COMPRESSIVE FAILURE OF PULTRUDED UNIDIRECTIONAL CARBON FIBRE COMPOSITES - EXPERIMENTAL CHARACTERISATION OF CONTROLLING PARAMETERS

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ABSTRACT

Generally the compressive failure of composite materials display a complex mix of competing failure mechanisms. This is because of the heterogeneity of the composite materials where failure can occur in any of the constituents, their interfaces and by interactions between them. Depending on the constituents, interfaces and loading scenarios, different failure mechanisms may lead to failure of the material. An overview of the most common compressive failure mechanisms in unidirectional (UD) fibre composite materials is presented in Fig. 1, Fleck [1].

![Compressive failure modes of fibre composites.](image)

Figure 1: Compressive failure modes of fibre composites. (a) Elastic micro buckling. (b) Fibre kinking. (c) Fibre crushing. (d) Shear band formation. (e) Matrix cracking. (f) Buckle delamination.
According to the classical strength models by Budiansky [2] and Budiansky and Fleck [3], the primary parameters governing the compressive strength of UD composites are the fibre misalignment angle $\phi_0$, the shear strength and the shear modulus of the composite material. A typical observation is that for very small ratios of $\phi_0$ to the shear strength and a low composite $G$ modulus the failure mode will be elastic microbuckling. By increasing the fibre misalignment angle the failure mode will switch to plastic micro buckling / fibre kinking. The shear modulus $G$ can be increased by changing or modifying the resin system, which might also improve the shear strength. If so the failure mode can switch to fibre crushing. Most engineering composites fail by plastic microbuckling / fibre kinking, see Fig. 2.

![Figure 2: Post mortem micrograph of UD CFRP tested in 3 point bending, showing kink band formations on the compressed side (left), Fiberline Composites A/S.](image)

Several suggestions for improvement of the elastic perfectly plastic kink band models have been proposed. However, the simple perfectly plastic formulation [3] remains a central part of most recent studies. Taking the classical kink band model by Budiansky as the basis, the principal parameters controlling the kink band formation in UD CFRP laminates, i.e. the initial fibre misalignment $\phi_0$ and the composite material shear properties, defined by the shear modulus $G$ and the shear yield strain $\gamma_y$ have been determined experimentally. For evaluation of the strength models, the compressive strength was also measured. A new image analysis procedure for experimental determination of the fibre misalignment, the Fourier transform misalignment analysis (FTMA), has been developed. Moreover, a modified asymmetric Iosipescu test specimen geometry has been developed and validated for accurate measurement of the composite material shear properties without parasitic effects due to axial splitting. In the test procedure the shear strain distribution is measured using Digital Image Correlation (DIC) and the results calibrated based on FEA modelling results. Using the measured properties as input, the predictions of the classic compressive strength models have been compared with measured compressive strengths, and a reasonable match has been found.

REFERENCES

