CONF-8610135--2

MASTER

INTEGRATION OF WIDE-PLATE CRACK-ARREST TEST RESULTS*

C. E. Pugh D. J. Naus

Oak Ridge National Laboratory (ORNL)
Oak Ridge, Tennessee 37831

CONF-8610135--2

TI87 000289

Current Light-Water Reactor (LWR) pressure vessel safety assessment methods are based in large measure on Sections III and XI of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (B&PVC). In pressurized-thermal-shock (PTS) scenarios, inner surface flaws have the greatest propensity to propagate because they are in the region of highest thermal stress, lowest temperature and greatest irradiation damage. If such a flaw begins to propagate radially through the vessel wall, it will extend into a region of higher fracture toughness due to the higher temperatures and less irradiation damage. Although the thermal stresses may decrease with propagation depth, the stress-intensity factor due to the elevated pressure loading will be increasing. Assessment of the integrity of a reactor vessel under such a postulated crack run-arrest scenario requires prediction of the arrest location, potential reinitiation, stable and unstable ductile crack growth, and structural instability of the remaining vessel wall ligament.

The fracture toughness correlations contained in the ASME B&PVC embody the position that one cannot assume a crack-arrest toughness value (K_{Ia}) above 220 MPa$\cdot\sqrt{m}$ for LWR pressure vessel steels. The imposition of this limit is based in part on the fact that no K_{Ia} data existed at or above this level, and because Charpy tests showed that impact energy levels exhibit on an upper-shelf behavior. Therefore, the nature of crack-arrest behavior and K_{Ia} extrapolations to temperatures higher than that at which this limit occurred could not be presumed.

---

*Research sponsored by the Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission under Interagency Agreements 40-551-75 and 40-552-75 with the U.S. Department of Energy under Contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

The primary objective of the crack-arrest studies under the Heavy-Section Steel Technology (HSST) Program is to generate data for understanding the crack-arrest behavior of prototypical pressure vessel steels at temperatures near and above the onset of the Charpy upper-shelf region. Specific program goals are to: (1) extend existing K_{Ia} data bases to temperatures beyond those associated with the upper limit in the ASME B&PVC; (2) clearly establish that crack-arrest occurs prior to fracture-mode conversion; (3) observe the relationship between arrest data and machine/specimen compliance behavior; and (4) validate the predictability of crack arrest, stable tearing, and/or unstable tearing sequences for ductile materials. In meeting these goals, the HSST program is generating crack-arrest data over an expanded temperature range through tests involving large thermally-shocked cylinders, pressurized-thermally-shocked vessels and wide-plate specimens. This presentation will focus on data from the wide-plate specimens which have the advantage that a more significant number of data points can be obtained at affordable costs.

The HSST wide-plate crack-arrest tests are being performed at the National Bureau of Standards (NBS), Gaithersburg, Maryland, in their 27-MN capacity testing machine. The tests are designed to provide fracture-toughness measurements approaching or above the onset of the Charpy upper-shelf regime, in a rising toughness region and with an increasing driving force. To date, seven tests have been completed, six utilizing specimens fabricated from HSST plate 13A of A533 grade B class 1 steel and one specimen fabricated from a low upper-shelf base material. Each test utilized a single-edge notched (SEN) plate specimen (1 by 1 by 0.1 m) that was subjected to a linear thermal gradient along the plane of crack propagation. During each test, strain and temperature measurements were obtained as functions of position and time. Load, crack opening displacement and acoustic emission data were also obtained during each test as a function of time.

Results obtained from the WP-1 test series exhibit a significant increase in toughness at temperatures near and above the onset of Charpy upper shelf (T = 55°C or T — RTNDT = 78°C for this pressure vessel steel). Additionally, cleavage crack propagation and arrest at temperatures above the onset of Charpy upper shelf have been demonstrated.

When series WP-1 data are combined with other large specimen K_{Ia} data (Japanese ESSO, French TSEs, ORNL TSEs, ORNL PTSEs and CE/EPRI MMCT), a consistent trend is formed above the existing ASME reference fracture curve. These results also indicate that the rate of increase of K_{Ia} with temperature becomes very high for T — RTNDT greater than about 70°C.