T73S04 Session 30 Homework – Shakedown

Last Update: 5/12/12

Mentor Guide K&S Questions

1.1 State the failure modes addressed by an R5 Volume 2/3 assessment. State the assumed initial condition of the structure.

1.6 Define the primary stress categories and state their maximum allowable values. State what these limits protect against.

1.7 Define the Equivalent Secondary Stress, Q, and the associated 'linear equivalent stress range'. State the maximum allowable value of the latter and what this protects against.

1.8 State how the significance of creep can be determined and how the creep rupture endurance is assessed.

1.9 State the requirements for cyclic loading to be insignificant and the features to which it applies

1.10 Define what is meant by "strict shakedown". Describe how the shakedown behaviour of a structure may be investigated in practice.

1.11 Describe the R5 concept of 'Global Shakedown' and how it is assessed.

1.12 Define "shakedown reference stress".

1.13 Explain what is meant by "cyclically enhanced creep" and how it is assessed within R5 Volume 2/3.

Numerical Questions

A CMV pipe has outer and inner diameters 204mm and 160mm. Its Young's modulus, Poisson's ratio, coefficient of expansion and lower bound 0.2% proof stress can be taken as temperature independent with the following values,

$$E = 180 \text{ GPa}; \quad \nu = 0.3; \quad \alpha = 14 \times 10^{-6} /^{o}\text{C}; \quad S_y = 190 \text{ MPa}$$

The conditions defining the extremes of the fatigue cycle have been identified as,

[1] Internal pressure of 160 barg with a linear through-wall temperature difference of 90°C, hotter on the ***inner*** surface, and with temperatures throughout in excess of 200°C;

[2] No pressure load but a linear through-wall temperature difference of 90°C, hotter on the ***outer*** surface. The limiting condition has been determined as 20°C on the inner surface and 110°C on the outer surface.

The resulting thermal stresses can be treated as secondary and both the hoop and axial stresses adequately approximated by the thin shell formula $\sigma = \mp \frac{E\alpha\Delta T}{2(1-\nu)}$ (through-wall bending stresses).

Questions:-

(a) Are the stress range criteria of R5V2/3 Section 6.3 met?

(b) Is the structure within strict shakedown?

(c) What have you assumed the shakedown residual stress field to be?

(d) Is the structure within global shakedown?

(e) Would it be valid to proceed to carry out a creep-fatigue crack initiation assessment to R5V2/3?

Hints

- Read the definitions of "primary membrane equivalent stress" and "primary bending equivalent stress" in R5V2/3 page 2/3.5 before starting.
- Think carefully about which surface is tensile or compressive under the thermal loading.
- Don't forget that the radial stress equals minus the pressure on the inner surface.