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CHANGES IN MECHANICAL PROPERTIES OF A GLASS FIBRE REINFORCED EPOXY BY ADDNG POLYAMIDE 6 NANOFIBRES

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ABSTRACT

Owing to their light weight and high stiffness and strength, fibre reinforced epoxy resin composites are widely used in industry. However, an epoxy matrix is a brittle material, which could lead to unexpected failure of the composite and an improvement of the interlaminar space is recommended. Therefore, secondary (sub)micron reinforcements are often incorporated in the matrix. Since it is difficult to obtain a homogeneous dispersion of these nano-particles, the mechanical improvement of the composites is only moderated. Thermoplastic nano-fibrous structures can tackle this dispersion issue. Therefore, this study investigated the effect of polyamide 6 nano-fibrous structures on the mechanical properties of a glass fibre/epoxy composite. These plates were manufactured by vacuum assisted resin transfer moulding (VARTM) using a closed steel mould and all plates had the same thickness of 3 mm.

The nanofibres are produced using a multi-nozzle electrospinning set-up, using an in house developed technology [1]. These nano-fibres are then incorporated in the glass fibre/epoxy composite either as stand-alone interlayered structures (noted NF-I) or directly spun on the glass fibre reinforcement (noted NF-C). Both ways of nano-fibre incorporation has no negatively effect on the impregnation of the epoxy. Fig. 1 (A) illustrates the cross section of the interlayered structures, whereas Fig. 1 (B) illustrates the nano-fibre rich epoxy. Compared to a standard VARTM glass/epoxy plate, it can be noted that the interlayer has a non-negligible thickness and the same can be said concerning the deposited version, although the effect is lesser in this case. Given the fact that all plates were 3 mm in thickness because of the closed mould, the thickness of the glass fibre reinforcement will be smaller when thicker interlayers are present. Also, different transfer of shear loads between neighbouring glass reinforcement is expected, compared to the basic plate without reinforcement.

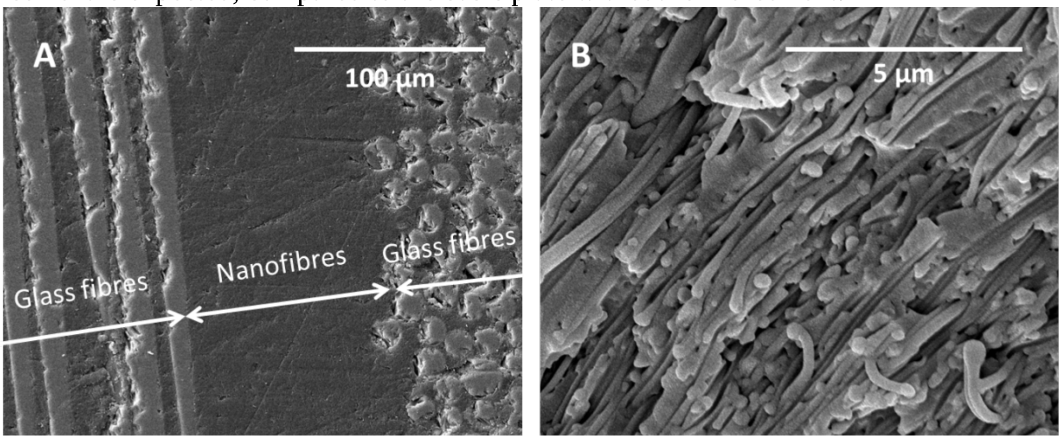
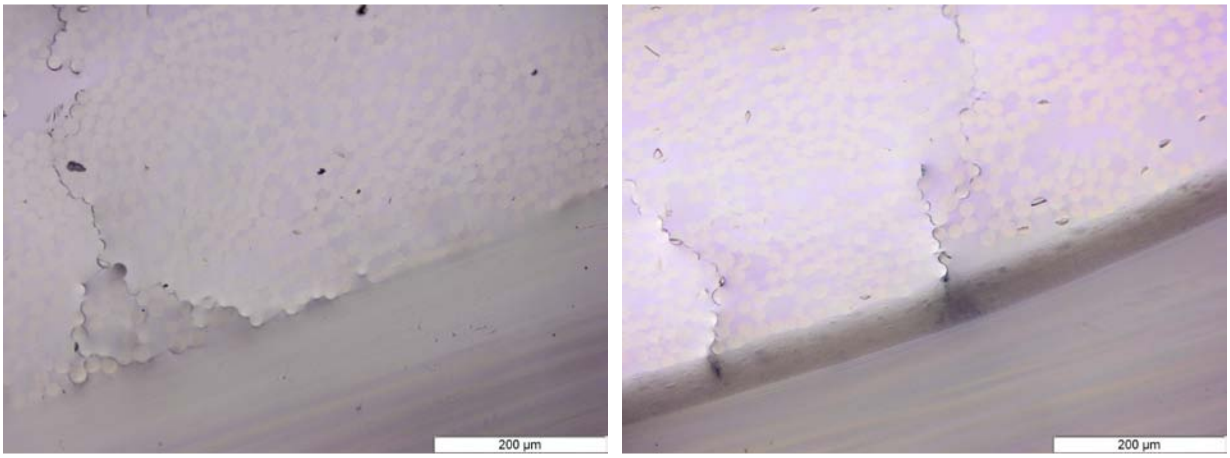


Figure 1 (A) Cross section of the secondary nano-fibre reinforced glass fibre composites and (B) a zoom of the nano-fibre containing interlaminar space.

To determine the influence of the effects of the added nano-structures, tensile tests were conducted on $[0/90°]_{2s}$ and on $[\pm 45°]_{2s}$ stacking sequences and this for both the interlayer, the deposited nano-fibres and for the base plate. For the $[0/90°]_{2s}$, the effects on the Young's modulus, Poisson's ration throughout the test and the ultimate tensile strength were assessed. For the $[\pm 45°]_{2s}$, both the in-plane shear behaviour as the Poisson's ratio was observed.
With respect to Young's Modulus E_{xx}, the differences between the three plates were so small that they are most likely caused by scatter in the production process. For the evolution of the Poisson's ratio ν_{xy}, however, a significant and reproducible difference was seen, especially for larger stress levels, meaning when damage was already present in the material. The evolution of ν_{xy} as function of the strain was highest for the deposited nano-fibres and the lowest for the interlayered plate. With respect to the failure strength, for the basic glass/epoxy, an average value of 550 MPa was found, compared to 581 MPa for the interlayered nano-fibres and 611MPa for the deposited nano-fibres. Therefore, an increase in strength is present when adding the polyamide nano-fibres. To examine how the nano-fibres contributed to this increase in strength, the polished surfaces of the failed specimens where examined. Fig. 2 illustrates the crack growth in the 90° layers. For the standard glass-epoxy composites, the transverse cracks shift into a delamination upon hitting the 0°layer (Fig. 2 (a)). However, for the deposited nano fibres, it seems that the crack is arrested in the deposited region and does not shift into a delamination (Fig. 2(b)). Similar effects were seen over the entire specimen and also for the interlayered nano fibres.



(a) benchmark glass-epoxy (b) Deposited nano-fibres

Figure 2: Microscopical investigation of the failed specimens

For the $[\pm 45°]_{2s}$ stacking sequence, although there is not much difference between the interlayered and the basic glass/epoxy, the influence of the deposited nano-fibres cannot be neglected. For a given shear strain, the corresponding shear stress is significantly higher for the deposited version. With respect to the shear strain, both nano-reinforced versions show a value of 4.7 GPa, compared to 4.0GPa for the basic plate. For the Poisson's ratio, now both the nano-reinforced plates showed a lower evolution of ν_{xy} as function of the strain ε_{xx}, with the lowest values for the interlayered version.

In conclusion, the nano-fibres do seem to have an influence on the evolution of some mechanical properties, especially with growing damage. This influence is most likely due to their capacity of stopping transverse cracks into changing in delaminations and by changes in microstructure they impose by their non-negligible thickness.

REFERENCES

[1] P. Westbroek, T. Van Camp, S. De Vrieze, K. De Clerck, PCT/EP2008/056050, 2008