Composites Australia

Mechanically Fastened Joints in Composite Structures

Composite Engineer's Viewpoint
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Part 11 – Off-Axis Loading

This is the final article in this series related to mechanically fastened joints in composite structures. In this article the off-axis loading of composite structures is discussed. Off-axis loading is of significant importance in composite structures because laminated fibrous composite materials are general orthotropic. Thus any loading off the material axis results in general orthotropic behaviour. This has significant implications for the laminate structural design with fasteners that are loaded off-axis.

A common example of off-axis loading can be illustrated by a lug joint as shown in Figure 1. Axial and transverse loads are independently axially loaded for an orthotropic material. The combined axial and transverse loads result in an oblique loading action which is off-axis to the material and structural orthotropic axis. With composite materials this may result in a poor structural efficiency.

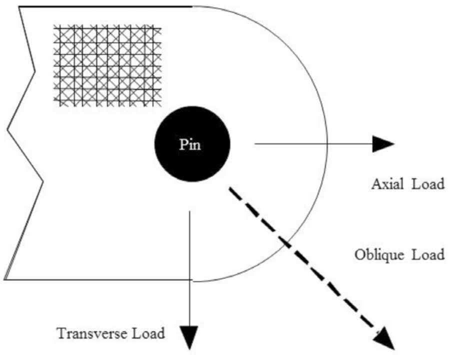

Figure 1: Off-axis Loading in Lug Joints

From Figure 1 the off axis failure modes of interest are illustrated in Figure 2. Thus the material properties against shear-out, bearing and net-tension need to be determined in the off-axis position. Initial this can be estimated by transformation of the orthotropic strength properties to the off-axis loading angle using the 2nd order stress transformation equations (Mohr's circle equations in stress).

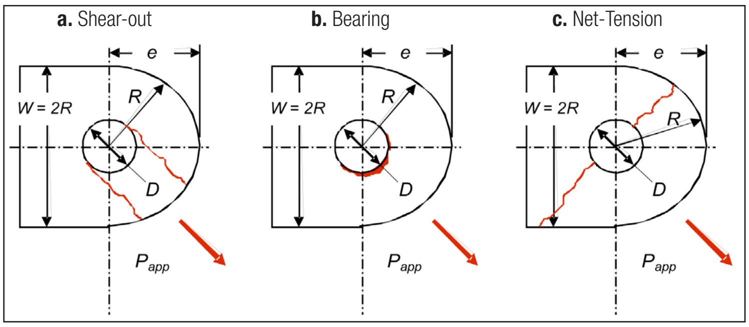

Figure 2: Oblique Composite Lug Loading and Failure Conditions

When a highly orthotropic laminate is loaded off-axis the radial stress distribution can change rather dramatically, see Figure 3 for example. A lack of appreciation of this issue will more than likely result in poor composite structural performance of mechanically fastened joint.

What is often required in the composite laminate configuration in the presence of off-axis bolt/pin loading is a near quasi-isotropic ply configuration.

Figure 4 represents the ideal range of ply percentages in the 0 degree, 90 degree and ±45 degree directions. Whilst this may seem rather restrictive in ply selections it is a better approach for the mechanically fastened joint efficiency. However, with localised ply additions around the fastener hole the local properties can be adjusted to be near quasi-isotropic.

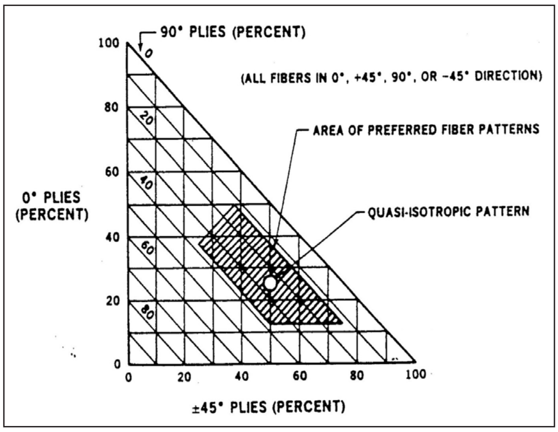

Figure 3: Circumferential Stress Distribution at Loaded Bolt Holes (Garbo and Ogonowski, AFWAL-TR-81-3041)

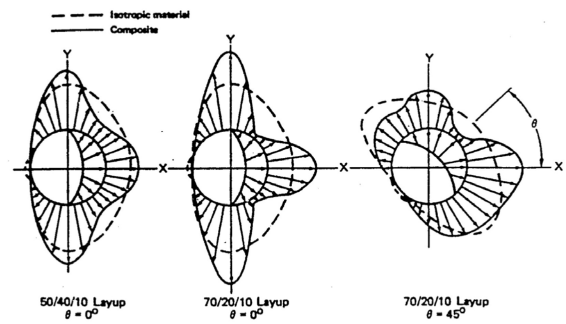

Figure 4: Preferred Ply Orientations for Mechanically Fastened Joints (Hart-Smith)

In the next article we will begin a new series that discusses 'Sandwich Structures with Composite Facings – the Design Challenges to be Faced. I also welcome questions, comments and your point of view. I may publish your questions and comments, and my response in future newsletters.

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