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1960-2010 50 Years of excellence in engineering education & research

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Solution

The Annual News Letter of Process & Steel Research Laboratory

Department of Materials and Metallurgical Engineering

Since 2006, we have been publishing "*Solution*", the yearly news letter of the Process & steel research laboratory, IIT, Kanpur towards the end of a calendar year. We are extremely happy to sustain "Solution" and present before you the 2008 issue summarizing various ongoing activities and achievements during the past one year. Our effort has been lauded by many prominent personalities associated with the domestic steel industry, educational institutes and R & D organizations. Thanks to the generous support of the participating steel industries and encouragements from the readers.

The past year has been extremely fruitful as several mission oriented projects have been executed in the laboratory in record time and results implemented in steel melt shops. Most notable among these have been the "tundish skull reduction project" which we have been able to successfully implement at JSW, Toranagallu and JSPL, Raigarh. A patent has been filed jointly by JSW Steel and IIT, Kanpur. In addition, a static thermo-chemical model for charge proportionating and end-temperature prediction has been developed as a user friendly, menu driven software package so that melt shop operators can foresee process on a heat to heat basis. In our efforts to popularize physical modeling among steelmakers, scaled Perspex^{TM} models of tundish systems have also been commissioned at two different steel mills. It is heartening to report that shop floor and R & D engineers now frequently use such facility and try out many novel processing concepts prior to full scale trials. We are currently negotiating with two different integrated steel mills for setting-up of comprehensive physical modeling research facility in their premises. I must take this opportunity and mention that a text book on "Modeling of steelmaking processes" is going to be soon launched by the CRC Press. The book, with Prof. James W Evans (of UC, Berkeley) as a co-author, is expected to fulfill a long standing demand of metallurgical engineering students as well as practicing engineers.

In all such and related activities, we have been receiving generous support and immense co-operation from many Indian steel plants and allied industries; be these for conducting industrial trials, funding of research projects or organizing short term courses. We wish to place on record our sincere appreciation in particular to Jindal Steel and Power, Hospet Steel, Jindal South West Steel, Ispat Industries, RINL, Tata Steel, Essar Steel, Usha Martin, IFGL refractories and Vesuvius! At the "Process and steel research laboratory", we stand committed to the cause of the Indian steel industries.

Research projects and R&D activities

Numerous projects in diverse area of steelmaking, funded by a many domestic steel plants and federal agencies are being executed currently in the Process & steel research laboratory. A brief overview of some these is presented below.

Long term projects

These are typically funded by federal agencies. Apart from boosting up research activities and technical 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. Two different long term projects are being currently executed:

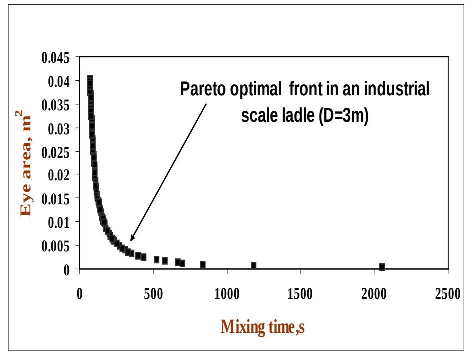
- Modeling and optimization of argon rinsing practice

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 critical since it has the potential to jeopardize 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 (in SI unit) i.e.

$$\left(A_{eye}/L^2\right)=9.65\times10^{-2}\left(Q^{1/3}L^{1/4}R^{-1/3}\Delta L^{-1/2}\right)-0.0189$$

$$\tau_{mix,95\%}\approx155.5Q^{-0.33}L^{-1.3}R^{2.33}\Delta L^{0.3}$$

A typical Pareto front for a 150 tonne ladle (D=3.0 m) is shown in the ad-joining figure. Predictions from the "optimization study" are being currently applied to rationalize rinsing practice in six different integrated steel mills.

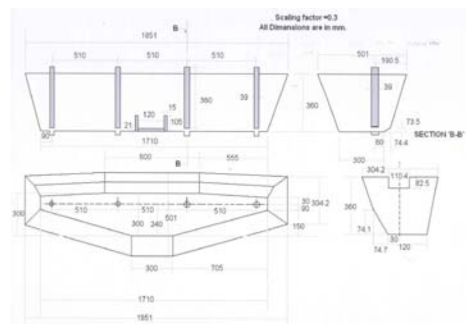


• Measurements, modeling and control of temperature in steelmaking

The project has been approved recently by the Department of Science and Technology (DST) for long term funding at IIT Kanpur. Industrial trials at JSPL, Raigarh and Hospet Steel are planned so that wall heat flux working through refractory lined steelmaking ladles and tundishes, slag covered melt surfaces etc. can be measured with a heat flux transducer. In addition, laboratory scale experiments are planned in a 5 kg induction furnace to quantify heat loss through an overlying slag as a function of composition and thickness of the slag. Heat flux thus measured shall be embodied in a turbulent convective heat transport model to predict the evolution of melt temperature during various stages of steelmaking such that superheat prior to casting can be inferred accurately.

Mission oriented projects

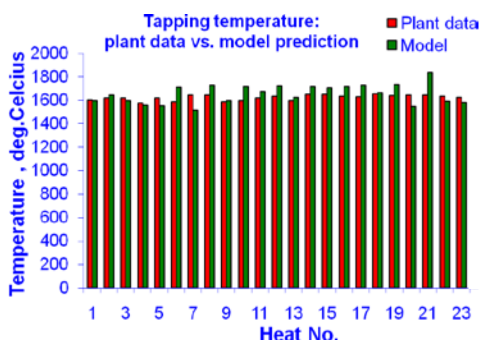
Several domestic steelmakers have tied up recently with the Process & steel research laboratory seeking answers to many of their impending shop floor problems. Such collaborative efforts have resulted in short term, mission oriented projects and a number of these have been executed in the recent past. Ongoing projects under this head include:



• Enhancing yield and inclusion float out from a four strand bloom casting tundish

Through extensive physical modeling, appropriate modifications have been introduced in the existing tundish design to ensure minimal skull volume and superior inclusion float out. While design modifications are arrived at via scaled physical models and CFD, inclusion floatation efficiency is studied by examining steel samples collected from tundish and solidified bloom under optical and electron microscopes. A schematic of the original bloom casting tundish design is shown in the ad-joining figure.

• Thermo-chemical modeling of Energy optimizing furnace (EOF)



A heat and material balance model for an Energy optimizing furnace has been developed. A GUI interface has also been created for easy and efficient use of the software on the shop floor. The model has been fine tuned with a large number of industrial data which were applied to realistically determine such parameters, as heat loss, exit gas composition and so on. A comparison between predicted and experimentally measured temperature from a 60 tonne EOF operation is shown in the ad-joining figure. EOF operators now routinely use the procedure for charge proportionating and end temperature prediction.

• Mapping of inclusion in EN52100 (i.e. ball bearing) steel

Definition of steel cleanliness is continuously getting more and more stringent and therefore acceptable size and volume fractions of inclusions are getting smaller year by year. Cleanliness in the final product is a matter of serious concern particularly in critical application areas. In this study, extensive optical and electron microscopy are being carried out to establish volume fraction distribution, size range and composition of inclusions in carefully collected samples from ladle, tundish and mold. The objective is to identify the level as well as the stages of contamination and thereby suggest remedial measures for superior cleanliness.

• Reduction of tundish skull in a four strand combi-caster tundish

The project is exclusively concerned with the reduction of skull from a combi-caster tundish which presently stands at 7 tonne per sequence. The project is in the final stages of negotiation with an integrated steel mill. Water modeling and CFD studies are being planned to evolve a tundish design leading to at least 50% reduction in skull volume. It is desired to complete the investigation and implement results on the shop floor in ninety days.

Publications & presentations

1.Anil Kumar, Dipak Mazumdar and S.C.Koria: *Modeling of fluid flow and residence time distribution in a multi strand tundish for inclusion removal*, ISIJ International, 2008, Vol.48(1), pp.38-47.

2.Rajiv Singh, Dipak Mazumdar and A.K.Ray: *Mathematical modeling and validation of wall shear stresses in gas stirred vessels*, ISIJ International, Vol. 48(7), 2008, pp.1033-1035.

3.S. Anand and Dipak Mazumdar: *A review and analysis of flow volume calculation procedures and inference of tundish hydrodynamic performance from RTD*, ISIJ International (in Press).
4.Dipak Mazumdar: *Mixing Models for Slag covered ladles Part I: Slag Metal Interactions*, Materials & Metallurgical Transactions (in Press).
5.S.P.Patil, D.Satish and Dipak Mazumdar: *Mixing models for slag covered ladles Part II: Mixing time correlations*, Metallurgical and Materials Transactions (in Press).
6. Xiang Qi Wang, A.S.Mujumdar and Dipak Mazumdar: *Vortex forming mechanisms in the tundish,* in Procd., International Conference on Advances in Theory of Iron and Steelmaking, 2009, Bangalore (in Press).
7.Pradeep Kumar Sharma, S.K.Gupta and Dipak Mazumdar: *Homogenization vs. re-oxidation: an investigation of argon rinsing practice through modeling and optimization,* in Procd., Asia Steel 2009 International Conference, Busan, Korea (in Press).
8.Dipak Mazumdar, S.Ghosh and J.Dutta: *Slag vortexing and its consequences on steel quality and mill productivity*, in Procd., International Conference on Liquid Metals Processing & Casting, New Mexico, 2009 (in Press).

News

1. A short term course on *Modeling in Metals Processing: concept, theory and application* has been planned between January 15th and 17th, 2009 for engineers working in the steel industry and R & D. The 3 day course is intended to provide comprehensive training on steelmaking and modeling through class room teaching as well as physical modeling sessions.

2. Water models of slab caster tundish were commissioned at JSPL, Raigarh and JSW Steel, Toranagallu. Shop floor and R&D engineers now frequently use the facility and try out many novel processing concepts before conducting full scale trials. The adjoining figure shows one such facility now available in the steel melt shop of JSPL, Raigarh works.

Prof. Mazumdar with JSPL engineers celebrating installation of slab caster water model tundish in SMS of JSPL , Raigarh works:

3. "*Modeling of steelmaking processes*", a text book intended to serve metallurgical engineering students, shop floor personnel and R&D engineers is slated for release during April 15th, 2009 by the CRC Press. The book is authored jointly by Professors Dipak Mazumdar and James. W. Evans (of UC Berkeley).The content is designed to serve for a full one semester course on modeling of steelmaking processes, at the senior undergraduate or post graduate levels.

4. At the 61st Annual Technical meeting of IIM at Mumbai, Professor Dipak Mazumdar was awarded the best prize in Metal Science II for the presentation titled "*Mathematical modeling of post combustion in an electric arc furnace*". The work is based on a collaborative research between IIT Kanpur and National University Singapore. Dr. Xiang Qi Wang, and Prof. A.S.Mujumdar of NUS, Singapore were the co-authors.

The Team

D.Mazumdar
Professor

A. Sharma
Technical assistant

J.S.Virdhi
Chief technician

Gurinder Singh
Technician

A.Muthuchamy
PG student

S.K.Rajasekhar
PG student

M. Peraanandhanathan
PG student

Sumanta Bagui
PG student

Ranjit K. Singh
PG student

Pradeep K. Sharma
PG student

Navneet Kumar
UG student

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

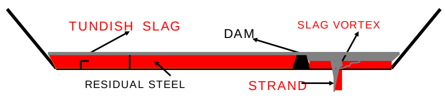
Flagship project of the Process & Steel Research Laboratory

Improving yield in Indian steel plants through reduction of tundish skull

INTRODUCTION

Considerable metal in tundish is wasted during the final stages of a sequence casting in the form of skull. Entrainment of slag prohibits drainage of all liquid from the tundish. The residual liquid leads to what is known in the steel melt shop as " tundish skull".

Schematic of slag vortexing during final stages of a sequence casting



How much of liquid steel is down graded every sequence? This is a function of tundish capacity and practice. In Indian steel industries, this ranges between 500 kg to about 8 tonnes per sequence !!

Example:

4 MMTPA plant, 130 T heat size, Sequence length: 8 heats, skull : 2.5 ~3.5 T

Loss in yield:

$$\frac{4\times10^{6}\times2.5}{130\ \times\ 8}\sim10{,}000\ \text{T}$$

24 Crores annually!!

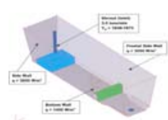
GOAL

To enhance plant productivity through reduction of tundish skull, increasing the prime slab/bloom volume as well as minimizing the intermixed liquid volume during grade transition.

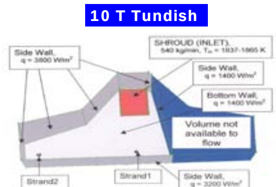
MISSION ACCOMPLISHED

Four industrial tundish systems have been investigated so far:

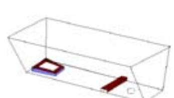
28 T tundish

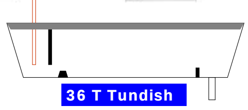


10 T Tundish



32 T Tundish

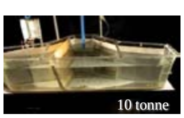




36 T Tundish

METHODOLOGY

To suggest remedial measures, flow visualization, RTD and slag vortexing investigations were carried out in geometrically and dynamically similar water model tundish systems



Slag Vortexing

Flow visualization

Residence time distribution (RTD)

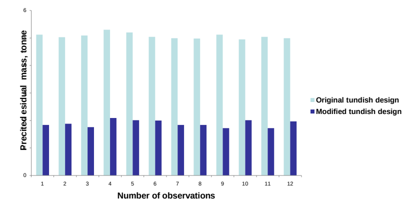
Residence time distribution measurements were carried out to quantify the metallurgical performance (inclusion float out, mixing etc.) of a steelmaking tundish system. We used the electrical conductivity technique.

$$\text{Nominal residence time} = \frac{V_{tundish}}{Q_{tundish}}$$

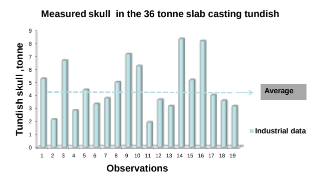
MODIFICATIONS & PROJECTED OUTCOME

Four stages of design modifications

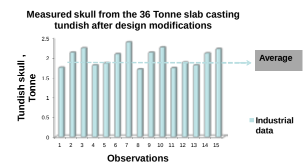
1. Modified Basal design
2. Modified near strand dam
3. Modified Pouring box design
4. Slotted baffle



Predicted skull for original and modified tundish designs (deduced from physical modeling and CFD)



Original tundish design



Modified tundish design

In the 10 T bloom casting tundish, the skull is down from ~ 0.9T to about 350 kg. The 0.5MMT plant has have reported about 0.4% increase in yield leading to an annual benefit of +70 cr. !!

In the 28T thin slab casting tundish, the skull is down consistently to about 2.5T (as opposed to ~5T)

Recommendations have been implemented in the 32 T tundish and the amount o tundish skull is down to 1.5 T per sequence .

In the 36 T tundish, the amount of skull has been consistently reduced to less than 2 tonne (see figures above)

We now routinely execute these projects and deliver within 75 to 105 days, *which none can match in the country!!*

PLANT DATA ON YIELD IMPROVEMENT

A. 0.5MMT mini steel mill

Heat size =44 T;
Average tundish skull= 900kg;
Length of sequence =L+2 heats;
Number of heats/day=35
Actual tundish skull after modification=350 kg

Productivity improvement:

$$\frac{0.550}{(3x44)}\times100=0.4\%$$

> Rs. 70.cr. annually

B. 4 MMT integrated steel plant

Heat size =130 T;
Average tundish skull=3.25 T;
Frequency of tundish change =8 heats;
Number of heats/day=28
Maximum tundish skull after modification~ 1.5 T

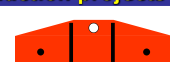
Productivity improvement:

> Rs.16 cr. annually !!!

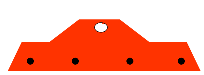
$$\frac{1.75}{8x130}\times100=0.2\%$$

FUTURE

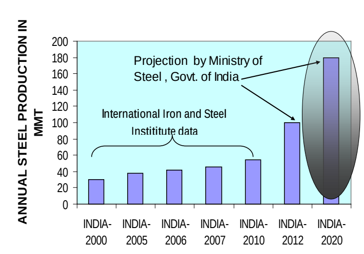
Ongoing skull reduction projects



9 T Tundish



17 T Tundish



Our mission is to help indigenous steelmakers realize the dream and add an additional 0.25% or 0.5MMT of steel per annum to the Ministry's final projection.