Shear Characterisation and Modelling of Advanced Thermoplastic Composites

Comparison between bias extension test results and simulations by a multi-scale-energy-model

Introduction
In order to make composite materials a more attractive option for industry, it is essential to develop simulations for virtual design and manufacture of industrial components for continuous fibre-reinforced composites (CFRC). An important input for forming simulations are constitutive models which can predict the complex rheological behaviour of viscous CFRC.

Objective
The objective of this project is to perform bias extension experiments to characterize the shear behaviour of one thermoplastic composite. The obtained results are normalised and compared to predictions made by a multi-scale energy model (MSEM) developed by Harrison, 2004. The MSEM requires several material properties as input parameters which are determined within the scope of this project, too.

Bias Extension Test
Material: Pre-consolidated, uniaxial cross-plied sheet, four layers of e-glass fibres initially oriented at 90° to each other, polypropylene matrix

Set-up: In the bias extension test, a rectangular shaped sample with a length to width ratio of at least 2 is clamped such that the fibres are oriented +/- 45° to the direction of the applied tensile force. An innovative approach for the clamps is used which constrains the fibre kinematics with 20 needles which are pierced through the material. In this way the material is forced to deform by pure shear as assumed for the simulation and as valid for many industrial forming processes, too.

Specimen clamped with the needle approach. Four thin aluminium frames are used to hold the needles. Thermocouples sandwiched by the same material for temperature measurements.

Experiments: 9 in total, 3 temperatures each with 3 crosshead displacement rates
• 150°C, 180°C and 200°C
• 140, 400 and 1140 mm/min

Specimen and clamps were at room temperature when loaded into the preheated oven. A uniform temperature profile for the entire sample could not be achieved due to a cooling effect of the clamps and a temperature gradient in the oven.

Evaluation of the force curves for physical consistency: the force must increase for increasing displacement rates (at a given temperature) and for decreasing temperatures (at a given rate). ✔

Inaccuracies are high, e.g. due to friction (see error bars)

Predictions with the multi-scale energy model
All inputs have been determined within the scope of this project:

Results / Comparison
• Predicted forces are too low for most of the experiments
• Predictions fit better for higher deformation rates
• Shape of the curves of prediction and experiment matches well

Sources of error:
1) Bias extension results:
• Temperature profile across the specimens
• Huge influence of friction on the measurements
• Difficult shear angle measurements due to bad video quality

2) Simulative predictions:
• Meso-scale kinematics difficult to measure → inaccuracy
• Viscosity predictions not verified for the test temperatures

Conclusions
The results of the performed bias extension tests and the predictions by the multi-scale energy model match well in terms of the shape of the curves and the magnitude of the values. This indicates that no major mistakes in the procedure of either was done. However, both forces can deviate about a factor of up to 2. The inaccuracies for both experiment and prediction have to be reduced for more reliable results.


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