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Strain rate dependent material model for dynamic damage evolution in unidirectional composites

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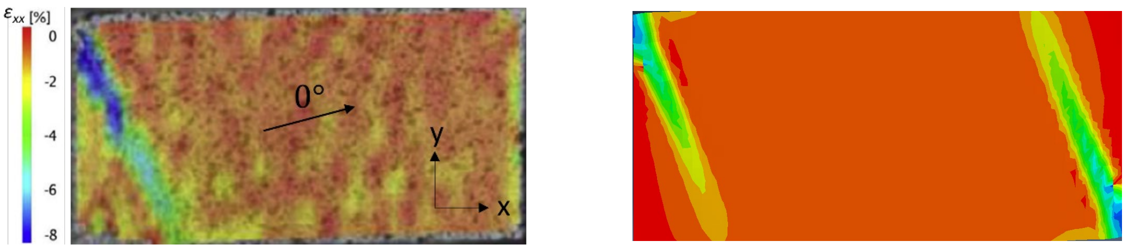
Polymer composite materials have several applications in aeronautics and the automotive industry. However, due to anisotropy and a complex non-linear rate dependent behaviour the material/damage modelling of polymer composites under dynamic loading, e.g. impact or crash, is challenging. To support the modelling of composites under such rapid transient loading, a computational multiscale constitutive model has been developed for the progressive failure of unidirectional carbon fibre composites.

Computational homogenization and micromechanics are utilized in the modelling at the ply scale. A major focus is to predict the strain rate dependent nonlinear constitutive behaviour of unidirectional composite plies [1]. The fibres are assumed transversely isotropic, whereas the polymer is viscoelastic–viscoplastic, including a pressure dependent strength. Degradation of the polymer matrix is described by a recently developed continuum damage mechanics approach [2]. The model has been successfully implemented as a VUMAT subroutine in Abaqus/Explicit. Figure 1 shows FE simulation of strain localization as compared to experimental results of IM7/8552 in dynamic off-axis compression [3]. Reasonable correlation was found between the measured and numerically predicted results.



a) strain ε_{xx} in experiment   b) strain ε_{xx} in simulation

Figure 1. Measured and predicted dynamic failure of 15° off-axis specimen in compression. Experiments are from Koerber et al. [3].

In the present paper the model is applied to simulate quasi-static and dynamic off-axis tension and compression experiments on composite coupons studied in two of our collaborative projects. The composite is a unidirectional (UD) carbon fibre non-crimp fabric (NCF) uniweave impregnated with LY556 epoxy, manufactured by Resin Transfer Moulding (RTM). The tests have been performed using a high-speed hydraulic test machine and a Split Hopkinson Bar (SHB) setup, involving strain rates of up to about 140 /s in tension and 1100 /s in compression.

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