WEDNESDAY, AUGUST 25, 2004, A.M.

SESSION 45: INTERNATIONAL SYMPOSIUM ON OXYGEN IN STEELMAKING: MILESTONES AND CHALLENGES

SPONSOR: IRON AND STEEL SECTION, THE METALLURGICAL SOCIETY OF CIM
Room: 314
Chairmen: F. MUCCIARDI, McGill University, Montréal, Québec, Canada, and
J. KAPUSTA, Air Liquide, Boucherville, Québec, Canada

PAPER 45.1 — 9:00

COHERENT JETS IN STEELMAKING: PRINCIPLES AND LEARNINGS

P. MATHUR, Praxair Metals Technology, Indianapolis, Indiana, USA

Praxair's *CoJet*® technology was introduced in 1997 to effectively inject chemical energy in electric arc furnaces. Coherent jets were invented as a revolutionary means of injecting oxygen and other gases into the EAF and into converters. Today, steel makers have widely accepted this concept in over 70 EAFs worldwide. Indeed, the whole industry has shifted to this new standard for chemical energy input in EAFs. *CoJet*® technology has also been implemented successfully in BOF converters. This paper will review the principles of coherent jets as applied to steelmaking. The key learnings garnered from several furnaces are also reviewed. In addition, while the *CoJet*® program has been widely accepted worldwide, based on steady feedback received from customers and the market place, several programs are underway in development and commercialization. These enhancements and new applications of *CoJet*® technology are also overviewed in the paper.

PAPER 45.2 — 9:30

CARBON-SLAG REACTION KINETICS – SATURATION INJECTION RATE AND AVAILABLE REACTION SURFACE AREA

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The use of oxygen in electric arc furnace steelmaking is tied to the use of fossil fuels, and slag foaming. The current work examines the kinetics of carbon injection into EAF slags especially the saturation injection rate and available reaction area in the slag foam. Based on individual rate data and experimental gasification rates of carbon in the slags, the available reaction surface area in the gas bubbles was found to be around 1900-4700 $\text{cm}^2\cdot\text{kg-slg}^{-1}$ for carbon injection into EAF like slags at appropriate injection rates and steel making temperatures. The ratio of number of bubbles to number of particles is 1 to 17 and the weights of carbon per unit reaction area are 0.001-0.008 $\text{gC}\cdot\text{cm}^{-2}$. Using the relationship between active reaction area and χ supplied in this study, the gasification rates of carbon in slags can be estimated with gas-slag interfacial reaction rates.

COFFEE BREAK — 10:00 – 10:15

PAPER 45.3 — 10:15

NITROGEN CONTROL IN THE EAF AND POST EAF PROCESSES

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The levels of nitrogen in steel produced in various metallurgical vessels vary significantly. For example, the tap nitrogen levels in steel produced in the BOF are around 40ppm, as compared to 70-100ppm in both DC and AC electric arc furnaces. Given the pressing need to reduce nitrogen levels in steel to satisfy customer demand, IPSCO Inc. has gained considerable experience in controlling nitrogen levels in steel over the course of the last three years. Hence, a cost effective process has been developed through an intensive nitrogen control program from steel melting in the EAF through to the continuous slab casting stage. This paper describes the practices employed at each stage of the steelmaking process that have enabled IPSCO Inc. to reduce and control nitrogen levels in steel.

PAPER 45.4 — 10:45

THE GAS-LIQUID INTERFACIAL AREAS IN BUBBLE PLUMES

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Many metallurgical processes use submerged gas injection to increase the contact area between gas and liquid phases in order to promote faster overall reaction rates. The work presented in this paper is part of an experimental investigation to measure the gas-liquid interfacial area available in bubble plumes within molten metal baths. Measurements of the nitrogen absorption rate during submerged injection into molten iron baths have been used to estimate the interfacial areas of the bubble plumes. A theoretical model was used to predict the superficial nitrogen transfer rate under mixed liquid phase mass transfer – interfacial reaction control. The interfacial area was calculated by dividing the overall nitrogen absorption rate by the superficial rate. Reasonable agreement was obtained between the interfacial areas measured in our laboratory with data from a comparable system reported in the literature. The experimental results were compared with the predictions of three theoretical models and one empirical correlation. The models of Turkdogan and Zhao and Themelis gave the best agreement with our data.

PAPER 45.5 — 11:15

MIXING TIMES AND CORRELATION FOR DUAL PLUG STIRRED LADLE: QUANTIFYING THE ROLE OF AN UPPER BUOYANT PHASE

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95% bulk mixing times in three different size water model ladles of a 140 T cylindrical shaped , *dual plug* (located diametrically opposite at mid bath radius position) stirred, industrial ladle were determined experimentally with and without an upper buoyant phase. Based on dimensional analysis and a regression of the experimental data and, it was shown that in the inertial and gravitational force dominated flow regimes, 95% bulk mixing times for a slag-less situation can be described via:

$$\left(\frac{\tau_{mix,95\%}{}^{2}\,g}{R}\right) = 2842\ .2\left(\frac{Q^{2}}{gR^{5}}\right)^{-0.28}\left(\frac{L}{R}\right)^{-1.04}$$

Parallel to this, a large number of experiments were also carried out in one of the water models (D=0.30m) to quantify the influence of an upper buoyant phase on mixing. These indicated that mixing time, operating variables and thermo-physical properties of the upper phase liquid can be correlated via a dimensionless relationship of the type:

$$\left(\frac{\tau_{mix,95\%}{}^{2}\,g}{R}\right) = 1.76\,x10^{4}\left(\frac{Q^{2}}{gR^{5}}\right)^{-0.33}\left(\frac{L}{R}\right)^{-2.0}\left(\frac{\Delta L}{R}\right)^{0.6}\left(\frac{\sigma^{2}}{\mu^{2}gR}\right)^{-0.022}$$

in which, Q is the ambient gas flow rate, L is the depth of liquid , ()L) is the slag layer thickness and σ and μ are respectively the surface tension and viscosity of the upper phase fluid The dimensional analysis, regression of experimental data as well as the adequacy of the proposed correlations are discussed in the text.

CLOSING REMARKS – 11:45 – 11:50

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