Fundamentals of High Temperature Processes

Thermodynamics of Mn-O interactions in liquid copper alloys and activities of MnO in MnO-SiO_2 slag

AHMAD SOBANDI et al.

As a provision for measuring the thermodynamic data of high MnO slag by equilibrating with liquid copper in the temperature range of hot metal pretreatment, thermodynamics of manganese-oxygen interactions in liquid Cu-Mn alloy were investigated. The liquid alloys containing 0.2～1.0% mass% Mn were equilibrated with solid MnO in a molybdenum crucible under an argon atmosphere. The following equations for the interaction coefficient (f_O^{Mn}) were obtained for the range of 0.2～1.0mass% Mn.

$\log f_O^{Mn} = -0.8122 - 1.27[\%Mn] + 0.37[\%Mn]^2$ at 1 573 K

$\log f_O^{Mn} = -0.7536 - 1.14[\%Mn] + 0.33[\%Mn]^2$ at 1 623 K

$\log f_O^{Mn} = -0.6189 - 1.07[\%Mn] + 0.37[\%Mn]^2$ at 1 673 K

Using the above values of f_O^{Mn}, the activities and activity coefficients of MnO in MnO-SiO_2 slag were determined at 1 673 K and examined in comparison with the values reported by other investigators.

Expansion of injected gas bubble and its effects on bath mixing under reduced pressure

T. TATSUOKA et al.

The behavior of a single bubble was observed and the complete mixing time was measured under reduced pressure (～1.33×10^2Pa (1 Torr)) using a silicon oil model. The bubble expanded greatly and changed from oval to a spherical-cup shape. The complete mixing time tended to be constant independent of the stirring power of gas perunit bath volume in the low vessel pressure range (<6.66×10^2 Pa), because most of the expansion energy was dissipated and the mixing occurred near the bath surface; this was confirmed by observation of the flow.

Ironmaking and Reduction

Thermodynamics of Fe_tO-TiO_2-SiO_2 melts in equilibrium with solid iron

K. MATSUZAKI et al.

The activities of Fe_tO in a Fe_tO-TiO_2-SiO_2 system in equilibrium with solid iron at 1 623 and 1 673 K were measured by equilibrating molten slag with a H_2-CO_2 gas mixture. The iso-activity contour of Fe_tO for this system was calculated and influence of slag composition on the activity coefficient of Fe_tO and the Fe^{3+}/Fe^{2+} ratio was determined. On the assumption that the Fe_tO-TiO_2-SiO_2 system is based on an ideal mixture of the pseudo-binary components, the activities of SiO_2 and TiO_2 were estimated using Richardson's method.

A model for softening and resolidification of coals heated at different rates

K. MATSUOKA et al.

Needle penetration and dilation characteristics were examined for cylindrical coal pellets upon heating. The net penetration depth obtained from the observed penetration and dilation curves was analyzed by an equation of motion to derive the apparent viscosity of coal. Mass loss due to volatiles release and yields of pyridine extract were also measured for the pellets. These experiments were carried out for a range of the heating rate from 1 to 50 K/min, the holding temperature from 773 to 823 K and the nitrogen gas pressure of 1.0 MPa and the results depended on the operating variables as well as coal nature. Changes of the apparent viscosity with heating were well explained by a simple model with the following assumptions: 1) Coal behaves instantaneously as a Newtonian fluid. 2) Coal consists of two reactive components; one converting to semicoke *via* an intermediate along with volatiles release and the other converting to volatiles directly. 3) The intermediate is represented by the pyridine extract and behaves as a liquid while the others, *i.e.*, unreacted coal, semicoke and ash as solids. 4) Apparent viscosity change is described by Vand's equation for slurry combined with Andrade's equation for liquid viscosity.

Model study of liquid flow in the blast furnace lower zone

G.X. WANG et al.

Countercurrent gas-liquid interactions in the lower zone of a blast furnace play an important role in achieving stable operations with high productivity and efficiency. Previous gas-liquid flow models for the blast furnace did not adequately consider both the discrete nature of liquid flow and the strong, localised gas-liquid interactions occurring in the cohesive zone, which have been elucidated experimentally. The present work details a two-dimensional numerical model and a cold two-dimensional physical model, used to study gas-liquid flow in the blast furnace cohesive zone. The numerical model utilises a force balance approach to describe the discrete liquid flow and a stochastic treatment to take into account the complex packing structure. The validity of this model was demonstrated by the good agreement between model predictions and experimental observations. The model can be applied to simulate gas-liquid two-phase flow in a layered packing with multiple liquid sources, similar to the blast furnace lower zone condition.

Forming Processing and Construction

The weldability of modern structural TMCP steels (Review)

B. DE MEESTER et al.

The basic principles of the thermomechanical control process (TMCP) are recalled. The chemical compositions, mechanical properties and weldability of TMCP structural steels, especially those with a yield strength between 355 and 500 MPa, are reviewed with a special attention given to the work produced by IIW Commission IX: "Behaviour of metals subjected to welding".

Microstructure

Ferrite formation characteristics in Si-Mn TRIP steels

A. ZAREI-HANZAKI et al.

If the austenite-to-proeutectoid ferrite reaction is the first phase transformation which occurs during cooling of a hypoeutectoid steel, growth of ferrite takes place by rejection of carbon into the untransformed austenite, such that the carbon content of the austenite increases with increasing ferrite volume fraction. The carbon enrichment of austenite affects the state of retained austenite in the final microstructure. Such an effect is important when designing microstructures of transformation induced plasticity (TRIP) steels, which are a new class of high formable steels. These grades of TRIP steels, which are in excess of Si and Mn, make use of ferrite and bainite as the major micro-components. This work details the results of a systematic investigation on the ferrite formation characteristics and their effects on the state of the retained austenite. The results showed that the retained austenite volume fraction increases with the amount of ferrite and, after a plateau. decreases. Furthermore. the presence of acicular ferrite resulted in a significant increase in the quantity of the retained austenite.

Experimental study on diffusion induced recrystallization in Cu/Fe/Cu diffusion couples using Cu single crystals

Y. KAWANAMI et al.

Diffusion induced recrystallization (DIR) in a face-centered-cubic (f.c.c.) Fe phase was experimentally studied in the Fe (Cu) system. The notation Fe (Cu) means that Cu atoms diffuse into a pure Fe or binary Fe-Cu phase. The Cu/Fe/Cu and Cu/(Fe-4.8Cu)/Cu diffusion couples consisting of a polycrystalline Fe phase specimen and pure Cu single crystals with the same crystallographic orientation were annealed at 1 193 and 1 323 K for various times between 3.0×10^2 and 8.6×10^4s. The penetration of Cu in the f.c.c. Fe phase was found to occur at rates 100 times greater than the one evaluated from the volume diffusion.

This unusually rapid penetration is due to DIR, which takes place in the Fe phase from the interfaces of the diffusion couples. DIR was observed to occur only in the Cu/(Fe-4.8Cu)/Cu diffusion couples annealed at 1 323 K under the present experimental conditions. The thickness w of the Fe phase decreases with increasing annealing time t according to the equation $w/w_0=1-7.09\times10^{-8}(\sqrt{t}/w_0)$, whereas the thickness l of the DIR region increases with increasing annealing time according to the equation $l=1.58\times10^{-6}(t/t_0)^{0.29}$. Here, w_0 is the initial thickness of the Fe phase, and t_0 is unit time, 1 s. The thicknesses w, w_0 and l are measured in m, and the annealing time t is measured in s.

Influence of AlN precipitation on thermodynamic parameters in C-Al-V-N microalloyed steels

N.GAO et al.

An estimation of the equilibrium compositions of the austenite and carbonitride phases, as well as the mole fraction of each phase in C-Al-V-N microalloyed steels at different austenitising temperatures was made by calculations based on experimental data. Further, a comparison of the mole fraction was made from two thermodynamic models due to Adrian and Rios, with and without considering aluminium in the steels. The results indicate that both models produce very similar results and can be used to calculate the equilibrium parameters and predict the solution temperature of carbonitrides and aluminium nitride in the range 800-1 300℃ for an alloy system contained up to three microalloying elements and aluminium. Both models predict that most of the carbon remains in solution at the calculated temperature. When AlN precipitation is included in the calculation, it is seen that the mole fraction of the carbonitrides f_p and the atomic fraction of carbon in the interstitial lattice of the carbonitrides f_c decreases, while the atomic fraction of nitrogen in the interstitial lattice of carbonitride f_N, increases. The effect of aluminium on these equilibrium parameters depends on the chemical composition of the steel. Increasing the contents of Al, N, C, and V together in the experimental steesls has a more significant influence on these equilibrium parameters than changing only the contents of Al; Al and V or Al and N.

Physical and Mechanical Properties

New corrosion resistant iron-based shape memory alloys

H.LI et al.

The development of two low cost, corrosion resistant Fe-Mn-Si based shape memory alloy systems: Fe-Mn-Si-Al-Cu and Fe-Mn-Si-Cr-Cu is discussed. The new alloys exhibited a shape memory capacity which is clearly superior to traditional Fe-Mn-Si ternary alloys. Corrosion test results indicated that the new alloys have good corrosion resistance in acid solutions. In addition, anodic polarisation measurements established that alloying with copper increases the passivity of the corrosion film formed in the passive potential range and indicated that Cu improves the general corrosion resistance.

Calculation of the effect of texture on the Snoek peak height in steels

K.ELOOT et al.

Contrary to the effect of substitutional atoms and grain size, the influence of crystallographic texture on the Snoek peak height of carbon and nitrogen in internal damping experiments rarely has been considered quantitatively. Therefore, in this paper the orientation dependence of the Snoek peak height (Q^{-1}_{max}) of carbon and nitrogen is calculated both for the very popular torsion pendulum (operating at about 1 Hz) and for the recently developed Automated Piezoelectric Ultrasonic Composite Oscillator Technique (APUCOT), working with longitudinal resonation at 40 kHz. The distribution function of the calculated proportionality factor $K_Q(=Q^{-1}_{max}/C_i$; C_i is the interstitial concentration) is represented in the Euler space, facilitating not only the interpretation of the results, but also the calculation of K_Q for experimentally measured textures. The latter can be done by making the convolution product of the orientation distribution function (ODF) of the measured texture and the distribution function of K_Q. The K_Q-values of the most important texture components and fibers of low carbon steels are calculated and compared with the renges of the experimentally determined proportionality factors found in the literature for anelastic relaxation by carbon and nitrogen atoms.

Effect of texture on the height of the Snoek peak in electrical steels

K.ELOOT et al.

The most important foctors affecting the Snoek peak height of carbon in commercial steel sheets are shortly reviewed. It is shown that the proportionality factor $K^*_Q(=Q^{-1}_{max}/C_i)$ – for a given interstitial and a given internal damping technique-mainly is affected by the steel texture and the presence of substitutional atoms. The influence of texture and composition is illustrated for four non oriented electrical steels with Si-contents between 0 and 1.8 %. This difference in Si-content, combined with differences in C-content between the internal damping specimens, resulted in significant texture changes, providing an interesting frame not only to apply the theory on the orientation dependence of the calculated proportionality factor K_Q (developed in a previous paper), but also to discuss the effect of alloying elements on the Snoek peak height. The proportionality factors of the experimentally measured textures are calculated by making the convolution product of the orientation distribution function (ODF) of the measured texture and the distribution function of K_Q. Doing so, the effect of texture on the experimentally measured K^*_Q can be separated from the direct effect of the substitutional elements (mainly Mn, Al and Si). The latter effect is discussed in terms of the elastic strain present around substitutional atoms due to their size difference with Fe atoms.

New Materials and New Processes

Prediction of surface temperature on metal beads subjected to argon-hydrogen transferred arc plasma impingement

A.M.FUDOLIG et al.

Surface temperatures of metals subjected to transferred arc plasma impingement in 100 % argon and Ar-H_2 (90 : 10 and 70 : 30 by volume) mixed gas arc plasmas are predicted based on a combined mathematical model of the arc plasma and the metal bead. The numerical simulation involves solution to conservation equations of mass, momentum, energy, and current continuity of the arc plasma and the target metals of Nb and Ta. An increase in hydrogen content of the introduced gas resulted to higher surface temperatures as well as an increase in the size of the molten pool. Predicted threshold arc current that causes an onset of melting is in good agreement with experiment.

Numerical analysis of the flow characteristics and temperature distribution in metal beads subjected to transferred arc plasma impingement

A.M.FUDOLIG et al.

Flow characteristics and temperature distribution in metal beads subjected to transferred arc plasma impingement is described based on combined mathematical models of the arc plasma and the metal target. This problem is of interest to ultrafine powders (UFP) generation by the "reactive arc plasma" process. The influence of operating parameters in this particular UFP production method on the heat and fluid flow in the metal are likewise examined. The flow behavior in the melt is characterized by a recirculating flow governed by electromagnetic forces. The size of the molten portion in the metal target is affected by the process gas and supplied current. The coolant temperature and gas inflow rate indicated no significant effect on the melt size.