FRACTURE MECHANICS FOR HEAVY SECTION STEEL NUCLEAR PRESSURE VESSELS

T.R. MAGER, P.C. RICCARDELLA, E.T. WESSEL,

*Westinghouse Electric Corporation,
Nuclear Energy Systems, Pittsburgh, Pennsylvania, U.S.A.*

The ability of a pressure vessel steel to resist fracture constitutes an important factor in ensuring nuclear reactor safety. In nuclear reactor pressure vessels some regions (belt-line) are subjected to irradiation damage. Irradiation hardening and embrittlement of mild steels are important in connection with the safety of reactor pressure vessels. Fracture mechanics is considered as providing the best general approach to understanding the brittle fracture phenomenon in reactor pressure vessel steels.

Experimental testing of a group of reactor vessel steels utilizing Compact Tension specimens was performed to investigate the application of the fracture mechanics approach to these materials in the irradiated condition. Materials investigated include A533 Grade B Class 1 base plate and weldment. Compact Tension (CT) fracture mechanics specimens up to two inches in thickness (2T-CT) were irradiated at 550°F to a fluence of 1 to 5×10^{19} n/cm². Tensile and Charpy V-notch specimens from the same materials were also included in the irradiation package to provide correlation data.

The fracture toughness of the irradiated pressure vessel material was determined by measurements of K_{IC} , the critical stress intensity factor, which is considered to be a basic material property. The fracture toughness K_{IC} for the unirradiated and post-irradiated conditions and the fatigue crack growth rate as a function of the change in stress intensity ΔK_I were utilized to demonstrate the integrity of heavy section nuclear reactor pressure vessels. The application of these parameters in conjunction with the normal coolant system design transients for a typical pressurized water reactor demonstrated that an initial allowable flaw size that could exist at the start of life would not grow to a critical size during the design lifetime of the nuclear reactor pressure vessel (40 years).