Stress concentrations in 2-D carbon/epoxy composites

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Introduction

In the area of fibre-reinforced composites the stress concentration factor (SCF) resulting from a fibre break is a key parameter with respect to the failure strength and failure mode of a composite. Until recently, a direct measurement of the SCF was not possible and research into the SCF was a purely analytical matter. However, we were able to show that Raman spectroscopy can be used to measure such SCFs in 2-D modelcomposites.

Objectives

- Determine influence of fibre/matrix adhesion, inter-fibre spacing, and matrix yield stress on the SCF in 2-D model composites with Raman.
- Use Raman results to check validity of finite element (FE) model.
- Predict SCFs in a real fibre-reinforced composite with the FE model.

Materials and methods

Materials

- Tenax HMS-40 carbon fibre
- epoxy resin cured with a mixture of two aliphatic amine curing agents, allowing for variation of yield stress

Methods

- Make modelcomposite with 5 fibres parallel aligned at desired inter-fibre spacing (Fig. 1)
- Load the composite and wait for fibre break
- Focus laser on carbon fibre and take a Raman spectrum every 10 μm (Fig. 1)
- Determine fibre strain from Raman shift (Fig. 2)

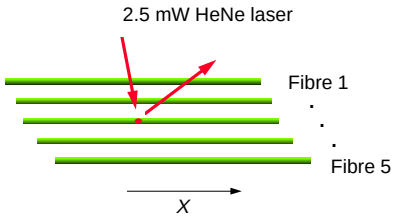

Fig. 1 *Schematic of the 2-D modelcomposite with laser focussed on one of the fibres*

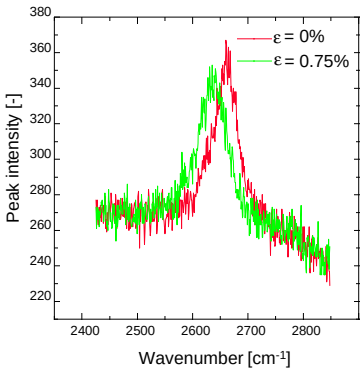

Fig. 2 *Raman spectra of a Tenax HMS-40 carbon fibre showing the shift of the 2660 cm^{-1} Raman band with increasing strain*

Results

- Strain profiles for each of the fibres in the modelcomposite can be obtained around a fibre break (Fig. 3). Stress concentrations in the fibres are easily determined.
- The SCF decreases exponentially with the inter-fibre spacing (Fig. 4).
- The lower the (shear) yield stress of the matrix, the lower the SCF (Fig. 4).

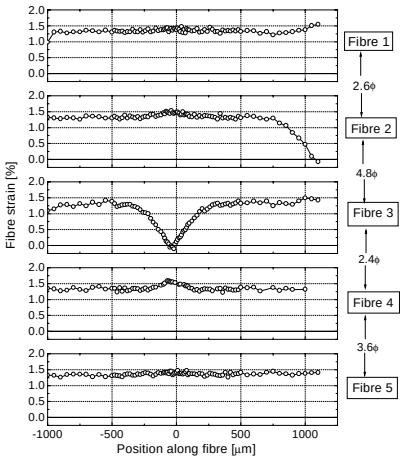

Fig. 3 *Strain profiles for each of the 5 fibres around a break in Fibre 3. The inter-fibre spacing is given in fibre diameters ϕ.*

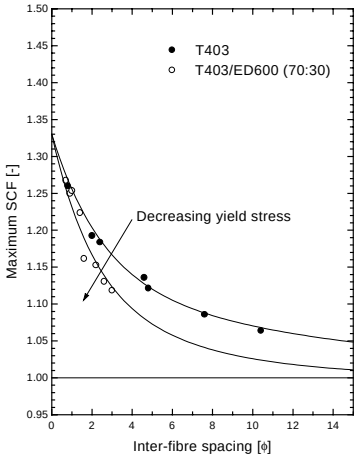

Fig. 4 *The influence of inter-fibre spacing and yield stress of the matrix on the SCF*

Conclusions

Raman spectroscopy can be used to measure stress concentrations in fibre-reinforced composites. The influence of various parameters on the SCF can be determined.