Fundamentals of High Temperature Processes

Control of foam height by using sound waves

S.V.KOMAROV et al.

Possibilities for control of slag foam height by sound waves were investigated using cold models. The foaming and defoaming rates were measured under various frequencies and intensities of sound.

Nitrogen gas was injected into a liquid containing a surfactant to produce the foam layer. Simultaneously, the foam surface was exposed to sound waves propagated through the gas phase to the surface. The sound waves were generated by a loudspeaker. Two liquids of different viscosities were used: water and a water-glycerin solution.

It was found that sound waves can control the defoaming rate, while the foaming rate does not vary practically under the application of sound. The latter finding is associated with the fact that the height of foam, produced in the experiments, was much smaller than the steady height. The defoaming rate is essentially reduced by the sound of lower frequency (200–1 000 Hz). This effect is explained in terms of a radiation force arising when the sound waves are propagated inside the foam layer. Sound waves of intermediate frequencies (1 000–8 000 Hz) cause the defoaming rate to increase compared with that in the absence of a sound field. The defoaming mechanism is assumed to be associated with a rupturing of the foam film accelerated by the sound waves. On the whole, the effect of sound on the defoaming rate increases as sound intensity and liquid viscosity become higher.

Decarburisation of liquid Fe–C–S drops using multiple oxidants of O_2, CO_2 and H_2O

N.J.SIMENTO et al.

The decarburisation of liquid Fe–C–S drops was studied at 1 723 K employing the electromagnetic levitation technique with two different types of gas mixtures, namely, mixtures of O_2 and CO_2, and mixtures of O_2 and H_2O. For the decarburisation with O_2 and CO_2, the rate is limited by the O_2 and CO_2 transport in the gas phase with additional resistance arising from the interfacial reaction kinetics of CO_2. Sulphur significantly reduces the surface reaction rate with CO_2, and the retarding effect appears to be enhanced by existence of the simultaneous oxygen decarburisation. For the simultaneous decarburisation by O_2 and H_2O, the basic mechanism of decarburisation is similar to that of O_2 and CO_2, but there exists evidence that the homogeneous gas phase flame reaction of O_2 and CO to produce CO_2 occurs in the vicinity of the interface. This results in a much lower rate of decarburisation than the expected one, since portion of the incoming O_2 gas is converted to CO_2 and the rate of decarburisation with CO_2 is slower to a great extent than that with O_2. The conversion rate is increased as the sulphur content in the melt is increased, and this is attributed to the increase in H_2O in the vicinity of the interface with increase in sulphur. Mixed control models are developed and found to adequately explain the observed results.

Characteristics of liquid metal motion driven by quasi-sinusoidal magnetic fields

Z.SU et al.

The free surface motion of a liquid metal has been investigated by changing the wave patterns of a quasi-sinusoidal magnetic field and a modulated quasi-sinusoidal one. The theoretical expression of Lorentz force induced by the quasi-sinusoidal magnetic field applied on an electrically conductive cylinder has been derived. The Lorentz force consists of a time-averaged part F_{ave} and oscillating parts F_ω and $F_{2\omega}$ with angular frequencies ω and 2ω, respectively. The surface disturbance of a liquid gallium was observed under the imposition of the magnetic fields. It was found that the oscillating part of F_ω dominants the surface wave motion in the low frequency range and the substantial frequency of the surface wave is the same as that of a coil current. This result agrees with the theoretical derivation. While in the high frequency range, the induced recirculating flow causes an irregular fluctuation on a free surface. It is noticed that the disturbance on the free surface is intensified at the resonance frequency and the around of 1 000 Hz.

Thermodynamics of the $MnO–AlO_3–TiO_2$ system

M.OHTA et al.

Isothermal phase relations for the $MnO–Al_2O_3–TiO_2$ system have been investigated under moderately reducing conditions, $P_{O_2}=2.29\times10^{-11}$ atm and 1.91×10^{-1} atm at 1 673 K and 1 873 K, respectively, equilibrated with a saturating oxide tablet. Activities of MnO in the $MnO–Al_2O_3–TiO_2$ system have been measured in equilibrium with silver at 1 673 K and copper at 1 873 K, respectively. Iso-activity curves for MnO have been drawn from the experimental results of the activities as well as those for Al_2O_3 and TiO_2 calculated by Schuhmann's tangent intercept procedure, which provide the deoxidation equilibrium of molten steels.

The sulfide capacity significantly depends on MnO content in this ternary system. It slightly increases when Al_2O_3 replaces TiO_2 at a constant MnO content in weight percent, whereas γ_{MnS} considerably decreases.

Ironmaking

Analysis of pore combination in sintering by hot stage X-ray computerized tomographic scanner

K.NUSHIRO et al.

The influence of the raw material bed condition on pore formation in the sinter cake was investigated by on-line observation of the sintering process in the hot stage and quantification of the pore combination behavior. Using a new sintering test device which employs an X-ray computerized tomographic scanner, on-line observation of cross-sectional images of the sinter cake in the sintering process has become possible. When the bulk density of the raw material bed was low, the combination of +5 mm pores was remarkable and large pores formed with comparative uniformity in the sintering bed. In contrast, when the bulk density was high, the combination of +5 mm pores was slight, and combination of −5 mm pores with +5 mm pores was remarkable. Then, large pores formed along local +5 mm pores. It is considered that this difference in the morphology of pore formation effects the permeability and uniformity of burning in the sintering process.

Steelmaking

Mechanism of wave excitation on a liquid metal surface submerged in an intermittent alternating magnetic field

Y.CHINO et al.

In order to increase an interfacial area for the promotion of mass transfer in refining processes, a new method exciting surface wave on a molten metal has been proposed in the way introducing an intermittent alternating magnetic field with the stepwise change of amplitude. For estimating the mechanism of the wave excitation on a metal surface and the value of an excited interfacial area, the surface wave behavior on a liquid gallium was measured by use of a laser level sensor by changing intermittent frequency, f_i, and duty, D. At lower intermittent frequency compared with the natural frequency of a liquid metal, the change in the magnetic amplitude excited surface motion on an equilibrium surface which could have been formed by the continuous imposition of each magnetic amplitude as a result of the balance between an electromagnetic pressure and a static liquid pressure. When the intermittent frequency is adjusted to the neighborhood of the natural frequency, descending of free surface in the wall vicinity takes place accompanying with increase in the magnetic amplitude and excites surface motion. When the intermittent frequency coincides with the natural one, a free surface area increases remarkably.

Casting and Solidification

Straightforward numerical analysis of casting process in a rectangular mold: from filling to solidification

J.LEE et al.

To see the effect of filling on the solidification process, an attempt is made to study numerically the fluid flow and heat transfer characteristics of pure metal during mold filling and subsequent solidification process simultaneously in a rectangular mold. To analyze the fluid flow and heat transfer with free surface motion, the MAC method is employed in the SIMPLER algorithm.

Thermal stresses are also calculated based on temperature distributions through finite element analysis. Results show the distinct difference between present analysis and conventional analysis which just deals with solidification process only. Present analysis makes it possible to predict the defects occurring during filling and solidification processes, since any section of a mold at any time can be examined without difficulty, which is very difficult in an experimental approach.

Initial solidification behavior of ultra low, low and middle carbon steel

H.MIZUKAMI et al.

The cooling curves at initial stage of solidification of carbon steel sample were measured using a new temperature measurement system that consisted of a two-dimensional optical pyrometer. Undercooling and recalescence phenomena were observed on the measured cooling curve of ultra low, low and middle carbon steel samples, and the solidification sequence at initial stage of solidification was shown to be different from normal solidification. A numerical analysis employing the dendrite tip growth model has been constructed, and fitted to a measured cooling curve by the parameter of interfacial heat transfer coefficient, and then the interfacial heat transfer coefficient between sample and chill plate which made of a transparent sapphire glass can be predicted accurately. The evenness of solidified shell is made clear to be influenced mainly by thermal deformation.

Solidification phase and microstructure selection maps for Fe–Cr–Ni alloys

S.FUKUMOTO et al.

Directional solidification and laser experiments have been performed in Fe–18.0%Cr–Ni alloys to evaluate the effects of alloy composition and growth velocity on microstructure and phase selection. Solidification microstructure selection maps are described by microstructure (dendrite/cell, plane front and eutectic) models and compared with experimental results. Theoretical predictions are in good agreement with experimental results. It demonstrates the potential of this approach to analyze the microstructure and phase formation.

Surface Treatment and Corrosion

The shear strength of galvannealed coatings on IF steels

I.HERTVELDT et al.

The present contribution focusses on the characterisation of the shear strength of galvannealed on Ti and TiNb interstitial-free steels currently used in the automotive industry. A modified lap shear testing method was developed which gave the shear strength of the substrate/coating interface independently of the mechanical charateristics of the substrate. The criteria for adhesive selection and the required sample geometry are reviewed in detail. An in-depth electron microscopic study of the fracture plane structure was also carried out. It revealed, among other things, a quantitative relation between the shear strength of the coating and the area of the steel/Γ phase fracture plane. It is shown that the shear strength of galvannealed coatings is influenced by (1) the Fe content of the galvannealed layer, (2) the type of steel substrate (Ti *versus* TiNb interstitial-free steel, drawing IF steels *versus* high strength IF steels) and (3) the effect of certain alloying elements.

Transformations and Microstructures

Pinning of austenite grain boundary of Fe–0.09 to 0.53 mass%C–0.02 mass%P alloys by primary inclusions of Ce_2O_3 and CeS

M.GUO et al.

The effect of the deoxidation and desulfurization products of Ce_2O_3 (the mean planar diameter, $\bar{d}_A$=1.6 to 2.1 μm) and CeS ($\bar{d}_A$=2.2 to 2.8 μm) particles on the austenite grain growth was studied in Fe–0.20 (0.09 and 0.53) mass%C–0.02 mass%P alloys. The melts at 1 873 K were continuously cooled to 1 673, 1 573 and 1 473 K and then were held for 0 to 180 min in the austenite single phase region. Grain growth in the presence of particles was strongly inhibited by the pinning effect and the mean grain size was independent of the carbon content for a given holding time, holding temperature, and volume fraction of Ce_2O_3 particles (f_V=0.08 to 0.12%). The planar limiting grain diameter, $\bar{D}_A$, obtained at holding times of more than 60 min, was found to be significantly smaller than that predicted from the Zener relation, and the deviation from this relation increased with increasing the $\bar{d}_A/f_V$ value. The fraction of particles at the grain boundaries, Φ_A=0.07 to 0.23, was about 20 to 60 times higher than that estimated from the random distribution from the Zener limit. Based on these values for Φ_A, the limiting grain size was discussed as a function of f_V value, and the present results for Ce_2O_3 and CeS particles were compared with those obtained for the MgO and ZrO_2 particles in Fe–0.20 mass%C–0.02 mass%P and Fe–10 mass%Ni alloys.

Austenite grain size distribution and topological properties in Fe–0.09 to 0.53 mass%C–0.02 mass%P alloys containing primary inclusions of Ce_2O_3 and CeS

M.GUO et al.

The effects of the primary inclusion of Ce_2O_3 (the mean planar diameter, $\bar{d}_A$=1.6 to 2.1 μm) or CeS $\bar{d}_A$=2.2 to 2.8 μm) particles on austenite grain size and grain shape distributions were studied in Fe–0.09 to 0.53 mass%C–0.02 mass%P alloys, which were continuously cooled from 1 873 to 1 673 K, followed by holding for 0 to 180 min. It was found that the shape of the relative spatial grain size distribution, $DV/D_{V,\,mean}$ (the mean grain diameter), was invariant with respect to the content of carbon, the number of Ce_2O_3 or CeS particles (the volume fraction of particle, f_V=0.02 to 0.19%) and holding time. The spatial grain size distribution could be best described by the log-normal distribution function. The heterogeneity parameter, D_{max} (the maximum grain diameter)/$D_{V,\,mean}$ ratio in three dimensions, increased with an increase in the f_V value. The distribution of the number of grain sides and the grain size distribution for each grain side follow approximately the log-normal distribution function, and these results were consistent with those observed in previous experimental results for normal grain growth, in which a second-phase particle was not present.

Determination of critical temperatures (T_{nr}, A_{r3}, A_{r1}) in hot rolling of structural steels with different Ti and N contents

M.I.VEGA et al.

The simulation method applied to determine norecrystallization temperature (T_{nr}) has also been used to simultaneously determine phase transformation temperatures on cooling (A_{r3}, A_{r1}) in a set of six steels with different Ti and N contents. A study has been made of the influence of Ti and N contents on these parameters for different strain conditions, and the results permit an estimation of what would be the most appropriate contents depending on the type of rolling (hot strip mill, near net shape casting). Austenite grain size was also determined at 1 100°C and 1 300°C for all the steels, it being found that a Ti/N ratio close to two gave the finest grain.