

tests of joints and microstructure analyses of the fractured surfaces. The results showed that the argon ion bombardment treatment before bonding was effective to clean the bonding surface and reduce the inclusions at the bonded interface, so that the tensile strength of the bonded joints was improved and bonding temperature was lowered. The joint properties of pure iron were more excellent than those of SUS304L stainless steel. The amount of the inclusions at the joints with argon ion bombardment treatment depended on affinity of oxygen to metal.

(cf. *ISIJ Int.*, **42** (2002), 1385)

Chromium nitride precipitation behavior in weld heat-affected zone of high nitrogen stainless steel

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High nitrogen stainless steels (HNS) containing about 1 mass% (%) nitrogen without adding Mn were manufactured by pressurized electro-slag remelting method. The chromium nitride precipitation behaviors at the weld heat-affected zone (HAZ) of HNS with different compositions were investigated. We also evaluated the localized corrosion resistance of the welded joints.

The nitride precipitates were identified as Cr₂N containing a small amount of Mo and Fe by TEM/EDS analyses. Time-temperature-precipitation curves of some HNS were obtained. It was found that for 23Cr-4Ni-2Mo-1N steel, aging for 2 s in the temperature range between 1173 K and 1373 K caused Cr₂N precipitation and decreased the critical pitting corrosion temperature (CPT) in the 6% FeCl₃ solution. Precipitation was delayed to 4 s by decreasing the nitrogen content from 1 to 0.8% and was further slightly delayed to over 5 s by adding the pre-deformation followed by the thermal treatment of 23Cr-4Ni-2Mo-0.8N steel.

Precipitation at the HAZ was accelerated by a continuous thermal cycle test compared to the prediction based on the additivity rule, and that the existence of a ferritic phase affected acceleration was estimated.

Joints welded by laser and minimum heat input conditioned plasma arc welding showed a 348 K CPT in a 6% FeCl₃ solution and no crevice corrosion occurred at 308 K in artificial seawater. The CPT dropped notably against holding time above 1073 K at the HAZ. The CPT drop was slightly relieved by decreasing nitrogen content in the base metal from 1 to 0.8%.

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In situ analysis of pitting corrosion in artificial crevice of stainless steel by X-ray absorption fine structure

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A new technique by XAFS (X-ray Absorption Fine Structures) and XANES (X-ray Absorption Near Edge Structures) has been developed for *in situ* observation of metal corrosion. XAFS and XANES spectra were obtained with a special electrochemical cell to elucidate pitting for stainless steel. A sheet of stainless steel was attached below a reservoir of a specific aqueous environment with thin films. The solution in the reservoir attached to

the metal through the film, and the solution inside the film corresponds to an artificial pit. X-ray beams pass through the film containing the solution, and XAFS and XANES measurements were performed in a transparent geometry with keeping the specimen at a pitting potential. Measurements were performed for Cr-K, Mo-K, Cl-K and Br-K edges, and changes of concentrations and coordination states of ions were successfully obtained as a function of the distance ($d(z)$) from the metal/solution interface.

Concentrations of chromium and bromide ions inside the artificial crevice of Fe-18Cr-12Ni-2Mo (mass%) alloy shows a linear dependence on the distance $d(z)$. Structures of bromide ion were changed with positions; the distance between bromide ion and the nearest-neighboring ion at a position near the interface was shorter than that at a position far from the interface. This indicates the formation of hydrobromo-complex near the metal/solution interface.

The state of molybdenum inside the artificial crevice of Fe-18Cr-20Ni-5Mo (mass%) alloy was investigated using two solutions: LiCl and LiBr. The formation of the [MoO₄(H₂O)₂]²⁻ octahedra was observed in both solutions, but there was observed a significant difference in networking of the octahedral. In LiCl solutions it was similar to that of molybdate ions (MoO₄²⁻), but in LiBr it was rather different form that of molybdate ions. This shows that the favorable effects of molybdenum can be attributed to the formation of MoO₄²⁻ network near the interface.

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Evolution of size, composition, and morphology of primary and secondary inclusions in Si/Mn and Si/Mn/Ti deoxidized steels

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Primary and secondary inclusions in Si/Mn and Si/Mn/Ti deoxidized structural steels subjected to different thermal histories were investigated in view of evolution of size, composition, and morphology. Primary inclusions quenched from 1600°C contained very low levels of sulfur, and hence MnS precipitation on them was hardly found. The mean diameter of secondary inclusions lied in the range of 1-3 μm depending on the cooling rate and chemical compositions of steels. Both MnO and MnS content were higher in smaller secondary inclusions. MnS which precipitated on manganese silicate inclusions in Si/Mn deoxidized steels mostly grew into the inclusions. As inclusion size increased, the number of MnS precipitates on each inclusion was also increased. Titanium in steel had a tendency to reduce SiO₂ content in inclusions and to associate with MnO in the inclusions to form a stoichiometric relationship of Mn/Ti ratio in the inclusions. If Ti content in Si/Mn/Ti deoxidized steels was low, the secondary inclusions were found to form with multiple phases; viz., manganese silicate phase, Mn-Ti oxide phase, and MnS phase. The MnS phase always precipitated in the manganese silicate phase. The proportion of manganese silicate phase in each inclusion decreased with a corresponding increase in Ti content in the steel, and eventually disappeared completely when the Ti content exceeded a certain

level (70 ppm in the present steel compositions). In this case MnS was found to precipitate outside Mn-Ti oxide inclusions and grew into the steel matrix. In order to interpret and predict the behavior of inclusion precipitation and growth, a model has been developed which incorporates both thermodynamic and kinetic considerations.

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Automated image processing and analysis of fracture surface patterns formed during creep crack growth in austenitic heat-resisting steels with different microstructures

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A computer program of automated image processing was developed for fractal analysis of creep fracture surface profiles in this study. Change in the creep fracture surface patterns during crack growth was examined by the computer-aided image processing and analysis. Fractal analysis was then made using software on the processed images. Creep crack growth experiments were carried out on the surface notched specimens of the austenitic 21Cr-4Ni-9Mn steel at 973 K. Creep crack growth rate was lower in the specimens with serrated grain boundaries than in those with straight grain boundaries. The fractal dimension of the grain-boundary fracture surface profiles was larger in the former specimens than in the latter ones. The fractal dimension was larger in the specimens tested under the lower stress, and decreased with increasing distance from notch root. Effects of grain-boundary microstructures and stress on the fracture patterns were correlated to the microstructure and stress dependence of the density of grain-boundary microcracks linked to the fracture surface. Quantitative evaluation of fracture surface patterns may give an important information about the fracture origin or crack growth direction.

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The application and the problems of high strength steel on penstock in Chinese hydroelectric station

M. LI et al.

The application of high strength steel has increasingly improved the technology on penstock manufacture and assembling, as well as management, with economy benefit being equally obtained. However, some misunderstandings on using high strength steel plate are still existed, which weaken their advantage. In this paper, the following problems are discussed.

1. The weldability of high strength steel plate is bad, therefore the more strict of the welding parameters and nondestructive test, the better.
2. The penstock standards are behind the times, and not applying to high strength steel plate.
 - 1) Technology requirements are not clearly specified when new materials are used in penstock, as prevent the application of new materials.
 - 2) According to the "Standards" the higher steel strength promises less cold roll deforming, but different materials and qualities with the same strength are not put into consideration.