Tutorial Session 12B Homework – Residual Stresses

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K&S Question

1.19 Explain what is meant by "residual stress" and give examples of how residual stresses can arise. Derive the residual stress in a bar of rectangular section made of elastic-perfectly-plastic material and subject to an applied moment of collapse magnitude which is then removed.

Numerical/Algebraic Questions

(1) A large, flat plate contains a central circular hole and is subject to a uniform tension in the *x*-direction at the allowable limit of a design code, namely $\sigma = 2\sigma_0 / 3$ where σ_0 is the yield stress. The hole is of radius a. On the *y*-axis, the elastically calculated *x*-stress at a distance $r \geq a$ from the centre of the hole is given by,

$$\sigma_x = \sigma\left[1 + \frac{1}{2}\left(\frac{a}{r}\right)^2 + \frac{3}{2}\left(\frac{a}{r}\right)^4\right]$$

The plate is thin and plane stress conditions can be assumed. The *y*-stress on the *y*-axis is positive and less than the yield stress σ_0 everywhere. The Tresca yield criterion and elastic-perfectly-plastic material can be assumed. Use the rough approximation method of the session 12B tutorial notes to,

(i) Estimate the residual stress at the surface of the hole when the applied stress is removed;

(ii) Estimate the extent of the yield zone;

(iii) Find an expression for the distribution of residual stress as a function of y when the applied stress is removed;

(iv) Why is (iii) obviously not really correct? What qualitative feature is missing from the naïve residual stress distribution?

(v) Is the situation likely to be benign or onerous as regards fatigue?

(2) A butt weld joins two lengths of pipe of austenitic material. It is a single-sided weld made from the outside (a single V-prep). The wall thickness is 15mm. The weld contains no repairs. It is an MMA weld made using an arc voltage of 35 V and a current of 85 A. The process can be taken to have a welding efficiency of 0.8. The average fill speed was 2.5 mm/second. The parent yield strength is $^2/_3$ the weld yield strength.

(i) Evaluate the heat input parameter, q.

(ii) For the assessment of a defect in the HAZ near the weld fusion boundary, what distributions of hoop and axial welding residual stress through the thickness are recommended by R6 IV.4? (Note that what R6 calls q/vt is simply what is referred to as q here, with units J/mm^2). Plot these distributions against the coordinate through-thickness, normalising the stress by the weld yield stress.

(iii) It is required to perform a sensitivity assessment looking at a more realistic (less pessimistic) residual stress distribution. Use Ref.[7] to derive an alternative residual stress distribution and plot on the same graph as (ii) for comparison.

(iv) In an R6 assessment of a fully circumferential, part-penetrating crack, how will the use of residual stress distributions (ii) and (iii) differ? (Consider the net load resultants N and M).