A NONLINEAR IN-PLANE SHEAR MODEL FOR UD COMPOSITES

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Abstract

The high performance of fibrous laminated composites has resulted in use of these materials over a wide range of structures specially, in aerospace engineering. In order to take full advantage of these materials, it is often desirable to load these materials beyond their linear-elastic limit. The in-plane shear stress-strain relationship of UD fibre-reinforced composites is a well-known example in which nonlinearity behaviour plays a dominant role while the linear-elastic regime is relatively small. The observed nonlinear behaviour may well be the result of combined effects of nonlinear elasticity, viscosity, plasticity and microscopic damage and some of these processes in the material are irreversible in nature. As a result, the nonlinear behaviour is loading history dependent.

A nonlinear elastic model was formulated in [1]. The effects of loading rate on the graphite-epoxy were studied in [2]. The influence of the damage state in terms of matrix micro-cracking, fibre-matrix de-bonding and inelastic strains on the mechanical properties of long fibrous composites was discussed in [3]. The model presented there allowed damage in the fibre direction with an elastoplastic damage behaviour for the in-plane shear. The nonlinear structural response was studied in [4] by one of authors, where a pseudo-plastic model was proposed to account for the nonlinear in-plane shear with an isotropic hardening mechanism. Some experimental loading, unloading, reversed loading unloading from reversed loading and reloading stress-strain hysteresis curves were also presented there. Apart from this account, there does not seem to be any experimental data available in the literature on the unloading and reversed loading characteristics of the in-plane shear behaviour of UD composites, to the best of the authors' knowledge, although nonlinear shear is such a well recognised feature and there have not been many theoretical models available to describe such nonlinear behaviour with due consideration of unloading and reversed loading characteristics. Given the history dependent nature of the problem, an appropriate understanding of this cannot be fully established without the knowledge of the materials' behaviour in unloading and reversed loading after loading into the nonlinear regime.

Systematic experiments have been conducted as reported in a separate publication, from which data on the loading, unloading and reversed loading of UD glass/epoxy composite have been generated under in-plane shear loading. A theoretical model based on the experimental observations made is presented in this paper. It is phenomenological in nature based on a number of assumptions which has been subjected to examination.

Summary of the model:

- It predicts nonlinear in-plane shear stress-strain relationship of UD composites under loading, unloading, reverse loading, unloading from reverse loading and reloading.
- The nonlinear shear model encapsulates the effects of plasticity and viscosity and damage and is presented in a phenomenological manner.
- The model requires the following as the input data (see Fig.1):
  - Loading curve (LC);
  - Master unloading curve (MUC) that is obtained from the unloading and reverse loading curve starting from point A (γ_A, τ_A) at about 80% to 90% of failure shear strain under a monotonic loading condition.

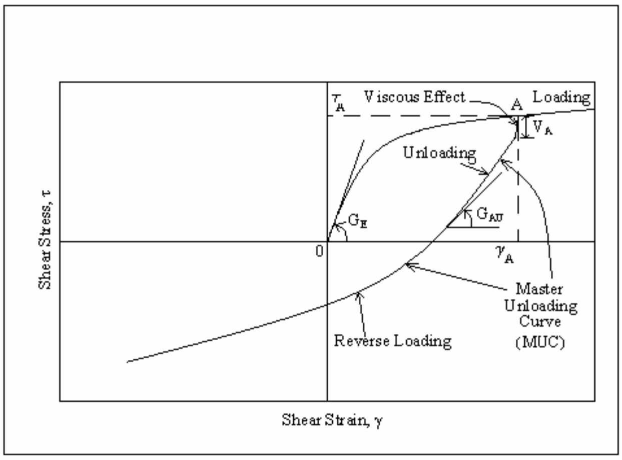

Fig. 1 Typical loading and unloading in-plane shear stress-strain curve

The present model has been validated against experiments. The comparisons between the model prediction and test data as shown in Fig. 2 suggests that that the model is capable of predicting the nonlinear in-plane shear stress-strain hysteresis for UD composites.

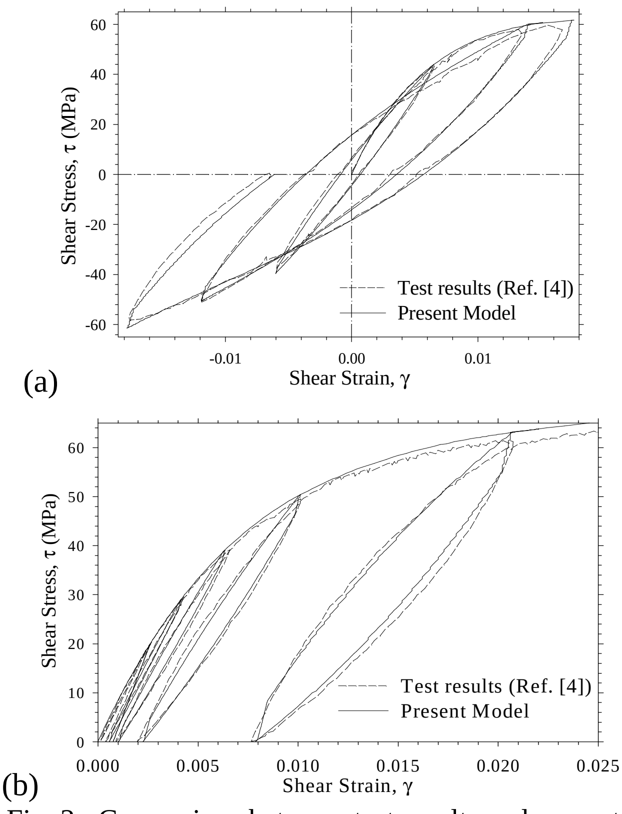

Fig. 2: Comparison between test results and present model under cyclic shear load

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