PROBABILISTIC FRACTURE MECHANICS ANALYSES OF RPV UNDER SOME PTS TRANSIENTS

Kunio Onizawa, Katsuyuki Shibata,
Japan Atomic Energy Research Institute,

Daisuke Kato and Yinsheng Li
Fuji Research Institute Corporation

Probabilistic Fracture Mechanics (PFM) has been used in the fields of reliability analysis, life cycle assessment and risk management for important structural components as a promising and rational evaluation methodology. The probabilistic approaches are also being introduced into regulations and standards related to structural integrity such as Pressurized Thermal Shock (PTS) for reactor pressure vessel (RPV), Leak Before Break (LBB) for piping and etc in USA.

At JAERI, the PFM analysis code PASCAL (PFM Analysis of Structural Components in Aging LWR) has been developed. This code can evaluate the conditional probability of crack initiation and failure of an RPV under transient conditions such as PTS. The probabilistic simulation methods used in this code are the importance sampling Monte Carlo and the stratified sampling Monte Carlo methods. The initial crack size, chemical composition, neutron fluence, fracture toughness and ductile to brittle transition temperature are all treated as probabilistic variables.

In this study, we performed sensitivity analyses on some important variables including pre-service inspection method, crack geometry, fracture toughness curve, irradiation embrittlement prediction equation. PTS transients analyzed in the study were three cases of LOCA and one case of steam line break for a typical 3-loop PWR. Overlay cladding of 5 mm thick was modeled at the inside of the RPV wall having 197 mm thick in total. Based on the result from thermal hydraulic analysis, a stress distribution in the vessel wall for each transient was determined by the finite element analysis tool in PASCAL. The fracture probabilities for a semi-elliptical surface crack and an infinite length surface crack in the axial direction were analyzed. The Marshall exponential model was used to simulate the distribution of an initial crack depth.

The results of PFM analyses showed that some major conclusions;
- Pre-service inspection according to Arakawa's NDE model has a significant effect on fracture probability and reduces more than 3 orders of magnitude for the fracture probability.
- Reflecting the difference in the equations, fracture toughness estimation method in Japan indicates about 2 orders of magnitude lower than USA's method for the fracture probability for the cases studied.
- Calculation method for a semi-elliptical surface crack used in PASCAL reduces the conservatism in the use of an infinite surface crack converted from an elliptic crack.

The applicability of PASCAL to PTS analyses was confirmed through these analyses.