Mechanically Fastened Joints in Composite Structures

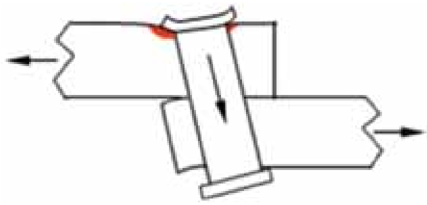
Composite Engineer's Viewpoint by **Rik Heslehurst** PhD, MEng, BEng(Aero) FIEAust, FRAeS, CPEng

Part 6 – Fastener Interaction

In this article we will consider the fastener interaction with the composite structure through the failure modes of fastener pull-through and fastener bending. These are important factors to consider because of the way a fastener interacts with a composite structure whilst under shear load transfer.

Fastener Pull-Through

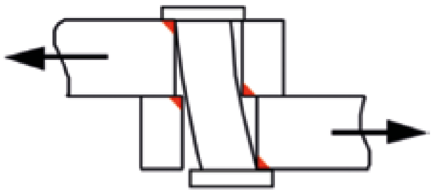
The failure condition of fastener pull-through can generally be attributed to using too large a fastener diameter to the component thickness. As a guide if the fastener diameter exceeds the component thickness by more than two gauge thicknesses then there is a high potential for fastener pull-through. This a particularly true for component thicknesses less the 2 mm.



Composite laminates are more prone to fastener pull-through because of the weaker through-the-thickness properties. The fastener pull-through load, which is determined by the fastener angle of tilt, (i.e. $P_{pull\text{-}though} = P\tan\theta_{tilt}$) is developed into a stress based on the fastener head faying surface (approx $3/8\pi D^2$), and is compared with the through-the-thickness shear strength oθf the composite laminate.

Fastener Bending

f the fastener is too small in diameter (relative to the laminate thickness) and/or the fastener flexural stiffness ($ED^4/_6 4$) is low, then the fastener could bend under load transfer. Fastener bending creates local high stress points around the fastener hole. In composite materials this will cause local matrix cracking and delaminations in the zones shown to the right. This oversizes the fastener hole and creates further fastener bending deflections.



The fastener bending resistance can be determined from the fastener bending modulus of rupture and if the calculated factor of safety is less than 100% then fastener bending is likely to be a problem. The bending modulus of rupture for a solid fastener can be estimated from:

$$\sigma bending = \sigma tu + 0.7f_o$$

where: σtu = ultimate tensile strength of pin

f_o = from the following table

Material Properties for Bending Rupture Modulus

(Modified from Bruhn)

		Yield Condition		Ultimate Condition	
Sheet Material	**Sheet Thickness (mm)**	σty (MPa)	f_o (MPa)	σtu (MPa)	f_o (MPa)
2014-T6 Aluminium Die Forged	t ≤ 100	359	130	427	396
6061-T6 Aluminium Sheet	t ≥ 0.5	241	121	290	279
7075-T6 Aluminium Die Forged	t ≤ 50	448	176	517	483
A-Z61A Magnesium Extrusion	t ≤ 6.5	145	52.4	262	108
Normalized AISI Alloy Steel	t > 4.75	483	298	621	573
Normalized AISI Alloy Steel	t ≤ 4.75	517	325	655	593
Heat Treated AISI Alloy Steel		710	356	862	814
Heat Treated AISI Alloy Steel		910	455	1,034	1,007
Heat Treated AISI Alloy Steel		114	365	1,241	1,186
Heat Treated AISI Alloy Steel		1,214	448	1,379	1,324
17-7PH Stainless Steel		1,034	427	1,241	1,110
PH15-7 Mo Stainless Steel		1,379	379	1,551	1,103
Ti-8Mn Titanium		758	248	827	800

NEXT ARTICLE

In the next article we will discuss the Clamp-up – How much should you tighten a fastener that bears down on a composite structures? What is the crushing resistance of the composite through-the-thickness? Such questions can be answered with proper understanding of composite material properties and directional relationships. I also welcome questions, comments and your point of view. Feel free to contact me via r.heslehurst@adfa.edu.au