THERMOELASTOPLASTIC AND CREEP ANALYSIS OF THICK-WALLED CYLINDERS

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ABSTRACT

Time-independent thermoelastoplastic and time-dependent creep stress and damage analysis of thick-walled cylinders have been investigated using incremental theory of plasticity in conjunction with improved material elastoplastic and creep constitutive models. The results are validated experimentally and numerically.

For time-independent thermoelastoplastic analysis thick-walled cylinders of SUS 304 stainless steel have been selected. The material's loading and unloading properties including the Bauschinger effect factor (BEF) are obtained experimentally and represented mathematically as continuous functions of effective plastic strain. The material's model and the BEF have been incorporated in an analytical-numerical model to predict the cylinder's plastic and residual stresses as well as the critical pressures of direct and reverse yielding. The analytical-numerical models for the prediction of critical inner pressure, plastic stress distributions and the subsequent residual stresses of thick-walled cylinders are validated experimentally. Several experiments are carried out on thick-walled cylindrical test specimens in which internal hydraulic pressure has been increased and the outer surface deformations are measured by the strain gauges.

Subsequently the load has been released and the residual strains are again measured at the outer surface of the cylinder. These experimental measured values are compared with the predicted values of the analytical-numerical model and, in most cases, the model predictions are accurate.

For time-dependent creep stress and creep damage analysis, thick-walled tubes of $\frac{1}{2}Cr, \frac{1}{2}Mo, \frac{1}{4}V$ ferritic steel have been considered. Improved material creep and rupture properties are obtained from the available literature. A numerical model has been developed for the computation of creep stresses and strains and the creep damages in a thick-walled tube which is subjected to an internal pressure and a thermal gradient. The model predicts histories of stresses and strains as well as the damage history during the life of the tube due to variation in stresses with time and through-thickness variations. The creep damage accumulation is based on the Robinson's linear life fraction damage rule which has been incorporated in a non-linear time-dependent stress analysis. Following the stress histories the damages are calculated and cumulatively summed during the life of the tube. From the effective stress histories a reference time has been identified when the effective stress distributions become uniform throughout the tube wall. Effect of internal pressure on this reference time is investigated. The accuracy of the results has been examined by comparing the theoretically predicted creep curves and the numerically followed curves. Deviation of the followed paths from the predicted paths is small.