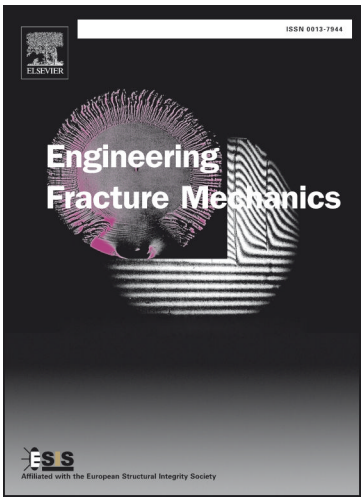

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The Beneficial Effect of Full or Partial Autofrettage on the Combined 3-D Stress Intensity Factors for Inner Coplanar Crack Arrays and Ring Cracks in a Spherical Pressure Vessel

by

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ABSTRACT

The distributions of the combined 3-D Stress Intensity Factor (SIF), $\boldsymbol{K_{IN}=K_{IP}+K_{IA}}$, due to both internal pressure and autofrettage along the front of coplanar crack arrays as well as ring cracks emanating from the bore of an overstrained spherical pressure vessel are evaluated. The 3-D analysis is performed using the finite element (FE) method employing singular elements along the crack front. A novel realistic autofrettage residual stress field incorporating the Bauschinger effect is applied to the vessel. The residual stress field is simulated using an equivalent temperature field in the FE analysis. Numerous coplanar crack array configurations are analyzed as well as ring cracks of various depths. SIFs distributions are evaluated for coplanar crack arrays of densities δ=0-0.95, consisting of cracks of depth to wall thickness ratios of $\boldsymbol{a/t}$=0.05-0.4, and ellipticities of $\boldsymbol{a/c}$=0.2-1.0, prevailing in fully or partially autofrettaged spherical vessels of different geometries $\boldsymbol{R_0/R_i}$=1.1, 1.2, and 1.7, bearing three levels of autofrettage ($\boldsymbol{\varepsilon}$=50%, 75%, and 100%). Furthermore, SIFs for inner ring cracks of various crack depth to wall thickness ratios of $\boldsymbol{a/t}$=0.025-0.6 prevailing in the same fully or partially autofrettaged spherical pressure vessels are also evaluated. In total, about two hundred different crack configurations are analyzed. A detailed study of the influence of the above parameters on the prevailing SIF is conducted. The results clearly demonstrate the favorable effect of autofrettage which may considerably reduce the prevailing effective stress intensity factor, thus delaying crack initiation and slowing down crack growth rate, and hence, substantially prolonging the total fatigue life of the vessel. Furthermore, the results emphasize the importance of properly accounting for the Bauschinger effect including re-yielding, as well as the significance of the three-dimensional analysis herein performed. Furthermore, it is shown that in some cases the commonly accepted approach that the SIF for a ring crack of any given depth is the upper bound to the maximum SIF occurring in an array of coplanar cracks of the same depth is not universal.

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