

Appendix A

Table A1: Characterisation of common defects in composite parts (modified from ¹).

DEFECT TYPE	DESCRIPTION	MATERIAL TYPE	CAUSE		
			Processing	Machining	In-Service
Contamination	Can cause regions of poor interfacial or interlaminar adhesion, and voidage. Can spread during processing.	All PMCs	Any processing route, solvents, volatiles, grit	Through use of solvents, volatiles, lubricants	Moisture of chemical ingress
Corrosion/Erosion	Galvanic corrosion often occurring with the coupling of metals to carbon composites.	All PMCs	N/A	N/A	Due to material mismatch contact, wear
Crushed sandwich core ²	Can result in localised de-bonding and lack of support to sandwich skins structures.	Sandwich laminates, all types of core	Local indentation, excessive loading through-thickness	Poor practice – all machine operations	Impact, local indentation, excessive loading through-thickness
Delaminations/ Disbonds ^{3,4}	Can be caused by other defect types and has a severely detrimental effect on mechanical strength; capable of reducing compression strength by >50%. Is directly considered a failure mechanism of composites.	Laminated PMCs	Out of date material, contamination and insufficient cure	Poor practice – all machine operations	Impact, lightning strike
Fibre fracture ⁵	Initiation point for failure, particularly poor fatigue resistance, and channel for moisture ingress.	All PMCs	All process routes, possible in tight curvature	Poor practice – all machine operations	Excessive loading, impact, lightning strike, fatigue
Fibre misalignment ^{4,6}	In-plane fibre misalignment; detrimental to mechanical properties. A deviation of 5° can have a significant effect on strength and stiffness. If over a large area, can cause bending during cure.	Aligned fibre systems	Lamination process routes	Cutting of material at wrong angle	N/A
Fibre wrinkling ^{6,7,8}	Out-of-plane fibre misalignment; local strains are greatly increased, impacting on the strength of the laminate.	All PMCs	All process routes, present in tight curvature	N/A	N/A

Table A1 cont.: Characterisation of common defects in composite parts (modified from ¹).

DEFECT TYPE	DESCRIPTION	MATERIAL TYPE	CAUSE		
			Processing	Machining	In-Service
Foreign bodies ^{4, 6}	Inadvertent inclusion, impacting on mechanical properties due to delamination of surrounding material and providing a failure initiation point.	All PMCs	Backing/release film, scalpel blades, staples	N/A	N/A
Incorrect stacking sequence	Produces incorrect mechanical properties and potential warpage depending on resulting sequence.	Laminated PMCs, sandwich construction	Lamination process routes	N/A	N/A
Matrix micro-cracking ⁹	Caused by mechanical and thermal stresses, can lead to degradation in thermomechanical properties. Provides a damage nucleation site to induce delaminations and fibre breakage.	All PMCs	All processes that require significant temperature changes or resin shrinkage	Poor practice – all machining operations	Excessive loading, impact, lightning strike, fatigue
Residual stresses/ Thermal cracking	Impact on the properties to induce warpage, fibre buckling, matrix micro-cracking, and delaminations. This arises from thermal gradients within the structure.	Thermoset resin-based PMCs	All processes that require significant temperature changes/resin shrinkage	N/A	All phenomena that involve significant temperature changes
Resin starvation	Areas of materials where fibres are still dry, potentially caused by inadequate wetting of fibres, poor consolidation or resin delivery. Often occurs at inner radii of curved components.	All PMCs	All process routes	N/A	N/A

Table A1 cont.: Characterisation of common defects in composite parts (modified from ¹).

Resin rich areas ⁶	Potentially caused by displacement of fibres during process, particularly in structures with small radii, steps and chamfered edges. Location for the initiation of failure forming eventual delaminations.	All PMCs	All process routes	N/A	N/A
Sandwich skin-to-core de-bonding ^{2, 10, 11}	Analogous to delamination, de-bonding can greatly degrade the mechanical properties of the structure. Can be attributed to degradation of bond quality, core crush or core crack.	Sandwich laminates	Lack of consolidation/ poor adhesion during lay-up	Poor practice – all machining operations	Impact, local indentation, excessive loading
Excessive heating/ Lightning strike ¹²	Results in thermal material degradation due to exothermic chemical reaction of the matrix.	All PMCs	Excessive exothermic heating	Poor practice – all machining operations	Exposure to high temperature, lightning strike
Voidage/ Porosity ^{6, 13, 14}	Can cause a reduction in structural performance (in particular, composite interlaminar shear strength), resulting in premature failure. It is generally accepted that porosity content should not exceed 1-2% for high performance laminates.	All PMCs	Trapped air, volatiles, solvents during cure	N/A	N/A

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