（＊掲載記事題目及び掲載頁は変更になる場合があります。）

Fundamentals of High Temperature Processes

Carbide capacity of $CaO–SiO_2–CaF_2(–Na_2O)$ slags at 1 773 K

J.H.PARK et al.

The influence of CaF_2, Na_2O, and basicity on the solubility of carbon in the $CaO–SiO_2–CaF_2–Na_2O$ slag at 1 773 K was investigated on the basis of carbide capacity concept. The carbide capacity of the $CaO_{satd}–SiO_2–CaF_2$ system increases with increasing CaF_2 content up to about 40 mass%, followed by nearly constant value. The capacity of the slags saturated with Ca_2SiO_4 also increases with increasing the content of CaF_2 and this trend can be explained from the depolymerization reaction of silicate network by F^- ions. The carbide capacity of the slags increases by increasing the ratio of $(\%CaF_2)/(\%SiO_2)$ up to about 0.8, followed by slight increase or nearly constant value at a fixed CaO content. The capacity also increases by increasing the ratio of $(\%CaO)/(\%SiO_2)$ at a fixed CaF_2 content. The carbide capacity of the Na_2O-containing slags linearly increases with increasing the basicity, B ($\equiv\{(\%CaO)+(\%Na_2O)\}/(\%SiO_2)$) and the dependence of the capacity on the basicity decreases by increasing the CaF_2 content. On the other hand, the capacity decreases with increasing CaF_2 content at basicity, B of the slags greater than about 2.0 and *vice versa* in the composition of $B \leq 2.0$. The capacity of the slags containing CaF_2 and Na_2O could quantitatively be described by the activity of CaO rather than optical basicity.

(cf. *ISIJ Int.*, **44** (2004), 223)

Diffusional dissolution of alumina in various steelmaking slags

W.D.CHO et al.

Fast dissolution of nonmetallic inclusions such as alumina particles in molten slags has been required in secondary steelmaking—ladle and tundish—to minimize the amount and the size of nonmetallic inclusions in steel products. In the present work, the dissolution behavior of alumina particles in molten $CaO–Al_2O_3$ and $CaO–Al_2O_3–SiO_2$ slags at the temperatures between 1 500 and 1 550°C have been investigated in terms of kinetics and mechanism. Alumina particles were added directly into the slags and the variation of the particle size with time was determined using optical and electron microscopes. The conventional types of slag for ladle and tundish were included in the dissolution study. The effects of Al_2O_3, SiO_2, CaF_2 and MgO contents on the dissolution rate of alumina particles have also been determined. The diffusion boundary layer between alumina particle and bulk slag phase was observed and analyzed using SEM and EDS. Based on the analysis of kinetic data and the boundary layer, the dissolution mechanism has been discussed.

(cf. *ISIJ Int.*, **44** (2004), 229)

Dynamic interfacial phenomena between gas, liquid iron and solid CaO during desulfurization

J.LEE et al.

Interfacial phenomena between liquid iron and solid CaO is important due to the extensive use of solid CaO in steelmaking processes. In this study, the dynamic change in surface tension and contact angle of liquid iron (Fe–4mass%C–S) on CaO substrates during desulfurization was investigated at 1 623 K using a sessile drop technique with varying initial sulfur content (0.002–0.514 mass%). In addition, an electron probe microanalysis (EPMA), a field emission scanning electron microscope (FE-SEM) and an atomic force microscopy (AFM) were applied to investigate the interface between metal and substrates and the surface of the solid substrates. The surface tension increased rapidly just in a few minutes, and then approached an easy constant slope in every experiments. The contact angle decreased considerably with time for most samples, approaching a constant value. Exceptionally, the sample initially containing 0.002 mass% sulfur showed just slight decrease in contact angle. Based on experimental results, the dynamic reactive change in the work of adhesion of liquid iron on solid CaO was computed. The work of adhesion was increased by both the increase in the surface tension and the decrease in the contact angle. Especially, the change in the work of adhesion in the initial stage of desulfurization was considerable.

(cf. *ISIJ Int.*, **44** (2004), 235)

Kinetics of decomposition and re-oxidation resistance of θ- and χ-iron carbides at elevated temperatures and influence of their formation conditions

Y.IGUCHI et al.

The rate of decomposition of θ-ron carbide (Fe_3C) and χ-iron carbide (Fe_5C_2), which were produced by carburizing reduced iron from a hematite ore and a limonite ore with $80\%CO–H_2–H_2S$ mixture of $a_S=0.5$, was determined from their compositional change. Their decomposition starts from about 873 K with Fe_5C_2 and about 973 K with Fe_3C. To mass fraction variation curves of θ- and χ-iron carbide, the integrated rate equation for the first order reaction was applied to obtain the rate constant, k. The value of k for Fe_5C_2 is much greater than that for Fe_3C. Fe_5C_2 firstly decomposes to Fe_3C plus carbon and secondly the formed Fe_3C decomposes to metallic iron plus carbon. Microscopically, the metallic iron grows as if the flat interface between Fe_3C and metallic iron propagates through the grain of Fe_3C. And the iron carbide and formed metallic iron are always in front of pore. Therefore, the gas molecules in the atmosphere can react with the carbide, metallic iron and carbon throughout the reaction. The re-oxidation in dry air accelerated by the exothermic reaction for both iron carbides begins from about 623 K. The reason why the re-oxidation starts at the lower temperature than the decomposition does is direct oxidation of Fe_5C_2 and Fe_3C to iron oxides and CO_2 before their decomposition. The re-oxidation starting temperature is raised by the increase of the temperature of reduction and carburization, but the improvement is not very large.

(cf. *ISIJ Int.*, **44** (2004), 243)

Sulfur sorption rate and equilibrium content of reduced iron in $H_2–H_2S$ mixtures

Y.IGUCHI et al.

Contents and rates of the sulfur sorption on the reduced iron from hematite and limonite were measured in the atmosphere of $H_2–H_2S$ mixture of sulfur activity less than unity by combining the thermogravimetric method with the reaction interruption method. The sulfur content by the former was a half the content by the latter presumably owing to the sorbed sulfur exchanged with sorbed oxygen. In this study, the saturated content of sulfur, which is attained after enough long time, was estimated by the latter and the sorption rate was measured by the former. The equilibrium content was properly expressed by the Langmuir's isotherm. The simulation of the sorption rate by the parallel model, in which the diffusion of gas molecules in the pore and the diffusion of adsorbed species on the wall of the pore were taken into account, was tried. It was successful with the sulfur sorption of the reduced iron from limonite and the diffusion was mainly surface diffusion at 873 K, but it gradually shifted to the diffusion in pore with increasing temperature. But any trial was unsuccessful with that from the hematite. The reason may be attributed to, in the reduced iron from the hematite, the contribution of sulfur segregated on the grain boundary of reduced iron is significant relative to the total sorption content to the content of sulfur adsorbed on the surface pore.

(cf. *ISIJ Int.*, **44** (2004), 250)

Feasibility study for recovering waste heat in the steelmaking industry using a chemical recuperator

N.MARUOKA et al.

This paper studies the possibility of developing a new heat recovery system from various hot wastes generated by the steelmaking industry, by utilizing the endothermic heat of reaction instead of sensible heat. In the proposed system, the waste heat of the gas was first stored using a Phase Change Material (PCM), and then supplied to an endothermic, methane–steam reforming reaction (MSR) as a heat source. The molten slag was granulated using a rotary cup atomizer (RCA) and the sensible heat of the slag was recovered using MSR. A heat and material balance model was developed to evaluate this system and to predict all its operating data. An exergy analysis and an economic evaluation were conducted on the basis of the predicted data. The results showed that the exergy loss in the proposed system was only 15% from the total exergy losses in the conventional system, and that the annual cost benefit of the proposed system totaled US$ 409 million from heat recovery, and US$ 1 945 million from slag granulation.

(cf. *ISIJ Int.*, **44** (2004), 257)

The dissolution rate of solid lime into molten slag used for hot-metal dephosphorization

T.HAMANO et al.

Highly efficient dissolution of CaO into melt has an important role in reducing the amount of steelmaking slag produced in the hot-metal dephosphorization process because the existence of free-CaO in the melt prevents reuse of the slag. There are numerous studies related to the rate of CaO dissolution, however, in

many cases the experimental conditions have been limited. The present work measured the dissolution rate of CaO into several kinds of slags: Fe_tO–CaO–SiO_2–X (X; CaF_2, $CaCl_2$, Al_2O_3 and B_2O_3) systems at hot-metal temperatures. To apply the results to practical operations, the efficiency of additives in dissolving CaO in the melts was compared using "the enhancement factor" based on the results.

(cf. *ISIJ Int.*, **44** (2004), 263)

Performance evaluation of arc ash melting systems by computational simulation

H.NISHIYAMA et al.

For the optimization of arc ash melting process, present study has proposed the new numerical model to consider the arc–electrodes boundary condition without assumptions and also the complex interactions between the arc flow and molten soil interface with phase change. The effects of arc current, inlet gas flow rate, electrode gap and cathode vertex angle on the thermofluid field and net effective process efficiency of arc–ash melting systems are clarified by computational simulation.

(cf. *ISIJ Int.*, **44** (2004), 268)

Acoustically controlled behavior of dust particles in high temperature gas atmosphere

S.V.KOMAROV et al.

The present study focuses on the behavior of dust particles in a high temperature gas atmosphere exposed to powerful standing sound waves. Six resonance frequencies within the range of 0–1 000 Hz were chosen for the experiments because they provide high values of sound pressure in the working space. The particles (0.1~80 μm) were produced by evaporating a sample of Zn at temperature about 1 173 K under Ar atmosphere, cooling the Zn vapor and transferring the formed particles to a sonoprocessing chamber for sound exposure. The particle samples were taken at the upper place of the chamber, and the samples were analyzed for size distribution and number density in the gas phase.

Application of sound waves is found to result in enlargement of particles (acoustic agglomeration), and reduction of their number density and concentration in the gas. The experiments showed that the particle agglomeration is enhanced as the sound pressure amplitude increases, while the effect of sound frequency played a smaller role in the particle behavior. In the frequency range tested, the most evident agglomeration effect was obtained at frequencies of 210 and 991 Hz at which a 50% increase in particle size and 60% decrease of particle number density in exhaust gas can be achieved in comparison to the corresponding values without sound application. The experimental results are discussed on the basis of the orthokinetic mechanism in relation to the acoustically forced oscillation and collision between the differently sized particles.

(cf. *ISIJ Int.*, **44** (2004), 275)

Production of niobium powder by preform reduction process using various fluxes and alloy reductant

T.H.OKABE et al.

In the previous study of the authors, a preform reduction process (PRP) based on the magnesiothermic reduction of a feed preform containing niobium oxide (Nb_2O_5) was established with the aim of minimizing contamination during the reduction process, and its effectiveness in producing fine niobium powder was demonstrated. In this study, various species of fluxes (*e.g.*, $CaCO_3$, $CaCl_2$, Na_2CO_3, and NaCl) were tested to find the optimum conditions for producing a homogeneous powder. Feed preform in the form of plates was fabricated by mixing Nb_2O_5 powder, flux and binder. The sintered solid preform containing Nb_2O_5 with various flux compositions was placed in a stainless steel container, and reacted with magnesium vapor at a constant temperature ranging between 1 073 and 1 273 K. Niobium powder with a purity of 99 mass% was recovered from the reduced preform by acid leaching. When $CaCO_3$ or $CaCl_2$ flux with cationic molar ratio $X_{Cat./Nb}=1/5$ to 1/2 was used, a homogenous fine powder, around 1 μm in diameter, was obtained. Furthermore, an alloy reductant was used to decrease the activity of magnesium reductant with the aim of preventing nickel contamination. The use of an alloy reductant is found to be effective in eliminating the deposition of excess reductant on the preform and on other reaction components. It was found that the particle size of niobium powder can be reduced by using an Mg–Ag alloy instead of pure magnesium.

(cf. *ISIJ Int.*, **44** (2004), 285)

Ironmaking

Effect of reduction conditions on the swelling behaviour of cement-bonded briquettes

M.SINGH et al.

Cement-bonded agglomerates of by-products generated in iron and steel plants are commonly used as burden material for blast furnaces. It has been observed that under certain conditions the briquettes containing pellet-fines show a tendency to swell catastrophically when reduced at 900–1 000°C using carbon monoxide as reducing agent. This swelling is dependent upon a number of factors like: reducing temperature, reducing conditions and composition of reducing gas. The optical micrographs do not show the formation of iron whiskers as the cause of swelling; instead, the reduced iron particles seem to move apart, thereby causing swelling. This paper describes the effect of various parameters that cause the abnormal swelling of briquettes.

(cf. *ISIJ Int.*, **44** (2004), 294)

Numerical analysis of static holdup of fine particles in blast furnace

S.PINTOWANTORO et al.

With increased in pulverized coal injection rate into blast furnace, the importance of understanding flow characteristics of powders within packed bed increases because more unburned char and coke fragments would be generated, it would be deteriorate permeability in the blast furnace. Although flow characteristics of dynamic or total holdup of powders in packed beds is found in several reports,[3-6] behavior of powders in blast furnace using separate treatment of dynamic and static holdup has yet to be reported. In this study the behavior of static powders was examined through numerical simulation using the "four fluid model",[3] which included the formulation of static powders behavior. The model results were compared with two dimensional temperature distributions measured in the furnace for three different pulverized coal injections (PCI) rates (100, 200 and 250 kg/thm) for validated. The model was applied to quantitative analysis of static powders holdup in the blast furnace operation with high-rate pulverized coal injection. The higher amount of static powders holdup was found mostly in the center lower deadman, above and below the tuyere level, and in upper shaft, for PCI rate 100 kg/thm, 150 kg/thm, 200 kg/thm and 225 kg/thm respectively. The lower amount of static powders holdup was found in the raceway region throughout the surface of deadman.

(cf. *ISIJ Int.*, **44** (2004), 304)

Mechano-chemical activation of magnetite concentrate for improving its pelletability by high pressure roll grinding

D.ZHU et al.

In this paper a study of the pretreatment of magnetite concentrate by using high pressure roll grinding (HPRG) is presented, which aims to improve the pelletability, reduce bentonite dosage and increase the iron grade of pellets. The effect of the HPRG parameters on the green pellet strength was investigated. The mechanism of the pretreatment of magnetite concentrate by HPRG was revealed by determining the surface activity by means of BET nitrogen adsorption, laser size analysis, scanning electron microscopy (SEM), X-ray diffraction (XRD), micro calorimeter and pelletability index. It is demonstrated that the surface activity is improved by increases in specific surface area and the amount of micron size fractions with favored plate and flake morphologies, and higher lattice deformation and defects, resulting in more wetting heat and higher pelletability index. The effect of the HPRG is concluded as mechano-chemical activation of the magnetite concentrate. All of which is further supported by the fact that the drop number of the green pellets increased to 4.9 times by pretreating the concentrate using the HPRG compared to 3.3 times without pretreating, and bentonite reduced by 50%.

(cf. *ISIJ Int.*, **44** (2004), 310)

Steelmaking

Analysis of hot metal desiliconization behavior in converter experiments by coupled reaction model

M.ISHIKAWA

The data in the hot metal desiliconization experiments were analyzed using the coupled reaction model and the reaction mechanisms were investigated. Desiliconization reaction is controlled by the mass transfer in the metal when (FeO) in slag is larger than 35 mass%. Higher (FeO) and agitation energy cause larger apparent volumetric rate constant V_{Si}. This seems to be a result of enhanced mass transfer in metal and slag caused by stronger agita-

tion, enhanced mass transfer in slag caused by higher (FeO) content in slag and larger driving force caused by higher oxygen activity at the slag/metal interface. Strong agitation and low (FeO) content in slag are effective for preferable desiliconization reaction with suppressing the decarburization reaction.

(cf. *ISIJ Int.*, **44** (2004), 316)

Fundamental mathematical modeling of gas injection in AOD converters

A. TILLIANDER et al.

A novel mathematical model of gas injection in the AOD converter process has been developed. The model is based on fundamental transport equations and includes separate solutions of both the steel and the gas phases and their coupling by friction. The inlet boundary conditions at the nozzle are predicted using a separate fundamental mathematical model of an AOD nozzle. This approach, together with the two phase solution, avoids the need to guess the inlet boundary conditions. The predicted gas plume has been compared to a plume from a scaled down water model of an AOD nozzle in a qualitative manner. The plume shapes are very similar, which indicates that the model predictions are of the right order of magnitude. The AOD model has also been used to predict fluid flow patterns, turbulence characteristics and bubble diameters.

(cf. *ISIJ Int.*, **44** (2004), 326)

Decomposition of Li_2CO_3 by interaction with SiO_2 in mold flux of steel continuous casting

J.-W. KIM et al.

The effect of SiO_2 addition on the decomposition of Li_2CO_3 was investigated using the thermo-gravimetric and differential scanning calorimetric method (TG-DSC) at temperatures up to 1 000°C. Addition of SiO_2 greatly enhanced the decomposition of Li_2CO_3. The main decomposition reaction began to take place around 600°C, and completed just above the melting point of Li_2CO_3. The decomposition product was $Li_2O \cdot SiO_2$ irrespective of the Li_2CO_3 to SiO_2 mixing ratio as long as both reactants were available. It was ascertained that a liquid layer between Li_2CO_3 and SiO_2 particles formed and facilitated the decomposition reaction. The governing reaction of the decomposition was the reaction between the dissolved Li_2CO_3 and SiO_2 in the liquid layer to form $Li_2O \cdot SiO_2$. The decomposition rate was independent of the Li_2CO_3/SiO_2 mixing ratio until either one had been completely exhausted. When excess Li_2CO_3 existed, it further reacted with the initial product of $Li_2O \cdot SiO_2$ to form $2Li_2O \cdot SiO_2$. When SiO_2 was found in excess, on the other hand, no further reaction took place. This is attributed to the fact that upon Li_2CO_3 exhaustion there is no liquid phase available to facilitate further reaction. The apparent activation energy of the decomposition of Li_2CO_3 in existence with SiO_2 is 198 kJ mol^{-1}.

(cf. *ISIJ Int.*, **44** (2004), 334)

Casting and Solidification

Improvement of in-mold electromagnetic stirrer by feeding of magnetic system with polyharmonic current

A.F. KOLESNICHENKO et al.

The elaboration relates to a method of electromagnetic stirring in continuous casting of carbon steels, when the surface quality and entrapping of nonmetallic inclusions still remain as the major problems concerning of ingot quality and success on the steel market.

The improvement of surface quality of ingot means a decreasing or elimination of oscillating mark, corner cracking, and pinholes. Intensity of nonmetallic particles entrapping depends on meniscus disturbance: inclusions do not penetrate into liquid portion of ingot through quiet meniscus. Based on the phenomenon of electromagnetic edge effect, which exists in each of asynchronous stirrer, by condition of feeding of magnetic system by polyharmonic currents the new method of in-mold electromagnetic stirring has been developed. Thanks to that the depth of oscillating marks decreases, the flow on the meniscus is suppressed, and the meniscus disturbance and inclusions entrapping is prevented.

(cf. *ISIJ Int.*, **44** (2004), 342)

Wood metal experiment of swirling flow submerged entry nozzle for round billet casting

Y. TSUKAGUCHI et al.

The swirling flow formation in the submerged entry nozzle has been proposed by Yokoya *et al.* as a fundamental and effective technology for controlling the flow pattern in the mold.[1-4] We started a joint study in 1997 with Nippon Institute of Technology, Osaka University and Kyushu Refractories to develop a swirling flow submerged entry nozzle as a root measure to improve flow pattern in molds.

As a first step of the development, the basic effect of the swirling flow in the single port submerged entry nozzle for the round billet casting was confirmed by a wood metal experiment, which forms upward flow along the mold wall caused by centrifugal force. As a result, we achieved conclusions as follows;

(1) The basic effect of the single port swirling flow submerged entry nozzle appears in the case that Swirl number in the nozzle S_W=0.3 or more, which forms upward flow along the mold wall.

(2) In the case that the swirling flow in the submerged entry nozzle and the M-EMS (Electromagnetic stirring in mold) were combined in the opposite direction of rotations by appropriate balance of intensity, the upward flow along the mold wall in the same level as the case without M-EMS was formed. It means that the outlet flow from the swirling flow submerged entry nozzle limited at the upper portion of the mold and the rotation flow formed by the M-EMS at the lower portion of the mold were separated clearly with less interaction.

(cf. *ISIJ Int.*, **44** (2004), 350)

Chemical and Physical Analysis

Measurement of inclusion size by laser ablation ICP mass spectrometry

A.V. KARASEV et al.

By using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), the measurement of particle size has been made for one component oxide (Al_2O_3 and MgO) and multicomponent oxide ($12CaO \cdot 7Al_2O_3$ and $CaO–Al_2O_3–MgO$) located on surface of iron or glass sample. The method of particle size estimation by LA-ICP-MS has been developed coupled with a new method of making samples with particles. The size calibration lines for Al_2O_3, MgO and CaO particles have been obtained. The results of particle size measurement by LA-ICP-MS are compared with those by SEM and single-particle optical sensing (SPOS) methods. It was confirmed that LA-ICP-MS has the perspective to be used for the quick measurement of inclusion composition and size in metal and other materials. The size frequency distributions of Al_2O_3 particles measured by LA-ICP-MS in iron samples with particles agree reasonably well with those by SEM and SPOS in the range of particle diameter from 2 to 20 μm. The size of Al_2O_3, MgO and complex oxide ($12CaO \cdot 7Al_2O_3$ and $CaO–Al_2O_3–MgO$) particles measured by LA-ICP-MS is in good agreement with that by SEM in the range of particle diameter from 10 to 40 μm.

(cf. *ISIJ Int.*, **44** (2004), 356)

Analysis of composition and size distribution of inclusions in Fe–10mass%Ni alloy deoxidized by Al and Mg using laser ablation ICP mass spectrometry

A.V. KARASEV et al.

The laser ablation ICP mass spectrometry (LA-ICP-MS) has been applied for the quantitative analysis of the inclusion composition and size distribution in an Fe–10mass%Ni alloy deoxidized by Al and/or Mg. The composition and size distributions of particles in the range of d_V<10 μm obtained from LA-ICP-MS are compared with those from SEM with EPMA. It was found that total size distribution of inclusions in the range of d_V>1 μm obtained from LA-ICP-MS agrees reasonably well with that on film filter after electrolytic extraction from SEM. The underestimation of particle number density obtained from LA-ICP-MS is found in the range of d_V<1 μm and it can be explained by the limit of LA-ICP-MS analysis for small size particles on polished metal surface. The LA-ICP-MS is superior to EPMA for the analysis of nonuniform complex inclusions. The inclusion size obtained by Mg followed by Al addition is smaller than that obtained by Al followed by Mg addition. The total compositions for most of inclusions in these experiments are not spinel composition.

(cf. *ISIJ Int.*, **44** (2004), 364)

Forming Processing and Thermomechanical Treatment

Analysis of carbides in multi-component white cast iron for hot rolling mill rolls

M.HASHIMOTO et al.

A multi-component white cast iron was developed for rolling mill rolls. The morphology and alloy concentration of carbides precipitated during solidification were investigated using X-ray diffraction, SEM, TEM and EDS analysis in the cast iron with typical chemical composition of Fe–2%C–5%Cr–5%V–5%Mo–5%W–5%Co (mass%). When the iron solidifies, petal-like MC carbides with face-centered cubic lattices and plate-like M_2C carbides with hexagonal lattices crystallize. During heat treatment, M_2C carbide (hexagonal) reacts to γ-Fe and transforms to M_6C (fcc), M_7C_3 (orthorhombic) and MC (fcc) carbides, but the reaction is not followed by a change of carbide morphology. MC carbides mainly consist of V, and M_7C_3 carbides are mainly formed by Cr and Fe. M_2C carbides contain 20–25 atomic% each of Cr, V, Mo, and Fe, and 12 atomic% of W. M_6C carbides are composed of approximately 33 atomic% of (Mo+W), and 50 atomic% of Fe and (Cr+V) in the balance.

(cf. *ISIJ Int.*, **44** (2004), 372)

Effect of silicon on the interaction between recrystallization and precipitationin niobium microalloyed steels

L.JIANG et al.

The effect of Si addition on the interaction between recrystallization and precipitation was investigated in terms of the no-recrystallization temperature (T_{nr}) on three microalloyed steels containing about 0.035 mass% Nb. The T_{nr} was measured using torsion testing over the Si concentration range from 0.01 to 0.48 mass%. It was observed that the T_{nr} increased with Si level, but appeared to saturate at long interpass times. In addition, high strains reduced the influence of Si on the T_{nr}. This behaviour is attributed to the acceleration of Nb(C, N) precipitation by the addition of Si.

(cf. *ISIJ Int.*, **44** (2004), 381)

Welding and Joining

Strength of the diffusion bonded joints between CP Ti and 304 stainless steel processed below and above β-transus

M.GHOSH et al.

Diffusion bonding was carried out between commercially pure titanium and 304 stainless steel in the temperature range of 800–900°C for 9 ks under uniaxial load in vacuum. The transition joints thus formed are characterized by optical metallography, scanning electron microscopy and tensile testing. The scanning images reveal the presence of different reaction bands in the diffusion zone and the composition of these bands were determined by energy dispersive spectroscopy. The concentrations of chemical species in the layers indicate the formation of intermetallics like σ, λ, χ and FeTi in the reaction zone and they were confirmed by X-ray diffraction technique. Highest bond strength (71 % of that of cp Ti) has been obtained for the diffusion-welded joints processed at 800°C owing to thinner width of brittle intermetallic phases. At high joining temperature like 900°C, strain generation near interface along with the presence of brittle intermetallics and generation of micro-voids are responsible for lowering the bond strength of the transition joint.

(cf. *ISIJ Int.*, **44** (2004), 388)

Transformations and Microstructures

A microstructural study of destabilised 30wt%Cr–2.3wt%C high chromium cast iron

A.WIENGMOON et al.

An as-cast 30wt%Cr–2.3wt%C cast iron was destabilised in the temperature range of 900–1 100°C for times of 2–8 h, followed by air cooling to room temperature. The resultant microstructures were examined using light microscopy (LM), scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Volume fractions of secondary carbide within the martensite matrix and of $M_{23}C_6$ in eutectic carbides were determined. Vickers macrohardness and Vickers microhardness of the dendritic regions were also measured. It was found that morphologies of secondary carbide were cube, plate-like shape or discrete-rod. A duplex core-shell structure was found in the eutectic carbides after destabilisation. It consists of M_7C_3 as a core surrounding by $M_{23}C_6$, while the secondary carbide in these alloys was identified as $M_{23}C_6$. Higher destabilisation temperatures resulted in coarser secondary carbides with comparable volume fraction, but less in counts per area. The volume fraction of $M_{23}C_6$ within the duplex structure was also increased when increasing destabilisation temperature and time. The results from hardness measurements revealed that the overall macrohardness of the iron was increased with increasing the destabilisation temperature up to about 770 HV (30 kgf/15 s) at 1 025°C, whereas the microhardness of the dendritic regions reached the maximum value of 800 HV (100 gf/15 s) at about 1 025°C.

(cf. *ISIJ Int.*, **44** (2004), 396)

Evolution of texture in ferritically hot rolled Ti and Ti+Nb alloyed ULC steels during cold rolling and annealing

K.M.TIITTO et al.

The effect of chemical composition and ferritic hot rolling on the formation of texture in the hot rolled and coiled, cold rolled, and cold rolled and annealed ultra-low carbon steels was studied. One of the experimental steels was fully stabilized with respect to carbon, whereas two others were expected to have some carbon in solution under equilibrium conditions. The steels were processed to yield mainly gamma fiber texture intensities in the austenitically hot rolled condition. Three different thermomechanical treatments were applied, including rolling in the ferrite temperature region. After hot rolling and coiling, the steels were cold rolled and annealed. The crystallographic orientations for each condition were presented in the form of so-called skeleton plots along the RD-, TD- and ND-fibers. It was found that the resulting texture in the hot rolled and coiled as well as in the cold rolled and annealed steels was dependent on the degree of recrystallization of the ferritic substructure. A well-advanced state of recrystallization eliminated the detrimental rotated cube component, leaving behind texture with a complete gamma fiber. The average strain ratio, measured for the cold rolled and annealed steels, increased with advancing state of recrystallization and increasing intensity of the $\{111\}\langle 110\rangle$ texture component. It was also found that adding 100 ppm of Nb to the Ti alloyed ULC steel increased the average strain ratio by 15% at a given $\{111\}\langle 110\rangle$ texture intensity.

(cf. *ISIJ Int.*, **44** (2004), 404)

Instability of the delta-ferrite/austenite interface in low carbon steels: the influence of delta-ferrite recovery sub-structures

D.PHELAN et al.

An *in-situ* study of the delta-ferrite/austenite phase transformation in low carbon steels utilising laser scanning confocal microscopy has found that the presence of a recovery sub-structure in the delta-ferrite phase plays an active role in the apparent instability of delta-ferrite/austenite interfaces. Phase field modelling conducted in an attempt to quantify the influence of sub-boundaries on the transformation rate of delta-ferrite to austenite in Fe–C and Fe–C–Mn alloys, confirmed the *in-situ* observations that austenite grows preferentially along delta-ferrite sub-boundaries. The modelling studies also predicted that the transformation kinetics of the delta-ferrite to austenite would be enhanced if a sub-boundary network were present in the delta-ferrite grains.

(cf. *ISIJ Int.*, **44** (2004), 414)

Mechanical Properties

The influence of microstructural features and mechanical properties on the cold formability of ferritic steel sheets

M.A.AKOY et al.

In the present study, the formability of cold rolled and annealed steel sheets having carbon equivalent values in the range of 0.028 to 0.098 wt% were investigated. The steel sheet having the lowest carbon equivalent was a titanium-stabilized interstitial free steel, which established the highest strain hardening exponent, anisotropy coefficient and higher Forming Limit Diagram (FLD). Since plain strain intercept (FLD_0) is the most critical strain limit on the FLD, the empirical equations were derived between FLD_0 and microstructural features and mechanical properties. As a microstructural feature grain size and as a mechanical property anisotropy coefficient gave the most reliable correlations.

(cf. *ISIJ Int.*, **44** (2004), 422)

Social and Environmental Engineering

Nitrogen oxides (NOx) formation and control in an electric arc furnace (EAF): analysis with measurements and computational fluid dynamics (CFD) modeling

E.CHAN et al.

A computational fluid dynamics (CFD) model of an electric arc furnace (EAF) has been developed and validated against measurements at the EAF combustion gap. Modeled processes include fluid flow, combustion reactions, radiative heat transfer, turbulence, and NOx formation. This model is used to identify the NOx formation mechanisms and to analyse potential NOx control strategies.

The model successfully predicts the NOx emission trends. NOx formation is primarily due to N_2 from air ingress through the slag door or roof ring gap, flowing into the high temperature regions near the burners. N_2 in the oxygen supply is also important. NOx levels correlate with N_2 and O_2 levels in the furnace. Reducing N_2 and excess O_2 in the furnace is recommended for NOx abatement. Unlike many combustion devices, controlling temperature is not recommended for reducing NOx emissions. Large reductions in NOx emissions are predicted by (in order of importance, from highest to lowest): controlling exhaust flows to limit air ingress, closing the slag door and increasing the purity of the oxygen supply.

(cf. *ISIJ Int.*, **44** (2004), 429)