EFFECTS OF SERVICE AGE ON THERMAL-MECHANICAL FATIGUE OF A 2.25CR-1MO STEAM HEADER

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Abstract
Understanding the remaining life of a component is critical to maintaining safe operation and is necessary for budgeting repairs. This paper uses Finite Element Analysis to predict the performance of a steam header under realistic loading scenarios, comparing the difference between life expectancies of service-aged material to that of virgin material.

1. Introduction
Numerous components in high-temperature energy plants were initially designed for steady-state operation. However, as renewable energy sources are incorporated into the grid system, the energy demand shifts away from carbon sources resulting in high-temperature plants experiencing transient loading. Industry standards, such as ASME BPVC Section VIII Division 2 codes, include methods to evaluate the remaining life of a component subjected to thermal-mechanical loading. During this process, components are often evaluated using FEA models to represent the component. This process relies on an accurate representation of the material being evaluated used in the analysis. However, it is well known that material properties can change due to environmental factors in service. This paper illustrates how changes in material properties from environmental factors can lead to overestimations of the remaining life of a component.

2. Results
The procedure used to conduct the remaining life analyses was used as described below:

a. The service age material was evaluated using strain-controlled testing to determine the Non-Linear Kinematic Hardening, NLKH, behavior of the material.
b. Virgin material properties for the NLKH model were determined from existing online databases.
c. Several types of loading were applied to both materials to represent three different transients. The first loading profile represented a typical startup and shut-down procedure separated by steady-state operation. The second and third loading profiles represented transients that often occur at the junction of the tube and the header, where both standard and limit case transients were evaluated.
d. The remaining service life of the component was evaluated using the Ostergren damage model for low cycle fatigue, LCF.

The effect that the material had on the predicted service life of the component varied with respect to which transient was applied. In the case of a typical plant startup and constant operation, neither material predicted damage to the header leading to high cycle fatigue. Similarly, both materials predicted failure in less than five years in response to the limit case transient. However, differences between the two materials were found in response to typical thermal transients during regular operation. In response to the common transient, the service-aged material accumulated damage when the virgin material did not. Figure 1 demonstrates the difference in the accumulation of both materials in response to the limit case transient. The increase in plastic strain resulted in the predicted failure of the service-aged material in 70 years, whereas the virgin material was considered high cycle fatigue.

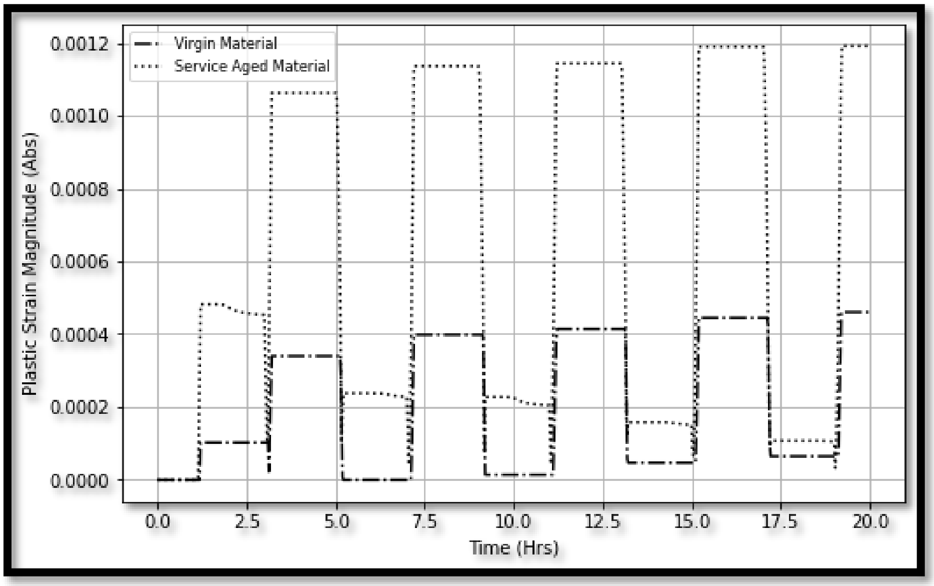

Fig.1 –Plastic strain accumulation in response to limit case transient loading.

3. Conclusions

This study demonstrates that the aging of materials in service can alter the remaining usable life of the component. Subsequently, individuals who do not account for such changes can over-predict the component's remaining life, leading to premature failure.

Acknowledgements

The support of the Department of Energy under Award Number(s) DE-FE0031747 is gratefully acknowledged.