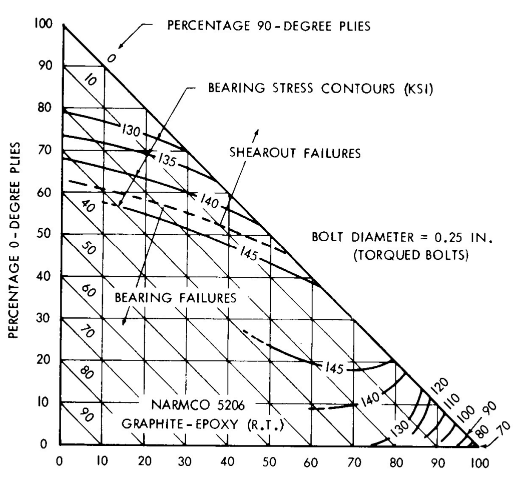
Composite Engineer's Viewpoint
Rik Heslehurst PhD, MEng, BEng(Aero)
FIEAust, FRAeS, CPEng

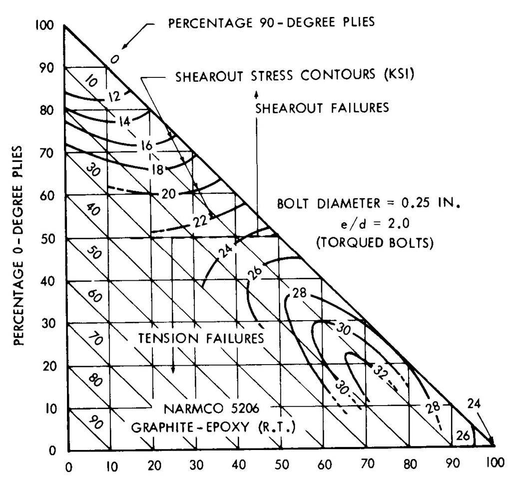
Designing with Composite Materials
Part 7B – Detail Design – Mechanically Fastened Joints

The comments of this article are confined to mechanical fastened in composite structures. Whilst welding of composite structures is also part of the joining processes available the principle of this joining techniques are essentially the same as adhesive bonding. In terms of load transfer the stress stresses generated in the welded bondline and those in an adhesive are both in pure resin. Please note that the discussion in this article is for primary load bearing structures and the joint is designed to transfer high loads.

Whilst the failure modes of the composite structure and the fastener (pin) are pretty much the same irrespective of the materials being joined there are some important issues to be understood. I will mainly direct my comments on the failure modes of the composite, but pin failures must be negated by the appropriate selection of the fastener (diameter and material). One issue to always consider is torqued fasteners and the potential of crushing the composite matrix (resin), this is overcome by reducing the fastener torque to appropriate levels. Shear-out of the composite can be a major problem. The interlaminar shear strength of the composite is not great, but is improved with plies that have fibres running in transverse and angled directions to the applied load. The free edge distance is also important and should be at least two fastener diameters. Multiple rows of fasteners will also improve shear-out failure conditions. I strongly recommend that shear-out failure modes is designed out of the potential failure conditions. Cleavage failure mode, like shear-out, is controlled by edge distance, and transverse and angled plies. With a healthy percentage of plies (fibres) running at angles from ±45 degrees to 90 degree direction then the cleavage failure mode should not be a problem. Typically, we drive the failure condition to be either net tension or bearing. Actually, the net tension failure mode is the preferred failure condition for composite structures. This is due in part to the relatively low bearing strength of composites. The bearing strength is controlled by fibre volume ratio and the percentage of ±45 degrees plies (the more the better). Bearing capacity can also be improved with increasing number of fastener rows. The following two diagrams from John Hart-Smith's work in the 1970s shows the variation in shear-out and bearing strength as a function of unidirectional ply orientations (0, ±45, 90 degrees) for a graphite/epoxy laminate. The effects in other fibre/resin systems will have similar outcomes.



Bearing Stress Contours



Shear-out Stress Contours

So remember the following:

- Use a healthy percentage of plies at 45 degrees in the joint region.
- Have a good edge distance of 2D, up to 3D. Anything greater means you have a problem with too many 0 degree plies.
- Restrict bearing failure with larger bolts or even better not too great a spacing between fasteners in a row.
- Fastener spacing recommendations are 3D to 5D. A great fastener spacing will result in bearing failure to dominate.
- Multiple rows of fasteners will improve shear-out and bearing strength capacity, but when tensile failures are the dominate failure mode adding more rows will do little to increase the strength.
- Torqued fasteners will improve bearing capacity and failure life. However, over-torquing a fastener will cause transverse crushing of the matrix.
- Limit torque to about ¼ to ½ a turn after finger tight.
- Always remember to support the back of a laminate when drilling composite structures so not to cause back surface delaminations.

In the next article I will cover the issues of adhesively bonding composite structures. 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.