sustainable Technology and Practices(SMCSTP 2020)

Tata Steel and CSIR-NML, in association with the Jamshedpur Chapter of Indian Institute of Metals, is organising an International Conference on “Steelmaking and Casting –Sustainable Technology and Practices” (SMCSTP 2020). The conference will be held during February 6 -7, 2020 at Alcor Hotel, Jamshedpur.

Conference Topics: (Focus on Sustainable Practices and Advances)

1. BOF & Electric Steelmaking
2. Ladle and Secondary Refining
3. Continuous Casting
4. Waste and By-product Management & Pollution Control Technologies in Steelmaking Area
5. Artificial Intelligence, Automation and Control Systems for Steelmaking and Casting

Organising Committee:

Chairman : Mr Akshay Khullar

Co-Chairman : Dr Mita Tarafder

Convener : Mr P P Sahoo

Treasurer : Ms Soumya V Nalluri

Registration Fees :

Category	Fees
<i>Indian delegates (INR)*</i>	
Delegate-Non IIM member	10000
Delegate-IIM member	8000
Student Delegate	5000
Accompanying Partner/Spouse	3000
Plant visit (Tata Steel Works and R&D)	1000
<i>Foreign delegates (USD)</i>	
Delegates	400
Student Delegates	300
Accompanying Partner/Spouse	100
Plant visit (Tata Steel Works and R&D)	50
<i>*Excluding GST (18%)</i>	

Address for Communication :

Mr P P Sahoo, Convener,

Principal Scientist, R&D, TATA STEEL, Jamshedpur

Pin: 831 007, Jharkhand, India

Ph: +91- 9263634183

E-mail : smc.stp@tatasteel.com

TYPICAL STEEL CO-PRODUCTS

Over the past 20 years, the use of the steel industry's co-products has increased significantly.

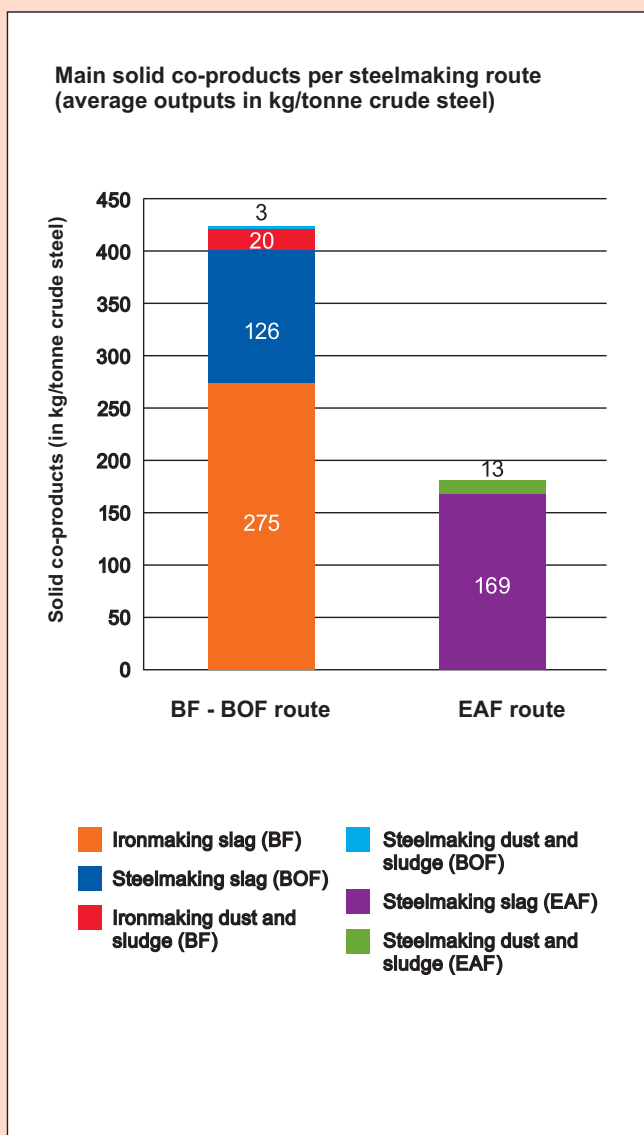
Innovative technology developments and synergies with other industries have brought the steel industry ever closer to its goal of zero waste to landfill.

Co-products refer to materials that are produced in parallel to or, as a consequence of, the production of a primary product and which also have a potential value.

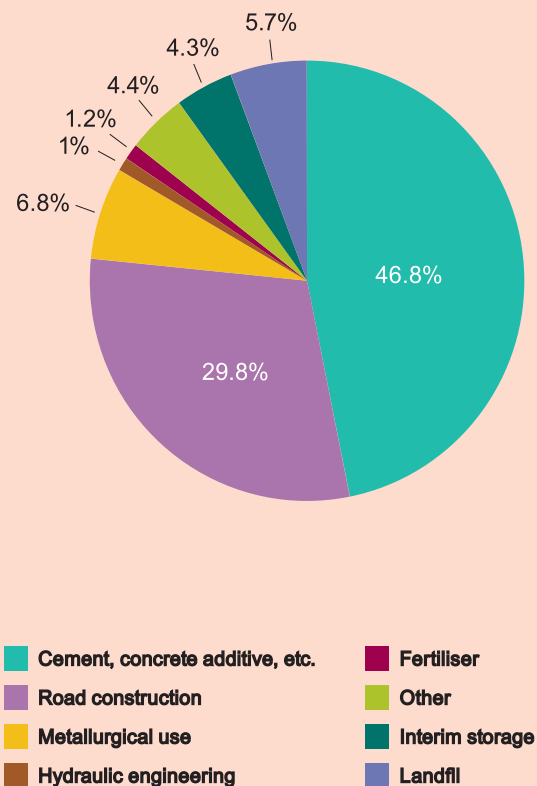
The main solid co-products produced during iron and crude steel production are slags (90% by mass), dust and sludge.

On average, the production of one tonne of steel results in around 200 kg of co-products for the electric arc furnace (EAF) route and 400 kg for the blast furnace - basic oxygen furnace (BF-BOF) route.

Alongside solid co-products, process gases from coke ovens, BF's or BOF's are also important steelmaking co-products.



Typical use of iron and steelmaking slags in Europe* in 2016 (total 41 Mt)



*At a global level, percentages vary from region to region

Source : World Steel Association

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#SteelFact
Globally the steel industry is
developing technologies to
**reduce CO₂
emissions**
by more than 50%

Source: World Steel Association



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METAL STATISTICS

Primary Non-ferrous Metals : Production (unit: Metric Tonne)

	June'19	May'19	Apr'19	2018 - 19	2017 - 18
ALUMINIUM					
National Aluminium Co Ltd	38,138	36,577	37,416	4,40,242	4,25,515
Hindalco Industries Ltd#	1,11,221	33,711	35,100	4,09,037	4,08,904
Bharat Aluminium Co. Ltd	47,465	44,023	48,236	5,71,814	5,68,932
Vedanta Ltd	1,11,532	1,10,450	1,13,207	5,44,651	4,39,567
TOTAL	3,08,356	2,24,761	2,33,959	19,65,744	18,42,918
# Now onward HINDALCO will submit figures of all the four plants (Renukoot, Hirakud, Mahan, Aditya Aluminium)					
ZINC (One major producer)					
Hindustan Zinc Ltd	58,282	58,786	56,292	6,96,283	7,91,461
COPPER (Cathode)					
Hindustan Copper Ltd	588	1,554	1,000	16,215	25,949
Hindalco	29,925	17,993	27,943	3,51,291	4,13,806
Vedanta Ltd	5,312	5,352	5,608	89,739	4,08,168
TOTAL	35,838	24,899	34,551	4,57,245	8,47,923
LEAD (One major producer)					
Hindustan Zinc Ltd	12,044	13,703	17,435	1,97,838	1,68,246

Source : <https://mines.gov.in/>

Non-Ferrous Metal Prices in India (October, 2019)

Rs./ kg (Mumbai Local Price)

Product	14-Oct-2019	Product	14-Oct-2019
Copper Armature	393	Brass Shell 40mm	359.2
Copper Cathode LME ++	440	Aluminium 6063 scrap	128
CC Rod LME ++	444	Aluminium scrap Taint/Tabor	115
Copper Cable scrap	406	Aluminium Cable scrap	138
Copper Shell 40mm	434	Aluminium Ingot	139
Electrolytic Copper strip 25mm	429	Aluminium utensil scrap	121
ACR Copper Coil 3/8	493	Zinc Slab	188
Brass Sheet scrap	340	Lead ingot	150
Brass Pales scrap	340	Tin Slab	1240
Brass Pallu scrap	340	Nickel Cathode	1290
Brass Honey scrap	285		

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

Crude Steel Production (August 2019)

Country	in thousand tonne
World	1,56,038.5
1. China	87,250.8
2. India	9,350.0
3. Japan	8,115.5
4. United States	7,497.0
5. South Korea	5,940.7
Russia	5,900.0
Germany	3,266.2
Turkey	2,633.5
Brazil	2,523.6
Iran	2,200.0
Ukraine	1,938.0
Taiwan, China	1,890.0
Viet Nam	1,815.9
Mexico	1,410.0
Spain	1,133.0
Canada	1,060.0
France	1,049.5
Italy	857.0
Others	805.0
Poland	635.0
Belgium	630.0
Netherlands	578.2
Austria	576.7
United Kingdom	562.5
Egypt	525.0
Australia	500.7

Country	in thousand tonne
Saudi Arabia	440.0
Argentina	435.5
South Africa	434.0
Thailand	415.0
Kazakhstan	400.0
Czech Republic	364.3
Sweden	361.7
Pakistan	300.0
United Arab Emirates	286.0
Finland	257.9
Qatar	228.6
Byelorussia	210.0
Hungary	121.0
Colombia	115.0
Luxembourg	112.5
Serbia	111.6
Peru	105.0
Chile	95.0
Bosnia and Herzegovina	65.0
New Zealand	60.2
Uzbekistan	60.0
Norway	59.8
Bulgaria	55.0
Ecuador	55.0
Slovenia	45.0
Greece	40.0
Moldova	35.0

Source : World Steel Association

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Hot Rolled

Cold Rolled

Electrical Steel

Galvanised/
Galvalume

Colour Coated

Tinplate Coils
& Sheets

TMT Bars

Wire Rod

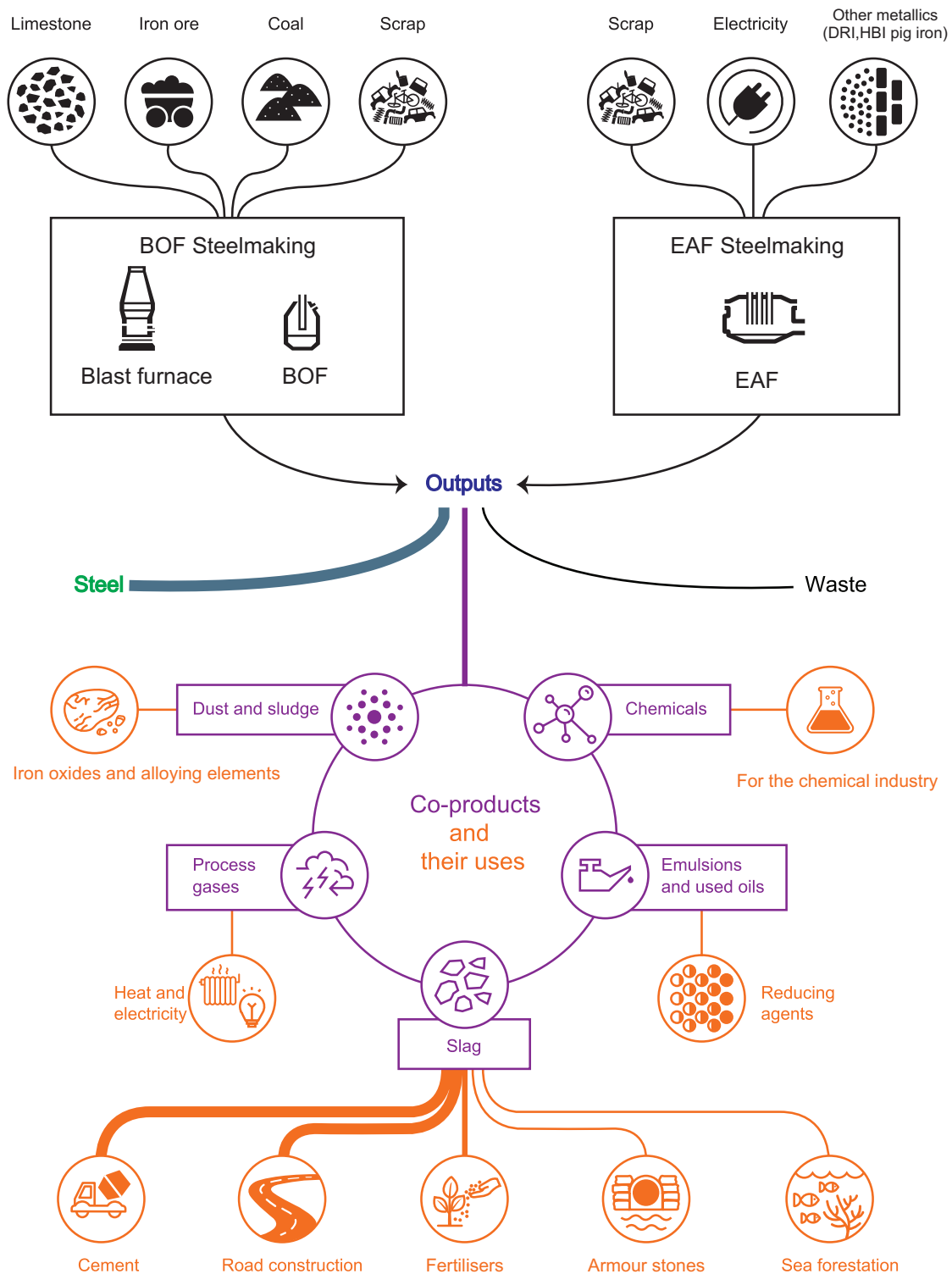
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Steel production and co-products at a glance



The use of co-products should be encouraged to :

Reduce CO ₂ emissions	Prevent landfill waste	Increase resource efficiency	Generate revenue
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