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AN ANALYTICAL APPROACH FOR LARGE SIZE OPTIMISED REINFORCED HOLE IN COMPOSITE CIRCULAR CYLINDRICAL SHELLS

Abstract

Upper inter stages of launch vehicles are invariably designed using composite structures with reasonably large size reinforced square holes to meet the functional requirements. It is well-known that even though hole edge stress reaches the strength of the laminate, composite structure does not fail due to the reduction in stress with the presence of plasticity associate with resin. Thus, many failure criteria are available in literature that considers stress gradient rather than peak stress. As on today design is based on finite element analysis and no analytical equations are reported for such case. Recently, author's study on infinite laminate under uniaxial tension with reinforced hole based on Lekhnitskii's solution for unreinforced hole reported in 1949 was obtained. Tangential stress distribution in the laminate was derived by solving unknown orthotropic coefficients in terms of a power series in hole shape parameter by an iterative technique for converting Lekhnitskii's solution around the hole into a Fourier series. In the present study, for reinforced square hole with a rounded corner and double barrel shape hole close to optimum stress distribution in circular cylindrical shell under uniaxial load is achieved by incorporating curvature parameter,β that depends on shell radius, thickness and hole size. A good agreement is obtained between finite element analysis and analytical prediction. The region of validity of the present analytical solution on reinforcement area is arrived at based on a comparison with the finite element analysis. In the case of shell type structure effect of hole edge bending with respect to hole shape is different. This aspect is also studied and it is concluded that design based on peak membrane stress is comparable to the sum of bending and membrane stress ahead of the reinforced hole.