## Casting and Solidification

### Influence of cooling rate on the hot cracking formation of nickel rich alloys

*S.K.Kim et al.*

Hot cracking formation and its mechanism in invar alloys (Fe–36mass%Ni) during continuous casting was investigated. The invar alloy is very sensitive to hot cracking due to its low transition temperature of brittle to ductile fracture even though its solidification interval is narrow. At the cooling rate of 10°C/min the transition temperature of brittle to ductile fracture is about 113°C below the solidus temperature. An increased cooling rate in invar alloy increases transition temperature of brittle to ductile fracture. It is increased to about 43°C below the solidus temperature when the cooling rate is increased to 100°C/min. A mechanism of hot cracking formation in invar alloys has been proposed. Hot cracks in invar alloys with a fast cooling rate are formed between the primary dendrites due to the equiaxed solidification structure. However, at slow cooling rate, hot cracks are formed between the grain boundaries due to the columnar structure.

(cf. *ISIJ Int.*, **42** (2002), 512)

### A three dimensional modified cellular automaton model for the prediction of solidification microstructures

*M.F.Zhu et al.*

A three dimensional modified cellular automaton model (3-D MCA) was developed in order to simulate the evolution of microstructures in solidification of alloys. Different from the classical cellular automata in which only the temperature field was calculated, this model included the solute redistribution both in liquid and solid during solidification. The relationship between the growth velocity of a dendrite tip and the local undercooling, which consists of thermal, constitutional and curvature undercooling terms, was calculated according to the KGT (Kurz–Giovanola–Trivedi) and LKT (Lipton–Kurz–Trivedi) models. The finite volume method, which was coupled with the cellular automaton model, was used to calculate the temperature and solute fields in the calculation domain. The present 3-D MCA model was applied to predict the microstructures, such as the free dendritic growth from an undercooled melt, the competitive dendritic growth in practical casting solidification. Some of the simulated results were compared with those obtained experimentally.

(cf. *ISIJ Int.*, **42** (2002), 520)

## Surface Treatment and Corrosion

### Damage mechanisms in salt bath nitro-carburised and plasma nitrided hot forging dies of H11 tool steel

*M.U.Devi*

Studies have been made to compare the effect of salt bath nitro-carburising and plasma nitriding treatments, on the working life of hot forging dies made of H11 grade of tool steel. Working life of the surface modified dies, that are used for the production of bearing races by high speed closed die forging, was evaluated in the real plant operation. Salt bath nitro-carburised tools are found to give an average life of 12 000 races with a very wide variation between 1 000 to 35 000 races. In sharp contrast, plasma nitrided tools showed a consistent two to four fold higher life than the salt bath nitro-carburised tools. The surface of worn out dies was examined by scanning electron microscopy (SEM) to understand the nature of damage processes involved in the dies subjected to two different surface treatments. Fatigue cracks, resulting from cyclic thermal and mechanical loading during operation, are the dominant modes of damage in the case of salt bath nitro-carburised as well as plasma nitrided dies. The severity of die damage by mechanical fatigue was more in the salt bath nitro-carburised dies. Abrasive wear due to micro cutting was observed to result in significant damage of the salt bath nitro-carburised die. Die damage due to micro cutting was not observed in the plasma nitrided dies. However, signatures of chipping and plastic deformation were noticed at few locations. The results obtained on service life and wear mechanisms after the two different surface treatments are examined in the light of the characteristics of the modified surfaces.

(cf. *ISIJ Int.*, **42** (2002), 527)

### Mechanical properties of native rust layer formed on a low alloy steel exposed in marine atmosphere

*Q.C.Zhang et al.*

Low alloy steel panels, exposed in marine atmosphere for 4 years, formed a compacted rust layer which could suppress the penetration of corrosive electrolyte and lower the corrosion rate. But in practical applications, the protective reliability is limited by the mechanical properties of the rust layer under the action of various loads. This paper presented the first attempt to evaluate the variation of mechanical properties of the protective rust layer with the exposure term by means of micro-indentation testing. Based on the analysis of energy release during cracking, the fracture toughness and the adhesion strength of the rust layer were evaluated. Results showed that the fracture toughness and adhesion strength of the rust layer were improved with the prolongation of the exposure term, the adhesion strength of the rust layer was higher than the fracture toughness of the rust layer itself.

(cf. *ISIJ Int.*, **42** (2002), 534)

### Effects of colloidal silica addition on the self-healing function of chromate coatings

*A.Suda et al.*

The corrosion prevention mechanism of the chromated metal materials is considered to be attributable to the self-healing function of the chromate coatings. In this study, the corrosion behaviors of dry-in-place type chromate coated galvanized steel specimens have been studied using a scanning vibrating electrode technique. By this method, the effects of colloidal silica addition in the chromate coating on the self-healing function have been examined. The results confirmed that the chromate coatings prevent the corrosion of metal under coating or at coating defects by their self-healing function. The self-healing function of the chromate coatings is due largely to the formation of a Cr compound layer from the dissolved Cr(VI) ions in the electrolyte. The addition of colloidal silica greatly enhances the self-healing function and corrosion protection of the dry-in-place type chromate coating.

(cf. *ISIJ Int.*, **42** (2002), 540)

## Transformations and Microstructures

### Solubility of titanium carbosulfide in austenite

*L.E.Iorio et al.*

A titanium carbosulfide solubility product of $\log[\mathrm{Ti}][\mathrm{C}]^{0.5}[\mathrm{S}]^{0.5}=-14\,646/T+5.51$ and a Gibbs free energy of formation for titanium carbosulfide of $\Delta^{\circ}G_{\mathrm{Ti_4C_2S_2}}=-1\,121.9+0.196T$ kJ/mol were calculated from dissolution temperature experiments using a series of titanium-modified secondary hardening ultra-high strength steels.

The presence of other precipitates such as TiN, TiC and TiS could be neglected for this class of steels. The effect of the alloying additions on the activity of carbon and hence on the dissolution temperature of titanium carbosulfide was also found to not be significant for these steels. The experimentally determined solubility product and Gibbs free energy of formation are compared with previously published data for titanium carbosulfide.

(cf. *ISIJ Int.*, **42** (2002), 547)

## Mechanical Properties

### Bauschinger effect in $\alpha$–$\gamma$ dual phase alloys Studied by *in situ* neutron diffraction

*S.Harjo et al.*

*In situ* neutron diffraction experiments during tension-compression deformation were performed on five Fe–Cr–Ni alloys with the volume fraction of ferrite ($\alpha$) ranging from 0.0 to 100%. Tensile deformation was applied in a step by step manner up to a strain of 1.3–2.0% followed by compressive deformation, and neutron diffraction spectra were recorded during temporary stops of a deformation machine with fixed crosshead. (111) reflection of austenite and (110) of ferrite, respectively, were measured simultaneously by using a position sensitive detector. Elastic lattice strains in both constituent phases were evaluated from measured diffraction spectra as a function of external load. Based on these experimental results, heterogeneous deformation behavior in the $\alpha$–$\gamma$ dual phase alloys is discussed considering the Bauschinger effect. It is concluded that large compressive residual lattice strains detected in the $\gamma$ phase after tensile pre-straining, causes the large Bauschinger effect in $\alpha$–$\gamma$ dual phase alloys.

(cf. *ISIJ Int.*, **42** (2002), 551)