

Application of the Beremin model to the nuclear reactor pressure vessel of Chooz A

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Abstract

After the permanent shutdown of the French Chooz A nuclear power plant in 1991, a comprehensive study program of its components was launched, aimed to improve understanding of the effects of irradiation on materials, especially reactor pressure vessel (RPV) steel. The C shell ring, which had been monitored during operation through the Irradiation Surveillance Program (PSI), underwent extensive mechanical testing and characterization and will be dealt with in this presentation. The main objective of the study is to validate the applicability of the Beremin model to irradiated RPV steel, in particular by assessing whether the shape modulus and the threshold stress remain unaffected by neutron irradiation. To this end, a large number of mechanical tests conducted on both irradiated and unirradiated states were interpreted using finite element simulations. The results of these tests was never published before in the open scientific literature. The critical cleavage stresses observed in irradiated specimens were found to be comparable to those measured in unirradiated low-alloy steel. Likewise, the shape parameter identified on the irradiated vessel was identical to that determined on the unirradiated one. Finally, both the location of cleavage initiation sites in the irradiated state and the Weibull stress density profile along the crack front showed good agreement. The study therefore concludes that the Beremin model parameters are independent of irradiation, thereby reinforcing the relevance of its industrial application for demonstrating RPV structural integrity in the context of extended nuclear plant operation. However, certain limitations were identified, notably the presence of metallurgical

segregations in the studied material and the fluence level being lower than that expected after 60 years of operation. It thus appears advisable to extend the study to other irradiated materials representative of the current French nuclear fleet.

Keywords:

Reactor pressure vessel Low alloy steel Brittle fracture Irradiated material Beremin model