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# The Bauschinger Effect on 3-D SIFs for Networks of Radial and Longitudinally-Coplanar Semi-Elliptical Internal Surface Cracks in Autofrettaged Pressurized Thick-Walled Cylinders

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## Summary

Networks of radial and longitudinally-coplanar, internal, surface cracks are typical in rifled, autofrettaged, gun barrels. In two previous papers, the separate effects of large arrays of either radial or longitudinally-coplanar semi-elliptical, internal, surface cracks in a thick-walled, cylindrical, pressure vessel under both ideal and realistic autofrettage were studied. When pressure is considered solely, radial crack density and longitudinal crack spacing were found to have opposing effects on the prevailing stress intensity factor, $K_{IP}$. Furthermore, the addition of the negative stress intensity factor (SIF), $K_{IA}$, resulting from the residual stress field due to autofrettage, whether ideal or realistic, tended to decrease the combined SIF $K_{IN} = K_{IP} - |K_{IA}|$. Therefore, to assess the fracture endurance and the fatigue life of a cylindrical, autofrettaged, pressure vessel containing such a network of cracks, it is necessary to determine the $K_{IA}$'s and the $K_{IN}$'s. This paper presents the $K_{IA}$ and the $K_{IN}$ distribution for numerous configurations of semi-circular and semi-elliptical, crack networks affected by pressure and autofrettage. The 3-D analysis is performed via the finite element (FE) method and the submodeling technique, employing singular elements along the crack front and the various symmetries of the problem. The networks considered included up to 128 equally spaced cracks in the radial direction; with relative, longitudinal crack spacing, $2c/d$, from 0.25 to 0.99; for 100 percent autofrettage; employed a wide range of crack depth to wall thickness ratios, $a/t$, from 0.01 to 0.4; and, involved cracks with various ellipticities of crack depth to semi-crack length, $a/c$, from 0.2 to 2. The results clearly indicate that the combined SIFs are considerably influenced by the three-dimensionality of the problem and the Bauschinger effect to such an extent that cracks predicted closed or partially closed by the ideal autofrettage model are predicted as remaining open by the realistic autofrettage model. In addition, the SIFs are found to depend upon the other parameters enumerated previously, namely: radial crack density,

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longitudinal crack spacing, crack depth, crack ellipticity, and the autofrettage level.