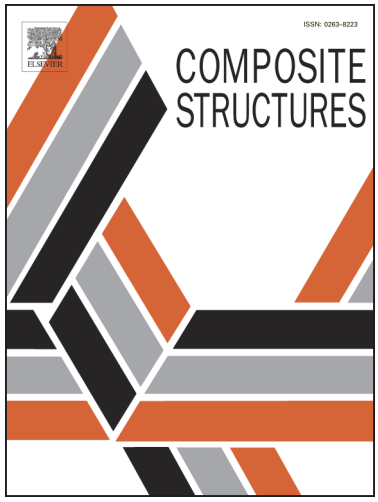

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PII: S0263-8223(15)00951-4
DOI: http://dx.doi.org/10.1016/j.compstruct.2015.10.019
Reference: COST 6928

To appear in: *Composite Structures*

Please cite this article as: Caminero, M.A., Rodríguez, G.P., Muñoz, V., Effect of stacking sequence on Charpy impact and flexural damage behaviour of composite laminates, *Composite Structures* (2015), doi: http://dx.doi.org/10.1016/j.compstruct.2015.10.019

Effect of stacking sequence on Charpy impact and flexural damage behaviour of composite laminates

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Abstract

The objective of this work is the characterization and the assessment of the damage in CFRP composite laminates with different stacking sequences subjected to low velocity impact and flexural loading. Charpy impact test and three-point bending test were used in order to obtained the impact response and flexural behaviour of different laminates. An experimental test series was carried out to determine impact energy absorption, flexural strength and stiffness and failure mechanisms of composite laminates made from M21E/IMA, an unidirectional prepreg used in Airbus A350 XWB primary structures. It is important to note that both elastic moduli and strength in the principal material directions are different under tension and compression. The flexural modulus is expected to have an intermediate value between the tensile and compression moduli. We analyze the effect of this type of multimodulus materials [1], [2], [3] in order to evaluate the influence of the geometry of the specimen on the failure modes (shear or flexural failure modes) observed in the three-point bending test and compare the results with tensile and compression behaviour.

Two main lay-up configurations have been analyzed: Unidirectional laminates $[0]_{12}$, $[90]_{12}$, $[45]_{12}$ and multidirectional laminates (cross-ply $[0/90]_{3s}$, angle-ply $[\pm 45]_{3s}$ and quasi-isotropic laminates $[0/90/(\pm 45)_2]_s$). Unidirectional laminates are rarely used in structural components but help to assess the different types of damage (splitting, matrix cracking, delamination) and response of the specimens under low-velocity impact and flexural loading. They are usually combined with plies of varying orientation in multidirectional laminates. These laminates exhibit a more complex behaviour due to coupling effects and the combination of different failure modes. In this study, both impact and flexural response for the different laminates have been compared. Special attention is paid in the response of multidirectional laminates under flexural (and impact) loading. Shear effects are very important in this type of laminates. Only a limited number of experimental studies have been developed in this context [4], [5], [6], [7]. Additionally, the failure modes observed under impact and flexural loading were correlated with fracture energy absorption and load-deflection behaviour respectively for the unidirectional and mulitidirectional laminates.

The results have shown that the effect of the stacking sequences on the impact and flexural response depicted similar trends than in the case of tensile response studied in previous works [8], [9], [10], [11]. Furthermore, the present work has shown a distinctive behaviour of $[\pm 45]_{3s}$ angle-ply laminate.under impact loading due to its pseudo-ductile behaviour. This laminate exhibited the best impact performance in terms of averaged absorbed energy but the flexural strength and stiffness drastically decreased compared to $[0]_{12}$ laminate. Finally, SEM and optical micrographs of fracture surfaces were used to gain an insight into the assessment of different type of damage of the previous laminates.

Keywords: Carbon fibre, Laminates, Impact Damage, Energy absorption, Flexural Response, Fracture mechanism

1. Background

The demand for advanced composite structures in the modern industry is constantly growing as these materials offer many advantages compared to more conventional ones, especially in applications where high strength and stiffness to weight ratios are required [8], [12], [13], [14]. Thus composites have been used widely in applications such as aerospace, sport equipment, presure vesels and automotive parts [12], [15], [16], [17]. For example, new