Fundamentals of High Temperature Processes

Electromagnetic confinement including the dynamic effect due to melt flow

X.-R. ZHU et al.

A 2 dimensional model has been developed to predict the free surface shape of liquid metal in an electromagnetic field, in which the field calculations have been coupled with the free surface shape change and the dynamic effect of the liquid metal flow. This has allowed the interactive phenomena in a coreless induction furnace to be simulated comprehensively and resulted in satisfactory agreement between the predicted and the measured meniscus shapes. Studies of the recirculating flow in molten aluminium have shown interactions of the meniscus shape with the flow field and therefore demonstrated the importance of having detailed knowledge of the free surface shape in the electromagnetic processing of materials. In addition, the influence of the electrical conductivity and the skin effect in the induction coil on the electromagnetic confinement and the melt flow have been analysed.

Ironmaking and Reduction

Process development for production of hard pitch from coal tar for electrode industries

A. J. CHAUDHURI et al.

Coal tar pitch is a residue of coal tar distillation and can be processed suitably to produce hard pitch of desired quality in terms of softening point (SP), benzene insoluble (BI), quinoline insoluble (QI), β-resin and coking value (CV). As per customer requirement, these properties could be achieved by controlling coal tar quality, different parameters during distillation of tar and processing of soft and medium pitch. Coal tar pitch with CV in the range of 55–58%, BI content of 30–32%, QI content of 13–16% and SP of 95–105°C, finds its use as a binder for manufacture of electrodes.

During 1993, Bokaro Steel Plant (BSL), SAIL produced poor quality coal tar with high BI and QI content in it due to poor health of coke oven batteries. The by product Plant, found it difficult to produce hard pitch to the specification of aluminium and electrode industries. The R & D Centre at SAIL in association with BSL undertook a project of process development for converting high BI and QI content tar to hard pitch by blending it with low BI and QI tar from other Plants in an appropriate ratio, modifying operating procedure (tar flow rate to pipestill, second stage evaporator temperature, air flow rate & temp. of soft pitch in a batch reactor) to the customer's requirements. Bokaro Steel Plant produces and sells about 3000 t/year of hard pitch to electrode industries.

Three-dimensional dynamic simulator for blast furnace

K. TAKATANI et al.

Three-dimensional dynamic mathematical model which is constructed as a simulator of an actual blast furnace is developed based on the mass, momentum and energy conservation in the furnace. In this paper, following things are investigated.

(1) The wholesome of this mathematical model is clarified checking the total mass and energy conservation.

(2) Then, comparison with simulated and measured results for steady state is done for actual operating conditions in order to clarify the validity of this simulator.

(3) Dynamic behavior of the blast furnace such as the blown-in/off operations which are most hardly estimated is simulated by this model.

(4) The effects of the shape of a blast furnace on the operating results such as total pressure loss, fuel rate and so on are investigated by this model.

Steelmaking and Refining

Modeling and simulation of an electric arc furnace process

J. G. BEKKER et al.

The model derived in this paper is intended for the testing of control strategies using off-gas variables in the control of an Electric Arc Furnace (EAF). The derivation of a multivariable non-linear state space model of an EAF process is treated. Assumptions are made that facilitate the modeling effort. First principles of thermodynamics, together with empirical relationships, are used to derive the model equations. A state-space model is developed with physical variables such as carbon content in the steel as model states. Rates of change such as decarburization are also considered. Typical operating conditions for a furnace are discussed and initial conditions for a simulation are derived from this. A timeline of events corresponding to operating conditions is determined for the simulation. A simulation is conducted starting with the initial conditions and proceeding with the line of events. The results of the simulation are shown and discussed in terms of the purpose of the model.

Casting and Solidification

Effect of solute convection on the macrosegregation in Pb-Sn binary alloys during upward directional solidification

M. LI et al.

Upward directional solidification experiments have been carried out on Pb–Sn binary alloys. The macrosegregation along the length of a sample in hypereutectic Pb–Sn alloys is not observed. However, it is observed in the hypoeutectic Pb–Sn binary alloy. The intensity of the longitudinal macrosegregation increases as the solidification rate decreases. It can be found that solute convection resulted from the density profile of interdendritic melt and induced the macrosegregation. The intensity of the interdendritic solute convection responsible for the longitudinal macrosegregation can be represented by the effective partition coefficient of the alloy. The change in the length of a mushy zone affects the intensity of the solute convection during the upward directional solidification even when steady-state dendritic growth is maintained.

Instrumentation and Control System

Strip thickness control of reversing mill using self-tuning PID neurocontroller

J. FAN et al.

A self-tuning PID control approach is presented for improvement of the head and tail strip thickness accuracy in a reversing cold mill for offering a cost saving. A neural network is used on-line to tune the parameters of a conventional PID controller in AGC to improve the response of strip thickness during a transient rolling process, which results in a reduction of off-gauge strip length. The effectiveness of the presented approach has been demonstrated through a simulation example. The results of simulation show that a neural network can reduce the strip thickness error quickly during mill starting process while the PI controller parameters are being tuned on-line, so that a saving of off-gauge strip length about 73% is achieved.

Analysis and Characterization

Hydrogen embrittlement of a HSLA-100 steel in seawater

K. BANERJEE et al.

Hydrogen embrittlement of a copper precipitation strengthened and niobium microalloyed HSLA-100 steel on cathodic changing in synthetic seawater has been studied using slow strain rate technique. The effects of potential applied for hydrogen changing, pre-charging with hydrogen and chasnges in strain rate have been studied. A loss in ductility in terms of drop in percent elongation and percent reduction in area has been observed, the effect being prominent at potentials beyond −900 mV (SCE). SEM fractography shows an increase in brittle quasi-cleavage features with decreasing potential. A hardening effect on hydrogen charging up to −700 mV (SCE), followed by a softening effect, has been observed. Precharging has led to a similar behaviour, but an overall increase in the strength values compared to material without precharging.

Forming Processing and Construction

Effects of retained austenite parameters on warm stretch-flangeability in TRIP-aided dual-phase sheet steels

K. SUGIMOTO et al.

Effects of volume fraction and carbon concentration of retained austenite on warm stretch-flangeability in high-strength TRIP-aided dual-phase (TDP) sheet steels with different silicon and manganese contents were investigated. A significant improvement of the stretch-flangeability was obtained by warm hole-punching at temperatures between 150 and 200°C and the successive hole-expanding at temperatures between 50 and 200°C, relating to martensite-start temperature of the retained austenite. The warm stretch-flangeability was affected by carbon concentration of the retained austenite rather than by the volume fraction of retained austenite. Namely, the higher the carbon concentration of the

retaind austenite, the larger the hole-expanding ratio of the steel. Such a large hole-expanding ratio was resulting from the following two reasons; (1) smaller surface damage and a large amount of retained austenite untransformed on hole-punching and (2) large localized ductility due to the TRIP effect on hole-expanding.

Microstructure

Effect of carbon on precipitation of MnS inhibitor in grain-oriented 3% silicon-steel

A. A. Kononov et al.

The solubility of MnS in 3% silicon-steel was shown to depend on carbon content. An increase in carbon concentration raises sharply the temperature, below which the solution becomes supersaturated, and leads to growth of the driving force for MnS precipitation. The effect of these factors on the strength of the sulphide particles as inhibitors of the primary recrystallization process was discussed and correlation between thermodynamic parameters of the precipitation reaction and magnetic properties of the finished grain-oriented steel were established.

Physical and Mechanical Properties

Effect of microstructure on short fatigue crack growth of $\alpha+\beta$ titanium alloys

K. Nakajima et al.

Fatigue crack initiation and early stage of crack growth for Ti–6Al–4V and Ti–4.5Al–3V–2Fe–2Mo were investigated on notched specimens. *In-situ* observation of fatigue cracking processes was made using a fatigue testing machine mounted in a scanning electron microscope. It was found that Ti–4.5Al–3V–2Fe–2Mo alloy with very fine α grains of approximately 2 μm exhibited a much higher fatigue strength at 10^7 cycles than Ti–6Al–4V alloy. However, in fatigue life an opposite trend was obtained in the short life regime. The observed fatigue behavior in both the long and short life regimes is discussed in terms of metallurgical factors responsible for the fatigue behavior of the present materials.

Evaluation of intergranular embrittlement of a low carbon steel in austenite temperature range

C. Nagasaki et al.

The hot ductility of a low carbon steel was investigated at various strain rates in austenite temperature range. The embrittlement with intergranular fracture occurs in the specimen deformed in lower temperature range of austenite following solution-treatment at higher temperature range of austenite, especially at 1680K just under the melting point. Sulphides are dissolved and sulphur is segregated to grain boundary by volume diffusion during the solution-treatment. Fine particles of FeS precipitate on grain boundaries during cooling to deformation temperatures. Voids are initiated at such fine precipitates because of incoherence with the matrix. The precipitation of FeS is caused by decrease in sulphur solubility with lowering temperature. The embrittlement occurs when a difference in the solubility of sulphur between at solution-treatment temperature and at deformation temperature reaches higher than 65 ppm. The critical reduction in area, at which brittle fracture was distinguished from ductile fracture, was 60%. The intergranular fracture feature depends on strain rate. At high strain rates, the specimen was fractured after plastic deformation and the dimple pattern is found in the intergranular fracture. At low strain rates, the specimen was fractured with extremely small plastic deformation after a crack is initiated and intergranular decohesion fracture is found. The energy required for crack propagation is calculated to be 3.45 J/m^2 at low strain rates.

Reassessment of the solubility of TiC and TiN in Fe

L. F. S. Dumitrescu et al.

The experimental information on the solubility in the various Fe phases of TiC, TiN and solutions between them has been assessed using thermodynamic modelling. A set of values for the model parameters is proposed and it is capable of reproducing the experimental information with reasonable accuracy. It is noted that the TiC–TiN solution was found to have a small negative deviation from ideality. A previous assessment resulted in a strong, negative deviation from ideality but it did not reproduce all the information on the solubility very well.

High temperature deformation behavior of carbon steel in the austenite and δ-ferrite region

D. J. Seol et al.

Stress–strain relations of carbon steels in the γ phase and δ phase regions have been analyzed through the high temperature tensile tests at various temperatures from 1100 to 1450°C and strain rates from 10^{-4} to 10^{-2}/s using Gleeble system. During hot tensile test, a ceramic fiber tube was used to reduce the radial temperature gradient in the heated specimen. The flow stresses of carbon steels varied not only with the test temperatures and strain rates, but also with the process condition of cooling rate. The measured flow stress of δ phase was lower than that of γ phase. The degree of strain hardening of δ phase was negligible compared with that of γ phase. A simple constitutive equation, which takes into account temperature, strain and strain rate, could successfully describe the measured flow stress of carbon steel by hot tensile test. The calculated flow stress was in good agreement with experimentally measured data.