Analysis of Alloy 600 Stress Corrosion Cracking with an Artificial Neural Network.

Alloy 600 is widely used in pressurized water reactors (PWRs) and boiling water reactors (BWRs) as a construction material. It has long been known that this nickel-based alloy is susceptible to cracking when exposed to some of the environments which exist in these reactors. Axial cracks in vessel head penetration (VHP) nozzles fabricated from alloy 600 were first identified in the 1980s, but the recent discovery of circumferential cracks, which could theoretically lead to an ejection event, have heightened concerns about the structural integrity of these components.

A large number of experimental data for the crack growth rates (CGRs) of this alloy in conditions similar to those which may be found in PWRs are available, and a database comprising about 200 sets of data for CGRs under conditions of constant load was used in this work. CGRs are dependent on the physical properties of the material, the applied stress, and the environmental conditions. Characteristics of the alloy which may influence the CGR include the amount of cold work, the composition (e.g. carbon or sulphur content) and the microscopic properties such as grain size. Temperature is an important environmental factor, and water in reactors typically contains additives such as boron and lithium. Although several empirically-based correlations for the CGRs can be found in the literature, the large number of variables involved makes it difficult to derive algebraic correlations to cover the whole range of data. With a large number of variables affecting the CGR, the use of artificial neural networks was an appropriate choice for analysis of these data.

The artificial neural network code MetaComp was used to analyse the data available. Neural networks have the ability to learn patterns and trends in datasets with several variables and can effectively use interpolation to make predictions for cases when there are no data, though it should be pointed out that since the networks are not mechanistically based, they are not well suited to extrapolation. After experimenting with different input variables, the final version of the neural network used four input parameters: temperature, applied stress, lithium concentration, and the yield strength. The yield strength correlates with the amount of cold work and was used to represent the physical properties of the specimens. Validation of the model gave good agreement with experimental data, including data not used in the model development.

Sensitivity studies for PWR conditions showed similar trends to those observed in other studies. Over the temperature range from 310ºC to 350ºC, the CGR was predicted to increase by a factor of about 3, and an increase in lithium concentration from 0ppm to 10ppm led to a factor of 10 increase in the CGR. Specimens with a high yield strength were much more prone to cracking, with a yield strength of 500MPa resulting in CGRs about 30 times higher than for 200MPa. Over the range of applied stress from 20-60MPam$^{1/2}$, the CGR increased by a factor of about 10 for specimens with high yield strengths, and a factor of around 300 for specimens with a low yield strength.