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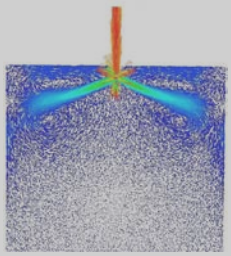


Department of Materials Science and Engineering

Solution

The Annual News Letter of Process & Steel Research Laboratory

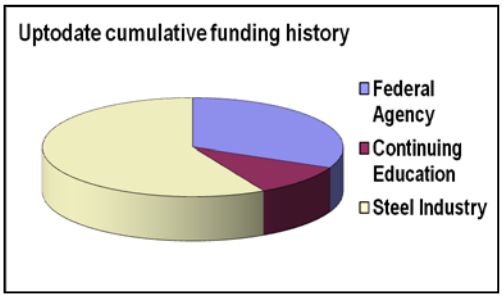
Vol. V
November, 2011

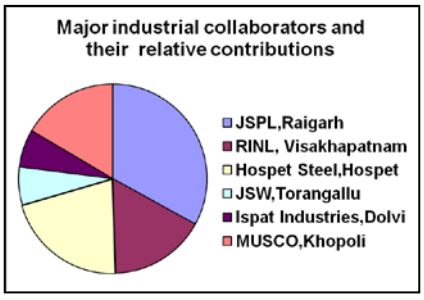
Theme: Industry- research- academia synergy

From Prof. Mazumdar's desk

Since the resurgence of steel industry, a steady increase in steel production has been reflected in the performance of Indian steelmakers. From a meager 40 MMTpa production in the late nineties, nearly 80 MMT of finished steel was produced in the country in 2010. This is expected to increase further, reaching a figure of about 200 MMTpa by the year 2020. Accordingly, several new steel plants are being set up in the country. Parallely, existing steel mills are being modernized and process route upgraded. In the changing scenario, steel plants are relentlessly trying to be more competitive and cost effective in terms of man power, material, energy, productivity, emission and so on. As a consequence, industrial R & D and continuing education have assumed considerable significance in steel plant management. Serious efforts are being made by steelmakers to pursue various R & D activities for improving process efficiency and to empower their task force with knowledge and know how, essential to combat shop floor problems on a routine basis. Academicians and Institutions are naturally playing increasingly important roles in such endeavors. Thus, industry – academia interaction which used to be largely absent in the country during the past decades, has gained significant momentum in recent years. In their efforts to up-grade and improve existing processes, remove obsolesce, improve productivity and minimize specific energy consumption, many domestic steel plants have joined hands with the Process and Steel Research Laboratory, IIT Kanpur, a pioneering centre for steel education and research.

Support from steel industry has gone a long way in reinforcing our research activities. *Solution* should not be seeing the light of day, but for the generous support of the industry. It has now been five years we are bringing out *Solution* and I am extremely happy to able to sustain and present before you the 2011 issue of the newsletter. There, customarily, yearlong R & D activities are summarized to provide readers a glimpse of our involvement and contributions to the science and technology of steelmaking. As the partnership with domestic steel industries has grown remarkably over the years and that we have been able to make many innovations and improvements, in contrast to previous years, a theme issue of *solution* focusing exclusively on industry aided research and continuing education activities has been designed. Accordingly, the present issue of *solution* provides a summary of the breadth of our involvement with domestic steel and refractory industries at various fronts. Noteworthy accomplishments form such collaborative efforts have also been highlighted.





In bringing out the present issue of *solution,* I sincerely acknowledge the support extended by various steel industries. Beyond funding, I wish to mention, in particular, the support and encouragement of shop floor personnel towards conducting plant trials. It is this spirit that helps us break the barrier creating an environment for application of knowledge on the shop floor, a subject so close to our heart. Thank you!

Industry supported projects

In recent years, more than a dozen, mission oriented projects, funded by a large number of steel industries have been executed in our laboratory. In a vast majority of these, physical and mathematical modeling has been used as the investigating tool. The table overleaf provides a glimpse of various projects completed in recent times. These, as one would note, pertain to practically all major areas in steelmaking, starting from oxygen steelmaking through to continuous casting. Recommendations, in almost all cases, have been implemented in the plants leading to substantial improvement in yield, better process efficiency and superior plant performance.

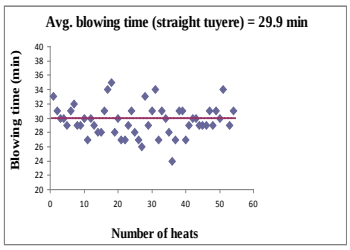
Industry aided completed and on-going R &D projects:

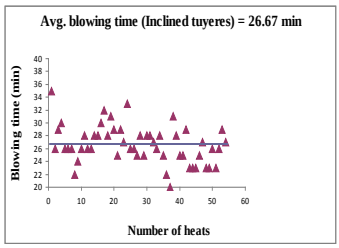
Year	*Sponsor*	*Project title*
2004	Ispat Industries, Dolvi	Improvement of thin slab caster tundish performance
2005	Ispat Industries, Dolvi	On the relocation of porous plugs in LF for superior process performance through physical and mathematical modelling
2005	Mukand Ltd., Mumbai	Performance enhancement and optimisation of tank degasser
2006	Mukand Ltd., Mumbai	Enhancing productivity at through improvement in tundish design
2008	Mukand Ltd., Mumbai	A charge calculation model for increased throughput operation of the Energy Optimising Furnace (EOF)
2010	Mukand Ltd., Mumbai	Reduction in tap to tap time for EOF (Energy Optimizing Furnace Operations)
2007	Jindal South West, Torangallu	Improving yield and steel cleanliness in the 32T new tundish
2008	Jindal Steel & Power, Raigarh	Improving yield from the 36T slab casting tundish
2010	Jindal Steel & Power, Raigarh	Improving yield and steel cleanliness in the four strand combicaster tundish
2010	Jindal Steel & Power, Raigarh	Defect free casting of larger section continuously cast slabs (>2500mm)
2009	RINL, Vishakhapattnam	Improving yield and steel cleanliness in the 27T, four strand bloom casting tundish at RINL's Vizag steel works
2011	RINL, Vishakhapattnam	Minimisation of transition bloom volume from the 27T, four strand bloom casting tundish
2011	Mahindra Ugine Steel Co., Khopoli	Improving yield and steel cleanliness in the three strand T shaped tundish

Recent breakthroughs

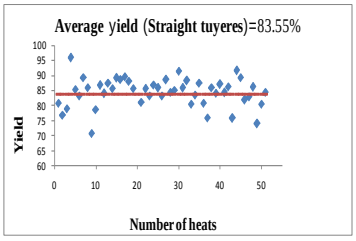
(a) Reduction in tap to tap time and increase of yield from a 60T energy optimizing furnace

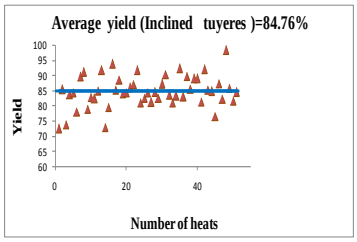
Excessive bath oxidation and carbon boil have been long recognized to be one of the major weaknesses of the EOF steelmaking technology. This often forces the operator to blow oxygen at a less than desired rate, prolonging the refining period which tends to offset plant productivity. In such context, a novel, yet simple, tuyere design, evolved through physical modeling has been developed in our laboratory and implemented successfully in the industry. The extent of process performance improvement is shown through a set of adjoining figures. The innovation has paved way for four additional, 60T heats on a daily basis offering tremendous economic benefits!





Blowing time saved per heat=200 s



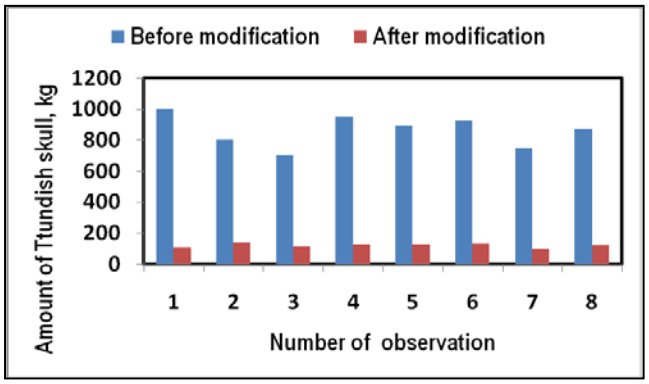


Yield improvement=1.21%

(b) Reduction of tundish skull and yield improvement during continuous bloom and slab casting

Considerable amount of steel is lost from tundish in the form of solidified skull at the end of sequence casting. This is so as the presence of an upper slag phase prohibits drainage of entire volume of the melt present in a tundish. Thus, towards the end of a casting campaign, as the tundish is being continuously emptied out and the bath level reaches a threshold, a vortex typically forms above the drainage nozzle, initiating entrainment of the deleterious, upper slag phase into the mold. This affects product quality and induces many operational hazards including bulging and break out. It is therefore customary to leave behind some residual metal in the tundish during the final stage of a sequence casting to avoid little or no entrainment of slag into the mold. The residual metal finally manifests, at the end of a sequence, as a solidified mass that is frequently referred to as "tundish skull". Significant amount of high quality steel is downgraded or lost in sequence casting (this depends on tundish size, casting rate and so on) affecting plant productivity adversely. To reduce tundish skull from slab and bloom casting tundish at the end of sequence casting, physical and mathematical modeling studies were carried out in our laboratory. There from, flow friendly tundish designs were evolved and implemented in the industry. Shop floor data obtained from four different steel plants and presented overleaf clearly show the extent of yield improvement and associated cost savings.

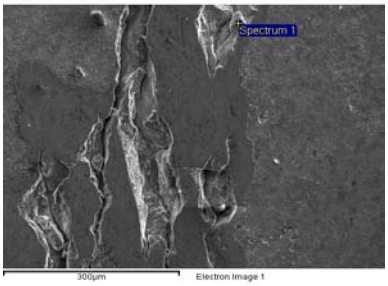
Reduction of skull from a 3 strand, 10T bloom caster



Yield improvement and cost savings

Plant	Plant features	Annual yield improvement, MT	Equiv. ₹ x10^6
RINL (2006)	5 MMT long product mill	20,000	800
JSPL (2008)	3 MMT long + flat product mill	12000	500
Hospet (2005)	0.5 MMT alloy steel plant	5000	200
JSW (2007)	4 MMT flat product mill	8000	300

Most recently completed project



The tendency to form various defects during continuous casting of steel slabs increase significantly with the increase in section size. SEN design, powder feed rate, flow as well as super heat in mold, mold oscillation and taper are important process variables and determine the extent of various types of cracks/defects that originate in the mold affecting the soundness of cast products. To reduce the occurrence of such defects, casting speed, particularly for larger section sizes, is deliberately lowered. As a consequence, caster shop productivity gets adversely affected. A typical defect, frequently observed in plates rolled from 2520 mm slab at JSPL, Raigarh, is shown in the adjoining figure. SEM and EDS analysis indicated these to be inclusions, primarily of deoxidation origin. In order to create hydrodynamic conditions conducive to inclusion floatation in cc mold and thus produce internally sound steel slab, operations with a new type of SEN (Submerged Entry Nozzle) design evolved through extensive physical modeling and CFD (Computational Fluid Dynamics) has been advocated. Industrial scale trials are being currently carried out to assess the adequacy of our recommendations and ascertain the validity of modeling results.

Continuing education activities

Continuing education is integral to modern day professional life. It allows an individual to grow with time, empowers one with knowledge and problem solving skills which are essential to propel one's professional life on a fast track. For smooth running of business and maximum profitability, steel Industry therefore naturally takes enormous interest in continuing education programs and encourages its employees to participate in such programs periodically. Innumerable steel, refractory and design industries have taken advantage of various intensive courses that are being offered by us on a regular basis. It is estimated that more than 250 shop floor personnel have undergone training on iron and steel related subjects during the last decade. We conduct regular continuing education programs at IIT-Kanpur as well as organize need based, tailor made, refresher courses for various steel plants at their premises. As seen from the following tables, overwhelming participation of industry in our continuing education programs is readily apparent.

Tailor-made intensive courses:

Year	*Sponsoring Industry*	*Course title*	*Number of participants*
2009	Vesuvius	Iron and steelmaking (Foundation level)	32
2010	Hospet steel	Ladle metallurgy and continuous casting	30
2010	L&T Special Steels , Hazira	EAF steelmaking & casting processes	10
2011	Hospet Steel	Blast furnace Ironmaking	30
2011(Proposed)	Musco, Khopoli	Ingot and continuous casting	15

Subject specific intensive courses conducted periodically at IIT Kanpur:

Year	*Course Title*	*Number of participants*	*Participating Industry*
2005	Modeling of steelmaking processes	23	Tata Steel, RDCIS, MECON, IFGL,BSL (SAIL) and JSW
2006	Modeling of steelmaking processes	20	Tata Steel, Usha Martin, Jindal Stainless, Essar Steel and JSW
2007	Modeling of steelmaking processes	20	MECON,RDCIS, Tata Steel, BSP (SAIL), RINL, JSW, JSPL and Vesuvius
2008	Modeling of steelmaking processes	18	JSPL, Vesuvius India, JSW, Essar steel and Hospet Steel
2010	Iron and Steelmaking	22	DSP (SAIL), JSPL, Hospet Steel, MUSCO, Kalyani Carpenter Special Steels, Vardhaman Special Steels, RINL and L&T Special Steels
2011	Iron and Steelmaking	22	Tata steel, JSPL, RINL, Hospet Steel, MUSCO, L&T Special Steels and Vesuvius

New projects

Three new projects have been launched during 2011. Of these, one is funded by the Ministry of Steel, GoI and the remaining two by RINL, Vishakhapattnam and MUSCO, Khopoli, respectively. Their mandate and deliverables are described below briefly:

• A comprehensive water modeling laboratory for steelmaking process analysis and design

A small water modeling laboratory, built with the assistances received from several steel industries and IIT Kanpur is already functional at IIT Kanpur. Efforts are being made to convert this facility to a full fledged, comprehensive water modeling laboratory dedicated to steelmaking process analysis, design, optimization and control. The facility shall house water models of BOF, EAF (with EBT), ladle, tundish, mold, slide gate and SEN and augmented by many measuring devices such as, load cell, anemometer, conductivity meter and so on. With the support of Ministry of Steel, GoI, commissioning of various facilities has already commenced.

• Reducing mixed grade bloom production during grade intermixing in tundish

Casting of different grades of steel through the same tundish often leads to the production of considerable amount of bloom and slab, having a composition that is intermediate between those of the 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 the reduction of mixed grade bloom production from a four strand, delta shaped tundish, funded by RINL, Vishakhapattnam has been launched during September 2011 and research work is under progress.

• Improving yield and metallurgical performance of a 3 strand, T- shaped bloom caster tundish

Process performance of a tundish which is commonly evaluated in terms of inclusion floatability, slag entrainment, solid skull etc., is a strong function of the tundish design and the fluid flow conditions therein. Tundish size and dimensions (width, breadth and depth of liquid) are normally fixed and cannot be varied at will. The metallurgical performance of a given tundish can therefore be suitably altered by incorporating new furniture. A physical model investigation coupled with CFD has been planned to address the following:

1. Reduction of volume of residual liquid the end of sequence casting resulting into less tundish skull and more prime bloom volume. Efforts will be mad to reduce skull from the current value of 400 kg to about 150-200 kg at the end of every sequence!
2. An assessment of inclusion floatation from the original and modified design tundish systems and
3. Evaluation of metallurgical performance of 2 vs. 3 strands operations.

The project, supported by MUSCO, Khopoli (Maharashtra) has been launched recently.

Forthcoming events

1. The 5th Iron and Steel Metallurgy (foundation level) course shall be held at IIT Kanpur during May 2012. The fully residential, intensive course shall be on for five days, between May 7th and 11th, supported by class room lectures, tests and comparative evaluation.

2. A two days intensive course on Ingot and continuous casting of steel is being planned exclusively for MUSCO engineers at Jagdishpur, Maharashtra during December 23rd and 24th, 2011.

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