ANISOTROPY OF REINFORCEMENT FIBRES AND ITS INFLUENCE ON THE APPARENT INTERFACIAL SHEAR STRENGTH IN THERMOPLASTIC COMPOSITES

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ABSTRACT

Optimization of the stress transfer capability of the fibre-matrix interphase region is critical to achieving the required performance level in thermoplastic matrix composites. Despite the ever increasing diversity of the reinforcements available for polymer composites, glass fibres still account for 95% of fibre reinforcements used in the composites industry, primarily due to of their highly attractive performance/price ratio. Due to its initial location on the glass fibre surface, the sizing layer is an important component in the formation and properties of the composite interphase. A large proportion of the research published on interphase optimization in these materials has focussed on the role of the organosilane coupling agents which are almost universally present in glass fibre sizing. Perhaps due to their common name of "coupling agents", perhaps due to their reactive nature or even perhaps due to the early focus of composites research on chemically reactive thermosetting matrices, there exists a dominant mindset in the composites research community to approach the interphase from a chemical bonding viewpoint. While this approach may very well be justified in thermosetting matrix composites it is not at all clear that this is also the case for reinforced thermoplastics, in particular for the commercially important polyolefin based composites.

The ability to transfer stress across the fibre-matrix interphase in thermoplastic composites is often reduced to a discussion of 'adhesion' which is a simple term to describe a combination of complex phenomena on which there is still significant debate as to what it means and how to measure it. Certainly, one of the generally accepted manifestations of 'adhesion' is in the mechanically measured value of interfacial shear strength (IFSS). Over the years a number of authors have commented on the role of shrinkage stresses contributing to the stress transfer capability at the fibre-matrix interface [1-4]. Most thermoplastic composite materials are shaped at elevated temperature and then cooled. Since in most cases the thermal expansion coefficients of polymers are much greater than reinforcement fibres this cooling process results in compressive radial stress σ_r at the interface. Assuming that the coefficient of friction (β) at the interface is non-zero these compressive stresses will contribute a frictional component $\tau_f = \beta . \sigma_r$ to the apparent shear strength of the interface. In the case of thermoplastic polymer matrices where there may often be little or no chemical bonding across the interface these frictional stresses can make up a large fraction of the apparent IFSS.

In this paper we shall present data comparing the apparent IFSS in injection moulded glass fibre reinforced composites based on four different thermoplastic matrices over a range of fibre contents. IFSS data have been obtained and compared from both single fibre micromechanical testing and also macromechanical composite testing. In all these cases we will show how the data for the apparent IFSS can be well fitted by the residual stress model when an appropriate value for the static coefficient of friction is selected. Having established the relevance of this model in glass reinforced thermoplastics we go on to explore its

relevance to the use of carbon, aramid and natural fibres in thermoplastic composites. Unlike glass, many of the other typical reinforcement fibres available are anisotropic in their mechanical and thermal properties and this may have significant influence on the residual stress state at the fibre-matrix interface. The effect of this anisotropy is clearly illustrated in Figure 1. All these systems exhibit compressive residual stress at the interface at room temperature and all show a mild dependence on the fibre content. However, the magnitude of these residual stresses is strongly dependent on the fibre properties. These results are well in line with the generally accepted view on interfacial adhesion in thermoplastic composites that glass and carbon are often well bonded, aramid fibres present some challenges to obtained good adhesion, and that there are serious problems with IFSS levels in natural fibre composites. Although the explanations and remedies for these issues are often sought in the chemistry of the system, these results suggest that, for improved reinforcement of polyolefins, we also need to better understand the role of fibre structure, the levels of residual stress, and the interfacial friction, on the apparent interfacial strength in thermoplastic composites.

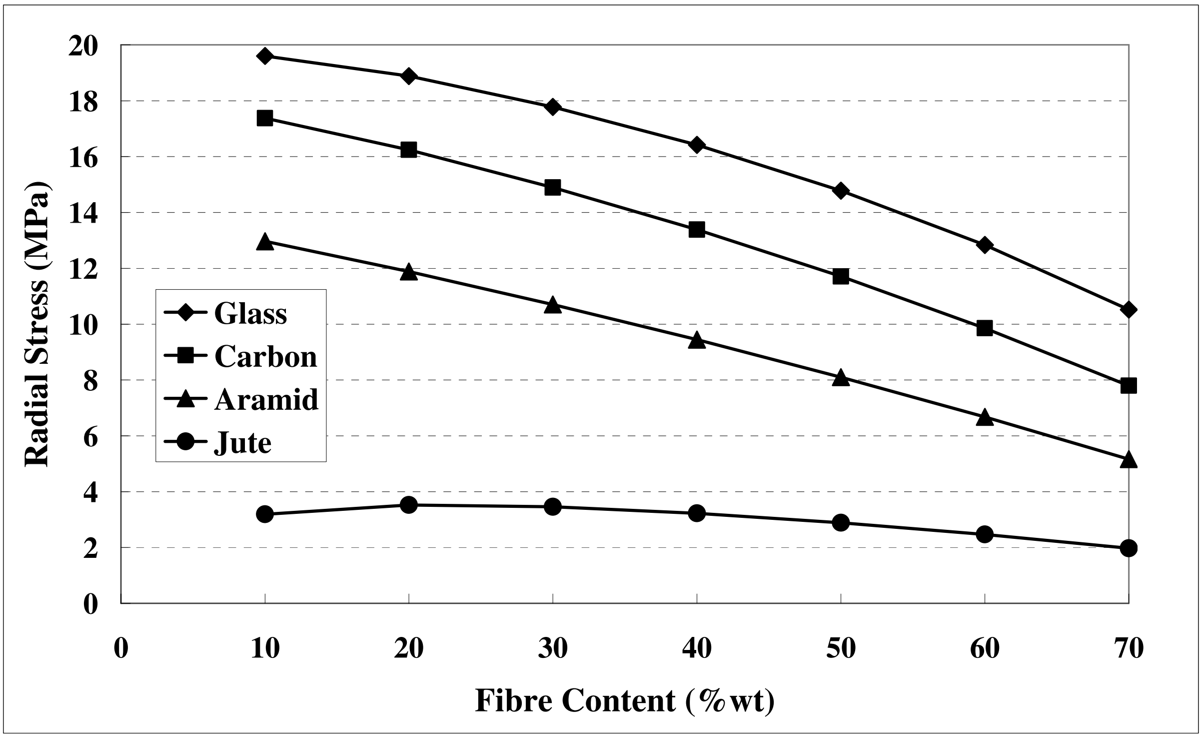

Fig. 1: Residual radial compressive stress at the interface in polypropylene composites

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