IDENTIFICATION OF PARAMETERS FOR DIRECT AND INVERTED MODEL TO PREDICT PERFORMANCE OF MATERIALS EXIBITING NON-LINEAR VISCOELASTIC BEHAVIOR

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Keywords: Viscoelasticity, viscoplasticity, material model, time-dependent materials

ABSTRACT

Some types of polymer composites may exhibit highly non-linear performance (e.g. bio-based composites, conventional composites exposed to elevated temperatures). Behaviour of such materials in stress controlled tests can be described by combining material model developed by Schapery [1,2] for non-linear viscoelastic material with Zapas model [3] for viscoplasticity and model accounting for damage [4]

$$\varepsilon = d(\sigma_{\max})\cdot\left(\varepsilon_{el} + g_1\int_0^t \Delta S(\psi-\psi')\frac{d(g_2\sigma)}{d\tau}d\tau + \varepsilon_{VP}(\sigma,t)\right) \quad (1)$$

The parameters for this model are obtained from creep test.

However there are number of reasons that make simulation of displacement (strain) controlled tests more desirable from the practical point of view. For example, constitutive model where stresses are expressed as a function of strain and time can be used in most of the codes for numerical structural analysis, analytical micromechanics models (rule of mixture, concentric cylinder assembly model) and classical laminate theory require. Besides, experiments are also usually performed in displacement (strain) controlled mode.

Non-linear viscoelastic model where stress is expressed through strains was developed by Schapery [5]

$$\sigma = \sigma_{el} + h_1\int_0^t \Delta E(\xi-\xi')\frac{d(h_2\varepsilon)}{d\tau}d\tau \quad (2)$$

But both forms of Schapery models are not compatible (exact inversion is possible only for linear viscoelastic materials), non-linearity parameters obtained from creep tests cannot be used in eq. (2). Therefore, relaxation modulus has to be obtained in relaxation tests, where viscoelastic part of the strain is kept constant, which is rather simply to do for materials with no viscopalstic strain component. This however is not the case for most of materials because viscoplastic strain component is increasing with time. Thus in test with constant applied strain the viscoelastic strain component is decreasing and the measured stress cannot be used to define the strain dependent relaxation modulus.
This means that it would be very convenient if creep tests can be used at least for partial identification of the parameters in eq. 2.

Based on considerations described above, for the cases when viscoplastic strain is present, material model where strains are expressed through stresses has been rewritten in inverted incremental form. Previous results with simulations of simple stress-strain curves have showed good agreement with experimental data (See Fig. 1(a)), whereas simulation of loading-unloading tests has demonstrated unrealistic trends in unloading part of the curve (See Fig. 1(b)). This could be result of above mentioned incompatibility of both models.

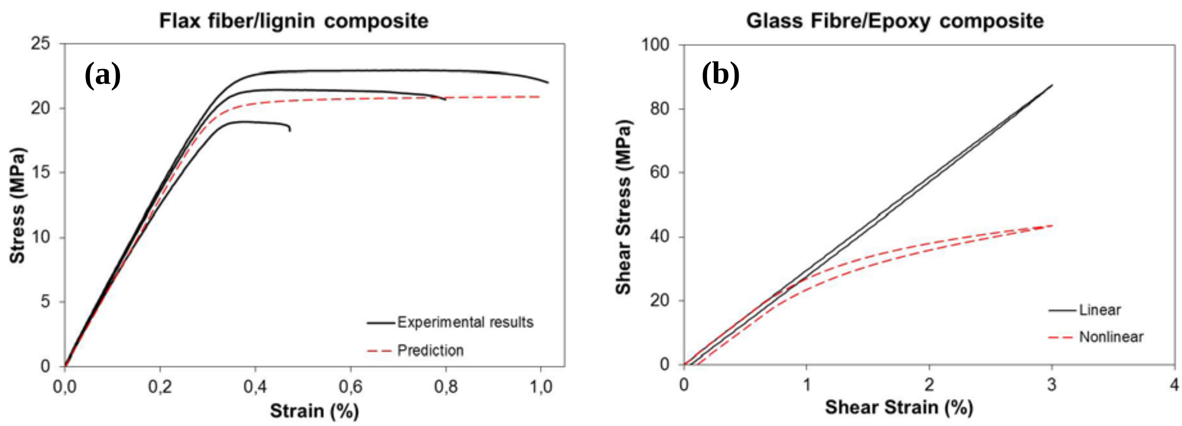

Figure 1: Simulated and experimental tensile stress-strain curves in strain controlled test for (a) standard loading ramp for flax fibre/lignin composite and (b) slow loading-unloading ramp for Glass fibre/epoxy $[\pm 45]_S$ composite using linear and non-linear viscoelastic models

The goal of this work is to investigate capabilities and restrictions of both modelling schemes. The results include simulations obtained by using direct and inverted incremental model with viscoelastic parameters obtained from relaxation and creep tests.

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