# MECHANICAL PROPERTIES AND FAILURE OF NON-CRIMP FABRIC COMPOSITES SUBJECTED TO SHEAR STRESS

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## INTRODUCTION

Until recently (and still in large extent currently) need for high performance polymer composites in marine and aerospace industries was fulfilled by using traditional pre-preg based laminates. But due to extensive research on alternative type of high performance reinforcements which are well suited for structural components, namely non-crimp fabric (NCF), the situation start to change. Composites based on NCF combine fairly good mechanical properties with low production costs, high deposition rates and virtually unlimited shelf life. In terms of mechanical performance NCF composites are almost as good as pre-preg laminates, however NCF composites exhibit some rather unique properties and behaviour. To begin with, NCF composites have an inherently heterogeneous structure of fiber bundles and matrix areas, this arrangement adds more size scales to consider when dealing with these materials. As a result, the mechanisms controlling damage evolution and failure in NCF composites are in most cases more complex than for a pre-preg based composite. For example, although NCF composites perform in tension fairly similar to the pre-preg laminates [1], it has been shown that in case of compression NCF composite perform rather poor due to imperfections caused by bundle waviness [2].

The objective of this work is to evaluate performance of NCF composites in shear. This includes characterization of shear properties, identification of main failure events and description of fracture sequence in connection with microstructure of the material.

## BODY OF THE ABSTRACT

Carbon fiber/epoxy (CF/EP) and glass fiber/vinyletster (GF/VE) NCF laminates are examined in this paper. Carbon fiber laminates are produced from bi-axial (-45/+45) fabric, whereas for glass fiber composites three different NCFs are used: (+45/-45), (0/90) and uni-axial (0). In order to characterize in-plane shear properties of CF/EP composite, tensile and compression tests of $[\pm 45_2]_S$ specimens are carried out. Carbon fiber laminates with the following lay-up are tested (SP corresponds to warp direction and ST to weft): SP = $[(+45/-45)_2]_S$; ST = $[(-45/+45)_2]_S$. These specimens have been cut from the same plate but in directions perpendicular to each other. In order to verify results from CF/EP material, similar (in terms of layer stacking sequence and loading directions) glass fiber laminates are tested in tension.
Although both types of specimens (SP and ST) are cut from the same plate, which makes these laminates identical from the laminate theory point of view, mechanical performance in tension is rather different. As seen from Fig. 1a, ST laminate exhibit higher shear modulus, shear strength and shear strain at failure than SP samples. Similar differences can be noted from the experimental results obtained from compression tests of these composites, see Fig. 1b. However, in case of compression SP laminates exhibit superior properties compare to ST specimens, which is opposite to the behaviour shown in tension.

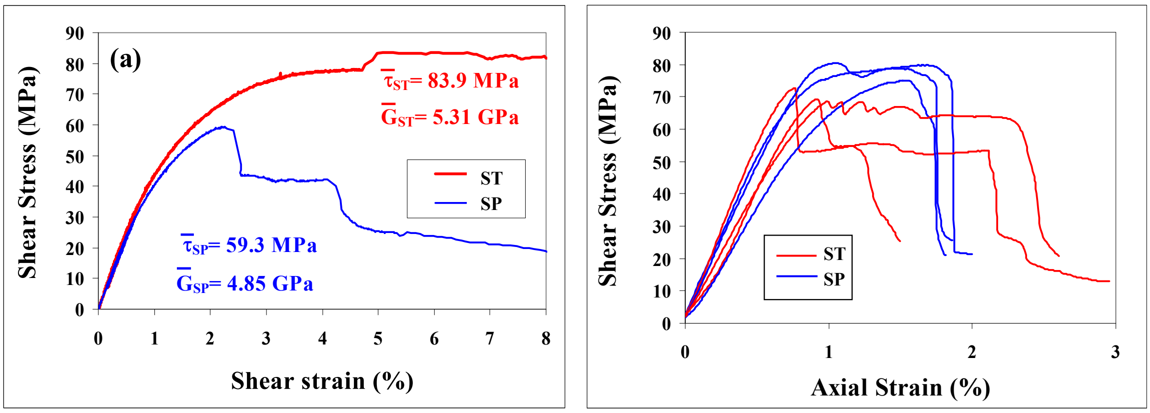


*Fig. 1: Stress-strain curves for carbon fiber NCF laminates in tension (a) and compression (b).*

Images made from the edge of the specimens tested in compression (tests were interrupted after there was indication of first damage event on stress-strain curve, see Fig. 1b) are shown in Fig. 2. These micrographs indicate different amount of damage in ST and SP laminates. From analysis of these images it is clear that different compression stress-strain curves for these materials can be explained by earlier damage initiation and accumulation in ST specimens compare to SP material (transverse cracks in ST specimen, see Fig. 2). However, it should be noted that in tension damage in SP samples will occur earlier than in ST specimens as seen from tensile stress-strain curves, see Fig. 1a.


*Fig. 2: NCF laminates tested in compression. Tests were interrupted before final failure.*

This difference in behaviour between laminates containing the same number of layers with the same orientation but different layer stacking sequence can be only explained by considering different internal structure of those layers. Particularly, the direction of stitching with respect to the loading direction seems to be of great importance. In order to make any concrete conclusions about influence of stitching on performance of NCF composites in shear, analysis of local stresses cause by presence of these stitches should be performed. Such study should be carried out by means of numerical analysis, for example by use of finite element or boundary element methods.

## REFERENCES

1. Edgren F., Mattsson D., Asp L.E., Varna J., "Formation of damage and its effects on non-crimp fabric reinforced composites loaded in tension". *Compos Sci Technol*, Vol. 64, pp 675–92, 2004.
2. Joffe R., Mattsson D., Modniks J., Varna J., "Compressive failure analysis of non-crimp fabric composites with large out-of-plane misalignment of fiber bundles". *Composites Part A*, Vol. 36, pp 1030–46, 2005.