Fundamentals of High Temperature Processes

Electro slag crucible melting for recycling of low oxygen high conductivity copper scrap

V.V.SATYAPRASAD et al.

Recycling of oxygen free high conductivity (OFHC) copper scrap was carried out through a modified electro slag melting technique using a graphite electrode and graphite crucible. Of the three slags used, a cryolite based slag was found to yield copper ingots with low (2 to 40 ppm) oxygen content and high (upto 98 % IACS) conductivity. A slag as well as graphite of high purity are essential since the impurities resent in the slag and graphite may contaminate the copper during melting. Possible mechanisms of impurity (Fe, Si, Mg, Ca and S) pick-up by copper are discussed. Identical results were obtained using cathode copper instead of OFHC copper scrap indicating that the process may be used to produce low oxygen high conductivity copper ingots directly from cathode copper.

Incorporation of chlorine in a secondary steelmaking slag based on the $CaO-Al_2O_3-SiO_2$ system

F.PATSIOGIANNIS et al.

$CaO-Al_2O_3-SiO_2$=50-42-8 wt% eutectic slags, similar in composition to a secondary steelmaking slag, containing 1-15 wt% $CaCl_2$ were heated to 1 798 K. DTA was performed and the system was cooled. Samples were characterized by electron microprobe and X-ray powder diffraction. Four main crystalline phases were present, $CaO.Al_2O_3$, $2CaO.Al_2O_3.SiO_2$, β-$2CaO.SiO_2$ and $11CaO.7Al_2O_3.CaCl_2$. The chlorine phase was very similar to the mayenite phase ($12CaO.7Al_2O_3$). It forms first at 1 321 ($\pm$27) K and remains solid as a separate phase because of its high melting point. The rest of the system upon cooling crystallized according to the well known $CaO-Al_2O_3-SiO_2$ phase diagram. It was seen that if chlorine is present in sufficient amounts (greater than 4.9 wt%) the chlorine phase constitutes 92 % by weight of the final slag. Also when the chlorine phase was less than 92 % by weight in the final slag, the recovery of chlorine was over 90 %. For comparison, $CaO-Al_2O_3-SiO_2$=48-12-40 wt% representing an ironmaking slag, was mixed with 10.0 wt% $CaCl_2$ and also similarly heated and characterized after cooling. The phases observed were $2CaO.Al_2O_3.SiO_2$ and two new chlorine phases all of which were glassy.

Modelling of fluid flow conditions around the slag/metal interface in a gas-stirred ladle

L.JONSSON et al.

A three-phase model of a gas-stirred steel bath covered with a slag layer has been developed. Predicted steel surface velocities have been shown to be in at least five times greater agreement with experimental data compared to predicted velocities from a model which excludes the effect of a slag phase. It has also been shown that it is possible to predict the amount of slag dispersed into the steel.

Ironmaking and Reduction

Kinetics of aluminothermic reduction of MnO_2 and Fe_2O_3 : a thermoanalytical investigation

B.SARANGI et al.

This paper presents the main kinetic parameters for aluminothermic reduction of MnO_2 and Fe_2O_3. Aluminothermic reduction which in fact is a redox reaction requires an initial input of heat which is obtained through external reaction and/or oxidation of aluminium. In a system where oxidation as well as reduction take place simultaneously it is difficult to predict the kinetics of either reduction or oxidation. The present work aims at to describe the kinetics of reduction of MnO_2 and Fe_2O_3 during aluminothermic reductions using simultaneous DTA/TG technique. If one understand the aluminium oxidation reaction then kinetics for the reduction of MnO_2 and Fe_2O_3 can be obtained from DTA data for the overall reaction.

Using suitable calibration constant a theoretical DTA curve is generated from the TG data to describe oxidation of aluminium. The oxidation data were deducted from the overall DTA data on redox reaction to obtain data on reduction only. The rate of generation of peak area for MnO_2 and Fe_2O_3 thus obtained was a measure of reduction reaction rate.

Prediction of a blast furnace burden distribution variable

M.J.NIKUS et al.

A model for prediction of a variable that characterizes the burden distribution in the blast furnace is presented. The neural network model makes use of short-term temperature measurements from an above-burden probe as well as information about the charging program, and predicts a normalized temperature change, which can be considered to reflect the burden distribution. The basic structure of both an on-line and an off-line model is presented. By applying the models on process data from a Finnish blast furnace it is demonstrated that accurate predictions are obtained of the temperature changes caused by the dumps for the entire charging cycle.

Activity coefficient of silicon in molten Fe-C-B-Si alloy

X.HUANG et al.

The activity coefficient of silicon in the molten Fe-C-B-Si alloy was determined by conducting the following measurements:

i) Equilibrium contents of boron in the Fe-B-Si-N alloys saturated with solid BN under $Ar+N_2$ gas mixture at 1 723 K.
ii) Solubility of carbon in the molten Fe-C-B-Si alloy at 1 573 and 1 723 K.
iii) Equilibrium distribution of silicon between the molten Fe-C-B-Si alloy and molten silver at 1 723 K.

By using the interstitial solution model, the activity coefficient and the interaction parameters of silicon in the Fe-C-B-Si alloy were determined to be:

$\theta_B^{Si}=7.54$ ($y_{Si}<0.15$, 1 723 K),

$\ln\psi_{Si}^{o}=-8.7$, $\theta_{Si}^{Si}=18.4$ ($y_{Si}<0.2$, 1 723 K),

$\theta_c^{Si}=\dfrac{297\,000}{T}-2.63$ ($y_{Si}<0.4$, 1 573~1 873 K)

Casting and Solidification

Numerical analysis on cold crucible using 3DH-ϕ method and finite volume method with non-staggered BFC grid system

P.-R.CHA et al.

Generally, numerical analysis of MHD systems including cold crucible requires much amounts of calculating resources. These systems often include 3D electromagnetic field, fluid flow in irregular boundaries, solidification, even coupling between electromagnetic field and fluid flow. Two kinds of basically different simulation techniques are necessary for effective calculation of these MHD systems. These are FEM (Finite Element Method) for calculation of electromagnetic field and FVM (Finite Volume Method) with BFC (Body Fitted Coordinate) for fluid flow. But many researchers have been tried to solve these problems by other methods because the use of the combined method consumes large quantity of memory and computing time. Most of numerical models on cold crucible do not include the analysis of fluid flow. For calculation of electromagnetic field, 2D axisymmetric wire model, it's improved model or Boundary Element Method have been widely used instead of fully 3D FEM.

In this study, 3D H-ϕ formulation for electromagnetic field by FEM and a technique using non-staggered grid system for fluid flow by FVM with BFC were employed to save the memory space and calculation time in numerical analysis of cold crucible. A package of numerical models including electromagnetic, fluid dynamic, heat transfer and solidification model was constructed and applied to the numerical simulation of cold crucible. Validity of the electromagnetic model was confirmed

by comparison between the results from calculation and those from direct measurement. Verification of the developed code on fluid dynamic calculation was carried out by its comparison with the commercial code PHOENICS. Influence of some important operating parameters on the meniscus shape and solidification front were investigated using the developed package. Temperature distribution in the molten tin was uniform because of the circulating flow induced by non-uniform distribution of electromagnetic force and the heat transfer through mold wall at the melt-mold contacted region was noticeably reduced as a result of magnetic pressure.

Criteria for water modeling of melt flow and inclusion removal in continuous casting tundishes

Y.SAHAI et al.

Water modeling of tundish melt flows offers useful insight into the underlying flow phenomena occurring in the tundish. Most of the water modeling studies have been carried out under isothermal conditions with water at room temperature, and have employed full as well as reduced scale models. In water modeling, a reduced scale model can not simultaneously satisfy the Reynolds as well as Froude similarity criteria. Many industrial modeling studies have employed full scale models while many university researchers have used small scale models based on the Froude similarity criterion. This paper discusses the importance and validity of these criteria. For simulation of inclusion flotation in water models, gravitational force becomes important. The choice of model inclusion to water density and the model inclusion size needed for proper simulation of a given inclusion size in molten steel are discussed. A criterion for quantitative determination of inclusion agglomeration in the water model is also suggested. Thus, a procedure and appropriate criteria for water modeling of flow and inclusion flotation and removal are outlined.

Physical modeling of tundish plasma heating and its mathematical interpretation

J. de J.BARRETO-SANDOVAL et al.

Steel flow and heat transfer in tundishes heated by plasma is physically modeled using a water model with tracer injections and the experimental results are interpreted through a turbulent k-ε mathematical model. The thermal modeling was carried out using step temperature inputs to decrease by 7 K the initial water temperature followed by a heating stage by a steam jet that simulates the plasma heating process of liquid steel in the tundish. To make valid the scaling operation of the plasma heating from the steam jet experiments a dimensionless plasma heating number was derived.

The thermal response of the cooling-heating cycles was well predicted by a double dispersion coefficient model. On the other hand, the mathematical model indicates that the steam jet acts as a brake of the velocity for the liquid volume just under its direct contact lossing momentum. This loss of momentum is compensated by slight increases of the liquid velocities in the liquid volumes that are out the direct action of the steam jet.

Forming Processing and Construction

Processing and properties of 3-layer laminated composites based on ultra high carbon steel and mild steel

G.BANU PRAKASH BABU et al.

A combination of high temperature and low temperature hot rolling has successfully been used to prepare 3-layer laminated composite strips based on Ultra High Carbon Steel (UHCS) and Mild Steel (MS), having good interfacial bonding, no profuse carbon diffusion across the interface and fine spheroidized structure. No electron beam welding of the starting UHCS and MS plates at the edges was necessary.

It has been shown that high temperature % elongation at fracture depends upon the volume fraction of UHCS in the composite strip. Despite a relatively high strain rate sensitivity value, a 70 % elongation has been observed for the 3-layer UHCS-MS composite strip having 0.7 volume fraction of UHCS at 670°C and 3×10^{-4} sec^{-1} strain rate. Although the UHCS layers exhibit superplastic behaviour at the chosen experimental conditions, the MS layer do not. This results in extensive damage in the MS layer leading to premature failure of the composite strip.

It has been demonstrated that the high temperature % elongation at fracture can be improved upon by increasing the number of layers while keeping the volume fractions of UHCS and MS constant.

Microstructure

Microstructure and mechanical properties of strip cast 1008 steel after simulated coiling, cold rolling and batch annealing

A.GUILLET et al.

As-cast low carbon steel strips produced by twin roll strip casting process were treated by cold rolling and batch annealing. The microstructure and mechanical properties were compared to those of drawing and commercial quality strips. The mechanical properties of the as-cast strip are inferior to those of an industrial hot band due to the presence of Widmannstätten ferrite microstructure. After simulated coiling, cold rolling and batch annealing the ductility of the strip cast steel is lower than that of the industrial products, due to the hardening effect of small Cu-S precipitates and coarser iron carbides. However, for the strip cast steel processed according to a drawing quality (DQ) route, the mechanical properties are within the range of a commercial quality (CQ) product. Therefore, mechanical properties falling within the range of commercial quality steel can be obtained with strip cast steel without a hot rolling step if appropriate cold rolling and annealing treatment is used.

Evolution of the microstructure in the processes of hot compression and drawing-rolling

Z.KEDZIERSKI et al.

The paper deals with the problem of the prediction of the microstructure evolution during the hot deformation of carbon-manganese steels. The objective of the work is the validation of the approach which incorporates an advanced thermal-mechanical finite-element model with the conventional closed form equations describing processes of static recrystallization and grain growth. Two types of the experiments are performed. The first is a typical multistage hot compression test for the axisymmetrical samples. The second is hot drawing of the flat samples through a set of the roller dies. An influence of initial grain size, starting temperature, strains and interpass times is investigated. The results include validation of various equations describing austenite grain size and kinetics of static recrystallization for the carbon-manganese steels.

Physical and Mechanical Properties

Effect of dispersoids on tensile deformation of Fe-20Cr ODS alloys

Y.KAWASAKI et al.

Tensile deformation properties of nine kinds of mechanically alloyed Fe-20Cr-based oxide dispersion strengthened (ODS) steels were examined over a temperature range from 300 to 1 073 K. One of the specimens used was an alloy without any addition of oxide and the others were eight kinds of ODS alloys with the addition of Y_2O_3, Al_2O_3, SiO or ZrO_2. All of the alloys had fine grain structures. With the addition of Y_2O_3 the 0.2 % yield stress of Fe-20Cr alloys increased all over the temperature range, and the work-hardening following the yield at 300 and 673 K also increased considerably. But at higher temperatures than 673 K, the increment of work hardening due to the oxide dispersion was small. Fracture elongation at 673 K was found to be about 5 %, while those at 873 and 1 073 K were more than 17 %. The dispersion strengthening due to the other oxides, Al_2O_3, SiO and ZrO_2 were very small except that of ZrO_2 at 1 073 K.

New Materials and New Processes

Effect of hot working on room temperature mechanical properties and stress-rupture behaviour of ESR processed Fe-16 wt. % Al intermetallic alloy

R.G.BALIGIDAD et al.

The effect of hot working (forging) on structure and mechanical properties of electroslag remelted (ESR) Fe_3Al based intermetallic alloys containing approximately 16 wt.% (28 at. %) aluminium and 0.013 to 0.50 wt.% carbon are reported. The ESR alloys having low (0. 013 to 0.06 wt.%) carbon content were severely cracked during forging probably due to the presence of pre-existing microcracks. ESR ingots with high (0.14 to 0.50 wt.%) carbon content were successfully forged at 1 000°C. At high (60 % or more) forging reductions the cast columnar structure of ESR alloys was transformed into recrystallized grain structure. The room temperature mechanical properties did not improve significantly after forging. During creep and stress-rupture tests carried out at 600°C and 140 MPa, the cast ESR ingot with columnar structure exhibited lower minimum creep rate and higher creep life than those exhibited by the corresponding forged ingots with recrystallized grain structure. There is only a marginal improvement in creep life with increase in carbon content from 0.14 to 0.50 wt. %. The stress-ruptured specimens exhibited predominantly ductile dimple failure with elongations in excess of 50 %. The creep and stress -rupture properties of the alloys with high (0.14 to 0.50 wt.%) carbon contents are better than those reported for wrought Fe-16wt.%Al alloys with low (<0.01 wt.%) carbon contents. This may be attributed to the presence of uniformly distributed Fe_3AlC precipitates as well as the interstitial carbon present in the alloys.

Modeling of the flow, temperature and concentration fields in an arc plasma reactor with argon-nitrogen atmosphere

A.M.FUDOLIG et al.

A mathematical formulation was developed for describing the flow behavior, temperature profile and concentration fields in pure or mixed argon and nitrogen arc plasmas impinging on a metal target inside a reactor. The simulation involves solution to conservation equations of mass, momentum, energy, $k-\varepsilon$ model, chemical species, and current continuity. "Combined" diffusion coefficients were used in chemical species conservation to account for all species present in the plasma. An increase in the proportion of nitrogen introduced in the reactor results in higher arc velocity and temperature, reduced arc column diameter and increased heat flux imparted to the metal target. Demixing resulted to an increase of mass fraction of nitrogen at the central portion of the arc.