The Treatment of Residual Stresses

R5 requires that an allowance for creep damage due to initial residual stress relaxation be included in an R5V2/3 assessment. But note that if the creep-fatigue damage due to service load cycles is large then it is likely that there are non-trivial cyclic plastic strains due to the service cycles. If so, the cyclic plasticity will tend to wash out the initial residual stresses. So it unlikely that the damage due to the initial residual stresses and the damage due to service load cycling will both be large. An algorithm which might be used to incorporate the damage due to initial residual stresses is outlined below. The illustration is for a creep dwell which lies to the right of the first cycle peak, though it will be obvious how this should be changed in other situations.

(1) The User supplies the initial hoop and axial residual stresses;

(2) The total elastic Mises stress at the peak of the first service load cycle is evaluated by combining the residual stresses and the operational stresses;

(3) The Neuber construction using the parent monotonic stress-strain curve is employed to convert this total elastic Mises stress to an elastic-plastic Mises stress;

(4) The above stress is reduced by the elastic unloading between the cycle peak and normal operation (if applicable);

(5) The amount by which the stress derived as above exceeds the start-of-dwell stress calculated by the usual R5V2/3 Appendix A7 procedure for the first cycle is taken as the net extra stress due to welding residual stresses, after allowance for plasticity, σ_{WR};

(6) The ratio of the total hoop to total axial elastic stresses, including residual stresses, is used to adjust the sampled ductility to form the biaxial ductility appropriate during residual stress relaxation, ε_f^{WR};

(7) The additional creep damage due to the residual stresses is estimated as $D_c^{WR} = \dfrac{Z\sigma_{WR}}{\overline{E}\varepsilon_f^{WR}}$.

Here Z is the elastic follow-up factor and $\overline{E} = 3E/2(1+\nu)$ is the modified Young's modulus. (For simplicity the same elastic follow-up factor can be used for this purpose as for the service loads alone. In reality the residual stress is likely to have a smaller effective elastic follow-up).

(8) Any of the quantities contributing to the calculation of D_c^{WR} described above may be distributed so that D_c^{WR} will vary trial by trial.

(9) The above procedure will give only a rough estimate of the extra damage due to initial residual stresses. However this is sufficient if it is found that the impact of this additional damage on the probability of crack initiation is negligible.