76019

Low-cycle Fatigue in Welds

Paper by W. R. Miller and H. S. Amin was published in EXPERIMENTAL MECHANICS, June 1975, Pages 230-233

Discussion

by Bruce R. Dewey

By testing hourglass-shaped specimens, the authors have shown that, for a certain steel weldment, the weld metal is significantly less resistant to fatigue-crack initiation and propagation than is the base metal.

Since details of the stress analysis of the hourglass have not been given in the paper, it could be assumed that the authors determined the total axial-strain range $\Delta\epsilon^T$ from an equation of the form

$$\Delta\epsilon^T = \Delta\sigma(1 - \nu_e/\nu_p)/E + \Delta\epsilon_d/\nu_p$$

where $\Delta\epsilon_d$ is the measured diametral-strain range, ν_e and ν_p are the elastic and plastic Poisson ratios, $\Delta\sigma$ is the stress range and E is the modulus of elasticity. It should be noted that this formula is derived using deformation theory of plasticity for monotonic loading and assuming isotropic, homogeneous material.

As is well known, the anisotropy of weld metal precludes stating any values for E, ν_e and ν_p. It would have been interesting for the authors to quantify the influence of the anisotropy by running fatigue tests on specimens cut at different orientations through the weld bead, and also to repeat tests with the same material orientation but with the diametral extensometer rotated to different positions around the neck of the hourglass.

The uncertainty in stress analysis of the hourglass-shaped specimen, therefore, leads one to doubt the validity of the results of the cumulative-damage tests published in this paper. A better approach is that of Brinkman and Korth[1] who, recognizing the limitations of the hourglass geometry, used uniform gage specimens for fatigue tests of weldments.

Reference

1. *Brinkman, C. R. and Korth, G. E., "Heat to Heat Variations in the Fatigue and Creep-Fatigue Behavior of AISI Type 304 Stainless Steel, and the Fatigue Behavior of Type 308 Stainless Steel Weld Material," Aerojet Nuclear Company Report ANCR-1097 (December 1973).*

Bruce R. Dewey is Associate Professor, Department of Engineering Science and Mechanics, the University of Tennessee, Knoxville, TN 37916.

Authors' Closure

The authors used an hourglass specimen for several reasons. It was much easier to get the weld centered at the minimum section. When using a cylindrical section, it is difficult to keep from undercutting slightly in the transition from the end fillets to the cylindrical portion, even though great care is taken to prevent this. The authors believe this is borne out by the tendency of such specimens to fail near the fillets. A profiling attachment may have alleviated this, but none was available to them. The hourglass specimen has been used for many years by NASA.[1,2]

In determining strain, the following equation was used:

$$\epsilon = 2\,ln\,\frac{d_o}{d}$$

where

d_o = original diameter of specimen
d = diameter of specimen at any time.

This was reported as total strain range, since the elastic strain in the region of the tests—from approximately one cycle to slightly over 1000 cycles—is quite small compared to the plastic strain. If ν_p is 1/2, then the strain is given by the last term in the equation given in the discussion. This expression for total strain range is also given in Ref. 1 and is applicable to either hourglass or cylindrical specimens.

The authors do not agree that the use of an hourglass specimen invalidates the cumulative-damage tests, since they find no uncertainty in the stress analysis. An ample radius was used and it is felt that the measurement of diametral strains is acceptable. The only difference in the authors' strain range and that given in the discussion is in the first term, which accounts for the elastic strain. Since this is small compared to the second term, it would have little effect in the region in which these tests were run.

References

1. *Smith, R. W., Hirschberg, M. H. and Manson, S. S., "Fatigue Behavior of Materials Under Strain Cycling in Lows and Intermediate Life Range," NASA TN D-1574 (April 1963).*
2. *Manson, S. S., Freche, J. C. and Ensign, C. R., "Application of A Double Linear Damage Rule to Cumulative Fatigue," NASA TMX-52226 (1966).*