（＊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

Degradation of iron oxide caused by alumina during reduction from magnetite

T.PAANANEN et al.

The degradation mechanism of iron oxides caused by alumina during reduction from magnetite has been studied. The experiments were carried out by reducing briquettes containing various mixtures of commercial magnetite fines and Al_2O_3 in a CO/CO_2 atmosphere at 950°C in thermo-gravimetric equipment. Following reduction, samples were examined using optical microscopy, SEM-EDS and XRD.

The diffusion of Al cations into the magnetite during reduction induces swelling and cracking of the briquettes. The composition of the magnetite phase approaches the composition of hercynite during reduction. Assuming the spinel structure is that of hercynite, reduction to non-stoichiometric wüstite ($Fe_{0.88}O$) causes an expansion of over 16%. This transformation causes high tension forces in the magnetite/hercynite phase in the vicinity of the interface with the wüstite which presumably account for the breakdown of the structure during the reduction.

(cf. *ISIJ Int.*, **43** (2003), 597)

Mechanism of formation of amorphous silica inclusion in silicon deoxidized copper

K.WASAI et al.

To investigate the formation mechanism of secondary amorphous silica inclusion in iron and copper, silicon-deoxidation experiment of copper at 1 423 K was performed.

In the copper quenched into water after deoxidation, three types of secondary amorphous silica inclusions (pinecone-like inclusion, gourd-shaped inclusion and network-like inclusion) were observed. In the copper cooled ultra-rapidly, fine spherical inclusion and coral-like inclusion, which were secondary and amorphous, were observed.

The experimental temperature of 1 423 K is not only 573 K lower than the melting point of silica[9] but also 20 K lower than the glass transition temperature of silica (1 443 K[10]). Therefore, the presence of secondary amorphous silica inclusion should be strong evidence of the formation of liquid silica during cooling of the copper without temperature rise. It would also support the formation of secondary liquid silica inclusion in the iron alloy.

Consideration based on Ostwald's Step Rule indicated that liquid silica inclusion could be formed from the supersaturated state of copper.

(cf. *ISIJ Int.*, **43** (2003), 606)

Simultaneous synthesis of iron carbide and rutile from ilmenite ore by thermochemical reactions

S.HAYASHI et al.

Simultaneous synthesis of iron carbides (mainly Fe_3C) and rutile (TiO_2) from natural ilmenite ore (mainly $FeTiO_3$) were examined by thermochemical reactions with H_2–CO or H_2–CH_4 gas mixtures at temperatures of 1 073–1 273 K. The low sulfur pressures incapable of forming FeS was added to these gas mixtures to make stable iron carbides without free carbon. Iron carbide is currently interesting as alternative pure iron sources in steelmaking. The rutile is also available as a feedstock for titanium industry.

First, partial conversion from ilmenite to rutile and metallic iron mostly proceeded and subsequently iron carbidization occurred together with further reduction of rutile. Finally, these processes with both gas mixtures provided iron carbide (Fe_3C) and lower titanium oxides such as Magneli phases (Ti_nO_{2n-1}, $4 \leqq n \leqq 9$ namely TiO_{2-x}) and/or Ti_3O_5 rather than rutile.

Reaction time, H_2/CH_4 ratio, sulfur potential, and temperature dependence of reaction behavior was examined further. The iron carbidization rates were analysed using the first order rate model. Ilmenite samples prepared from reagents showed slightly slower conversion rates to titanium oxides at 1 073 K than the natural ore ones, though both samples showed similar iron carbidization rates.

(cf. *ISIJ Int.*, **43** (2003), 612)

Ironmaking

Estimation of stack profile of burden at peripheral zone of blast furnace top

S.MATSUZAKI

We, in an off-line distribution testing equipment, have developed a device capable of measuring the stack profile with high accuracy through an ultrasonic sensor. We have further devised a method which derives distribution of inclination angle, angle of repose and terrace length quantitatively and automatically by making use of the measurement data acquired from the device. We have also invented a method estimating theoretically the stack profile at peripheral and confirmed that it accords well with the measurement results obtained from the experiment or at an actual furnace.

(cf. *ISIJ Int.*, **43** (2003), 620)

Quantifying the resistance to airflow during iron ore sintering

C.E.LOO et al.

Sintering tests, involving airflow measurements before and after bed ignition, were carried out on three optimized iron ore blends—containing only hematite (HAEM), hematite with pisolite (PISO), and hematite with pisolite and hematite–goethite (PIMM)—to assess the resistance of the flame front and associated regions. Results showed that post–ignition airflow rates for the three blends were comparable for the same pre-ignition airflow rate, indicating that reactive ores *i.e.* pisolite and hematite–goethite ores, did not have an adverse effect on flame front resistance. For the PIMM blend, increasing the level of fines (minus 0.15 mm fraction) also did not have any effect on the flame front resistance. Reducing the coke level in all the three blends and increasing basicity decreased the value of the resistance. The resistance was shown to be a strong function of green bed airflow velocity and semi-empirical equations, with single variables, were derived to characterize the 'sinterability' of iron ore mixes.

(cf. *ISIJ Int.*, **43** (2003), 630)

Casting and Solidification

A physical model for the two-phase flow in a continuous casting mold

R.SÁNCHEZ-PEREZ et al.

Two-phase flow in a water–air model of a continuous casting slab mold is studied using Particle Image Velocimetry technology. At low gas-loads (mass flow rate of gas/mass flow rate of liquid) fluid flow patterns of phases, gas and liquid, are different and with increases of this parameter both flow fields become similar. In the liquid phase, angles of the jet-root (in front of the SEN's ports) and jet core (main jet-body) are complex functions of the gas flow and casting rates. The first is decreased well below the angle of the SEN's port and the second is increased well above the same angle for all gas-loads. The jet-root angle increases, from small values, while the jet-core angle observes a maximum with the gas flow rate at any casting rate. The jet-core angle approaches to the angle of the SEN's port at high gas flow rates. Accumulation of bubbles is observed in the mold cavity when the casting rate is high at low or high flow rates of gas. Averaged bubble sizes depend on the coalescence-breakup kinetics, which vary with the gas-load. Liquid entrainment by gas to the flux is greatly increased with the casting rate even at low gas-loads. Further understanding of the two-phase flow dynamics should be attained in order to improve the boundary conditions of mathematical models.

(cf. *ISIJ Int.*, **43** (2003), 637)

Analysis of gap formation at mold–shell interface during solidification of aluminum alloy plate

K.Y.KIM

Thermal contraction of the casting and the thermal expansion of the mold result in gap formation at the mold–casting interface, which affects greatly the heat transfer between the mold and casting. Information on the movements of the mold and casting during solidification and cooling is also the basis for the investigation of the casting deformation.

Movements of the casting and mold were analyzed simultaneously using coupled thermo-mechanical contact boundary model for the plate casting of aluminum alloy. The calculated displacement and temperature distributions of the casting and mold were compared with the previous measured data. It was confirmed that the mold and the casting moved together until the air gap formed by the calculation. Comparing the air gap curve with the displacement curve of the casting just before and after air gap formation made it apparent that the growth of the air gap was mainly due to contraction of the casting because the change in the mold displacement was not significant. Gap formation time increased with increase in initial mold temperature.

(cf. *ISIJ Int.*, **43** (2003), 647)

Mathematical simulation and modeling of steel flow with gas bubbling in trough type tundishes

A.RAMOS-BANDERAS et al.

Flow of steel in a one-strand slab tundish

equipped with a turbulence inhibitor (TI) and a transversal gas bubbling curtain was studied using mathematical simulations, PIV measurements and Residence Time Distribution (RTD) experiments in a water model. The use of a bubbling curtain originates two recirculating flows, upstream and downstream at each of its sides. The first one meets, at some point along the tundish length and close to the bath surface, the downstream that is driven by the TI. After, free shear stresses provided by the upstream make the downstream be directed toward the tundish bottom forming a bypass flow. At the other side, in the outlet box, there is strong recirculating flow which impacts the end wall and goes directly toward the outlet. Two-phase flows simulated mathematically matched experimental flow fields measured with PIV measurements. Tundish performance for inclusions flotation is maximized when only the TI is used followed by using only the bubbling curtain. Increases of gas bubbling flow rate increase the mixing processes in the tundish according to the RTD determinations.

(cf. *ISIJ Int.*, **43** (2003), 653)

Model experiment on the behavior of argon gas in immersion nozzle

K.ISHIGURO et al.

Model experiments were carried out to understand the behavior of argon gas introduced into the immersion nozzle through the sliding gate. Water and air were modeled for molten steel and argon gas, respectively. A transparent straight pipe made of acrylic resin was used for a model of the immersion nozzle. Two kinds of repellents were coated on the inner wall of the pipe to change its wettability. The wettability was evaluated in terms of the contact angle. When the wettability was poor, air attached preferably to the wall. The attachment of air to the wall became more obvious as the contact angle increased. The flow pattern of a water-air two-phase flow was significantly dependent on the wettability of the pipe. In particular, when the contact angle reached 142°, liquid droplet flow and inverted annular flow were observed. The inverted annular flow is beneficial for the prevention of alumina particle adhesion to the immersion nozzle. An empirical equation was proposed for the boundary between the liquid droplet flow and inverted annular flow regimes.

(cf. *ISIJ Int.*, **43** (2003), 663)

Chemical and Physical Analysis

EELS and EDS fracture mode analysis at grain boundaries of Cr–Mo steel

X.ZHANG et al.

Electron energy loss spectroscopy (EELS) and energy dispersion spectroscopy (EDS) were used to study the chemical composition and bonding of grain boundary in CrMo steel. The bonding change in grain boundary of commercial CrMo steel is induced by P element segregation. The normalized $3d$ occupancies of states of irons both in bulk and at grain boundary were calculated according to the EELS spectra and they were related to the change in the chemical compositions of grain boundaries and the fracture mode. If the grain boundary has a higher occupancy of $3d$ state of iron than the bulk, the sample tends to have intergranular fracture, while if the grain boundary has almost the same occupancy of $3d$ state of iron as the bulk, the sample tends to have transgranular fracture.

(cf. *ISIJ Int.*, **43** (2003), 671)

Forming Processing and Thermomechanical Treatment

Numerical prediction of austenite grain size in round-oval-round bar rolling

H.-C.KWON et al.

In bar or rod rolling process, improvement of mechanical properties of the hot rolled products requires numerical prediction of austenite grain size (AGS) for better controlling the microstructural evolution. In this study, a fully three-dimensional finite element (FE) program, which can simulate three-dimensional deformation and heat transfer was integrated with an AGS evolution model available in the literature. It was applied to a four-pass round-oval-round rolling sequence to characterize the AGS distributions depending on the change of roll gap and rolling speed. The predicted AGS distribution obtained from the FE based approach was compared with that obtained from the approximate analytical approach based on elementary theory of plasticity, developed for practical purpose. It was found out that reducing roll gap and increasing the rolling speed leads to fine and uniform grain distribution and recrystallization behavior divided into meta-dynamic and static recrystallization region, respectively. In addition, AGS predicted from the approximate analytical approach was in agreement with that from the FE based approach, but showed discrepancies at higher rolling speed conditions investigated in the present work.

(cf. *ISIJ Int.*, **43** (2003), 676)

Initiation of dynamic recrystallization in constant strain rate hot deformation

E.I.POLIAK et al.

In constant strain rate tests, the occurrence of dynamic recrystallization (DRX) is traditionally identified from the presence of stress peaks in flow curves. However, not all materials display well-defined peaks when tested under these conditions. Using plain carbon, Nb-bearing and 321 austenitic stainless steels, it is shown that the onset of DRX can also be detected from inflections in plots of the strain hardening rate θ against stress σ or, equivalently, from inflections in $\ln\theta$–$\ln\sigma$ and $\ln\theta$–ε plots regardless the presence of stress peaks in the flow curves. These observations are verified by means of metallography. A unified description of the flow curve is introduced based on normalization of the stress and strain by the respective peak or steady state values. This approach reveals that, in a given material, the ratio of DRX critical stress to the peak or steady state stress is constant, as is that of the critical strain to the corresponding strain values. Furthermore, it is shown that the present technique can be used to establish the occurrence of DRX when this cannot be determined unambiguously from the shape of the flow curve.

(cf. *ISIJ Int.*, **43** (2003), 684)

Critical strain for dynamic recrystallization in variable strain rate hot deformation

E.I.POLIAK et al.

In rolling, the strain rate in a rolling pass is not constant but depends on pass reduction r_p, decreasing or increasing along the arc of contact. In the present work, high temperature compression tests were performed with the rate varying according to strain rate profiles pertaining to various flat rolling pass reductions. Due to the high rate sensitivity of the stress at elevated temperatures, the stress follows such variations in strain rate. This can lead to peaks in the flow curves without regard to dynamic recrystallization (DRX). Nevertheless, critical strains for the onset of DRX can still be defined if the stresses and strains in variable strain rate deformation are normalized by the peak stresses and strains that would be observed if the deformation were being performed at a series of constant strain rates equal to that of successive points along the roll bite. Using plain carbon and Nb-bearing steels, it is demonstrated that the DRX critical strains are lower when r_p <30% and higher when r_p >30% than in constant $\dot{\varepsilon}$ deformation at the same initial strain rate. The present method permits the more accurate extrapolation of laboratory test results to industrial conditions and enables rolling loads to be analyzed with greater precision.

(cf. *ISIJ Int.*, **43** (2003), 692)

Axial contraction during torsion simulation of steel rolling at high temperatures

J.J.JONAS et al.

The deformation textures determined in previous experiments on the free-end torsion testing of pure copper (99.95%) bars are reviewed. At room temperature and 125°C, lengthening is observed up to shear strains of 11 or 12. By contrast, at 200 and 300°C, shortening takes place after initial shear strains of about 10 and 5, respectively. Simulations are carried out using polycrystal plasticity methods with the aim of reproducing the experimental textures. It is shown that the lengthening generally observed at ambient temperatures is entirely attributable to the characteristics of dislocation glide in fcc metals. By contrast, the "shortening" that takes place at elevated temperatures cannot be reproduced in this way and requires introduction of the concepts of the nucleation and growth of new grains. Comparison of the experimental results and the predictions of the simulations leads to the conclusion that the very large axial contractions frequently reported during the torsion simulation of steel rolling schedules are due to dynamic recrystallization.

(cf. *ISIJ Int.*, **43** (2003), 701)

Welding and Joining

Effect of microstructural variation on weld metal cold cracking of HSLA-100 steel

H.J.KIM et al.

The effect of microstructural and microhardness

variations on the formation of hydrogen induced cold cracks (HICC) has been investigated in the multipass weld metals. Multipass weld metal cracking tests were performed with submerged arc welding on 25 mm thick HSLA-100 steels using commercial welding materials. All the cracks observed in the welds were transverse and vertical to the welding direction, and most of them were located in the interior of top layer beads except the final pass. The morphology and preferred location of cold cracks imbedded in the weld metal were studied by scanning acoustic microscopy (SAM) and were confirmed on the sectioned specimens by optical microscopy. Overlapping the two-dimensional crack morphology on the microstructure demonstrated that most of cracks were located in the areas having a structure of columnar grains but not in the areas of recystallized grains. Thus they tended to stop their propagation at the fusion boundaries. Microhardness measurement showed that the recrystallized region had a high hardness and was surrounded by tempered band that had a minimum hardness. Crossing over the tempered band, the hardness increased gradually to a high level. Most of the cracks were densely populated in this region in which the hardness increased gradually. These results indicated that the columnar grain structure would be the most susceptible microstructure to cold cracking and the hardness did not play a major role in developing cold cracks in the present welds. Those cracks were developed predominantly in intergranular mode following the elongated columnar grain boundaries. Based on these results, several suggestions could be made for developing preheat-free welding consumables.

(cf. *ISIJ Int.*, **43** (2003), 706)

Surface Treatment and Corrosion

Localized corrosion behavior of high nitrogen-bearing austenitic stainless steels in seawater environment

M.SAGARA et al.

Crevice corrosion behavior of high nitrogen-bearing stainless steels with up to 1.1 mass% nitrogen were investigated in artificial seawater. Specimens were highly purified and contained ultra-high nitrogen of about 1 mass% obtained by using nitrogen gas pressurized electroslag remelting (P-ESR) system. 23%Cr–4%Ni–0 to 2%Mo–0.7 to 1.1% N stainless steels were used as test specimens. Crevice corrosion resistant properties of the stainless steels were evaluated by means of electrochemical corrosion test method using multiple crevice assemblies. Crevice corrosion was confirmed by visual observation to be generated after test and by in-situ current response under test. It was seen that there was a positive correlation between nitrogen content and crevice corrosion potential. High nitrogen-bearing austenitic stainless steels produced by P-ESR had good crevice corrosion resistance. It was also found that ultra-high nitrogen stainless steels containing molybdenum had superior crevice corrosion resistance. Surface of high nitrogen stainless steel was analyzed using X-ray photoelectron spectroscopy (XPS). After polarization at the passive potential region (at +300 mV *vs.* SCE), an alloying nitrogen or nitride peak of N1s spectra appeared at higher take-off angle measurement, indicating that nitrogen concentrated at the inner layer of the interface between passive film and bulk metal. Enriched nitrogen at the interface may be possible to improve crevice corrosion resistance.

(cf. *ISIJ Int.*, **43** (2003), 714)

A new approach to predict the pit depth extreme value of a localized corrosion process

D.NAJJAR et al.

Depth of pits that propagate during a pitting corrosion process is an important characteristic of the damage of steels; the greater the depth, the more dramatic the damage. For evident reasons of safety and reliability of industrial installations, statistical procedures must be constructed to assess the maximum pit depth to perform proper maintenance from limited inspection data.

This paper outlines a new methodology to predict accurately the pit depth extreme value related to a localized corrosion process independently of the nature of the unknown parent distribution of the experimental data. Based on computer calculations and simulations, this methodology combines the Generalized Lambda Distribution (GLD) and the Bootstrap statistical methods.

The GLD method was used in this study to determine a modeled distribution that fits the experimental frequency distribution of pit depths produced on a ferritic stainless steel sample during an accelerated corrosion test. This modeled distribution was used to generate, thanks to the Computer-Based Bootstrap Method (CBBM), simulated distributions of corrosion pit depths equivalent to the experimental one. An estimation of the mean with a 90% confidence interval of the maximum pit depth can be finally deduced not only for these simulated samples of equivalent surface size than the experimental one but also for a large scale installation.

(cf. *ISIJ Int.*, **43** (2003), 720)

Transformations and Microstructures

An attempt to establish the variables that most directly influence the austenite formation process in steels

F.G.CABALLERO et al.

The aim of this work is to evaluate the influence of heating rate and initial microstructure on the anisothermal formation of austenite. In this sense, the start (Ac_1) and finish (Ac_3) temperatures of austenite formation have been determined on dilatometric curves obtained at various heating rates in steels with ferrite and/or pearlite initial microstructures. As it was expected, Ac_1 and Ac_3 temperatures rises linearly with heating rate, except for steels with a pure ferrite initial microstructure where the Ac_1 temperature is almost insensitive to heating rate over the range studied. Experimental results in steels with a pearlite and ferrite–pearlite initial microstructures also show that the elevation of the critical temperatures with heating rate is quite sensitive to the morphology of pearlite. It seems that the higher the heating rate is, the stronger the influence of morphology on the critical temperatures are. This experimental study and the knowledge of the mechanisms that control the austenite formation process have allowed to establish the variables that most directly influence this reaction in steels with pearlite and ferrite–pearlite initial microstructures. Those are the heating rate and the two parameters that characterise the morphology of pearlite, the mean true interlamellar spacing and the edge length of the pearlite colonies interface in pearlitic steels, together with the volume fraction of pearlite and the mean free distance of pearlite in ferrite plus pearlite initial microstructures. Likewise, two equations have been proposed for the determination of the start (Ac_1) and (Ac_3) finish temperatures of austenite formation as a function of those variables.

(cf. *ISIJ Int.*, **43** (2003), 726)

The improvement of primary texture for sharp Goss orientation on grain oriented silicon steel

T.KUMANO et al.

The relationship between primary and secondary recrystallization texture, and the improvement of primary texture on grain oriented silicon steel was examined. The specimens were prepared by using different C content and different hot rolling conditions in the acquired inhibitor method. Higher reduction of the later passes of hot rolling gave the same effect to primary texture as more C content. As a result, the sharpness of Goss texture became similar. Higher reduction of the last two passes of hot rolling caused {411}⟨148⟩ texture to enhance, and higher C content caused {111}⟨112⟩ texture to enhance in primary texture. Both orientations are $\Sigma 9$ orientations of Goss. As a result $I_C\Sigma 9$ of Goss is enhanced. Furthermore, not only $\Sigma 9$ orientations but also $\Sigma 5$ might contribute the secondary recrystallization.

(cf. *ISIJ Int.*, **43** (2003), 736)

Formation of ultrafine ferrite by strain-induced dynamic transformation in plain low carbon steel

J.-K.CHOI et al.

Strain-induced dynamic transformation (SIDT) is of great advantage to obtaining ultrafine-grained ferrite in low carbon steels partly by early impingement of ferrite nuclei which are very rapidly and concurrently formed due to the deformation and partly by random crystallographic orientation distribution of ferrite grains. The SIDT fraction increases with the increase of strain. There is, however, a critical strain under which no SIDT occurs. In order to apply this refining mechanism to actual production lines, it is necessary to reduce the critical stain and enhance the kinetics of SIDT. It has been known that refining prior austenite grain is the most effective for this purpose. The influences of deformation temperature and strain rate on SIDT were also examined. Because SIDT is a kind of softening mechanism of strained austenite, it competes with dynamic recrystallization (DRX) at below Ae3 temperature. Comparing the critical strains of SIDT and DRX, SIDT is predominant softening mechanism, which enables us to utilize it for grain refinement. This provides an important clue to overcome the limitation of conventional thermomechanical control process

(TMCP) in grain refinement area.

(cf. *ISIJ Int.*, **43** (2003), 746)

High-resolution TEM analysis of defect structures in mechanically milled, nanocrystalline Fe

M.MURAYAMA et al.

Grain interior and grain-boundary structures of mechanically milled ultrafine-grained iron powder were investigated with atomic resolution using high-resolution transmission electron microscopy (HRTEM). Grain boundaries in the powder appear wavy and irregular, with no amorphous or other unusual defect structures present. Diffraction analysis of HRTEM images indicates that elongated grains approximately 100 nm long and 20 nm wide consist of several sub-grains along their length, each rotated by several degrees around a common ⟨110⟩ axis. The presence of partial disclination dipoles in the sub-grains was also observed by HRTEM. Such structures indicate that shear, fragmentation and rotation of grains several to tens of nanometers in diameter occurs during severe plastic deformation. A mechanism for the formation of an ultrafine-grained structure in mechanically milled Fe involving partial disclinations is proposed.

(cf. *ISIJ Int.*, **43** (2003), 755)

Formation of ultra-fine grain structure of plain low carbon steel through deformation induced ferrite transformation

Y.ZHONGMIN et al.

The purpose of this paper is to study the processing technology and formation mechanism for obtaining an ultra-fine grain structure in plain low carbon steel long products. The paper describes characteristics of austenite dynamic recrystallization (DRX), dynamic restoration (DR) and deformation induced ferrite transformation (DIFT) of plain low carbon steel.

(cf. *ISIJ Int.*, **43** (2003), 761)

The influence of carbon diffusion on the character of the γ–α phase transformation in steel

Y.van.LEEUWEN et al.

During the austenite–ferrite phase transformation the excess amount of carbon that can not be dissolved in the growing ferrite phase accumulates in the austenite phase ahead of the moving interface. This local carbon enrichment along the interface in the austenite decreases the driving force for transformation. Two processes therefore determine the actual interface velocity: the transformation rate of the iron lattice from fcc to bcc and the diffusion of the carbon along its gradient into the austenite grain. If the diffusion of the carbon is the rate-determining process, the transformation occurs in the diffusion-controlled mode. If the rate of transformation is determined by the lattice transformation, this is called the interface-controlled or mean-field mode. When the transformation rate is not determined by a single process, this is referred to as the mixed mode of transformation.

The mixed-mode character can be identified by the carbon concentration in the austenite at the α–γ interface, $x_C^{\gamma\cdot\gamma\alpha}$. If $x_C^{\gamma\cdot\gamma\alpha}$ is close to the concentration given by the local α–γ equilibrium, the character of the transformation is predominantly diffusion controlled. On the other hand, if diffusion is relatively fast, $x_C^{\gamma\cdot\gamma\alpha}$ is close to the average concentration in the austenite, and the transformation has a interface-controlled character. Due to the build-up of concentration gradients, the transformation character can gradually change during the transformation. In this paper, a two-dimensional study of a mixed-mode transformation is performed for Fe–C alloys of different carbon contents, and the character of the transformation is quantitatively determined.

(cf. *ISIJ Int.*, **43** (2003), 767)

Grain size distribution obtained from monte carlo simulation and the analytical mean field model

C.WANG et al.

The grain growth process in two dimensions was simulated by Monte Carlo Potts method. The observed quasi stationary state grain size distribution could well be fitted by the Weibull function. It can also be approximated by an analytical distribution with ν smaller than 4, rather than the Hillert distribution (ν=4). Our results suggest that here the microstructure would not evolve to the Hillert distribution but to the Weibull function or the analytical distribution with <4. It is also shown that the Weibull function is a better approximation to the quasi stationary state grain size distribution in present work.

(cf. *ISIJ Int.*, **43** (2003), 774)

Grain boundary mobility in Fe-base oxide dispersion strengthened PM2000 alloy

C.CAPDEVILA et al.

It has been possible to measure the average interfacial velocities of grain boundaries during the process of recrystallisation of an oxide dispersion-strengthened iron-base alloy manufactured using the mechanical alloying technique. The measurements could be made using optical microscopy because the recrystallised grains are orders of magnitude larger than the surrounding unrecrystallised material. Furthermore, the peculiar way in which the alloy recrystallises, made it possible to observe large, flat segments of boundaries as they advanced into the higher energy matrix. The data have been analysed bearing in mind the pinning effect of the non-random distribution of oxide particles. It is concluded that the boundaries have a high mobility. This conclusion adds to the growing evidence that the alloy has great difficulty in nucleating recrystallisation because of the ultrafine and uniform starting-microstructure in which the grain boundary junctions are so closely spaced that they prevent strain-induced grain boundary migration; in other words, the junctions themselves are powerful pinning points.

(cf. *ISIJ Int.*, **43** (2003), 777)

Microstructures and thermal fatigue behavior of Cr–Ni–Mo hot work die steel modified by rare earth

Q.F.GUAN et al.

The near-net-shape casting technology is an important process unattainable with traditional die-making processes. The key of this process is how to guarantee the safety application of dies. In this paper, the microstructures and thermal fatigue (TF) behavior of Cr–Ni–Mo hot work die steel modified by rare earth (RE) were investigated. The grains of cast Cr–Ni–Mo hot work die steel are refined by RE modification. With the increase of RE addition, both grain size and inclusion amount are reduced. The morphology and distribution of inclusions are improved by appropriate RE modification. RE modification favors fine plate martensite. When the residual RE content reaches 0.02%, no obvious changes in strength and hardness are found, while fracture toughness is increased. The impact toughness, elongation and reduction of cross sectional area are increased by a factor of two. The influence of microstructure on initiation and propagation of thermal fatigue crack was also studied. The results show that the microstructures have apparent effect on resistance to TF crack initiation and propagation. Steel with microstructure of martensite and bainite dual phase have higher resistance to thermal fatigue than that of martensite owing to the loosing stress increase. Wrought process increases TF crack initiation resistance, however, lowers TF crack propagation resistance compare to cast process

(cf. *ISIJ Int.*, **43** (2003), 784)

Mechanical Properties

Effect of carbide morphology on the susceptibility to type IV cracking of a 1.25Cr–0.5Mo steel

S.FUJIBAYASHI et al.

Type IV cracking is considered to be the likely failure mode of ferritic steel welds when operated for long duration. The carbide morphology of the service-exposed 1.25Cr–0.5Mo steel weldment, which is composed of a forged flange and pipe fabricated from plates, has been examined before and after a creep test. Higher susceptibility to Type IV cracking was observed at the Intercritical HAZ (ICZ) on the flange side despite higher creep resistance of the parent material compared with a pipe. The change in carbide morphology during the creep exposure was the most pronounced at the flange ICZ. The coarse bainitic carbide originally existing depleted the intragranular carbides and significant variation in carbide density inside the ICZ was generated. In contrast, carbides at the pipe ICZ were more uniformly distributed. It was interpreted that higher susceptibility of the flange ICZ was accelerated by the heterogeneous distribution of carbide density and the resultant variation of creep strength and would enhance grain boundary sliding associated with creep strain accumulation.

It was proved that the susceptibility to Type IV cracking was highly dependent upon the characteristics of a parent material by experiments using simulated ICZ specimens. Significant difference in the effect of heat treatment to simulate the microstructure at the ICZ upon the creep strength was observed between a flange and pipe. The simulated ICZ specimen generated by a pipe parent showed no apparent change due to the heat treatment compared with a parent material. On the contrary, it reduced

the time to rupture and changed the fracture mode from transgranular to intergranular for a flange material. The feature of grain boundary cracking was similar to that of actual weldment which took place preferentially at the inclined grain boundaries to the tensile direction, that was to be considered the evidence of grain boundary sliding.

(cf. *ISIJ Int.*, **43** (2003), 790)

◆❖◆*お知らせ*❖◆❖

「鉄と鋼」「ISIJ International」投稿規程・執筆要領一部改訂のお知らせ (2003年4月1日より実施)

「鉄と鋼」「ISIJ International」では2003年4月1日より下記の通り投稿規程・執筆要領の一部を改訂しました。本会ホームページに最新版の投稿規程・執筆要領を掲載していますのでご参照下さい。

投稿規程

【改訂前の本文】

2．原稿の内容

（2） 両誌掲載以前に公開刊行物に発表される可能性のないものに限る。但し，本会発行の和文の研究成果報告書の内容を補充完成させた原稿は，「ISIJ International」に投稿することができる。

【改訂後の本文】

2．原稿の内容

（2） 両誌掲載以前に公開刊行物に発表される可能性のないものに限る。但し，本会発行の研究会成果報告書は除く。

執筆要領

【改訂前の本文】

2．原稿書式

④ 引用文献は，本文中の引用箇所に[1), 2,3), 4-6)]のように，上付き通し番号を付けて示し，本文の最後に頁を改めて，番号順に記載する。執筆者名は全員記載する。雑誌については，和文，欧文にかかわらず英文表記とする（別紙リスト参照)。記載例は以下の通り。

【改訂後の本文】

2．原稿書式

④ 引用文献は，本文中の引用箇所に[1), 2,3), 4-6)]のように，上付き通し番号を付けて示し，本文の最後に頁を改めて，番号順に記載する。執筆者名は全員記載する。雑誌については，和文，欧文にかかわらず英文表記とする（別紙リスト参照)。記載例は以下の通り。2003年4月1日以降の本会発行の研究会成果報告書は、原則として引用不可とする。