T73S06 Session 33 Homework – Hysteresis Cycle Construction

Last Update 5/12/12

Mentor Guide Questions

1.20 State how a cyclic stress-range/strain-range curve is derived for use in constructing a hysteresis cycle according to R5V2/3

1.21 State the procedure for finding the total strain range in the absence of creep

1.22 Comment on the assumptions implicit in the use of the Neuber construction

1.23 Describe the simplified method for enhancing the strain ranges due to creep at the hysteresis loop tip

1.24 Describe the overall approach taken in R5 V2/3 Appendix A7 to constructing the hysteresis cycle (intermediate dwell)

1.25 Define the details of the construction of the half-cycle without creep

1.26 Define the details of the construction of the half-cycle with creep

1.27 Discuss whether the stress-strain hysteresis cycle would be expected to be closed

Numerical Questions (these are for Homeworks 33, 34 and 35)

A main steam component is made of forged 316/316H material. The component is subject to pressure loading and system loading, other loads being negligible. At the assessment location the nominal elastic Mises stress due to the working pressure of 160 barg is 130 MPa. The system load can be approximated as increasing the elastic Mises stress by 113 MPa. However, the assessment location is a notch feature (in parent material) which increases these nominal elastic Mises stresses by an SCF of 3.5. The maximum principal stress is tensile. The rupture reference stress has been evaluated to be 162 MPa. The working temperature is 550°C.

- Upon tripping the reactor the steam pressure routinely undergoes a pressure surge to 240 barg. This happens quickly whilst the system stresses and temperatures are unchanged. Thereafter the pressure and system loads reduce monotonically.
- When shutdown to cold conditions (20°C) both the pressure and system elastic stresses are zero.
- When the reactor is re-started the pressure and system loads can be assumed to increase monotonically to their steady operating levels.

The only significant cycles are as described above, i.e., reactor cycles between steady operation and cold shutdown conditions, via a trip. There are 3 such cycles per year, and yearly operation is at 80% average availability.

Assume nominal parent 316/316H tensile data and cyclic stress-strain data from R66 Rev.008. However creep tests on the particular cast of interest has justified the use of a uniaxial creep ductility of 10%. The stress state at the feature being assessed is biaxial and the ratio of the second-to-first principal stresses, $\frac{\sigma_2}{\sigma_1}$, is 0.25. Assume for assessment purposes that the steady cyclic state applies from the first cycle. Assume mean RCC-MR deformation behaviour and calculate stress relaxation by integration of forward creep assuming strain hardening. The elastic follow-up factor is Z = 2 defined via the relaxation equation $\frac{Z}{\overline{E}} \cdot \frac{d\overline{\sigma}}{dt} = -\left(\dot{\overline{\varepsilon}}_c(\varepsilon_c, \overline{\sigma}, T) - \dot{\overline{\varepsilon}}_c(\varepsilon_c, \sigma^R_{ref}, T)\right)$.

Construct the hysteresis cycle for the feature according to the procedure of R5V2/3 Appendix A7. Hence find,

[1] The reverse stress datum;

[2] The forward stress datum;

[3] The dwell stress;

[4] The stress relaxation in the first cycle;

[5] The creep damage in the first cycle;

[6] The strain range;

[7] The fatigue damage in the first cycle, based on an 1mm initiation crack depth (and using Mises strain ranges – ignore Tresca & Rankine strain issues);

Estimate the number of years to crack initiation assuming the damage per cycle remains constant, i.e., the same as the damage for cycle 1.

Optional Extra: Calculate the number of years to crack initiation taking due account of creep hardening in causing the damage per cycle to change over life.