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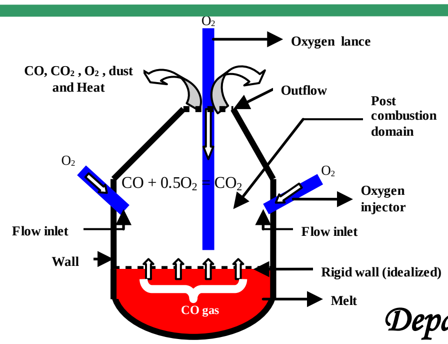

Solution

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The Annual News Letter of Process & Steel Research Laboratory

Department of Materials and Metallurgical Engineering

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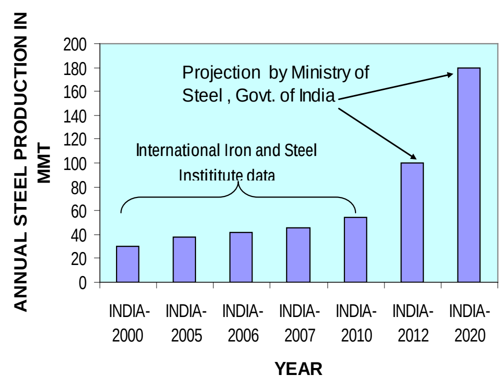
MME
IIT, Kanpur

A year ago, in 2006, we launched "*Solution*", the once a year news letter of the Process & Steel Research Laboratory, IIT, Kanpur. Our efforts were lauded by many prominent personalities connected with the domestic steel industry, educational institutes and R& D organizations. I am extremely happy to present before you the 2007 issue of "Solution" summarizing our ongoing activities and achievements during the past year. Thanks to the generous support from the participating steel industries and encouragements from the readers.



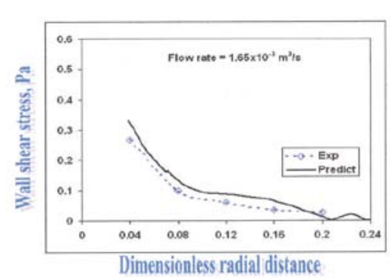
Globally, steel production is steadily growing at a rate of ~10 pct. and India is catching up fast. With the Ministry of steel, GoI setting a new production target by 2020, we are faced with many formidable challenges, of which perhaps most important is the issue of a sub critical mass, which has precipitated out of decade long neglect of steel education and research in the country. I had addressed this and other related issues as well as possible remedial measures in the very first issue of Solution. Thanks to the timely intervention of the Ministry of steel and constitution of a high level *Project Manpower Committee* under the umbrella of the Indian Institute of Metals, the committee is preparing a blue print of current manpower scenario in steel industry, academia and the associated R& D sectors to suggest corrective measures for a reversal of the grim situation. In the mean time, a full fledged steel research centre has been proposed to be set up at IIT Kharagpur. Several mega projects in diverse areas of iron and steelmaking are also being launched at National Laboratories and educational institutions. These are intended to impart training and attract young engineers to the area of steelmaking. While such steps are in the right direction, pragmatic, long term strategies are required keeping in mind the 2020 target. Industry must now come forward, take pro active roles and reinforce such initiatives at various levels. Disproportionate emphasis of the 3O's (Nano, Info and Bio technology) has adversely affected the core engineering sector and steelmaking is no exception. A developing country with enormous potential can no longer afford to take such a lop sided view. We must strike a balance here keeping in mind the long term interest of the nation. From the present issue onwards, we are inviting leading personalities for their views on steel education, research and related matter. I am sure educationists, industrialists and policy makers would take special note of this new feature in "Solution". I thank Prof. Ghosh and Dr.Chatterjee for agreeing to write for our Newsletter.

Major R&D Efforts

Numerous projects in diverse area of Steelmaking, funded by a large number of domestic steel plants and various federal agencies (viz., Department of Science & Technology (DST), Ministry of Steel (MoS), Council of Scientific and Industrial Research (CSIR) etc. are being executed in the Process & Steel Research Laboratory. A brief overview of some these is presented below.

Long term projects

These are generally funded by various federal agencies. Apart from boosting up research activities and output of the laboratory, these serve to reinforce infrastructure and set the ground work for the production of trained post graduate students in the field of steelmaking metallurgy. Three different long term projects are being currently executed:



- ***Modeling and plant scale investigation of bottom refractory wear in combined top and bottom blown steelmaking process***

Differential refractory wear pattern in the vicinity of the bottom gas injection tuyeres is investigated via physical and mathematical model embodying a large number of BOF operating data. As our first step, wall shear stress distribution at the bottom of a water model has been mathematically modeled and results thus obtained compared with equivalent experimental measurements. The hydrodynamic model is being extrapolated to computationally investigate the role of differential gas flow rates and line pressure through the tuyeres. Parallel to this multi phase VOF simulation is being carried out to investigate the effectiveness of the slag splashing procedure. Large numbers of refractory samples collected from relevant locations are also applied to assess the nature of refractory wear (e.g., hydrodynamic, chemical etc.).

- ***Modeling and optimization of argon rinsing practice***

Argon rinsing in ladles promotes bath homogenization through mixing. With the progress of mixing, melt re-oxidation occurs through the exposed slag eye area .The final rinsing operation is therefore naturally critical since it has the potential to destroy the steel quality through re-oxidation. For better process economics and steel quality, re-oxidation must be avoided as far as possible. However, conditions ensuring faster mixing also lead to relatively large exposed slag eye, making liquid steel susceptible to oxidation. Two objective functions for exposed slag eye area (A_{eye}) and mixing time $\tau_{mix,95\%}$ have been formulated i.e.,

$$\left(A_{eye}/L^{2}\right)=9.65x10^{-2}\left(Q^{1/3}L^{1/4}R^{-1/3}\Delta L^{-1/2}\right)-0.0189$$

$$\tau_{mix,95\%}\approx 155.5Q^{-0.33}L^{-1.3}R^{2.33}\Delta L^{0.3}$$

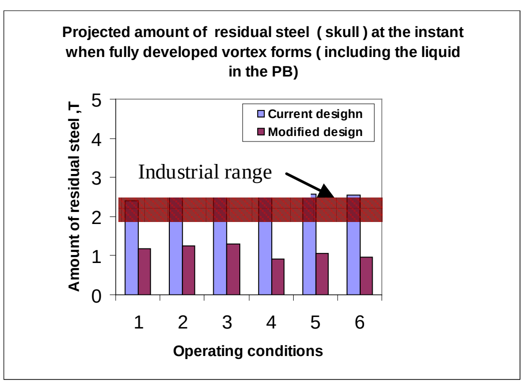
These in conjunction with the set of appropriate constraints are applied to deduce optimized operating parameters (vessel size, R, liquid depth L, gas flow rate, Q etc.) during rinsing operation. Predictions from the "optimization study" are applied to rationalize currently adopted rinsing practice in six different integrated steel mills.

- ***Measurements, modeling and control of temperature in steelmaking***

Wall heat flux through refractory lined steelmaking ladles and tundishes, slag covered melt surfaces etc. are being measured with a heat flux transducer. In addition to this, heat loss through the overlying slag layers are also measured in a laboratory scale induction furnace for different composition and thickness of the slag. Heat flux thus measured is embodied in a turbulent fluid and heat flow model to predict the evolution of melt temperature during various stages of steelmaking. *The project is currently considered by the Department of Science and Technology (DST), for possible long term funding. Technical support from industry is also explored.*

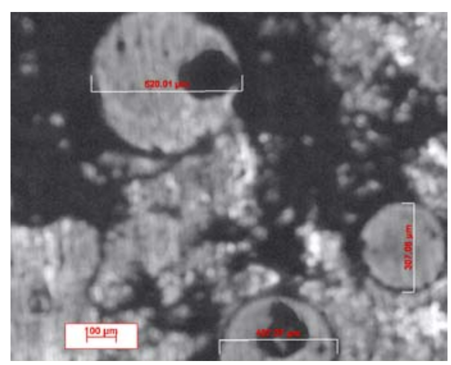
Mission oriented projects

Several domestic steelmakers have tied up recently with the Process & Steel Research Laboratory seeking answers to many of their immediate shop floor problems. Such collaborative efforts have resulted in short term, mission oriented projects and a number of these have been executed in the recent past. On going short term projects include:



- ***Enhancing yield and inclusion float out in a 32Ton slab casting tundish***

Extensive physical modeling was carried out to evolve a modified tundish design leading to minimal skull volume and superior inclusion float out. The amount of tundish skull in the industry was inferred from laboratory scale measurements and a comparison between prediction and actual industrial data for the current practice is shown the accompanying figure. The extent of yield improvements possible with the modified design is also shown.



- ***Maximizing lead (Pb) recovery during alloying of steel in an argon stirred ladle***

Dispersion of lead droplets during its bulk addition in an argon stirred ladle is investigated via physical modeling. To study the efficiency of droplet suspension and settling, trajectories of different size tetrachloro-, ethylene droplets in water is photographically studied in a 1000 kg water model in which actual jumbo and short porous plugs are applied to supply gas. Plant scale data are also being applied in conjunction to evolve operating strategy. Microstructure of a steel sample collected from an agitated ladle showing suspended lead particles is shown in the right.

Future Events

I. A short term course on Modeling in Metals Processing: concept, theory and application has been planned between Dec.21st t and Dec.24th, 2007 for the benefit of shop floor engineer, R & D personnel and college teachers,.

II. A two day intensive course focusing exclusively on "Tundish operations: productivity and quality issues" has also been planned for caster operators during April, 2008. Exact dates will be announced shortly.

International Collaboration

Recently, **M3TC** (**M**inerals, **M**etals and **M**aterials **T**echnology **C**entre) has been established at the National University Singapore. Process and Steel Research Laboratory, IIT Kanpur is collaborating actively with M3TC to execute projects for steel industries in the Asian region. Many challenging problems including post combustion in EAF, ladle filling and draining operations etc. are being jointly pursued by M3TC and our laboratory. More details of these and activities of this newly founded centre are available at ww.m3tc.sg as well as at http://serve.me.nus.edu.sg/arun.

Recent Publications

1. Sujay Pandit Patil and Dipak Mazumdar: *Prediction of strand superheat in continuous casting: modeling and industrial scale measurements in steelmaking tundish systems*, Steel Grips, Vol.1, 2007..
2. Dipak Mazumdar and J.W.Evans: *Modeling of slag eye formation over metal bath due to gas injection*, Materials and Metallurgical Transactions, Vol.38B, 2007.
3. Debasish Chatterjee, Dipak Mazumdar and Sujay Pandit Patil : *Physical and mathematical modeling of two phase flows in a Hollow Jet Nozzle*, Materials and Metallurgical Transactions B, Vol.38B, 2007.
4. S.Eck, A. Ludwig, D. Mazumdar and J. W. Evans: *Experimental and numerical modelling of Cu-Sn casting with adjustable solidification front*, Proceedings, SMP-2007, Sheffield (UK) (in Press) .
5. D.Mazumdar: *Mixing Models for Slag covered ladles Part I: Slag Metal Interactions*, Materials & Metallurgical Transactions (in Press)
6. S.P.Patil, D.Satish and D. Mazumdar: *Mixing models for slag covered ladles Part II: Mixing time correlations*, Metallurgical and Materials Transactions (in Press).
7. Xiang Qi Wang, A.S.Mujumdar and Dipak Mazumdar: *Simulation of ladle filling operation in steelmaking processes*, Procd., 16th International conference on Processing and Fabrication of Advanced Materials, Singapore, 2007 (in Press)

The Team

D.Mazumdar
Professor

A. Sharma
Techn ical Assistant

J.S.Virdhi
Chief Technician

Gurinder Singh
Technician

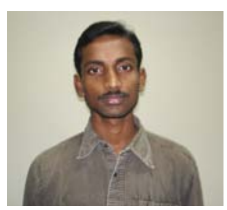
Rajeev Singh
Graduate Student

Amitava Paul
Graduate Student

M. Peraanandhanathan
Graduate Student

Anand S
Graduate Student

S.K Rajasekar
Graduate Student



A. Muthuchamy
Graduate Student

Viewpoints I: Steel eduction and research in India by Prof. A.Ghosh

Steel and Metals sector in India are on a growth path.. Although India has about two dozens of Metallurgical Engineering department, teaching and research in ironmaking and steelmaking are weak and extremely inadequate. Few young faculty members are joining in this area. Older members of faculty are either on verge of retirement or have retired. In addition, modern way of teaching requires a balance of theory and practice. Very few textbooks are available to cater to it. Research work undertaken in Academic Institutions, National and Regional laboratories, as well as in-house in the steel plants in India are very weak, in contrast to countries like China, South Korea, Japan and many Western countries. These need to be rectified. Joint efforts of all concerned are important in this context, but more specifically involvement of the steel industry, which will be the ultimate beneficiary, is the key. However, so far, there is no significant concern on this in India.

The undergraduate education is best taken care of in academic institutions. Active drive for recruitment of young faculty in this area, publication of textbooks suited for teaching in an interesting and modern way, and active interaction with industry are the ways to strengthen it. Setting up of Chairs (i.e. Professorships) in some academic institutions, and offering visiting faculty positions to retired persons from academic institutions and industries will also be very desirable. It is to be recognized that these will be possible only with the financial sponsorship of industries and Government agencies concerned with steel. Academic institutions have their own priorities and they are not per se concerned with steel. The above steps are likely to strengthen post- graduate education and research in steel as well. However, academic institutions alone cannot do it. Research in iron and steel will require large fund and infrastructure. It can be undertaken in a larger way by:

1. Strengthening of in-house R &D in steel plants
2. Setting up of a separate post-graduate institute for steel, which will have good funding facilities, and provisions for interaction with industry and academic institutions, as well as visiting faculty from other organizations.

Steel industry needs not only Metallurgical Engineers, but other engineers as well. Hence, the suggestions made above are not going to be sufficient for meeting manpower requirement. Some additional measures are to be taken with the objective of familiarizing the other engineers with basics of metallurgical engineering, specifically ironmaking, steelmaking , physical and mechanical metallurgy of steel, fundamentals of hot and cold working, heat treatment, surface treatment etc. In this context, a one-year post-graduate diploma course on steel technology has been started at IIT, Kharagpur with the initiative of steel plants, specifically Tata Steel. The participants are engineers working in steel plants, and are selected by their own organizations. We may consider further expansion of such program to train more number of engineers. Suggestions made above are expected to strengthen education, research and manpower in all areas of science and technology of steel.

Viewpoints II: Steel , steel, everywhere in India but where are the engineers? by Dr.Amit Chatterjee, Tata Steel

Production and consumption of steel in any country is often taken as a barometer of progress in that country. The Indian steel industry is no exception.

The steel industry in India began in the early part of the 20th century. When India became independent in 1947, the production of steel was around 1 Million tonnes per annum (Mtpa). Our Asian neighbour, China, produced less than 5 Mtpa at that stage. Their operations however were more 'primitive'. The Chinese used small sized (1-2 t) side-blown converters to produce steel as opposed to open-hearth furnaces and Bessemer converters used in India . In the decade that followed, the Chinese Dragon 'woke up' and made its presence felt all over the world. China is at present producing 400-420 Mtpa of steel while India's production is only 1/10th, i.e. 40-45 Mtpa. It is predicted by many that the Chinese bubble would burst, and China's progress in steel would be halted. Whatever ultimately transpires in China, for us in India, good times appear to be ahead. For the first time in its history, the Govt. of India, came out with the National Steel Policy in 2004-05, in which it was predicted that India's steel production would see a major upsurge and reach 110-115 Mtpa by 2015-2020. With the existing players – SAIL, Tata Steel, RINL, Essar, Jindals, Ispat, etc. -- as well as the new players and even international entities like Posco, Arcelor-Mittal, BHP, etc, announcing establishment of new steelmaking facilities in India, the annual steel production could total over 200 Mtpa by 2020.

Now that India is finally about to find its rightful place in the world's steel league, it is sad and in many ways tragic that metallurgical education in this country is getting steadily directed towards sophisticated material science rather than hard-core metal extraction. Interest in process metallurgy has waned to such an extent that most of the well-known educational institutes in India, including the pristine Indian Institutes of Technology, virtually have no teachers to lecture on iron and steel and no time for iron and steel in their curriculum. The students also consider Information Technology, Electronics, Media-related jobs as far more attractive than working in a steel plant. As a result, the quality of students taking up metallurgy leaves a lot to be desired, and even those who do graduate, often do not ultimately take up metallurgy as their career. Without belittling the importance of material science, it needs to be emphasized that unless India is able to make a radical transformation in the quality of students, the interest of students, quality of teaching faculty, the syllabi of teaching institutes, and a host of other requirements, it will be extremely difficult, if not impossible for India, to cater to the manpower requirements of the expanded iron and steel industry. With GDP growth rates of 8-10% in the manufacturing sector, while I am familiar with the future of the iron and steel business in India, it would perhaps be correct to assume that a boom in other manufacturing sectors would also be seen in the next 10-15 years. This makes the supply situation very alarming.

Given this background, it is imperative, in fact, I would go so far as to call it a 'battle', to make sure that India has the requisite workforce in terms of graduate engineers who would be working wholeheartedly in the manufacturing business in general and the iron and steel industry in particular. It is always possible to import raw materials, adopt appropriate technologies, and purchase the latest process control equipment, etc. from international suppliers; however, it is just not possible /practicable to run industry without dedicated Indian engineers.

For further information please contact: Professor Dipak Mazumdar, Department of Materials and Metallurgical Engineering, Indian Institute of Technology, Kanpur, 208016 ; e-mail:dipak@iitk.ac.in ; tel: 0512-2597328 ; cell:9415134718