EFFECT OF STRESS RELIEF TEMPERATURE AND COOLING RATE ON PRESSURE VESSEL STEEL WELDS

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The copper contents of welds in nuclear reactor pressure vessels is one of the key parameters that define the amount of embrittlement that occurs during service. Atom probe field ion microscopy has established that the copper that remains in the matrix after the stress relief treatment forms a high density of ultrafine copper-enriched precipitates that are also enriched in nickel, manganese, silicon and phosphorus. Extrapolation of high temperature solubility data and thermodynamic predictions have indicated that the solubility of copper in the matrix changes relatively rapidly over the temperature range (~575 to ~650°C) that is normally used to stress relieve the pressure vessel. Therefore, the temperature and the cooling rate after stress relief treatment should influence the level of copper in the matrix and hence the degree of embrittlement. In this paper, the influence of these parameters on the copper level in the matrix has been investigated by atom probe tomography.

The high copper weld (test plate 002A with a Linde 80 flux) used in this study has a composition of Fe - 0.29 at. % Cu, 1.69% Mn, 0.54% Ni, 0.69% Si, 0.25% Mo, 0.08% Cr. 0.38% C, 0.022 % P and 0.017% S. The material was characterized in the as-welded state and after the following three heat treatments, A) 24 h at 650°C, B) 24 h at 610°C, and C) 100 h at 580°C. Following each of these isothermal heat treatments, the material was slow cooled at a rate of 15°C/h to room temperature. In order to evaluate the influence of the cooling rate after the stress relief treatment, some material was examined after a heat treatment of 24 h at 650°C and water quenched to room temperature. In order to evaluate the effect of a typical post irradiation treatment, some material was also examined after a heat treatment of 24 h at 650°C, slow cool to room temperature and 168 h at 454°C.

The composition of the matrix of each of these heat treatments has been determined in an energy-compensated optical position-sensitive atom probe. The conditions used for analysis were a specimen temperature of 50 K, a 20% pulse fraction and a pulse repetition rate of 1500 Hz. These experimental results will be compared to extrapolations of high temperature solubility data and thermodynamic predictions.

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