Design Considerations for Dissimilar Material Modeling of RPV Lower Head Creep under Severe Accident Conditions

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Abstract

The lower head of the reactor pressure vessel (RPV) can be subjected to significant thermal and pressure loads in the event of a core meltdown accident. For the detailed understanding of its behavior, a real scale experiment of RPV creep with prototype material, namely low alloy steel, is in demand. But it is highly difficult to perform because of very high heat flux and pressure. If we can replace the real test of the prototype material using dimensional analysis with a model material that possesses constitutive similarity but has low melting temperature and mechanical strength, the experiment can be significantly simplified and less expensive.

From the mathematical structure of the constitutive equation for classical viscoplasticity, a simple rheological model was derived. The model explains the time dependent mechanical behavior of RPV creep. The creep equation was nondimensionalized using the dimensionless group of variables. By adopting lead (Pb) as a model material, heat flux and pressure conditions of the model experiment was defined.

Finite element analyses showed adequate agreement between prototype and model systems for the time dependent deformation behavior on nondimensional coordinates such that this novel approach can be used under the scaled temperature/pressure conditions to represent creep deformation behavior of prototype RPV.