COMPARISONS OF METHODS FOR CREEP-FATIGUE DAMAGE ANALYSIS OF HIGH TEMPERATURE PIPING

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SUMMARY

This paper presents a comparison of the life fraction rule in ASME Code Case 1592 with the strain range partitioning approach as proposed by Professor S.S. Manson. For comparison, a generalized plane strain finite element analysis was performed on a section of thick walled 2¼ Cr-1 Mo HTGR main steam pipe subjected to severe thermal transients. It is not intended to assess the validity of strain range partitioning or the life fraction approach but only to compare their sensitivity to variations in material properties and thermal stress fields.

High temperature alloys are known to have significant variations in material properties. The yield strength and creep rates are the most important properties used in high temperature analysis. Variation in the yield stress influences the magnitude of the residual stress produced by a thermal transient, while variation of the creep rate influences the time required for relaxation of these residual stresses. It is not immediately obvious how strongly the choice of yield values and creep rates affect the results of an analysis or even what choice will lead to conservative results. Results are presented for variation of both these quantities for transient conditions with steam temperature dropping from 1000°F to 300°F.

The rate of cooling was varied to demonstrate the sensitivity of each method to changes in the thermal stress fields. It is shown that the life fraction method is more sensitive to such changes than the strain range partitioning approach.

An increase in the yield stress used in the analysis results in either an increase or a decrease in the creep damage term of the life fraction rule depending on the magnitude of the change, while the fatigue fraction remains virtually unchanged. This phenomenon is less severe when the strain range partitioning measure of damage is used. In a similar comparison it is shown that a lower creep rate leads to a significant increase in damage when the life fraction approach is used but leads to a small decrease for the strain range partitioning method.

Finally, results are presented for a simple one-dimensional elastic transient thermal stress analysis of a thick walled pipe using only the temperature range, and yield stress. For the thick pipe, it is a simple matter to construct an accurate hysteresis loop. Using this loop, it is possible to determine the strain range components with a reasonable degree of accuracy. These partitioned ranges may then be substituted in Manson's interaction rule to determine life. This approach may be used as a preliminary design criterion. A similar procedure used with the ASME life fraction approach would necessitate evaluating the time relaxation of the residual stresses. The results of such a method would be extremely sensitive to the assumed relaxation shape.