（＊掲載記事題目及び掲載頁は変更になる場合があります。）

Casting and Solidification

The role of mould fluxes in continuous casting—so simple yet so complex (Review)

K.C.MILLS et al.

The performance of mould fluxes in providing the optimum levels of lubrication and horizontal heat flux is relatively simple since they rely on only three properties, the viscosity and break temperature of the flux and the crystalline fraction developed in the slag film. These parameters can be readily calculated according to the mould dimensions, casting conditions and steel grade. It is only when the flux is used to combat other problems, such as those arising from turbulent metal flow (*e.g.* slag entrapment) that flux behaviour becomes complex and more difficult to understand. Some recent developments may help to combat problems associated with turbulent metal flow and free the flux to carry out its principal duties of providing optimum lubrication and horizontal heat flux.

(cf. *ISIJ Int.*, **43** (2003), 1479)

Fundamentals of High Temperature Processes

Deoxidation equilibrium of manganese and silicon in liquid iron–nickel alloys

V.Y.DASHEVSKII et al.

The thermodynamic analysis of oxygen solutions in Fe–Ni melts containing manganese and silicon has been carried out. The deoxidation power of manganese essentially increases with the nickel content in melt. The solubility curves pass through a minimum, which shifts to lower manganese contents, as nickel content in melt increases. For alloys containing more than 50–60% nickel, the minimal oxygen concentrations are obtained at manganese content equal to 1–1.5%, the further increase of manganese concentration results in an increase of oxygen content. Silicon deoxidation power also increases with the increase of nickel content in melt, but not so sharply as in the case of manganese. In the range of silicon contents considered, no minimum was observed in oxygen solubility curves. Thermodynamics of oxygen, manganese and silicon solutions in the Fe–40%Ni melts has been studied experimentally in a temperature range of 1 823–1 923 K. With temperature drop, deoxidation power of both manganese and silicon increases. In the Fe–40%Ni melts in both cases it is higher than in iron but lower than in nickel. Dependence of oxygen concentration on manganese and silicon contents is expressed by empirical equations. Upon combined deoxidation with manganese and silicon, it is possible to obtain lower oxygen concentrations in metal, in comparison with separate deoxidation due to decreased activities of manganese oxide and silica.

(cf. *ISIJ Int.*, **43** (2003), 1487)

Numerical analysis of edge over-coating in continuous hot-dip galvanizing

S.J.KIM et al.

The edge over-coating (EOC) developed near the edge of a galvanized steel strip is numerically analyzed. The 3-D flow field with alternating vortices in the region away from the strip edge is investigated and the distributions of mean impinging pressure and shear stress on the strip surface are obtained by using a commercial 3-D flow analysis code, STAR-CD. It was found that the appearance of alternating vortices causes the surface pressure to decrease gradually approaching the strip edge. The coating thickness is calculated by one integral analysis method of the boundary layer momentum equation. A sample calculation of a benchmark experiment on EOC problem shows that the present analysis method yields a reasonably accurate prediction of EOC for a given plant operating condition. And the result demonstrates theoretically that EOC can be effectively remedied by adjusting the distance of the 2-D air-knife nozzle and by installing a baffle plate parallel to the end of the steel strip.

(cf. *ISIJ Int.*, **43** (2003), 1495)

Effect of water–gas shift reaction on reduction of iron oxide powder packed bed with H_2–CO mixtures

H.ONO-NAKAZATO et al.

Although the hydrogen reduction is thermally more disadvantageous than the CO reduction, it is advantageous that the reduction rate with H_2 is much larger than that with CO. In order to examine the effective use of hydrogen, the reduction of $FeO_{1.05}$ powder packed bed with H_2–CO mixture was conducted, and the results were analyzed by a proposed model. The temperature, at which the reduction equilibria of $FeO_{1.05}$ with H_2 and CO equal, is determined to be 1 093 K from the present results. The apparent rate constants are determined to be 33, 8.6 and 15 for the reduction of $FeO_{1.05}$ with H_2, CO and H_2–CO mixture ($\bar{V}_{H_2} : \bar{V}_{CO} = 1 : 1$), respectively. In the proposed model, when the water–gas shift reaction is taken into account, the additivity is established on the dependence of the rate constant of the reaction on the gas composition. When the water–gas shift reaction is not taken into account, the rate constant deviates negatively from the additivity. The apparent rate constants of the reduction determined in the present study take the middle values, and the contribution of the water–gas shift reaction is estimated to be 3% against its equilibrium. In reducing $FeO_{1.05}$ with CO, the time when the sample is perfectly reduced is shortened by adding a small amount of H_2, and the rate enhancement effect of H_2 on the gaseous reduction remarkably appears at 1 093 K. The effect originates in the proceeding of the water–gas shift reaction.

(cf. *ISIJ Int.*, **43** (2003), 1502)

Ironmaking

Coal-char/Slag interactions during pulverised coal injection in a blast furnace: reaction kinetics and wetting investigations

A.S.MEHTA et al.

The kinetics of reactions taking place in the slag/carbon interfacial region was investigated at 1 500°C for a range of carbonaceous materials, namely synthetic graphite, natural graphite and two coal-chars. Two blast furnace slags, one rich in iron oxide and other rich in silica were used in this study. Slag/carbon reactions were studied in a horizontal tube resistance furnace in argon atmosphere, using the sessile drop approach. The volumes of CO and CO_2 evolved were obtained from an analysis of off-gases with the help of a mass spectrometer. These reactivity studies were supplemented with wettability measurements on these systems. With iron oxide rich slag 1, all carbonaceous materials showed non-wetting behaviour without much improvement with time. With silica rich slag 2, natural graphite and coal-chars showed dynamic wetting after some time. Synthetic graphite however continues to remain non-wetting. Reduction of iron oxide was a predominant reaction with slag 1 and reached completion for all carbon substrates. Reduction of silica, main reaction with slag 2, was however partial with considerable amounts of unreduced silica remaining behind even after 1 800 s of contact. Overall reaction rates in the initial stages of contact were quite similar for both graphites whereas both coal-chars showed relatively high reaction rates. These results point towards the important roles played by the chemical composition of slags and carbonaceous materials in reduction reactions.

(cf. *ISIJ Int.*, **43** (2003), 1512)

Model analysis of the operation of the blast furnace hearth with a sitting and floating dead man

J.BRÄNNBACKA et al.

The phenomena in the blast furnace hearth are extremely complex and the possibilities to directly measure its internal state are practically non-existent. In order to control the process to achieve smooth operation and long campaigns, a thorough understanding of the conditions in the hearth is required. Such knowledge can be gained through mathematical modeling of the internal conditions. Since the properties of the dead man are known to considerably affect the hearth conditions, a model describing the operation of the hearth with a sitting, partially or completely floating dead man has been developed. Simulation of the tap cycle of a one-taphole blast furnace shows the effect of boundary conditions, hearth geometry, coke voidage and deadman floating state on the evolution of the liquid levels and the slag delay. On the basis of the computed inner geometry of the hearth, the model has been applied to data from a six-year period of a Finnish blast furnace, and it has been found to accurately predict the long-term variations in the slag delay.

(cf. *ISIJ Int.*, **43** (2003), 1519)

Micro-properties of Australian coking coals

N.ANDRIOPOULOS et al.

The properties of a suite of experimental cokes made from Australian coals were studied. Image analysis was used to quantify the coke pore and pore wall microstructure, while ultra-micro indentation characterised the strength of the coke wall textures. The micro-properties were compared with compact tension measurements of bulk coke strength. The microstructural features of good cokes included a relatively thick coke wall, and a pore size distribution

that has small mean pore size combined with a high pore density. It was found that inert maceral derived coke microtextures displayed the highest hardness values. The hardness of reactive maceral derived coke was lower and decreased with increasing mosaic size. For the set of cokes studied, the hardness and modulus were comparable for the same coke microtexture, irrespective of the coal source. Fracture toughness could not be determined for the coarser mosaic textures using the crack measurement approach. For those textures where measurements were possible, fracture toughness for the components was found to be independent of the parent coal.

(cf. *ISIJ Int.*, **43** (2003), 1528)

Casting and Solidification

Physical and mathematical modeling in development of metal delivery system for single belt casting process

K.-H.Moon et al.

A piston type metal delivery system has been designed for the single belt strip caster at the McGill Metals Processing Centre (MMPC) of McGill University, and water modeling equipment set up to validate the proposed enclosed metal delivery system. Water flows were inspected using dye injection, and velocity fields were measured with a dual Nd: YAG PIV (Particle Image Velocimetry) system using the metal delivery nozzles proposed for optimum delivery of liquid steel. Mathematical modeling was also carried out to help anticipate flow patterns in the output chamber and the exit nozzle. When a slot type nozzle was used without a flow-modifier, a strong jet flow impinging on the substrate was generated. Bubbles generated during the initial filling of the delivery system were entrapped within re-circulatory flows in the output chamber. Bubbles were removed using a three hole type nozzle, but the impinging jet flow still remained. The FD type nozzle which had a multi-channel as a flow modifier, a slot type inlet nozzle located at the right side of the multi-channel, and an upper chamber which had the same height as the inlet slot length, was found to be outstanding for bubble removal, moderating strongly impinging flows, and providing uniform exit flows. Calculated flows were shown to be good agreement with PIV measurements.

(cf. *ISIJ Int.*, **43** (2003), 1538)

Internal defects of continuous casting slabs caused by asymmetric unbalanced steel flow in mold

Y.Miki et al.

The molten steel flow in the continuous casting mold and entrapment of inclusions and bubbles on the inner surface of the solidified shell are examined to clarify the origin of internal defects in steel products. Defects on steel sheets are caused by inclusions and bubbles entrapped on the solidified shell during casting. It was found that bubbles are able to penetrate deeply due to an unbalanced time-dependent flow. This phenomenon can be explained by the Large Eddy Simulation model, which is capable of simulating the time-dependent flow.

The number of inclusions increases as the bubble diameter and the distance of the position of entrapment from the top free surface increase. This indicates that bubbles collect inclusions while traveling in the molten steel in the continuous caster. A simple mathematical model is presented to explain how the inclusions are collected by bubbles.

The calculation results also reveal that the static magnetic field generated by the FC Mold reduces time-dependent flow changes and thereby prevents internal defects caused by bubbles and inclusions.

(cf. *ISIJ Int.*, **43** (2003), 1548)

Contribution to the large eddy simulation of flows in electromagnetic stirrers for continuous casting

O.Peşteanu et al.

A numerical study in cylindrical coordinates of the statistically steady turbulent flow in a laboratory setup for modeling the rotational inductive stirring in continuous casting of round strands is presented using the large eddy simulation method. For simulation of the velocity increase in the flow-mechanically stable layers the turbulent viscosity of the Smagorinsky model is reduced by a term depending on the r-derivative of the angular momentum, which characterize the stability. The explicit discretization scheme is applied for the time integration with implicit calculation of the diffusive terms in the azimuthal direction in order to obtain a greater maximal admissible time step. On the z-axis unique interpolated velocity values are used in the finite difference equations. The pressure Poisson equation is solved applying the fast Fourier transform and a supplementary pressure gradient is introduced to vanish the axial flow rate resulted by the use of axial periodic boundary conditions. Comparisons with experimental data show good agreements for both mean velocity and flow statistics.

(cf. *ISIJ Int.*, **43** (2003), 1556)

Instrumentation, Control and System Engineering

Gauge and tension control during the acceleration phase of a Steckel hot rolling mill

B.H.Freyer et al.

The focus in this work is on linear model identification of a Steckel hot rolling mill process on a point during the acceleration phase of the process. It furthermore focuses on the controller design based on the linear models and on controller implementation on a non-linear simulator of this process. The linear models are identified for different cases simulated with and without gauge meter compensation and controlled tensions as part of the simulator. The system identification is accompanied by a heuristic justification of the data obtained. A diagonal PID/PI controller as well as MIMO H_∞ controllers, of which the designs are based on the linear models, are implemented on the simulator. From the system identification data for the different linear models it could be seen that gauge meter compensation successfully counteracts the adverse effect of mill stretch and eliminates oscillations in exit gauge, which result from tension oscillations. Simulations of the different controllers in closed loop with the non-linear plant simulator show that good control can be achieved by controllers of which the designs are based on linear diagonal models. One of these controllers, a diagonal H_∞ controller, tested on a non-linear simulator which incorporated gauge meter compensation and inner loop tension control, was found to be the most suited for a switching control system.

(cf. *ISIJ Int.*, **43** (2003), 1562)

Forming Processing and Thermomechanical Treatment

Finite element modeling of thermo-mechanical and metallurgical behavior of type 304 stainless steel in cold strip rolling

C.G.Sun et al.

A finite element-based, integrated process model is presented for the coupled analysis of the thermo-mechanical and metallurgical behavior of type 304 stainless steel occurring in the entire tandem mill during cold strip rolling. The validity of the proposed model is examined through comparison with measurements. The model's capability of revealing the effect of diverse process parameters is demonstrated through a series of process simulation.

(cf. *ISIJ Int.*, **43** (2003), 1572)

Cold rolled texture and microstructure in types 304 and 316L austenitic stainless steels

D.N.Wasnik et al.

Two grades of austenitic stainless steel (ASS), types 304 (UNS S 30400) and 316L (UNS S 31603), were cold rolled to different reductions by unidirectional and by cross-rolling. The steels had reasonable difference in stacking fault energy (estimated respectively as 15 and 61 mJ/m^2 in types 304 and 316L) and also in starting (or pre-deformation) crystallographic texture—being relatively weak and reasonably strong in types 304 and 316L respectively. The cold rolling increased texturing in type 304, but not in type 316L ASS. The more significant effect of cold rolled texture development was in the relative increase of Brass ($\{011\}\langle 211\rangle$) against Copper ($\{112\}\langle 111\rangle$) and S ($\{231\}\langle 346\rangle$) orientations. In type 304 the increase in Brass was significant, while in type 316L the increase in Copper and S was stronger. This effect could be captured by Taylor type deformation texture simulations considering stronger twinning contributions in type 304—for example the respective 'best-fits' (in terms of matching the changes in the volume fractions of Brass against Copper and S) were obtained by full constraint Taylor model with 1 : 100 and 1 : 10 slip : twin activities in types 304 and 316L ASS respectively.

Microstructural developments during cold rolling were generalized as strain induced martensite formation and developments of dislocation substructure. The former, as estimated by vibrating sample magnetometer (VSM), increased with cold reduction, being significantly more in type 304 and was also noticeably stronger in both grades under cross-rolling. The most significant aspect of substructural developments was the formation of strain localizations. These were observed as dense dislocation

walls (DDWs), micro-bands (MBs) and twin lamellar structures (TLS). The TLS contribution gained significance at higher reductions and during cross-rolling, especially in type 304. Large misorientation development and the accompanying grain splittings were always associated with such strain localizations. Efforts to relate Taylor factor (M) and textural softening ($dM/d\varepsilon$) values (of ideal texture components) with relative misorientation developments was, however, unsuccessful. No consistent trend could be established for any unique combination(s) of slip-twin in the respective alloys.

(cf. *ISIJ Int.*, **43** (2003), 1581)

Welding and Joining

Effects of oxygen additions to argon shielding gas on GTA weld shape

S.LU et al.

In order to investigate the effect of oxygen additions on the weld shape in gas tungsten arc welding, bead-on-plate specimens were made of SUS304 stainless steel using O_2–Ar mixed shielding gas with oxygen additions from 1 000 to 10 000 ppm. The weld bead cross-sections and the weld surface oxide layer were observed by optical microscopy after welding. The oxygen content in the weld metal was measured using a Oxygen/Nitrogen Analyzer. The weld depth/width ratio increases substantially as a result from the additions of oxygen to the argon shielding gas in the range of 3 000 to 5 000 ppm both for the 10 and 20 L/min shielding gas flow rates. When the oxygen addition contents are below 2 000 ppm or over 6 000 ppm, the weld D/W ratio decreases to approximately 0.2. The oxygen in the weld pool plays an important role as an active element affecting the Marangoni convection mode. The inward Marangoni convection occurs on the liquid pool surface when the oxygen in the weld is over 100 ppm, and hence the D/W ratio increases suddenly. The thicker oxide layer on the weld pool surface is not only a barrier for the oxygen to transfer and become a solute in the weld pool, but also prevents the weld pool from moving freely, and hence changes the weld pool shape.

(cf. *ISIJ Int.*, **43** (2003), 1590)

Dissimilar metal joining of aluminum to steel by MIG arc brazing using flux cored wire

T.MURAKAMI et al.

Dissimilar metal joining of aluminum to steel, which is difficult due to the formation of the brittle intermetallic compound at the interface of the welded joint, by DC pulsed MIG arc brazing in a lap joint with the flux cored Al–Si filler wire has been investigated for the application of the weight saving of automobiles. The major compound formed at the interface between steel and weld metal was determined to be $Al_{7.4}Fe_2Si$ as the Al–Fe–Si ternary compound. The composition control of weld metal can suppress the growth of the intermetallic compound layer less than the thickness of 2.5 μm. In this condition, the transverse tensile strength of the welded joint was about 80 MPa, 70% of that of Al base metal due to the fracture at HAZ on the aluminum side. The mechanism of the suppressed growth of the intermetallic compound layer during MIG arc brazing has been discussed.

(cf. *ISIJ Int.*, **43** (2003), 1596)

Surface Treatment and Corrosion

The microbiologically influenced corrosion behavior of C-Mn ship structural steel with different manufacturing processes

H.G.JUNG et al.

The MIC (Microbiologically Influenced Corrosion) of lower deck steel plates in double hull VLCC (Very Large Crude Oil Carrier) cargo tanks has been focused because of severe localized corrosion. Recently, ship companies have reported that TMCP (Thermo-mechanical Control Process) steel plates have been showed more severe localized corrosion than conventional rolled steels. In order to elucidate the MIC resistance of TMCP steels by comparison with conventional rolled steels and normalized steels in environments of double hull VLCC cargo oil tanks, various measurements and corrosion tests were performed such as measurements of polarization curves, immersion tests in bacteria culture medium.

All results revealed that three types of steels have almost the same corrosion resistance in bacteria culture medium. Three kinds of steel exhibit almost the same polarization behavior and the corrosion rate. The movement of the open-circuit potential first towards more negative values and later to more positive values is a phenomenon common to all kinds of specimens. This phenomenon resulted from an initial stimulation of the anodes by sulphide ions produced by the bacteria from the reduction of sulphate ions in the medium, followed by the formation of an insoluble partly protective film of ferrous sulphide on the surface of the electrode. The effect of SRB (Sulphate Reducing Bacteria) is clearly showed in the cathodic polarization curve. When the SRB is in a condition of rapid growth, there is a strong cathodic depolarization. However, as the sulphate is depleted and reaction products accumulate, the activity of the bacteria declines and the cathodic polarization curve returns the same form as in the inoculated culture.

(cf. *ISIJ Int.*, **43** (2003), 1603)

Transformations and Microstructures

Effect of heating rate on the development of annealing texture in nonoriented electrical steels

J.-T.PARK et al.

The magnetic properties of nonoriented electrical steels are influenced by grain size and texture. During the final annealing process, heating rate, annealing temperature and time, and cooling rate are the main factors which can influence the formation of annealing texture. Among these parameters, heating rate is more effective in controlling texture development through changes in the recovery and recrystallization processes. Therefore, it can provide the means to decrease core loss and increase permeability. In nonoriented electrical steels with different initial grain sizes, the effect of heating rate on texture development during final annealing is examined, and the reasons for texture changes are discussed. The average grain size decreases with the increase in heating rate both in the coarse-grained and in the fine-grained specimens. In the coarse-grained specimen, the Goss texture is significantly strengthened but the {111}⟨112⟩ texture component is slightly weakened as heating rate increases. On the other hand, in the fine-grained specimen, the {111}⟨112⟩ intensity is greatly decreased but the Goss intensity is slightly increased as the heating rate increases. The heating rate up to the annealing temperature affects texture formation differently depending on the initial grain size prior to cold rolling. These differences are mainly related to the difference in the number of shear bands formed during cold rolling in grains having different sizes.

(cf. *ISIJ Int.*, **43** (2003), 1611)

Effect of chemical composition and thermomechanical processing on texture in hot bands of Ti and Ti+Nb containing ultra-low carbon steels

S.YIM et al.

The effect of carbon, Ti and Nb on the formation of hot band texture in ultra-low carbon steels was studied. The chemical compositions were selected so that two of the four steels were fully stabilized with respect to carbon and the other two were expected to have some carbon in solution under equilibrium conditions. The slab reheating temperature ranged from 1 200 to 1 280°C. The first deformation was applied with a 50% reduction to simulate the roughing pass at 1 150°C. The samples were then deformed with another 50% reduction at either 1 050 or 920°C. The crystallographic orientations of the resulting ferrite were presented in the form of so-called skeleton plots along the RD-, TD- and ND-fibers. The main texture found was the cube-on-corner, {111}⟨110⟩, component. The rotated cube component, {001}⟨110⟩, was also present but its intensity was always lower than the intensity of the cube-on-corner component. The presence of the cube-on-corner texture was explained by the large grain size in the starting as-cast ingots and by the heavy reductions per pass. The combination of low reheating temperature and low finishing temperature generated the highest ratio of {111}/{100}. Decreasing the carbon content from 35 to 17 ppm and adding 90 ppm Nb to a Ti-alloyed ULC steel further increased the {111}/{100} ratio.

(cf. *ISIJ Int.*, **43** (2003), 1615)

Improving toughness of PH13-8 stainless steel through intercritical annealing

Z.GUO et al.

An intercritical annealing step was introduced in the treatment of a PH13-8 stainless steel to improve the toughness of the alloy in aged condition. Four different treatment cycles, *i.e.* austenitisation (Q-treatment) and intercritical anneal (L-treatment), LQ, 2B (QLQL) and 2K (LQLQ) were carried out before aging treatment at 510°C for 4 h (the commercial H950 treatment). Optical and scanning electron microscopies, and X-ray diffraction analysis

were employed to study the microstructures of the alloys after different heat treatments. Hardness and Charpy impact strength of the samples were measured.

Results show that significant grain refinement was observed after 2K and 2B treatment, but not after QL and LQ treatments. Such refinement of prior austenite grain did not lead to significant increase of hardness either before or after ageing. The Charpy impact strength of the alloy in aged condition was improved after the four pre-ageing treatments. The formation of a 'dual-phase' martensitic structure through intercritical annealing is thought to make the main contribution to the better toughness obtained, with beneficial effects also from grain refinement. All the four treatments offer better combined properties than the commercial treatment, whereas QL and LQ treatments may be cost-competitive. Relationships among heat treatment, microstructure and mechanical properties are discussed.

(cf. *ISIJ Int.*, **43** (2003), 1622)

Nucleation of proeutectoid ferrite on complex precipitates in austenite

T.FURUHARA et al.

Effect of various intragranular inclusions or precipitates (MnS, VC and V(C,N)) on the microstructure and kinetics of intragranular ferrite transformation at the temperatures between 973 and 823 K was studied using various Fe–2Mn–(0.13, 0.2)C(mass%) alloys with the small addition of sulfur, vanadium, and nitrogen. In Fe–2Mn–0.13C–50ppmS and Fe–2Mn–0.2C–470ppmS alloys, MnS particles, mostly incoherent in austenite, do not act as effective nucleation sites of ferrite. V addition slightly improves the potency of MnS as ferrite nucleation site by forming MnS+VC complex precipitates. The addition of both V and N largely enhances the intragranular nucleation of ferrite idiomorph on the MnS+V(C,N) complex precipitate. It is considered that two factors, *i.e.*, (1) the advantage in the balance of interphase boundary energy and (2) the increase in the fraction of V(C,N) precipitate by the addition of nitrogen, are mainly responsible for the promotion of intragranular ferrite formation on the MnS+V(C,N) complex precipitate.

(cf. *ISIJ Int.*, **43** (2003), 1630)

Mechanical Properties

Effect of Ti and W on the mechanical properties and microstructure of 12% Cr base mechanical-alloyed nano-sized ODS ferritic alloys

I.-S.KIM et al.

In recent years, research and development of high-temperature structural materials for ultra-super critical pressure plant with increased energy efficiency have actively been in progress so as to solve global environmental pollution and resource exhaustion issues.

Oxide-dispersed-strengthened (ODS) ferritic alloys produced by mechanical alloying (MA) have been developed as alternative materials with very high-temperature strength at the ultra-super critical pressure.

In this study, Fe–12%Cr ODS based alloys containing Ti and W have been made and the effects of Ti and W on the high-temperature strength of the alloys were investigated. The results show that high-temperature tensile strength and creep rupture strength of the 12YWT steel containing 0.4% Ti and 3% W were the highest. This is mainly due to the formation of fine complex oxides of Ti–Y–O by the addition of Ti and their homogeneous distribution. It is also suggested that solid solution hardening by W occurs as a result of uniform distribution of W in solution.

(cf. *ISIJ Int.*, **43** (2003), 1640)

Effect of chromium content on relationship between *r*-value and {111} recrystallization texture in ferritic steel

Y.YAZAWA et al.

The deep drawability of ferritic steels can be improved by increasing the *r*-value, which is closely related to the {111} recrystallization texture. Control of the {111} recrystallization texture in ferritic steel has been extensively studied as the means of improving the deep drawability of the steel sheet. However, no published research has compared the relationship between the *r*-value and {111} recrystallization texture in mild steels and ferritic stainless steels.

The aim of the present research is to clarify the effect of chromium on the relationship between the {111} recrystallization texture and *r*-value in order to improve the deep drawability of ferritic stainless steels.

The following results were obtained through the study using body-centered cubic steels with various chromium content: (1) Ferritic stainless steels show higher *r*-values than mild steels with the same level of {111} recrystallization texture. (2) Chromium addition is advantageous for realizing higher *r*-values in ferritic steel.

The authors propose that some slip systems in ferritic steels are constrained by chromium atoms, which results in higher *r*-values in ferritic steels.

(cf. *ISIJ Int.*, **43** (2003), 1647)

Effect of grain size on the fatigue crack growth in steels at temperatures 295 and 77 K

G.ROSENBERG

Fatigue crack growth (FCG) and threshold stress intensity in low carbon and HSLA steels with remarkably different ferrite grain sizes (d_f) at room temperature and temperature of liquid nitrogen were investigated. The FCG rates were found to decrease with decreasing temperature for all investigated microstructural states and the influence of temperature decrease was the most significant in coarse grain microstructures. The threshold values of the stress intensity factor, (ΔK_{th}), below which cracks do not propagate, decreased by between 29.1% (d_f=2.7 μm) and 49.3% (d_f=88.4 μm) when specimens were tested at the cryogenic temperature.

A general relationship between the FCG rate, the effects of grain boundary blocking on the plastic zone size and/or the crack-tip opening displacement and the effect of changing temperature, is discussed. Furthermore, the concept of a functional relation between tensile and fatigue data at cryogenic temperatures was also investigated. It was shown that the ratio of ΔK_{th} at 77 K to ΔK_{th} at 295 K is proportional to the second root of the ratio of the tensile strength values at these temperatures *i.e.* $\Delta K_{th\,77\,K}/\Delta K_{th\,295K} \approx (\sigma_{u\,77\,K}/\sigma_{u\,295\,K})^{1/2}$.

(cf. *ISIJ Int.*, **43** (2003), 1652)

Effect of Nb on hot rolled high strength steel sheets produced by thin slab casting and hot direct rolling process

S.HASHIMOTO

In order to meet to the demands from automobile industry such as weight reduction and safety improvement, the hot rolled high strength steel sheets have been used mainly for suspension parts. While, the steel production by thin slab casting (TSC) and hot direct rolling (HDR) process has been noticed. In this study, the characteristics of the high strength hot rolled steels produced by TSC–HDR were discussed comparing with the conventional process and concluded as follows;

(1) The effect of difference of production route on the relationship between tensile strength and elongation or tensile strength and stretch flangeability was small.

(2) Strength obtained by TSC–HDR route was higher than those of conventional production route in Nb bearing steel. This means Nb effectively works as a strengthening element in TSC–HDR route.

(3) The addition of Nb and Mn was effective on the improvement of tensile strength and stretch flangeabilty relationship. Especially when the stretch flangeabilty was compared in the same TS level, Nb bearing steels exhibited more than two times of the value of plain C–Mn steel.

(cf. *ISIJ Int.*, **43** (2003), 1658)

Social and Environmental Engineering

Reduction of the specific energy use in an integrated steel plant—the effect of an optimisation model

M.LARSSON et al.

Analysing the potential for improving the specific energy use in a steel mill can be difficult due to the interactions between the different subsystems. Changes in one unit can lead to several changes throughout the system. A process integration model taking into account the different interactions within the system is presented. The model is based on an optimising routine, making it a total analysis method for the steel plant system including the surroundings. The model is used to analyse the different possibilities for energy savings and practice changes within the system. The effect of optimising the total system versus separate optimisation of the different sub-processes is illustrated. The method development can serve as a benchmark for different steelmaking operations and constitute a basis for the continuous work involved in energy, material or economic analyses for the steel production system.

(cf. *ISIJ Int.*, **43** (2003), 1664)