Hierarchical carbon fibre reinforced plastics with tailored nanoparticle modification – benefits and limitations

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The use in structural parts requires detailed knowledge about failure initiation and propagation within composite laminates. Failure initiates at defects in the material as cohesion failure in the matrix between the fibres or as adhesion failure at the fibre matrix interface. Matrix cracks propagate between both characteristics, controlling the design in layers transverse to loading direction. In cross-ply laminates, this inter fibre failure (IFF) occurs first in the 90°-layers reduces the stiffness. With increasing load, further damage, such as delaminations may induce at the tips of transverse cracks when the reach the surrounding layers of different fibre orientation.

For graphene nanoparticle modified polymers, superior mechanical properties, compared to the neat material, due to stress relieving mechanisms such as microdamage at the particles are reported in literature. One promising approach to delay the formation of IFF and increase the mechanical properties of composite laminates is thus a modification of the matrix with carbon nanoparticles such as few layer graphene (FLG).

Previous approaches for modifying the matrix of FRP with nanoparticles only compare the unmodified with a completely modified configuration without any investigation of the effects in the respective layers of multidirectional laminates. In this work, the influence of a FLG matrix modification in the different layers of CFRP cross-ply laminates are investigated. Either the 90°-layers or the 0°-layers are modified with FLG nanoparticles.

The nanoparticles are dispersed in the matrix with a three roll mill, based on the principle of applying shear forces. Unmodified and nanoparticle modified prepregs are produces with an prepreg machine, laminated in the stacking sequence of $[0/90_2]_s$ and cured in an autoclave. Completely unmodified laminates are produced with the same process and used as a reference. From the laminates, specimens are prepared for tensile testing.

Tension tests with combined acoustic emission (AE) analysis are executed to determine the influence of the nanoparticle modification on tensile strength and stiffness, as well as the stress at IFF initiation. The Young's modulus of both nanoparticle modified laminates is about 5 % higher compared to the unmodified specimens. FLG modification of the 0°-layers increases the tensile strength at about 15 %, whereas a modification of the 90°-layers shows no significant change in tensile strength. The onset of IFF initiation is detected as a slight decrease in the stress-strain curve that results in a significant increase in cumulated energy of the AE-signals. Figure 1 shows the influence of the FLG modification in the different layers on the onset of IFF. Modification of the 90°-layers increases the stress at IFF.

Fractography analysis of the fracture surfaces using scanning electron microscopy reveals microdamage at the nanoparticles that dissipates energy and is an explanation for the observed delay of transverse cracking in the 90°-layers when modified with FLG nanoparticles.

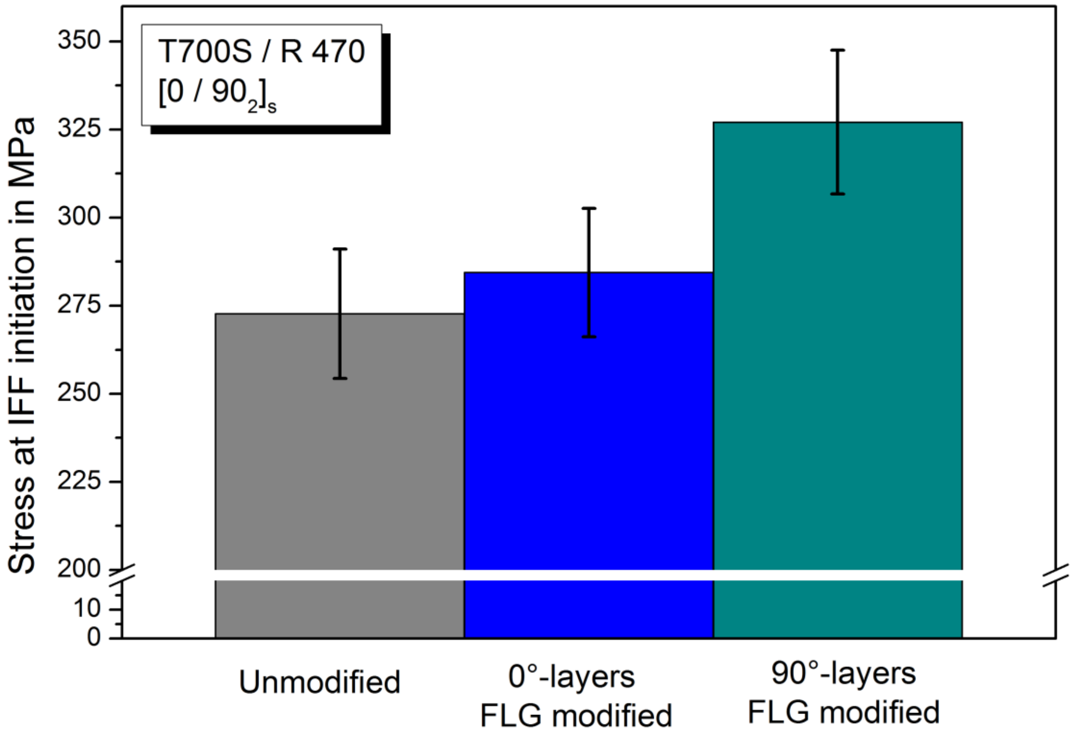

Figure 1: Influence of FLG nanoparticle modification in the different layers of cross-ply laminates on the onset of inter fibre failure (detected with AE-analysis)