Mechanically Fastened Joints in Composite Structures

Composite Engineer's Viewpoint by **Rik Heslehurst** PhD, MEng, BEng(Aero) FIEAust, FRAeS, FSAMPE, CPEng

Part 8 – Bolted Hole Stress Concentrations

Stress concentrations occur in all structural materials and applications. For bolted joints the load must still divert around the filled hole to be reacted on the bearing surface.

Whilst a bolt fills the open hole in a structure there is still a stress concentration effect in both tension and bearing failures modes. For composite materials the laminate configurations plays a key role in the variations of the local stress concentration factors (Figure 1) .

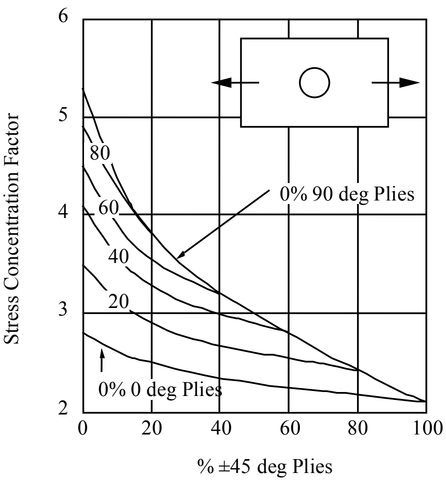

Figure 1: Open Hole Stress Concentration for a Graphite/Epoxy Composite Laminate

The impact of the stress concentration in the structure reduces the load carrying structural efficiency. For composite materials this is more significant than that found in ductile metallic structures. Figure 2 clearly shows the lower structural efficiency of bolted joints in composite materials when compared with ductile metallic structures.

Stress concentrations of brittle materials with bolts has been experimentally found and a design expression has been developed to fit the experimental data points. This expression for the tensile elastic isotropic (brittle) material stress concentration (kte) is provided at equation 1. Experimentally it has also been found that the composite material bolted hole tensile stress concentration factor (ktc) is linearly related to the elastic isotropic stress concentration factor (Figure 3). This relation of Figure 3 is expressed in equation 2.

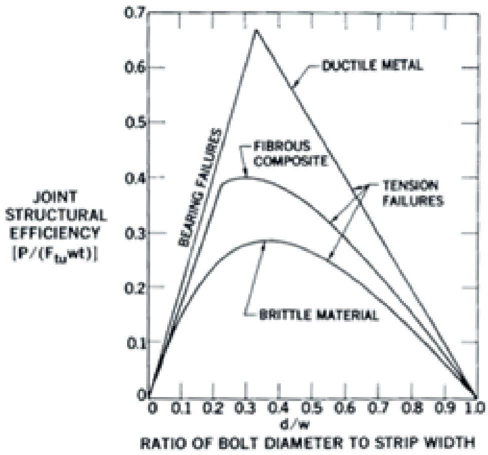

Figure 2: Structural Efficiency if Bolted Joints with Different Classes of Materials (Hart-Smith)

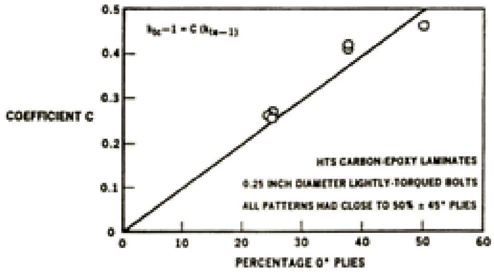

Figure 3: The Relationship Between the Elastic Brittle Material and Composite Material Tensile Stress Concentration Factors (Hart-Smith)

$$k_{te} = 1 + \left\{1-\left(\frac{D}{p}\right)^2\right\}^{2.41} + \frac{1-\left(\frac{D}{p}\right)}{\left(\frac{D}{p}\right)} - \frac{3}{2}\left\{\frac{1-\left(\frac{D}{p}\right)}{1+\left(\frac{D}{p}\right)}\right\}\Theta \qquad \text{Eqn 1}$$

Where: D = Fastener diameter
p = fasteners in a seam pitch distance
e = fastener edge distance

$$\Theta = \frac{3}{2} - \frac{1}{2\left(\frac{e}{p}\right)} \quad \text{for } \frac{e}{p} \le 1$$

$$\Theta = 1 \quad \text{for } \frac{e}{p} > 1$$

$$k_{tc} = \left[\frac{P0}{100}\left(k_{te} - 1\right)\right] + 1 \qquad \text{Eqn 2}$$

Where: $P0$ = percentage of 0 degree plies in the laminate stack

Likewise bearing stress concentration factor can be defined through similar relationship and simplified to a relationship between the pitch distance and the tension stress concentration factor (Eqn 3):

$$k_{bc} = \frac{Dk_{te}}{(p - D)} \qquad \text{Eqn 3}$$

NEXT ARTICLE

In the next article we will discuss the multiple row limitations in composite structures. Unlike metallic structures that have a better multiple row load sharing capability (due to local ductility), composite structures are linear elastic to failure and thus require better understanding of multiple rows of fastener bearing/by-pass load interaction. I also 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 newsletters.