Local Failure Characteristics of a Nuclear Reactor Pressure Vessel Nozzle under Severe Accident Conditions

Young J. Oh*, Kwang J. Jeong, and Il S. Hwang
Department of Nuclear Engineering, Seoul National University

Abstract

Most past studies for the creep rupture of a nuclear reactor pressure vessel (RPV) lower head under severe accident conditions, have focused on global deformation and rupture modes. Limited efforts were made on local failure modes associated with penetration nozzles as a part of TMI-2 Vessel Investigation Project (TMI-2 VIP) in 1990's. However, it was based on an excessively simplified shear deformation model. In the present study, the mode of nozzle failures is investigated using data and nozzle materials from Sandia National Laboratory's Lower Head Failure Experiment (SNL-LHF). Crack-like separations were revealed at the nozzle weld metal to RPV interfaces indicating the importance of normal stress component rather than the shear stress in the creep rupture. Creep rupture tests were conducted for nozzle and weld metal materials, respectively, at various temperature and stress levels. Stress distribution in the nozzle region is calculated using elastic-viscoplastic finite element analysis (FEA) using the measured properties. Calculation results are compared with earlier results based on the pure shear model of TMI-2 VIP. It has been concluded from both LHF-4 nozzle examination and FEA that normal stress at the nozzle/lower head interface is the dominant driving force for the local failure with its likelihood significantly greater than previously assumed.

Keywords : creep rupture, severe accident, nozzle ejection, elastic-viscoplastic finite element analysis, TMI-2 Vessel Investigation Project