Composite Engineer's Viewpoint

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Designing with Composite Materials
Part 7A – Detail Design

Now having developed the basic composite laminate configuration in terms of materials and general lay-up, and we have initially costed the composite component, we move into detailed design. Detailed design covers an assortment of activities, not the least of these is joining the laminate to other structures and components. Other issues in detailed design will include openings, local strengthening and stiffening, sandwich construction, etc.

A very critical part of any structural design is the joint. This is because the joint is typically a high stress location and in composite materials this is very different to joining metals. Because of the linear elastic behaviour to failure of high performance composite materials, joint failure is brittle in nature and thus needs to be specifically addressed in the design. The following table provides a summary of the advantages and disadvantages in joining composite materials. Here we cover mechanically fastened joints and adhesively bonded joints as the two major structural joining methods. Welding of composite joints with thermoplastic fillers can be covered by the adhesively bonded joint issues. Mechanically fastened joints in composite materials have to be designed very carefully as they are more critical than those of metal joints. However, adhesive bonding of composite materials is more effective and less stringent than metal bonding.

JOINT TYPE	ADVANTAGES	DISADVANTAGES
MECHANICAL FASTENERS (Bolts, Rivets, Screws, Pins, Staples, etc.)	Straight forward design in metals Inspectable Repairable by replacement Any thickness, caution thin structure Can be disassembled	Stress concentration effects Relative weaker joint Fatigue prone, requires clamping Must seal the joint as well Prone to fretting Prone to corrosion, dissimilar materials
ADHESIVE BONDING	Full load transfer achievable Repairable of sorts Fatigue resilient Sealing action as the same time Stiff connection Light-weight structure Smooth contour without penalty Corrosion barrier Reduced stress concentrations	Difficult to inspect Surface preparation is critical Environmental effects New design methods New trade skills required Thickness limited, thicker components Residual thermal stresses Cannot be disassembled easily Shear loading only

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 the lay-up of the laminate. Increasing the effective stiffness of the laminate will increase the stress concentration. 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.

Thus we see with both joints and cutouts there is a need to modify the local strength and stiffness of the laminate. This is done by the mechanism of ply drop-off or ply addition in the local area of the laminate.

Whilst there are no specific requirements of this activity, there are a number of guidelines to assist in producing quality laminates.

Finally, the use of sandwich construction is an important and common activity in composite structures. Sandwich construction provides the laminate with many benefits. The main objective in using a sandwich structure is typically to provide a very flexurally stiff laminate without the weight penalty. However there are some performance issues, such as environmental degradation, that also need to be addressed.

In the next few articles, we look at the joining processes, effects of cutouts, how to best introduce local ply increase and decrease (drop-off), and sandwich construction in greater detail. 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.