Evaluation of the Capabilities of Various Analytical Techniques to Predict Integrity of Structural Components Containing Surface Flaws

W.G. Reuter
Fuels and Materials Division, EG & G Idaho, Inc., P.O. Box 1625, Idaho Falls, Idaho 83415, U.S.A.

SUMMARY

Tests were conducted on annealed Type 304 stainless steel plate and pipe specimens containing surface flaws. Test data were analyzed with the following results:

(1) Gross Strain - Statistical analysis showed that the aspect ratio (a/2c) and the crack length-to-width ratio (2c/w) are the two most important parameters of a surface flaw. Equations developed for the plate specimens to predict either the gross strain corresponding to instability or defect penetration of the wall thickness were not successful in predicting failure conditions for pipes.

(2) Flow Stress - The ratio of measured flow stress ($\bar{\sigma}_{test}$) to calculated flow stress ($\bar{\sigma}_{calc}$) was plotted versus cF^2 (an indication of the severity of a surface flaw). The ratios first decreased from 1.4 to 1.0 and then increased to more than 2.0 as cF^2 increased. Results from flat-plate specimens can be used to predict pipe failure conditions when cF^2 values are less than 5.1 mm. The plot showed that use of a constant value of flow stress, regardless of the defect configuration, will generally be conservative. The ratio of $\bar{\sigma}_{test}$ to $\bar{\sigma}_{calc}$ will vary from 1.0 to in excess of 2.

(3) COD - The surface flaws were converted to equivalent through-thickness cracks and a plot of nondimensional COD (ϕ) versus the ratio of applied strain to yield strain was developed. The plot showed the conservatism of using the design curve for plate and pipe specimens, but it is not possible to accurately predict failure conditions.

(4) Two-Parameter Fracture Criterion (TPFC) - Plots of K_{1e} (an elastic fracture toughness value) versus cF^2 showed good correlation and suggest that it is possible to predict failure for pipe specimens using data from plate specimens.

(5) J Integral - Attempts were made to convert the surface flaw to an equivalent through-crack length and to divide the surface-flawed specimen into a single-edge-notch specimen and two unflawed specimens. Critical values of J are considerably less than those reported in the open literature.

For the material thickness tested, the TPFC and flow-stress approaches are the most accurate for predicting the conditions for failure. For application to other thickness ranges, the flow-stress approach appears valid, although more test data are desirable. For the TPFC approach, tests of representative configuration and thickness may be needed.