Designing with Composites: Suggested "Best Practices" Rules

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Most of us are probably well aware that polymeric composites have numerous applications because of the properties they bring to the table with their inherent advantages over metals and other materials – at least most of the time. In many instances, composites are the correct answer if designed, manufactured and used properly. Composites have distinct advantages in many areas when those properties are designed into the ultimate product. The important thing is to utilize composite materials uniqueness to achieve the best designs while capitalizing on their advantages and minimizing any disadvantages along the way.

A number of composite material advantages that we typically focus on are:

- Light weight (lower density materials)
- Corrosion and chemical resistance
- Electrical non-conductivity (<u>except</u> carbon and graphite)
- Tailorable stiffness and strength
- Near zero thermal expansion
- Complex shape generations
- Improved fracture toughness
- High strength-to-density
- High stiffness-to-density
- Electrical conductivity (carbon and graphite)
- Tailorable thermal properties
- Process flexibility
- Enhanced fatigue life properties
- Reduced assembly part count

However, over the years we have learned that using composites to arrive at structurally efficient parts requires that we design and manufacture composites with sound engineering judgment as our guideline. To that end, M&P engineers over time have acquired a number of "lessons-learned" and "best practices" that are believed to minimize design and manufacturing risks with composite structures. Table 1 defines a number of these for the record.

Table 1. Typical "Best Design Practices" for Composite Structures

Composite Practice	Reason Applied
• Try to employ "Balance" and "Symmetry" whenever possible	• Minimizes value of "B-matrix", avoiding bending, coupling, warping and twisting effects
• Avoid stacking too many plies all at one angle	• Delamination and residual stresses more likely if not avoided
• Add fabric ply to inner or outer layer	• Fabric ply can absorb more impact damage as well as minimize drilling "breakout" for holes
• Add ±45° plies with at least one pair on laminate extremes (except for specific designs where bending loads require 0° or 90° outer plies (moments)	• Increases buckling for thin laminates as well as better damage tolerance
• Use larger fraction of +/- plies in shear regions	• Shear loads are best handled with additional +/- plies in a structure
• 0°/90°/±45° laminate with minimum of one layer in each direction	• 0° layers for longitudinal loads • 90° layers for transverse loads • ±45° layers for shear loads • Makes it "quasi-isotropic" as well
• A +45° and -45° ply are in contact with each other	• Minimizes interlaminar shear
• 45° layers are added in pairs (±45°)	• In-plane shear is carried in tension and compression in the

	45° layers
• Minimize stress concentrations	• Composites are essentially elastic to failure
• Maintain a homogeneous stacking sequence by banding several plies of the same orientation together	• Increased strength achieved
• Minimize fiber orientation angle between adjacent plies	• Reduces free-edge stresses (delaminations) • Avoids microcracking – particularly for cryogenic or wide temperature excursion applications

Composite joints, whether (a) bonded, (b) bolted or (c) both bonded and bolted, also have documented lessons that have been learned over the years. Table 2 lists several of those as well.

Table 2. Typical “Best Design Practices” for Joining Composites

Joint Design Practice	Reason Applied
• For a 0°/±45°/90° laminate joint design, use the following: ○ Minimum of 40% plies at ±45° ○ Minimum of 10% plies at 90°	• Better strength overall ○ Better shear-out strength ○ Better bearing strength ○ Better net tensile strength
• Maintain a fastener edge distance-to-hole diameter of e/d = 2.5 to 3.0	• Improved bearing and shear-out strength
• Maintain a fastener hole spacing-to-hole diameter of s/d = 6.0	• Minimizes hole-to-hole interaction of stresses
• Design joint to be critical in bearing failure (non-catastrophic in nature): ○ Use fasteners of sufficient diameter ○ Use fasteners of sufficient strength ○ Locally reinforce if necessary	• Bearing failures in composites are not catastrophic in nature
• Apply all best practices in bonded joint “surface preparation” and “bond alignment control”	• Majority of problems occur due to inadequate surface preparation and bond alignment
• Bonded joints – no 90° plies in contact with metal surfaces	• Reduction in lap shear strength at issue
• Bonded joints – ±45° plies at last step in joint build-up	• Reduces peak loading by decreasing ply stiffness locally
• When adding plies, use a 0.3-inch overlap in major load direction when using a wedge type pattern	• Requires approximately that distance (~0.3-inch) to develop adequate strength
• Use mechanical joints for direct tension	• Bonded joints do not develop adequate strength in that mode
• Short, bonded joints are more efficient than long ones	• Peak shear stress occurs at ends of joints • Average allowable stress decreases with length
• Joint eccentricity produces large “peel” stresses – avoid wherever possible	• Chamfer thick laminates to reduce “peeling” effect • Double shear joints reduce “peel” effect (symmetry) • Thick laminates are affected more than thin laminates

Not covered in this series are the aspects pertaining to various bonded joint design options: single-lap shear, double-lap shear, scarfed joints, etc. These will be covered at another time along with a discussion on surface preparation aspects.