（＊掲載記事題目及び掲載頁は変更になる場合があります。）

Forming Processing and Thermomechanical Treatment

Current trends in cross wedge rolling for part forming (Review)

M.WANG et al.

Cross wedge rolling (CWR), as an efficient metal plastic forming process, has always been investigated perseveringly by many nations' scholars for a number of years. Currently, with the fast development of economy, the increased demand is asked for various stepped shaft in different departments, especially in automobile industry, which also makes CWR research and development vigorous. A historical perspective tracing research and development in CWR is summarized and the trends for future research given in this paper, which are helpful to the development and application of CWR technology.

(cf. *ISIJ Int.*, **45** (2005), 1521)

Fundamentals of High Temperature Processes

Wetting and interfacial reaction investigations of coke/slag systems and associated liquid permeability of blast furnaces

T.W.KANG et al.

An interfacial study between metallurgical coke and synthetic slags representing typical slag chemistry of bosh regions of an operating blast furnace was conducted at 1 500°C using a horizontal laboratory furnace. The wetting characteristics of coke with slag was studied by measuring dynamic contact angle of sessile droplet of slag on coke substrate, while reaction kinetics of interface was monitored by measuring the amount of CO and CO_2 gases with the help of infrared analyzer. The interface chemistry was also examined by SEM/EDS/EPMA. The study demonstrated that coke wettability was strongly dependent both on the slag composition as well as coke chemistry such that low basicity (CaO/SiO_2) of slag, that is high amounts of oxides of silicon enhanced the wetting propensity of slag. The study further showed that the wettability of coke with slag was found to improve with increased extent of gasification, and was attributed to higher ash content of partially gasified cokes. The CO/CO_2 measurements of off gases from the reacting chamber were used to demonstrate that slag wettability with coke was primarily controlled by the kinetics of reduction of metal oxides at the slag/coke interface particularly that of silica. The study demonstrates that in addition to slag composition, coke properties could also influence the liquid permeability of lower zone of the blast furnace, and hence needs attention while optimizing the bosh slag composition for high productivity blast furnace operation.

(cf. *ISIJ Int.*, **45** (2005), 1526)

Supersaturation of carbon in austenite during carburization by CO gas

I.SEKI et al.

Fine particles of electrolytic iron in austenite state absorbed carbon from CO gas to be in supersaturation. The carbon content in austenite was estimated from the spacing of lattice planes of iron, which was measured by a high temperature X-ray diffractometer. The supersaturation was depended on the flow rate of CO gas and temperature. The solute supersaturation ratio of carbon was from 1.2 to 1.8 at the temperature between 1 452 and 1 599 K. Iron particles reduced from hematite by H_2 gas behaved as same as electrolytic iron particles. However, the iron particles reduced from hematite by CO gas were not in supersaturation of carbon and melted at the solubility of carbon in austenite state. The supersaturation can be explained by the decline of heterogeneous nucleation sites per unit volume. The spacing of lattice planes of reduced iron by CO gas abnormally increased and then decreased during heating. The reduced iron particles melted at the solubility of carbon in austenite and did not become supersaturation.

(cf. *ISIJ Int.*, **45** (2005), 1536)

Experimental study of phase equilibria in the MnO–"TiO_2"–"Ti_2O_3" system

Y.-B.KANG et al.

Phase equilibria and liquidus in the system MnO–"TiO_2"–"Ti_2O_3" under controlled atmosphere have been investigated in the temperature range from 1 300 to 1 550°C and in the range of $\log pO_2$ (in atm) from −7.2 ($pCO/pCO_2=1$) to −16.6 (C–CO equilibration). High-temperature equilibration, quenching and electron probe microanalysis (EPMA) were employed to obtain equilibrium compositions of liquid and several solid solutions. The following phases have been observed; molten oxide, manganosite (MnO (s.s.)), rutile ($TiO_{2-\delta}$ (s.s.)), spinel (Mn_2TiO_4–$MnTi_2O_4$), pyrophanite ($MnTiO_3$–Ti_2O_3) and pseudobrookite ("$MnTi_2O_5$"–Ti_3O_5) solid solutions. Liquidus of manganosite and rutile were measured and compared with previous investigations. "$MnTi_2O_5$" compound was confirmed to be unstable phase in the MnO–"TiO_2" system. It was found in the present study that sub-solidus phase equilibria are affected considerably by oxygen partial pressure.

(cf. *ISIJ Int.*, **45** (2005), 1543)

Experimental study of phase equilibria in the MnO–SiO_2–"TiO_2"–"Ti_2O_3" system

Y.-B.KANG et al.

Phase equilibria and liquidus surface in the system MnO–SiO_2–"TiO_2"–"Ti_2O_3" under controlled atmosphere have been investigated in the temperature range from 1 200 to 1 500°C and in the range of log pO_2 from −7.6 ($pCO/pCO_2=1$) to −16.6 (C–CO equilibration). High-temperature equilibration, quenching and electron probe microanalysis (EPMA) were employed to obtain equilibrium compositions of liquid and several solid solutions. The following primary phases have been observed; molten oxide, manganosite (MnO), rutile ($TiO_{2-\delta}$), tridymite and cristobalite (SiO_2), tephroite (Mn_2SiO_4), rhodonite ($MnSiO_3$), spinel (Mn_2TiO_4–$MnTi_2O_4$), pyrophanite ($MnTiO_3$–Ti_2O_3) and pseudobrookite ("$MnTi_2O_5$"–Ti_3O_5) solid solutions. By decreasing oxygen partial pressure, homogeneous liquid oxide area becomes smaller. No ternary compounds or ternary solid solutions were observed.

(cf. *ISIJ Int.*, **45** (2005), 1552)

Thermal implications of phase transformations during induration of iron ore pellets produced from hematite

A.R.FIRTH et al.

Although extensive development has occurred in recent years for models of induration of iron ore pellets, none of these models have taken into account the partial melting of some of the raw materials. To determine the importance of partial melting and melt phase formation to the energy balance for induration, estimates have been made of the thermodynamic properties of silicoferrite of calcium, SFC, using published techniques. SFC was used in this paper as an example of the initial melt forming minerals in the pellets. Owing to the complexity of the structure of SFC, there was some doubt as to the accuracy of these estimates as they suggested that SFC was not a thermodynamically stable phase, though it exists between 1 050 and 1 250°C. As no experimental data was available, however, these 'best available' estimates have been incorporated into a mathematical model to determine the effect of melt phase formation on the induration process. It was found that while there was little effect on the pellet temperature profiles, the overall amount of energy required to indurate the pellets increased by about 1–1.5% when melt phase formation was included. This suggests that experimental determination of the thermodynamic properties of SFC and other phases produced from the melt would be of benefit in modelling the energy requirements for induration of pellets more accurately.

(cf. *ISIJ Int.*, **45** (2005), 1561)

Use of slag containing water as a lubricant in high straining rolling for ultrafine-grained steels

M.NAKAMOTO et al.

We investigated the possibility of using waste slag as a lubricant in high straining rolling for ultrafine-grained steels. When slag is applied as a lubricant, it might satisfy the requirement for stable biting workpieces because slag is as stable as glass with high hardness at the biting temperatures in rolling (100–200°C). On the other hand, ordinary slag doesn't have the fluidity necessary to provide a lubricating effect at rolling temperatures of 300–400°C since its melting temperature is usually high. However, slag containing water has been targeted as a new lubricant, and we focused on lowering the glass transition temperature and the structural change of slag containing water with the aim of improving the lubricity of slag in rolling. The microstructures of slag containing water and slag that released water were observed in the present study, along with *in-situ* observation of water released from the surface of slag containing water were conducted after heating in a SiO_2–Na_2O–B_2O_3 slag system. We found that water was mainly contained in the phase formed by ions dissolved from the original slag under hydrothermal conditions, and the amount of water was dependent on the state of the phase, such as glass or crystal. It was confirmed that slag containing water could provide a lubricating effect when the water is released from the slag above the glass transition temperature because a porous structure is formed

due to the water release.

(cf. *ISIJ Int.*, **45** (2005), 1567)

Complex deoxidation equilibria of molten Iron by aluminum and calcium

K.TAGUCHI et al.

The influence of oxygen potential in molten steel on the steelmaking reactions, such as desulfurization and denitrogenization by fluxes, is very significant, and it is important to control oxygen content of the molten steel. The use of the strong deoxidizing agents, such as Al and Ca, is effective for decreasing oxygen content of steel, and several researches on the complex deoxidation have been carried out. However, the experimental data do not necessarily accord with the thermodynamically calculated ones, because the reliable thermodynamic data on Ca deoxidation of molten iron are unavailable. In the present study, the complex deoxidation equilibria of molten iron by Al and Ca have been examined at 1 873 K. The oxygen activity in molten iron deoxidized by Al and Ca has been measured by an electro motive force (EMF) method at 1 873 K. The Al–Ca complex deoxidation equilibria are presented, and the validity is confirmed from the present experimental results and the previous ones in the literature on the complex deoxidation by Al and Ca. The Al–Ca deoxidation equilibria presented in the present study can represent the relationship of Fe–Al–Ca–O system more properly than the previously reported ones.

(cf. *ISIJ Int.*, **45** (2005), 1572)

Ironmaking

Laboratory scale investigation to improve the productivity of stamp charge coke oven through optimisation of bulk density of coal cake

P.S.DASH et al.

In the recent past, it was realised that the gross coke yield was going down as a result of lower oven throughput in the stamp charged batteries of Tata Steel. The basic reason for this being the net reduction in the ash content of the coal blend used due to the incorporation of higher percentage of low ash imported coals and reduction in the ash content of captive coals through washing. The coals having higher ash content improves the bulk density, as the specific gravity of ash is higher than that of pure coal. Moreover, the ash components have affinity for water and pure coal repels water, which in case of pure coal, works against the holding together of the blend. Hence, lower the ash content, less is the bulk density of cake under identical stamping energy and lower the bulk density, less is the oven throughput. In order to maximise the oven throughput and productivity, a study was conducted in the laboratory mainly to assess the effect of various blend constituents and their ash content on the bulk density of coal charge. The effect of ash content on the coal cake stability has also been dealt with. This study, in short, is a useful tool for selecting the right type of coals and designing the optimum blend for stamp charging to achieve maximum throughput and productivity.

In addition, studies were also carried out to assess the effect of addition of various binders on coal cake stability at lower moisture level which would also help in achieving higher throughput and productivity.

(cf. *ISIJ Int.*, **45** (2005), 1577)

Steelmaking

Continuous off-gas measurement and energy balance in electric arc steelmaking

R.KÜHN et al.

A system has been developed for continuous determination of off-gas composition and off-gas volume rate during EAF steelmaking. It comprises devices for gas sampling and analysis of carbon monoxide, carbon dioxide, hydrogen, nitrogen, oxygen and argon, and of measurement of off-gas temperature. The data are processed by a computer to set up the differential heat balance which indicates the flow rates of chemical and sensible heat of the off-gas leaving the furnace at each moment. Several operations during the melting process were investigated with respect to energy utilization. For instance, the hydrogen content during injection of natural gas decreases strongly with increasing oxygen input. During coal injection there is high loss of chemical energy due to non-complete combustion. Also, the extent of combustion depends on the position of the coal lances. Injection of oxygen in the upper furnace part leads to lower loss of chemical but higher loss of sensible heat. The system is optimized at present to decrease the dead time between gas sampling and print out of the analysis.

(cf. *ISIJ Int.*, **45** (2005), 1587)

Solid inclusion transfer at a steel–slag interface with focus on tundish conditions

J.STRANDH et al.

The separation of non-metallic inclusions from the steel to the slag phase in the ladle during secondary steel making operations and in the tundish and mold during casting is very crucial to the production of clean steel. In this work a theoretical study of the separation of solid inclusions, alumina and others, at the steel–slag interface applied to the actual conditions in the tundish has been carried out. The theoretical model is based on the equation of motion with the following forces acting on an inclusion as it tries to cross the interface between the metal and the slag; buoyant, added mass, rebound and drag force. A sensitivity analysis study was carried out in order to clarify which of the parameters in the model that had the largest influence on the inclusion displacement. The results showed that the interfacial tensions (σ_{MI}, σ_{IS}, σ_{MS}) and the slag viscosity (μ_S) have the largest influence on the predicted displacement. It was also concluded that the overall wettability should be positive and that the slag viscosity should be as low as possible to obtain the most favorable conditions for inclusion transfer at the steel–slag interface.

(cf. *ISIJ Int.*, **45** (2005), 1597)

Mechanism of resulfurization in magnesium desulfurization process of molten iron

J.YANG et al.

During magnesium desulfurization of molten iron, the desulfurization product of MgS floats up to the melt surface. After magnesium supply terminates, resulfurization tends to take place because of the transfer of sulfur from MgS into the melt. In the present study, a simplified experiment was designed to clarify this resulfurization mechanism. With MgS powders added onto the melt surface, the transfer rate of sulfur from MgS into the melt was measured.

Two kinds of mechanisms are revealed to be responsible for the resulfurization in the magnesium desulfurization process. One is decomposition of MgS under the inert atmosphere; the other is oxidation of MgS under the oxidative atmosphere.

It is also found that increasing temperature and oxygen partial pressure in the atmosphere increased the transfer rate of sulfur into the melt and the resulfurization ratio. But the increase in the added amount of MgS did not change the resulfurization ratio largely under the present experimental conditions. The resulfurization rate was smaller by using MgO crucible than that by using Al_2O_3 crucible. Addition of CaO and the activated charcoal powders onto the melt surface could significantly prevent sulfur of MgS on the melt surface from transferring into the melt.

With a simplified first-order rate equation, the calculated capacity coefficient for transfer of sulfur from MgS to melt is increased with increasing the temperature and the oxygen partial pressure in the atmosphere, but does not change with adding different amounts of MgS onto the melt surface.

(cf. *ISIJ Int.*, **45** (2005), 1607)

Casting and Solidification

Numerical investigation of fluid flow phenomenon in a curved shape tundish of billet caster

A.TRIPATHI et al.

The conventional delta shaped tundish (rectangular with sloping walls) is currently used in many industries for billet caster. The effective volume in this type of tundish is significantly low and results in a lower quality of steel. In the present work, a three-dimensional mathematical model has been used to study the fluid flow characteristics in a six strand billet caster tundish whose one side is curved. The results obtained were compared with a conventional delta shaped tundish and the strong role of curvature in modifying the fluid flow characteristics is noticed. Investigations were performed to study the effect of ladle pouring point in a curved shape tundish. It was found that fluid flow characteristics can be improved by placing the ladle pouring point at the right position. Simulations have been performed for two different shapes of pouring chamber to investigate the role of curvature in the flow control devices. The results obtained confirmed the strong role of curvature to get the improved characteristics for inclusion flotation. The mathematical model has been validated by the experimental results of Singh and Koria

for a single strand bare tundish.

(cf. *ISIJ Int.*, **45** (2005), 1616)

Experimental and numerical analysis of the free surface in a water model of a slab continuous casting mold

R.MIRANDA et al.

The flow patterns prevailing at the free-surface in a water model of a slab continuous casting mold using several water flow rates and entry nozzle submergence depths are experimentally and numerically studied in this work. The experimental study was carried out using an one-third scale cold water model, constructed in accordance with the Froude similarity criterion. Water level measurements were carried out with ultrasonic distance sensors and recorded in a computer. Numerical simulations were made with a commercial computational fluid dynamics software. It was found that free-surface oscillations are composed by several periodic components. There exists a fundamental periodic frequency of 1.2 Hz. Besides, there exist two other frequencies of 1.8 and 2.1 Hz whose contribution to the free surface dynamic behavior depend on the spatial position and on the process parameters, namely, the volumetric flow rate and the submerged entry nozzle (SEN) submergence depth. In accordance with the obtained results, several recommendations about operating policies of actual industrial casters are made.

(cf. *ISIJ Int.*, **45** (2005), 1626)

Forming Processing and Thermomechanical Treatment

Laboratory evaluation of new type of backup roll for strip shape control

W.-H.LEE et al.

In this research work, a new back-up roll was developed, which could be used in any type of 4 high mills to reduce the strip shape defects. The developed back-up roll consists of a sleeve, an arbor and a phase angle adjusting system for the arbor. The circumference of arbor was specially machined to adapt the strip width when changing the product and control the shape during rolling. The developed Φ530 mm×498 mm backup roll was installed in a pilot mill and the rolling test was carried out to prove the effectiveness of the newly developed back-up roll. The rolling tests showed that the new back-up roll has better performance in reducing the shape defects than conventional back-up roll. It was also found that the new back-up roll provided higher shape stability. In addition, the arbor can be manufactured using scrapped conventional backup rolls, and it can be multi-times used because only sleeve surface needs to be reground and changed in most cases.

(cf. *ISIJ Int.*, **45** (2005), 1636)

Mathematical modelling of roll cooling and roll surface stress

J.K.SAHA et al.

In a hot strip mill, the quality of the rolled products and the productivity of the mill depend on the efficiency of roll cooling to a great extent. To study the influence of the cooling system on roll performance, a good understanding of the thermal aspects of roll cooling is essential. Mathematical models to predict temperature development in the work roll and compute thermal strain induced at the roll surface during rolling were developed and applied to the upper work roll of the 1st stand of the finishing mill of HSM at Tata Steel. The models were used to predict temperatures and thermal stresses/strains in the roll under various cooling conditions, thus examining the efficiency of the existing roll cooling system and exploring the scope of optimizing it.

(cf. *ISIJ Int.*, **45** (2005), 1641)

Transformations and Microstructures

Microstructural and micro-textural evolution during single pass high Z-large strain deformation of a 0.15C steel

S.V.S.NARAYANA MURTY et al.

Ultrafine grained microstructures and micro-textures formed dynamically during single-pass, high-Z, large-strain deformation have been analyzed in 0.15C steel. A single pass compression technique capable of imposing large plastic strain up to 4 was employed in the present study. Hardness test data revealed work hardening type behavior by pancake type grains while softening behavior was exhibited by equiaxed grains. Detailed micro-texture analysis carried out on the specimens deformed at different temperatures and strains rates in the warm working region revealed no significant difference among them. Even up to fairly high deformation temperatures of 923 K the texture consists of typical deformation components. Finally, based on the results obtained, fundamentals of ultrafine grained product design are discussed.

(cf. *ISIJ Int.*, **45** (2005), 1651)

An unusual structure of an as-cast 30% Cr alloy white iron

A.WIENGMOON et al.

An unusual microstructure of an as-cast 30 wt% Cr and 2.26 wt% C iron has been examined by optical microscopy (OM), scanning electron microscopy (SEM) and transmission electron microscopy (TEM). It was found that the microstructure varied with positions in the cast bar. In the upper part of the cast bar where the cooling rate was faster, the matrix was essentially austenite with some patches of ferrite-plus-precipitated carbides as dendritic regions. Whereas, the central and the lower parts of the cast bar where cooling rates were slower, there was less austenite with greater amount of ferritic zones. The microstructure of core regions at the centre of the dendritic ferrite-plus-precipitated carbides zones contained interconnected carbides that are believed to be the product of a peritectic reaction. TEM examination confirmed that these peritectic carbides were M_7C_3 type. Bainite and martensite were also observed in the transition zones close to the ferrite-plus-precipitated carbides zones. These were believed to result from solid-state decomposition of the dendritic austenite in the later stage of cooling.

(cf. *ISIJ Int.*, **45** (2005), 1658)

Hot deformation and recrystallization of 3% silicon steel part 1: microstructure, flow stress and recrystallization characteristics

S.AKTA et al.

The recrystallization kinetics of 3% Si steel after hot rolling and plane strain compression at strain rates from 0.05 to 5 s21 over a temperature range of 800 to 1 100°C have been investigated. The flow stress of the ferritic 3% Si steel Indicates that the dynamic recovery rate is about two orders of magnitude faster than in austenite. Recrystallization rate after hot rolling is affected by deformation variables and is strongly influenced by the initial grain size. In coarse grained material, retardation of recrystallization resulted in the appearance of a plateau in the recrystallization curves. Austenite present during deformation affects both the strength during deformation and the subsequent recrystallization kinetics.

(cf. *ISIJ Int.*, **45** (2005), 1666)

Hot deformation and recrystallization of 3% silicon steel part 2: effect of microstructural variables on static recrystallization

S.AKTA et al.

The recrystallization kinetics and the recrystallized grain size of 3% Si steel after hot rolling at temperatures of 900 to 1 100°C and annealing at the rolling temperature have been investigated for a range of initial grain sizes from 140 to 850 μm and initial austenite contents from 0 to 16%. It is shown that, in single phase ferrite, nucleation of recrystallization takes place only at grain boundaries, whereas some intragranular nucleation also occurs when austenite is present during rolling. Finer initial grain size and the presence of austenite therefore lead to faster recrystallization and to finer recrystallized grain size.

Recovery during annealing causes a rapid decrease in stored energy, and therefore a decrease in the growth rate of recrystallizing regions with annealing time. This results in plateaux in the fraction recrystallized, which increase in level with increase in initial grain size and with decrease in initial austenite content. Recrystallization kinetics approximate closely to site saturated nucleation and to negligible coarsening of recrystallized grains, leading to simple relationships between the time for 0.3 fraction of recrystallization and the fully recrystallized grain size.

(cf. *ISIJ Int.*, **45** (2005), 1676)

Hot deformation and recrystallization of 3% silicon steel part 3: effect of hot deformation variables on static recrystallization

S.AKTA et al.

The static recrystallization kinetics and the recrystallized grain size of 3% Si steel after hot rolling at temperatures of 900 to 1 100°C to equivalent strains of 0.25 to 1.24 applied in a single pass or by two pass rolling have been investigated. When the annealing temperature was changed for a constant rolling temperature, an apparent activation energy of 230 kJ/mol, and a small increase in recrystallized

grain size with increase in annealing temperature were found. Rolling at different temperatures had a surprisingly small effect. The growth rate of recrystallizing regions showed a rapid decrease with annealing time, being inversely proportional to time initially, but decreasing more rapidly at longer times. For conditions leading to long recrstallization times, growth rate fell to zero, resulting in plateaux in fraction recrystallized. Increase in equivalent strain accelerated recrystallization, but the effect after two pass rolling is complicated by a change in rolling direction between the passes. The majority of results can be interpreted by a simple model based on site saturated nucleation and negligible coarsening of recrystallized grains, but smaller strains in single pass rolling, or in the second pass of two pass rolling give large discrepancies with the model.

(cf. *ISIJ Int.*, **45** (2005), 1686)

Hot deformation and recrystallization of 3% silicon steel Part 4: effect of recovery and partial recrystallization between passes on subsequent recrystallization behaviour

S.AKTA et al.

Two pass hot rolling experiments have been carried out on 3% Si steel rolled to total strains in the range 0.25 to 1.1 at temperatures of 850 to 1 100°C. Retardation of recrystallization after the second pass compared with after a single pass to the same total strain arises mainly from differences in the strain path history when only recovery takes place between passes. When partial interpass recrystallization occurs, rolling load in the second pass, recrystallization kinetics after the second pass and recrystallized grain size all follow laws of mixtures between the values for zero and full interpass recrystallization.

(cf. *ISIJ Int.*, **45** (2005), 1696)

Coherent-to-incoherent transition of intergranular bcc-precipitates by pre-/post-deformations in a Ni–43Cr alloy

Y.ADACHI et al.

Effects of light deformations before and after precipitation (pre-deformation and post-deformation) on orientation distribution of intergranular bcc-precipitates were examined in a Ni–43mass%Cr alloy by electron backscattered diffraction. It was found that the deviation angles from both the plane/direction parallel orientation relationships in the Kurdjumov–Sachs orientation relationship of intergranular precipitates were increased by both pre- and post-deformations, but post-deformation was more effective. Based on this result, microstructural evolution of intergranular precipitates formed dynamically was discussed with particular attention to coherent-to-incoherent transition of precipitates.

(cf. *ISIJ Int.*, **45** (2005), 1703)

Determination of driving and pinning forces for static recrystallization during hot rolling of a Niobium microalloyed steel

M.GÓMEZ et al.

The hot rolling process of a low Nb-microalloyed steel under different interpass time conditions is simulated by means of hot torsion tests. Subsequent graphic representation of the Mean Flow Stress (MFS) *versus* the inverse of the absolute temperature for each pass allows us to know the critical rolling temperatures (T_{nr}, A_{r3}, A_{r1}) and to characterize the progressive strengthening of austenite due to incomplete recrystallization between T_{nr} and A_{r3}, thanks to the measurement of a magnitude called accumulated stress ($\Delta\sigma$). Optical and electron microscopy studies demonstrate that the evolution of the microstructure and the precipitation state—particularly the mean particle size—over the rolling schedule is strongly dependent on the interpass time. A review is made of the expressions that have been proposed to estimate the values of recrystallization driving (F_R) and pinning forces (F_P). Using these expressions and the experimental data from the hot rolling simulations performed, the evolution of F_R and F_P during rolling is studied. A comparative analysis of hypotheses concerning the interaction between precipitates and migrating grain boundaries is achieved and the methods for estimating the volume fraction of precipitates and the dislocation density are assessed. Though the selected criterion significantly influences the values obtained for both forces, it is found that F_P always grows faster than F_R as the rolling temperature drops, which helps to explain the start of inhibition of the static recrystallization of austenite at temperatures below T_{nr}.

(cf. *ISIJ Int.*, **45** (2005), 1711)

Mechanical Properties

Influence of Mn content on the microstructure and mechanical properties of ultrafine grained C–Mn steels

R.SONG et al.

The effect of Mn content on the microstructure and mechanical properties of two ultrafine grained 0.2%C–Mn steels has been investigated. The ultrafine grained microstructure was produced by use of large strain warm deformation and subsequent annealing. The final microstructure consists of fine cementite particles within an ultrafine grained ferrite matrix. The increase in the Mn content leads to a decrease in the average ferrite grain size (from 1.3 to 0.8 μm for an increase in the Mn content from 0.74 to 1.52 mass%). This can be attributed to the enrichment of Mn in the cementite particles, which becomes finer in the steel with a higher Mn content. The increase in the Mn content results in an increase in strength at equal ductility and toughness.

(cf. *ISIJ Int.*, **45** (2005), 1721)

Characterization of the relation among the mechanical behavior and the texture features in high martensitic dual phase steels

C.MAPELLI et al.

Dual Phases are martensite–ferrite steels. In the present study the formability and the mechanical properties of two different dual phase steels with high content of martensite (60% and 80%) were analyzed to obtain a better understanding of the relationship among texture, microstructure and plastic anisotropy in these steels. The formability was evaluated by the measurement of the Lankford coefficients and the formability limit curves (FLD). The results were related to the crystallographic texture that was determinated by X-ray diffraction and by Electron Back Scattering Diffraction (EBSD) analysis in order to evaluate the possible influence of the presence of martensite. The intensity of texture components and the values of planar and normal anisotropy show the better formability of the steel with higher content of martensite.

(cf. *ISIJ Int.*, **45** (2005), 1727)

Ultra-high-strength bainitic steels

C.GARCIA-MATEO et al.

Novel bainitic microstructures, consisting of slender ferrite plates (tens of nm) in a matrix of retained austenite, have reported maximum yield strength of 1.4 GPa, ultimate tensile strength of 2.2 GPa, 30% ductility and respectable levels of fracture toughness (~51 MPa m0.5). The unusual combination of properties is attributed to the fine bainitic plates and the presence of retained austenite in the microstructure.

(cf. *ISIJ Int.*, **45** (2005), 1736)

Effect of microstructure on static and dynamic mechanical property of a dual phase steel studied by shear punch testing

J.QU et al.

The high-speed deformation behavior of a dual phase steel was studied by means of dynamic Hopkinson bar shear punch testing, with an emphasis on the influence of microstructure. Dual phase microstructures with different fractions of martensite were obtained by changing heat treatment parameters during intercritical annealing. The effects of low temperature tempering (170°C, 235°C, and 300°C) and bake hardening treatment (5% pre-strain followed by holding at 170°C for 20 min) were also investigated for two selected microstructures containing 22% and 61% martensite, respectively. Quasi-static shear punch property was also measured by a MTS hydraulic machine and compared with dynamic results. Additionally, quasi-static tensile tests for some specimens were also conducted for validating the shear punch data.

(cf. *ISIJ Int.*, **45** (2005), 1741)

Effects of Ni and heat treatment on long-term creep strength of precipitation strengthened 15Cr ferritic heat resistant steels

Y.TODA et al.

The effects of nickel content and heat treatment conditions on the creep strength of precipitation-strengthened 15Cr ferritic steel were investigated. The creep strength of the 15Cr ferritic steel was drastically improved by solution treatment and water quenching. However, over the long term, the detrimental effect of nickel on the creep strength was pronounced for water-quenched steels. The volume fraction of martensite phase increased with increased nickel content in both the furnace-cooled and water-quenched steels. The volume fraction of

martensite phase in the water-quenched steel was smaller than that in the furnace-cooled type, even for the same nickel content. Fine particles, smaller than 500 nm, were precipitated homogeneously within the ferrite phase of the water-quenched steel. On the other hand, coarse block-like particles 1 μm in size were precipitated sparsely within the martensite phase, and the recovery of martensitic microstructure was accelerated. The creep strength of the steels decreased with increased volume fraction of the martensite phase caused by furnace cooling and nickel addition. The lower creep strength and microstructural stability of the martensite phase is attributable to less precipitation strengthening. To enable this steel to be put to practical use, it will be necessary to suppress the formation of the martensite phase caused by addition of nickel by optimizing the chemical composition and heat treatment conditions.

(cf. *ISIJ Int.*, **45** (2005), 1747)