How do we measure fibre direction tensile strength and the factors affecting it?

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At a previous workshop it was proposed that the strength of a unidirectional fibre-reinforced composite should be defined as the maximum stress that the material can sustain under uniform uniaxial loading [1]. Measuring this is not easy because of the difficulty of introducing the high loads necessary without inducing stress concentrations. Even with careful tabbing arrangements, test specimens usually fail at the ends, e.g. Fig. 1. One approach to this is to machine the specimens to produce a waisted section with reduced cross-sectional area. Waisting can be carried out through the thickness, across the width, or both, and needs to be very gentle in order to avoid the specimens splitting [2]. With care it may be possible to produce consistent gauge section failures, but the specimen dimensions are typically large, and the machining or manufacturing can be expensive and time consuming. Recent work has shown that with the right equipment this can be done quite easily with prepreg [3]. Hybrid specimens can also be used to measure tensile strength, for example with carbon fibre plies sandwiched between glass fibre plies with a lower modulus and higher strain to failure. This has been shown to completely eliminate the stress concentration at the grips, producing consistent gauge section failures [4]. It is a very easy technique to use, and also eliminates the need for tabs, however it only measures strain at failure directly, rather than stress, and also needs a small correction for thermal residual strains. Bending tests can also eliminate failure at the points of load introduction, but only have a small volume of material at the maximum stress, and there is also a question as to whether the stress gradient may result in a different strength than in pure tension [5]. The merits of these different approaches and other alternatives will be debated at this workshop.

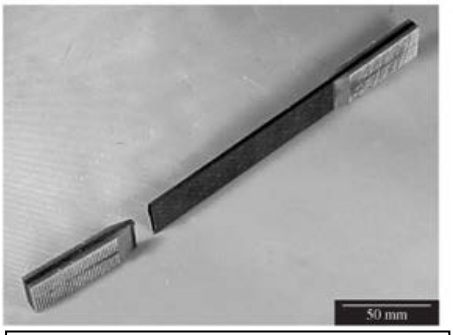

Fig. 1. Typical failure of tensile specimen at the end of the tab

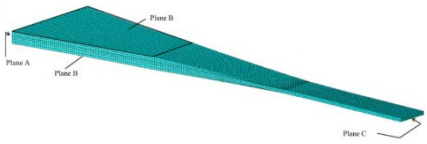

Fig. 2. Very gradually waisted tensile specimen [2]

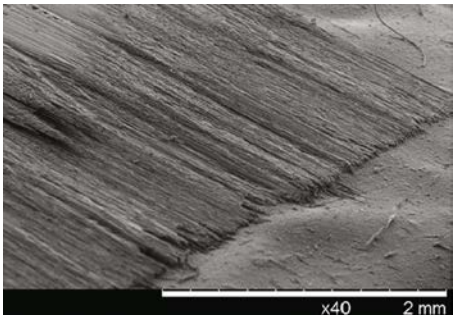

Fig. 3. Gradually chamfered ply [3]

Once reliable measuring methods have been established, they need to be used to investigate the factors affecting tensile strength. The size effect due to the volume of stressed material is quite well established [e.g. 6,7] but there are still questions as to the relative effect of changes in length and cross-section. Strain rate, temperature and humidity are generally considered to have less influence since the fibres themselves are not sensitive to these effects, at least for carbon. Some studies have shown that these factors can cause differences in strength, but are the test methods sufficiently robust? Many failure criteria such as Tsai-Hill or Tsai-Wu imply strong interaction between other stress components, but recent work using hybrid specimens has indicated very little effect of in-plane shear and transverse compression on fibre direction tensile failure strain [8,9]. We invite presentations on reliable tests demonstrating which factors affect measured tensile strength and where further research is needed to reach a consensus.

References

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