Weld Residual Stresses and Crack Growth in Bimetallic Pipe Welds

By F. W. Brust, Y. P. Yang, P. M. Scott, Battelle-Columbus

Abstract

There have been incidents recently where cracking has been observed in the bi-metallic welds that join the hot leg to the reactor pressure vessel nozzle. The hot leg pipes are typically large diameter, thick wall pipes. Typically, an inconel weld metal is used to join the ferritic pressure vessel steel to the stainless steel pipe. The cracking, mainly confined to the inconel weld metal, is caused by corrosion mechanisms. Tensile weld residual stresses, in addition to service loads, contribute to PWSCC (Primary Water Stress Corrosion Cracking) crack growth. In order to be able to predict crack growth rates, and therefore, predict the amount of time required before leakage occurs in normal Pressurized Water Reactors (PWR), a detailed analytical model of the VC Summer bimetallic pipe weld was performed.

This paper presents the results of an investigation of PWSCC in the bimetallic hot leg pipe. First, the weld process was modeled. This modeling includes buttering of the pressure vessel nozzle with inconel 625 followed by post weld heat treat of the nozzle. After the heat treat, which reduces the residual stresses caused by buttering significantly, the weld passes joining the nozzle to the stainless steel pipe are deposited. This is followed by a hydro-test (at room temperature) and then service loads are applied. *All of the above processes were included in the fabrication model.* The importances of including all of the history of fabrication in the analysis are clearly shown. In addition, the effects of selected weld repairs are considered.

Crack growth in the presence of the fabrication induced residual stress fields; along with the service loads were considered. A PWSCC crack growth law, which is based on stress intensity factors, was used. The stress intensity factors were calculated using the finite element alternating method (FRAC@ALT code).

It is shown that longitudinal cracks (caused by pipe 'hoop stresses') are expected to grow through the pipe wall first. However, it is also shown that circumferential cracks can grow through the pipe wall, although at a rate two to three times slower than the longitudinal cracks.