T73S04 (R5V2/3): Homework for Session 37 – Crack Initiation in Weldments

Mentor Guide Questions

1.38 Define the three Weldment Types in R5 Volume 2/3

1.39 Define what is meant by a Fatigue Strength Reduction Factor (FSRF) and discuss the recommendations regarding FSRFs for weldments in R5 and how they vary with material, weldment class and condition of the weldment

1.40 Discuss the requirement to include or exclude the local peak F-stresses in R5 fatigue assessments for dressed and undressed weldments

1.41 Discuss the influence of welding residual stresses on an R5 creep-fatigue initiation assessment

1.42 Itemise the key features of an R5 creep-fatigue initiation assessment of a dressed weldment which differ from that for a parent material feature or that of an undressed weldment

1.43 Itemise the key features of an R5 creep-fatigue initiation assessment of an undressed weldment which differ from that for a parent material feature or that of a dressed weldment

1.44 Discuss the requirement, or otherwise, for multi-material stress analyses, as opposed from homogeneous models

1.45 Discuss how the precise location of the assessment point in the vicinity of a weldment may be determined

1.46 Discuss recent developments in the methodology for initiation assessments of weldments

Numerical Questions

Repeat the homework for sessions 33/34/35 but as if the item in question was a partial penetration fillet weld with an undressed weld toe made on plates of thickness 50mm. The weld is made with a compatible 316 consumable. The weld cap angle at the attachment is 45^o.

The assessment point should be assumed to lie just within weld material, near the weld toe. The ratio of the weld-to-parent cyclic strengths is 1.3.

Use the new weldments procedure of R5V2/3 Issue 3 Rev 002 Appendix A4, as described in session 37. Use the weld toe SCF, WSEF and WER appropriate for this weldment in the assessment.

The homework 33/34/35 was for a parent feature with an SCF of 3.5. The weld is some way from this feature where the nominal SCF (excluding any weld toe effect) would be 1.2. All other data is the same. For this purpose the nominal stresses can be interpreted as the linearised stresses for the weldment.

Is the weldment more or less onerous than the neighbouring parent feature assesed in homeworks 33-35?

For completeness the parent material question is reproduced below…

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.009. However creep tests on the particular cast of interest has justified the use of a <u>uniaxial</u> 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 $\frac{Z}{\overline{E}} \cdot \frac{d\overline{\sigma}}{dt} = -\left(\dot{\overline{\varepsilon}}_c(\varepsilon_c, \overline{\sigma}, T) - \dot{\overline{\varepsilon}}_c(\varepsilon_c, \sigma_{ref}^R, T)\right)$.

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.

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