Composite Engineer's Viewpoint

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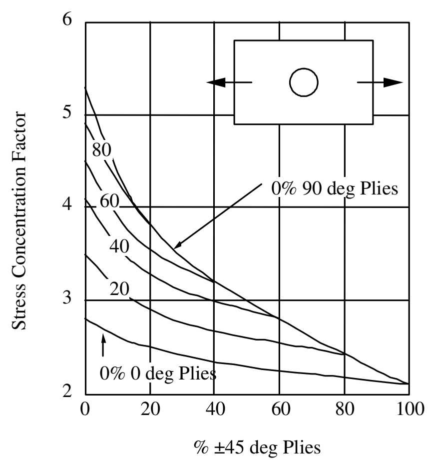
Designing with Composite Materials
Part 7C – Detail Design – Holes and Cutouts

The introduction of cutouts or holes in a laminate needs to be undertaken with a caution. The stress concentrations developed in composite materials is very much influenced by both the fibre type and the lay-up of the laminate. Increasing the effective stiffness of the laminate will increase the stress concentration around the hole as shown in the following figure.



With very stiff fibres and a dominance of fibres in the 0 degree direction this can produce a stress concentration factor in excess of 5. On the flip side though using a larger percentage of ±45 degree plies and less stiff fibres, this can reduce the stress concentration down to a value of 2.

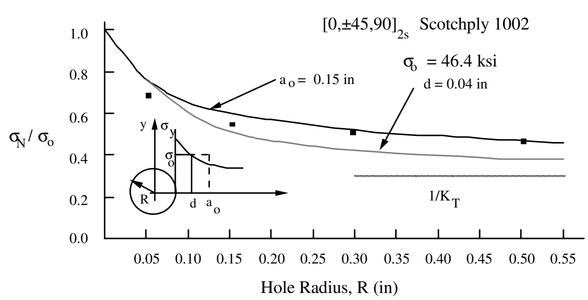
A simple approach to determine the effective stress concentration factors in composite laminates with circular hole and axial stress (in the laminate major axes direction) was developed by Whitney and Nuismer. Their approach, called the 'Point Stress Failure Criterion' is based on the ratio of the laminate effective orthotropic axial, transverse and shear stiffness coefficients from the in-plane stiffness matrix (A_{ij}). In the point stress failure criterion, the failure stress due to the presence of a hole of radius R in a composite laminate is predicted at a fixed distance d_o from the hole boundary, such that the notched to unnotched stress ratio is given by:

$$\frac{\sigma_N}{\sigma_o} = \frac{2}{2+\rho^2+3\rho^4-[K_T-3]\left[5\rho^6-7\rho^8\right]}$$

where; $\rho = \dfrac{R}{R+d_o}$

$d_o \approx$ 1.0 mm (characteristics dimension)

$$K_T = 1+\sqrt{\left[\frac{2}{A_{22}}\left[\sqrt{A_{11}A_{22}}-A_{12}+\frac{A_{11}A_{22}-A_{12}^2}{2A_{66}}\right]\right]}$$



The adjacent figure plots the stress distributions of both the average stress failure criterion and the point stress failure criterion from the hole edge. Note that average stress failure criterion and the point stress failure criterion only evaluate the stress concentration on a circular hole under an axial tension load. The stress concentration is determined at one point on the hole, perpendicular to the loading direction.

In the next article we investigate the general design guidelines for ply drop-off in composite structures. Ply drop-off need to be undertaken with caution and care as poor attention to this detail can result in a significant change in the structural response of the laminate. As always I welcome questions, comments and your point of view. Feel free to contact me via r.heslehurst@adfa.edu.au. I may publish your questions and comments, and my response in future articles.