Fundamentals of High Temperature Processes

Coanda effect on liquid flow characteristics in a bubbling jet rising near the side wall of a cylindrical vessel

M.IGUCHI et al.

An air-water bubbling jet rising near the side wall of a cylindrical vessel is known to be pulled towards the side wall through the Coanda effect. Once the bubbling jet attaches to the side wall, it rises along the side wall all the way. The mean velocity and turbulence components of water flow in the bubbling jet were measured with a two-channel laser Doppler velocimeter. In the vertical (axial) region located above the attachment position, the horizontal (radial) distributions of the axial mean velocity component $\bar{u}$ and the root-mean-square values of the axial and radial turbulence components, u'_{rms} and v'_{rms}, followed their respective similar distributions just like the horizontal distributions of bubble frequency and gas holdup. The maximum values of $\bar{u}$ and u'_{rms} agreed favourably with those obtained in a vertical bubbling jet free from the Coanda effect, and hence, these values were not affected by the side wall. However, the maximum value of v'_{rms} became smaller than that in the vertical bubbling jet because the horizontal turbulence motions were suppressed due to the confinement effect of the side wall.

The rate of nitrogen desorption from liquid iron by blowing argon gas under the condition of non-inductive stirring

Z.JUN et al.

The nitrogen desorption reaction by blowing argon gas onto the surface of liquid iron containing various oxygen contents with a resistance furnace has been studied. Using a periscopic high temperature lens the Marangoni convection was qualitatively observed in the process of nitrogen desorption. With the experimental results and gas-liquid metal reaction kinetic theory, the procedure of the nitrogen desorption is discussed. The nitrogen desorption from liquid iron under the condition of non-inductive stirring exhibits a 1.5^{th} order dependence with respect to the nitrogen concentration in the melt regardless of oxygen content. The rate of nitrogen desorption is controlled by the three mixed rate-controlling steps of gas- and liquid-phase mass transfers and chemical reaction at the gas–metal interface and mainly by the latter two steps. It was deduced that the decrease of the nitrogen desorption rate which accompanies the increment of oxygen concentration was mainly attributed to the attenuation of Marangoni convection and the increase of chemical reaction resistance at the interface in the present study.

Ironmaking and Reduction

Co-injection of noncoking coal and natural gas in blast furnace

A.BABICH et al.

The most radical method for saving coke in ironmaking is to inject gaseous, liquid and solid substitutes into the blast furnace (BF) hearth by means of tuyeres. Use of one or another type of auxiliary fuel depends on the ratio of their prices, their deposits and the peculiarity of the technology.

This paper presents the basic theoretical proposals of a technology for the simultaneous injection by tuyeres of natural gas (NG) and pulverized coal (PC) with any ratio up to complete exception of one of them. A laboratory study has been carried out of the thermal decomposition and gasification of different types of coals. Determination has been made of the softening temperature and melting temperature of the ash of these coals. These temperatures play an important role in optimizing the tuyere assembly design, raceway processes and slag regimes. The factors which determine the oxidizing potential of the raceway have been established.

A study has been made of the comparative estimation of NG and PC and the compensation rates for BF operational conditions with simultaneous injection ranges of 0–100 m^3/tHM NG and 0–200 kg/tHM PC, at a flame temperature of 1950–2150°C and maintaining other blast and burden parameters constant. The rates automatically compensate the changes in temperature and the thermal and oxidizing potential in the raceway.

This technology and tuyere assembly design are successfully used at two BFs.

Assimilation and mineral formation during sintering for blends containing magnetite concentrate and hematite/pisolite sintering fines

L.X.YANG et al.

Blends for sintering in China commonly contain domestic magnetite concentrate and imported hematite or/and pisolite sintering fines. Interactions between these ores will, no doubt, have an important impact on sintering performance and sinter quality of these blends. Studies have been carried out to look at assimilation of sintering fines and mineral formation during sintering of such blends.

The results show that at given mix composition, pisolite ores are easier to be assimilated than hematite and magnetite ores while magnetite shows the least assimilation. For the same ore, the assimilation depends on melt level and ore porosity. For this reason, higher assimilation was observed for porous ores or ores with high gangue content or when an easy-fusing ore was present in the blend.

Studies on mineral phase formation of blends containing magnetite, hematite and pisolite indicate that good sinter mineralogy with increasing SFCA (silico-ferrite of calcium and aluminium) content is obtained with increasing Ore E (hematite). Substitution of Ore J (pisolite) for various hematite ores did not lead to significant changes in sinter mineralogy. The only change was the reduced level of primary hematite owing to the high reactivity of Ore J.

Casting and Solidification

Numerical simulation of isothermal dendritic growth by phase-field model

J.S.LEE et al.

The phase-field model is applied to simulate microstructural evolution during isothermal dendritic growth of the δ-phase in undercooled Fe–C liquid. The parameters of phase-field equation are determined by a thin interface limit condition. Realistic dendritic structures at various temperatures and compositions of the alloy can be obtained using the phase-field model with the thin interface limit condition. The calculated results show various solidification features consistent with our experience. The calculated tip radius, the velocity and the concentration at the interface were compared with the predicted values from the conventional dendritic growth theory using Ivantsov solution and marginal stability criterion.

The effect of thermal history on the hot ductility of microalloyed steels

A.M.EL-WAZRI et al.

Transverse cracks in continuous cast steels can form if the hot ductility of the cast steel at the unbending stage is poor. To measure hot ductility, tensile specimens are usually reheated to a high temperature (preferably to the melting point), cooled to the test temperature and then isothermally fractured. In this work, high temperature tensile testing was used to determine the hot ductility of a Nb–Ti and a Ti–B microalloyed steel. However, instead of cooling directly to the test temperature after melting, the specimens were subjected to thermal histories typical of a continuously cast billet surface, and then, at the unbending temperature, subjected to a tensile test to fracture. In other words, physical simulations of the continuous casting procedure were performed. The results were compared with those generated by conventional isothermal tensile testing.

For the isothermal tests, both steels exhibited a temperature range of low ductility. However, the physical simulations did not reveal such hot ductility behaviour. For both steels, almost all the physical simulation variants led to hot ductility values lower than predicted by the isothermal tests at the corresponding tensile test temperature. For the Nb–Ti steel, it was revealed that there is a critical minimum temperature, attained by the specimen during the thermal history, below which the hot ductility, measured at the tensile test temperature, is much reduced. It is assumed that this critical minimum temperature leads to the formation of grain boundary ferrite, which probably enhances the rate of formation of Nb precipitates, decreasing the hot ductility in this way. However, for the Ti–B steel, the effect of thermal history could not be explained in such a straightforward manner.

Experimental study of free growth of equiaxed NH_4Cl crystals settling in undercooled NH_4Cl–H_2O melts

B.APPOLAIRE et al.

The present study deals with experiments carried out to assess the influence of the movement of equiaxed crystals on their growth kinetics. The principle of the experiments is based on the settling of crystals growing in melts of transparent alloy undercooled at constant temperature. Ammonium chloride–water mixtures have been chosen for their con-

venient properties. The experimental set-up is composed of a settling tube and a video-device which allowed us to record continuously the images of dendritic NH_4Cl equiaxed crystals all along their fall. On these images two kinds of morphology have been observed of which the difference seems to be related to the spinning movements of the crystals. Furthermore time evolutions of the vertical position and apparent sizes of the crystals have been measured. A careful examination of these measurements was necessary because of the uncertainties of the undercooling and of the actual shapes and sizes of the crystals which are inherent in the set-up and in the procedure. Average growth velocities were determined so as to identify some general trends concerning the effect of the settling on the growth of the equiaxed crystals. Finally, a short comparison between these average growth velocities and the corresponding theoretical ones without any convection has shown a strong influence of the convection on the equiaxed growth kinetics.

Microstructure

Analysis of the austenite grain size distribution in plain carbon steels

A.K.GIUMELLI et al.

The aim of this paper is to report methods for measuring the austenite grain size in plain carbon steels, including the estimation of the three dimensional grain size distribution. Prior austenite boundaries are revealed using a number of quenching and etching techniques. The grain size is measured by standard manual procedures and by the use of image analysis equipment. Results from these measurement methods are compared and systematic errors are identified. A correction is proposed to account for the systematic error in the measurement of the two dimensional grain size distribution by the use of image analysis. Methods for the estimation of the three dimensional grain size distribution are compared. It is concluded that the method proposed by Matsuura and Itoh is the most versatile.

Evaluation of transformation latent heat in C–Mn steels

J.-L.LEE et al.

Two sublattice thermodynamic model and DTA technique were adopted to determine the latent heat of $\alpha+Fe_3C \rightarrow \gamma$ transformation in C–Mn steels. The calculated latent heat varied with the transformation route. Supercooling resulted in higher latent heat than superheating. By splitting enthalpy change into components of specific heat and latent heat, the equilibrium latent heat was calculated and proven to be a constant indpendent of cooling or heating. The latent heat determined using DTA agreed very well with calculation as carbon content was higher than 0.45 wt%, while it was significantly lower than calculation at lower carbon content. The inconsistency was attributed to that lower carbon steels had a wide transformation temperature range, but DTA only detected heat change over part of the range. Molar fraction of pearlite, latent heat absorbed per unit temperature, and the temperature range of transformation were found to be the three main factors affecting latent heat. Carbon and manganese additions increased latent by increasing molar fraction of pearlite, while silicon addition increased latent heat by expanding temperature range of transformation.

Physical and Mechanical Properties

Effect of volume fraction of constituent phases on the stress–strain relationship of dual phase steels

T.HÜPER et al.

Ferrite–martensite and ferrite–bainite dual phase steels (DP-steels) were prepared by applying accelerated cooling (AcC) process on a linepipe steel. Their stress–strain relationships were predicted by micromechanics. In the predictions, the stress–strain relationships of the constituent phases whose chemistries were determined by microscopic examinations and some thermodynamic data were used. The effect of volume fraction of the constituent phases on the stress–strain relationships of the DP-steels was also examined. According to the applied model, a simple stress–strain curve can be divided into three stages. As a result of this investigation, work hardening takes place in stage II and at the beginning of stage III. Further, in stage II, the hardening rate is strongly dependent on the volume fraction of the harder phase. In stage III, the hardening rate for each DP-steel is smaller than that in stage II and is related to the difference in tensile strength between the harder and the softer phases.

Furthermore the second investigation by means of FEM analysis was carried out in order to evaluate the influence of variation of the volume fraction of the harder phase on the stress–strain behavior of a DP-steel. Tensile tests showed that by increasing the amount of the harder phase (bainite) in the DP-steel, Lüders elongation disappears. According to the results obtained by the FEM calculations, the stress–strain behavior is related to the microstructure, such as volume fraction and shape of the grains in the DP-steel.