



Every year, around the time National Metallurgists' Day (NMD) is celebrated in the country, *Solution*, the annual news letter of the Process & Steel Research Laboratory, IIT, Kanpur, is released. I am extremely happy to continue with the publication and present before you the 2009-10 issue, summarizing our achievements as well as various ongoing R&D activities. Previous issues of *Solution* have been well received by the domestic steel industries, educational institutes and R & D organizations. We could sustain due to the generous assistances from various industries dealing with the manufacturing of steel & refractory.

2009-10 has been an extremely fruitful period as many mission oriented projects are being completed and results implemented in different steel melt shops. Most notable among these have been the projects dealing with "tundish skull reduction", "reduction in tap to tap time in an EOF" and "ensuring defect free casting of larger cross section (up to 2500 mm) slabs". In our effort to popularize physical modeling among steelmakers, scaled Perspex™ models of tundish systems have been commissioned at two different steel mills. It is heartening to report that shop floor and R&D engineers now frequently use such facilities and try out many novel processing concepts before conducting full scale trials. It is also important for me to report that we are in the final phase of setting up of a comprehensive physical modeling research facility at IIT Kanpur with the support of the Ministry of Steel, Govt. of India. The facility shall house scaled Perspex™ models of BOF, EAF (EBT), ladle, bloom and slab caster tundish, molds together with those of SEN and slide gate and include many measuring devices like load cell, anemometer, conductivity meter etc. We anticipate that once the facility is fully ready, numerous fruitful interactions between domestic steel industries and IIT Kanpur will result.



Professor Mazumdar during the installation of a water model, bloom caster tundish outside SMS-2 at JSPL, Raigarh.

The past year saw the release of a text book on "*Modeling of Steelmaking Processes*" by the CRC press. The book authored jointly by Professors Dipak Mazumdar and James W Evans (of UC, Berkeley) is expected to fulfill a long standing demand of metallurgical engineering students as well as practicing shop floor engineers. Another notable achievement has been a graduate student, Mr. M. Peranandhanathan, receiving the best students' presentation award at the NMD-ATM 2009 for his work on "slag eye are : modeling and correlation". Several research articles in reputed journals of steelmaking and conference proceeding were also published from our laboratory. Carrying out meaningful research in steelmaking without the generous assistance from the steel industry is practically impossible. In all our efforts concerning with solving

industrial problems, carrying out fundamental investigations as well as organizing a refresher courses, we have been fortunate to receive generous support and co-operation from many Indian industries. We sincerely acknowledge the support from Jindal steel and Power (Raigarh), Hospet steel, RINL (Vishakhapatnam), L&TSSHF (Hazira), MUSCO (Khopoli), Vardhaman Steel (Ludhiana) and Vesuvius India limited (Kolkata). We are committed to the cause of the Indian steel industries and look forward to many collaborative endeavors in future.

Major R&D efforts

A number of projects funded by different domestic steel plants and several federal agencies are being currently executed in our laboratory. A brief overview of these is presented overleaf.

Long term projects

These are generally funded by federal agencies such as, Department of Science and Technology (DST), Ministry of Steel (MoS) and so on. Apart from boosting up research activities, these serve to reinforce infrastructure and set the ground work for the production of trained post graduate students in the field of steelmaking metallurgy. Two different long term projects are being currently perused:

• Commissioning of a comprehensive water model laboratory for steelmaking process analysis at IIT Kanpur



A section of the existing water model laboratory at IIT Kanpur

A small water modeling laboratory, built with the assistances received from several steel industries and IIT Kanpur is already functional at IIT Kanpur (see adjoining photograph). Efforts are being made to convert this facility to a full fledged, comprehensive water model laboratory dedicated to steelmaking process analysis, design and research. The facility shall house water models of BOF, EAF (EBT), ladle, tundish, mold, slide gate and SEN which will be augmented by many measuring devices such as, load cell, anemometer, conductivity meter and so on. A proposal submitted to the Ministry of Steel has in principle been approved. Installation of the said facility at IIT Kanpur is to begin soon.

• Measurements, modeling and control of temperature in steelmaking

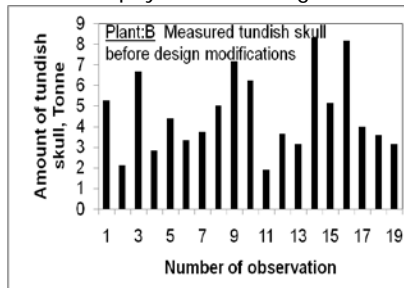
Knowledge of melt temperature during every stages of steelmaking is important and forms the basis of estimation of superheat, temperature loss/pick up, melting and the associated transport rates and so on. Comprehensive measurement and mapping of temperature in steel melts is difficult, if not impossible. To this end, properly validated mathematical models can provide respite. However, for successful mathematical modeling and accurate prediction, numerous empirical inputs such as, emissivity of the upper slag layer, refractory-steel contact resistance, outgoing heat flux through vessel walls etc. are needed. A comprehensive experimental and computational study on the prediction of steel melt temperature, funded by the Department of Science and Technology (DST), has been launched at IIT Kanpur about a year ago. In the first phase, laboratory scale high temperature experiments are being conducted to determine various thermal properties/parameters (viz., emissivity, rate of lining wearing, thermal contact resistances etc.), relevant to the processing of steel in refractory lined vessel.

Mission oriented projects

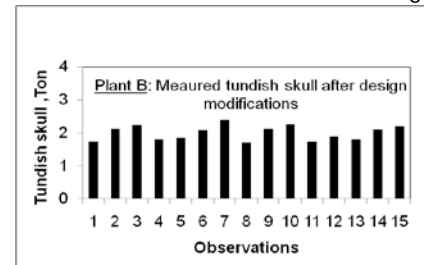
Several domestic steelmakers routinely fund projects on diverse themes seeking answers to many of their immediate shop floor problems. Such collaborative efforts generally result in short term, mission oriented projects and a number of these have been executed in the recent past. On going projects include:

• Enhancing yield from a four strand bloom casting tundish through reduction of tundish skull

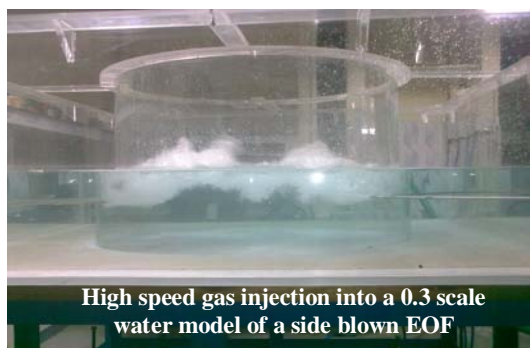
Extensive physical modeling was carried out to evolve plausible design modifications ensuring minimal skull volume without influencing



adversely metallurgical performance of the tundish systems. This was done recently for the four strand bloom caster tundish of Vizag steel and JSPL, Raigarh, respectively. It has been demonstrated that through marginal modification of existing tundish design, it is possible to substantially reduce tundish skull and thereby, improve yield. The extent of improvement achieved at JSPL, Raigarh, is illustrated in the adjoining figures.



• Reduction of tap to tap time in an energy optimizing furnace (EOF)



High speed gas injection into a 0.3 scale water model of a side blown EOF

It has been reported that oxygen injection through four side tuyeres into a 50 T EOF often leads to considerable amount of loss of hot metal through the slag door. This happens during the middle of the blow due to excessive carbon boiling and as a preventive measure, oxygen flow rate is generally reduced. This tends to prolong the blow period, affecting adversely steel melt shop performance.

To suggest remedial measures, a physical model investigation embodying a 0.1 as well as a 0.3 scale water models of EOF is being carried out at IIT Kanpur. In the smaller vessel, reactive system flow dynamics is studied using a KOH-CO₂ system, while flow and mixing are studied in the bigger vessel. Extensive analysis of operating data is also carried out simultaneously to pinpoint the reasons.

• Defect free continuous casting of 2500mm wide slab

The tendency to form various defects increases significantly as the slab section size increases. Often, to reduce the occurrence of defects, casting speed is deliberately lowered affecting adversely caster shop productivity. SEN design, powder feed rate and flow as well as super heat in mold are important metallurgical parameters that determine the soundness of the casting. A physical and mathematical model investigation coupled with plant scale trials is being planned to address various issues concerning the production of defect free slabs at a relatively higher casting speed. The project funded by JSPL, Raigarh has been launched recently.

• Minimization of casting of mixed grade bloom during grade transition

Casting of different grades of steel through the same tundish often leads to the production of considerable amount of bloom and slab, having composition that is intermediate between two successive grades. This is a matter of concern to steelmakers since mixed grade bloom/slab is often downgraded, affecting adversely the process economics. A project concerning with the reduction of mixed grade bloom production from a four strand, delta shaped tundish and funded by RINL, Vishakhapatnam will soon be launched at IIT Kanpur.

Publications

1. D.Mazumdar and J.W.Evans: *Modeling of steelmaking Processes* (ISBN: 978-14200-6243-4), CRC Press, Boca Raton, Florida, USA, 2009.
2. D.Mazumdar and R.I.L.Guthrie: *Modeling energy dissipation in slag-covered steel baths in steelmaking ladles*, Materials and Metallurgical Transactions B, Vol.41 (5),2010, pp.974 -987.
3. S.P.Patil, D.Satish, M.Peranadhanathan and .D.Mazumdar: *Mixing models for slag covered ladles*, ISIJ International, 2010, Vol.50 (8), pp.1117-1124.
4. M.Peranadhanathan and .D.Mazumdar: *Modeling of slag eye area in argon stirred ladles*, ISIJ International, Vol.50 (11), 2010, pp. 1622-1631.
5. Dipak Mazumdar: *Modeling Energy Dissipation in Argon stirred ladles*, in Procd. **Advances in the Theory of Iron and Steelmaking (ATIS)**, Bangalore, India, 2009, pp.374 -381.
6. W.Zhongshua, AS Mujumdar and D.Mazumdar: *Exploration of some new tundish designs via simulation*, in Procd. **Advances in the Theory of Ironmaking and Steelmaking (ATIS)**, Bangalore, 2009, pp.402- 409.
7. Dipak Mazumdar: *Physical modeling of slab caster tundish to improve yield and quality of steel*, in Procd. **Jim Evans Honorary Symposium, TMS2010**, Seattle, pp.191-197.
8. Dipak Mazumdar: *Engineering of argon rinsing operation in steelmaking ladles through modeling and optimization*, submitted to Trans. IIM.
9. S.Anand, S.Rajasekhar and Dipak Mazumdar: *Slab caster tundish designs and the associated metallurgical performances*, submitted to ISIJ International.

News

1. A short term course on **Iron and Steel Metallurgy** was conducted exclusively for the engineers of **Vesuvius India Limited, Kolkata** during May-June, 2009. Altogether 34 engineers associated with various steel plants in the country attended the course in two batches.



2. Mr. M.Peranadhanathan, a graduate student has received the best students presentation award for his work on "*Slag eye area: measurements and correlation*" during the 62nd Annual Technical Meeting of IIM, 2009, in Kolkata.











3. Professor Dipak Mazumdar received the coveted GD Birla Gold medal of IIM during NMD-ATM, 2009, at Kolkata. On the inaugural day, Prof. Mazumdar delivered the GD Birla Gold medal lecture titled "*The knowledge based foundation of steelmaking and application to steel melt shop*".

4. A short course on **Foundation of steelmaking and ladle metallurgy** was conducted by Professor Mazumdar for the Engineers of Hospet Steel at Hospet works (Ginigeri) during September 25th -26th , 2010.

Forthcoming events

1. L&TSSHF Limited (Larsen and Toubro special steels and heavy forgings limited, Hazira) sponsored short course on “**EAF steelmaking and ladle metallurgy**” will be held at IIT Kanpur during 28th and 30th January, 2011. Steel industries interested to sponsor their engineers are requested to contact the undersigned for enrollment.
2. A five day, foundation level, intensive course on “**Iron and Steelmaking**” will be conducted during May 9th -13th, 2011. Interested participants are requested to contact Professor Dipak Mazumdar directly for further details.

Students, staff and associates

	Mr. A Sharma , Technical Assistant e-mail:awsharma@iitk.ac.in		Mr. Bapin K. Rout , Masters candidate e-mail:bapirout@iitk.ac.in <u>Thesis topic: Modeling of mixing and particle flow in Energy Optimizing Furnace</u>
	Mr. J.S. Virdhi , Design consultant E-mail:j.singhvirdhi@yahoo.com		Mr. Ishant Jain , Masters candidate e-mail:ishant@iitk.ac.in <u>Thesis topic: Measurements of thermal properties and parameters in high temperature furnaces</u>
	Mr. Gurinder Singh , Associate technician		Mr. Sarvana Kumar R. , Masters candidate e-mail:sharvaan@iitk.ac.in <u>Thesis topic: Slag eye area and mixing in ladles fitted with a single asymmetrical porous plug</u>
	Mr. Amitava Paul , Doctoral candidate (Sopsored by RDCIS, SAIL, Ranchi) e-mail:apaul@iitk.ac.in <u>Thesis topic: Physical and mathematical modeling of slab caster mold</u>		Mr. Aniket Kumar Dutt , Masters candidate e-mail:anidutt@iitk.ac.in <u>Thesis topic: Industrial scale measurement of surface heat flux and prediction of evolution of temperature in steelmaking ladles</u>
	Mr. Anurag Nandwana , Masters candidate e-mail:anuragn@iitk.ac.in <u>Thesis topic: Modeling of fluid flow and heat transfer in slab caster molds of large width</u>		Mr. A. Murali Krishna , Masters candidate e-mail:murali@iitk.ac.in <u>Thesis topic: Mathematical modeling of grade intermixing in steelmaking tundish</u>

Our supporters, 2009 - 2010



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