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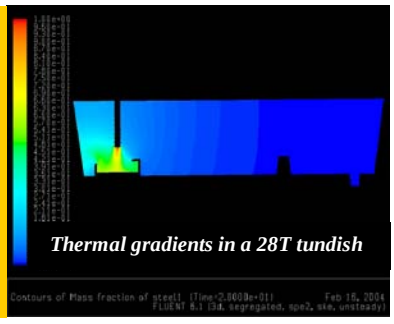


Solution

The Annual News Letter of

Process & Steel Research Laboratory

Department of Materials and Metallurgical Engineering

I/2006

MME

The Process & Steel Research Laboratory (PSRL) at IIT Kanpur has contributed immensely to the cause of steel education and research in the country during its four decade long existence. A periodic news letter summarizing various research facilities as well as ongoing R&D and allied activities of the laboratory was indeed long overdue. I am delighted to have this long cherished dream realized and present before you the very first issue of "Solution", the once a year News Letter of the Process and Steel Research Laboratory. The release of "Solution" coincides with a land mark event: global production of steel surpassing the thousand million ton mark for the first time in the history of mankind! This has been the result of a substantial increase in the demand of finished steel world wide, particularly among the developing nations. Domestic steel production has also grown steadily over the past few years, touching an all time record figure of 38 MT in 2005 . As India marches ahead to become a developed nation in the next decade or so, steel production in the country is expected to rise further and touch the 100 MT mark . Amidst this encouraging scenario, steel education and research in the country, unfortunately, has taken a back seat and this is indeed alarming. Slump in the market during the nineties, migration of graduating engineers to IT and management jobs have all inflicted irreversible damages resulting in an acute shortage of qualified engineers in plants and the associated R&D. Furthermore, the reluctance on the part of bright, young graduating engineers to consider steelmaking as a viable career option has largely affected the academia since expertise available during the 80's in many academic institutions has now ceased to exist. Thus, the number of professionals directly involved with steel research and education in the country has come down significantly during the last few years resulting in markedly diminishing activities in steelmaking in many university departments. This, in turn, has adversely affected the post graduate programs in steelmaking in many Metallurgical Engineering Departments across the country. As such , the overall scenario in steel education and research in the country currently looks extremely grim! Adequate corrective measures that would bring in a natural harmony in the arena of " steel research-education-production" must now be put in place, if we are to remain globally competitive . The MHRD and the Ministry of Steel must join hands , evolve long term policies and set things on track before it is too late. Time has come to reinforce steel research in academic institutions through setting up of steelmaking professorial chairs and providing generous funding. Never before the need was so acute for a full fledged university based steel research centre in the country . All these are required to be explored at the highest decision making level.

Research Facilities

Since inception, "Process and Steel Research Laboratory" (PSRL) , IIT, Kanpur has been in the forefront of steel research and education in the country. Over the years, R&D activities in the laboratory have grown remarkably despite many constraints e.g., diminishing number of post graduate students, paucity of funds etc. Despite such, the recent upward trend in the marketplace coupled with steel producers increasing reliance on the "academia and R&D" have ushered a new era of vigorous R&D activities in the laboratory. Considerable efforts are thus being made on diverse fronts of steel education and research which, in addition to routine R&D activities include, organization of courses for shop floor engineers , execution of mission oriented projects for steel plants, dissemination of knowledge through workshops and so on. The ever increasing R&D activities in the laboratory together with a vibrant and revitalized domestic steel sector have set the stage right for the present News Letter, providing an essence of its contributions and commitment to steel education and research in the country.

PSRL has been carrying out pioneering research in the area of steelmaking process analysis, design and optimization embodying both physical and mathematical modelling (primarily Computational Fluid Dynamics) . Many scaled models of various steelmaking reactors are available to carry out experimental research and these include:

•A number of water model ladles equipped with different bottom designs and side wall taper. These are applied to primarily investigate fluid flow, mixing, two fluid interactions, refractory wear, alloy trajectories etc. during ladle filling, ladle emptying and inert gas stirring operations.

•Delta and rectangular shaped water model tundish for investigating hydrodynamics and associated rate processes during ladle-tundish -mold transfer operations.

•A metallic tundish to investigate transfer operations under non isothermal conditions.
• Perspex™ and metallic Hollow Jet Nozzle assembly to investigate superheat control and removal in continuous casting.
•A thin slab casting model to study free surface/meniscus oscillation , SEN design for enhanced throughput etc. and
•A model of tank degasser to investigate flow phenomena, plume dynamics and mixing under reduced pressure conditions.

In addition to the physical modelling facilities, there is a full fledged CFD cell attached to the process and steel research laboratory. Over the years, we have developed strong interactions with Fluent Inc., and practically all complex CFD work related to steelmaking are currently being carried out via FLUENT®, which is pre-loaded in the workstations available in the laboratory. A host of other commercial software such as MATLAB, NAG which are available on the Institute main frame are also employed from time to time to carry out numerical work. To these ends, several desk top computers including two SUNBLADE 1000 work stations are available in the laboratory.

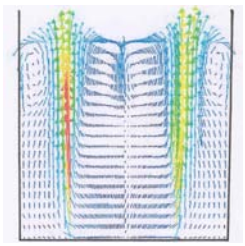
Major R&D Efforts

During the last decade, numerous projects in diverse area of Steelmaking have been carried out in the laboratory. These have been traditionally funded by various federal agencies like the National Mission for Iron and Steel, Steel Authority of India Limited, Department Science and Technology , Council of Scientific and Industrial Research and so on. In addition to these, involved participation of many steel plants in recent years have resulted in numerous short and mission oriented projects. The sections below provide an overview of the most recent R&D projects.

Long term projects

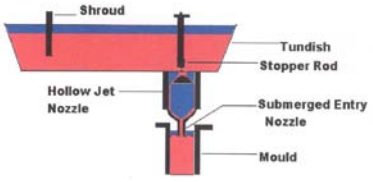
Long term or sponsored projects typically embody research of fundamental nature and are funded primarily by various federal agencies. Apart from boosting up research activities and output of the laboratory , these serve to reinforce the infrastructure as well as set the ground work for the production of trained post graduate students in the field of steelmaking metallurgy. Two different sponsored projects have been carried out and completed in the recent past . These are:

•*Mixing and Mass Transfer in ladles stirred with dual porous plugs: a physical and mathematical model investigation (Funded by the Ministry of Steel, Govt. of India)*

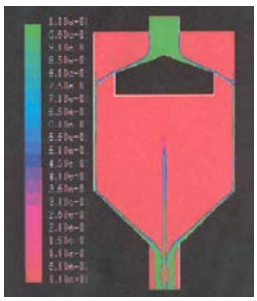


This three year long project was initiated at IIT Kanpur in July 2002 . In this, physical modeling and CFD were applied in conjunction to investigate various aspects of dual plug stirred ladles including fluid flow, mixing, slag-metal mass transfer etc. Several publications in archival journals and refereed conference proceedings resulted from the investigation. The present work has demonstrated for the first time that efficiency of chemical processes carried out in a dual plug stirred ladle is a strong function of the plug configurations as well as ladle bottom design. The outcome of the project generated considerable interest among domestic steelmakers and this has lead the Ministry of Steel to sponsor a follow up workshop on "Dual plug bubbling in ladles" at IIT , Kanpur which is being organised during March 24th -25th , 2006.

• *Control of superheat in continuous casting through the application of hollow jet nozzle: a physical and mathematical model study (Funded by the Department of Science & Technology (DST), Govt. of India)*



The project was initiated in June 2003 and involved the study of super heat removal in continuous casting through a novel device, known as the Hollow Jet Nozzle (HJN),. An in depth computational and experimental study of fluid flow and heat transfer phenomena was carried out to investigate the process dynamics and design of the Hollow Jet Nozzle This has confirmed the potential of the device and indicated that heat fluxes of same order as those prevalent in conventional continuous casting process, are required in order to accomplish a super heat reduction to the tune of 10^0 ~20^0 C. within the Hollow Jet Nozzle. Most notably, the present study has demonstrated that efficiency of a HJN can be substantially improved by marginally modifying its design, leading to a greater contact area between molten steel and the wall of the HJN. Such findings have been already presented in national and International conferences. Technical papers based on the study are being communicated to key metallurgical engineering journals.



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 typically result in short term, mission oriented projects and a number of these have been executed in the laboratory during the recent past. Significant projects under this head , funded by domestic steelmakers include:

• *Enhancing process performance of tank degassing operations*

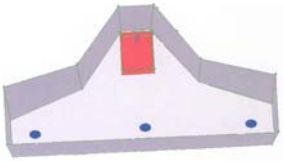
Melt phase transport during tank degassing operations was investigated with the aid of a physical model in the presence of an upper buoyant phase. In this , the role of plume eye and slag cover opening together with melt-vacuum interactions were investigated as a function of porous plug numbers, gas flow rates, slag volume etc. Based on thermodynamic evaluations, actual process calculations and physical model results, operating conditions for more efficient hydrogen removal were recommended, which are being currently explored on the shop floor.

• *Reduction of skull volume in tundish during a sequence casting*

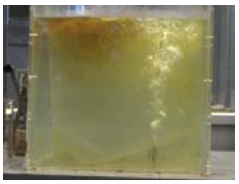
Extensive physical modelling of tundish hydrodynamics was carried out embodying various basal designs in order to evolve a modified tundish design which would ensure minimal loss of steel as skull without adversely affecting tundish process performance. Incorporating the suggested tundish design, industry has reported substantial enhancement in yield under high speed slab casting condition. Initiation of funnel vortex which constituted an important criterion for estimating residual metal in the tundish at the end of a sequence casting, is shown in the adjoining figure.

• *Tundish design and performance evaluation for enhanced throughputs*

This is an ongoing project and involves an in- depth study of a 2 strand vs. a 3 strand operating configurations in a delta shaped tundish The Primary goal is to investigate possible influences of opening up the 3rd strand on steel quality, which is to be adapted for enhanced plant productivity. Numerical computation and physical modeling are applied in conjunction to assess such change over.



• *Re-locating porous plugs in a dual plug stirred ladle for enhanced process performance*



Physical and mathematical modelling were applied in conjunction to suggest optimal porous plug configurations and flow rate regimes leading to reduced refractory wear, better slag –metal reactions and bath mixing in a dual plug stirred ladle. Industry has reported considerable improvement in ladle recycling time owing to reduced refractory wear. The extent of slag movement and high velocity region in the water model which were applied to qualitatively infer hydrodynamic wear of refractory, is shown for a 0.20 scale water model ladle corresponding to a full scale flow rate of 40 Nm^3 /plug/hr.

Continuing Education

Continuing education is an important and integral component of the IITK education system. Teachers from Educational Institutes, Engineers from shop floor and R & D orgainsations are routinely trained by the Institute Faculty under this platform . Several short term course and work shops focusing primarily on the science and technology of steel processing have been organized in recent past by the PSRL. In 2005, a short term course titled Modelling in Metals processing: concept, theory and application was organized. The course had two segments namely, class room teaching and laboratory sessions. Laboratory sessions were aimed at demonstrating how principles involved in modelling are applied to develop working models of ladles, tundish, molds, tank degasser etc. Altogether thirty seven participants drawn out from various steel plants (Tata Steel, Ispat Industries, JVSL, RINL,SAIL, Hospet steel, Usha Martin) , the Academia, R & D laboratories and the Ministry of steel were trained for 4 consecutive days. Leading experts from various Engineering Departments of the Institute comprised the team of instructors.

Some moments during the short course

Dissertations

A number of students have specialized in steelmaking and obtained their Master & Ph.D from the Institute while working at the Process and Steel Research Laboratory. List of dissertation include :

(i) Mr.M. Madan (M.Tech., 2004): Thesis topic: *"Numerical simulation of flows in rotating viscometers"*

(ii)Mr. D.Chatterjee (M.Tech.,2005): Thesis topic: *"A numerical and computational study of fluid flow phenomena in a Hollow Jet Nozzle (HJN)"*

(iii)Dr.Anil Kumar (Ph.D., 2005):Thesis topic: "*Physical and mathematical modelling of flow and Residence Time Distributions in a multi strand continuous casting tundish"*

(iv) Mr.Sujoy P. Patil (M.Tech., 2006) Thesis topic "Mixing models for slag covered ladles"

Recent Publications

1. M.Madan and D.Mazumdar: *A computational assessment of viscosity measurement in rotating viscometer through detailed numerical simulation*, Materials and Metallurgical Transactions , Vol.35B, 2004,754

2. D.Mazumdar and J.W.Evans: *A model for estimating exposed plume eye area in steel refining ladles covered with thin slag*, Materials and Metalllurgical Transactions,Vol.35B,2004,400.
3. Anil Kumar, S.C.Koria and D.Mazumdar: *An assessment of flow and RTD computations in steelmaking tundish system,* ISIJ International,Vol.44(8),2004,1234.
4. D.Mazumdar, and J.W.Evans: *Macroscopic models for gas stirred ladles: a review,* ISIJ International,Vol.44, 2004,447.
5..D.Mazumdar: The *role of modelling in steelmaking*, Metal News , Indian Institute of Metals , Vol.1 & 2 , 2004 ,16 .
6.D.Mazumdar and D.Satish Kumar: *Mixing times and correlation for dual plug stirred ladle: Quantifying the role of an upper buoyant phase*, Procd. 43rd Annual Conference of Metallurgists (CIM,Canada), 2004, 311.
7. M.Madan, D.Satish and D.Mazumdar*: Mathematical modelling of fluid flow and mixing phenomena in a twin plug stirred ladle*, ISIJ International, Vol.45,2005,677.
8.J.Mandal, M.Madan,S.Patil and D.Mazumdar: *Mixing time and correlation for ladles operated with dual porous plugs*, Materials and Metallurgical Transactions, Vol36B,2005,479.
9.Anil Kumar, D.Mazumdar and S.C.Koria: *Experimental validation of flow and tracer dispersion models in a water model of a four strand billet casting tundish*, Materials and Metallurgical Transactions,Vol.36B,2005,777.
10.Sabuj Halder and Dipak Mazumdar: *Modelling of time ~temperature evolution during heating of steel ingots and slabs*, Trans. of Indian Institute of Metals,Vol.58,,2005,873.
11. N.Mazumdar, A.Mahadevan, M.Madan & D.Mazumdar:*Impact of ladle design on bath mixing*, ISIJ International,Vol.45, 2005,1941.
12.S.P.Patil, D.Chatterjee and D.Mazumdar: *Prediction and control of superheat during continuous casting of steel*, Procd., International Conference of Present, Past and Future of Continuous Casting, Jamshedpur, 2005,7.
13.D.Chatterjee and D Mazumdar: *Physical and mathematical modelling of two phase flows in a Hollow jet Nozzle (HJN),* Procd. ICAMMP-06, Kharagpur,2006,671.

Future Projects

Negotiations are currently on with various Govt. funding agencies as well as domestic steel producers for both long term and mission oriented projects, on the following topics:

- *Hydrodynamic, thermal and chemical aspects of tank degassing operations*
- *Refractory wear in steelmaking ladles*
- *Heat losses through slag covered high temperature melts*
- *Comprehensive tracking of evolution of melt temperature from tapping through casting*
- *Erection and commissioning of a water modelling research facility*

The Team

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For comprehensive solution to many of your shop floor problems , setting up of water model research facility and information on ongoing activities on steel education & research at the PSRL, IIT, Kanpur, please contact: Professor Dipak Mazumdar, C/O PSRL, Department of Materials and Metallurgical Engineering, Indian Institute of Technology, Kanpur, 208016 ; e-mail:dipak@iitk.ac.in