Experimental study of interface effects on viscoplastic strain in CF/VE composite

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It is known fact that continuous fiber polymer based composites give viscoelastic, viscoplastic response to applied load. Both, vicoelastic and viscoplastic strains can be generally nonlinear. As has been shown in [2], the source of viscoplasticity is shear yielding of polymer matrix. The effect of the fiber - matrix interface properties on the viscoplastic strain of the composite is not clear.

The objective of this work is to study time - dependence and stress - dependence of the viscoplastic strain in composite, and the effect of the fiber/matrix interface properties on it. Vinyl ester resin with well characterized viscoelstic, viscoplastic behavior was used to produce two composite systems with different fiber/matrix interface properties. The T700 carbon fibers with two different types of sizing were used, leading to the interface shear strength of $\sigma_{12} = 33[MPa]$ and $\sigma_{12} = 62[MPa]$.

The nonlinear viscoplastic behavior of both, neat matrix and a composite system can be described by model developed from thermodynamics principles by Schapery [1] and formulated by Megnis et. al. [2] in form

$$\varepsilon_i = \varepsilon_i^0 + b \int_0^{\psi} \Delta S_{ij} \left(\psi - \psi'\right) \frac{d}{d\psi'} \left(\frac{a_4 \sigma_k}{a_2} \right) d\psi' + \varepsilon_i^p \left(\sigma, t\right) \tag{1}$$

where $\varepsilon_i^p \left(\sigma, t\right)$ is viscoplastic strain $\varepsilon_i^p \left(\sigma, t\right) = \int_0^t S_{ij}^p \sigma_j \left(t'\right) \frac{1}{a_1^p(\sigma, t')} dt'$.

The same way as in [2] the viscoplastic strain developing in creep test is described by two, time - dependent $\overline{\xi}\left(t\right)$ and stress - dependent $\overline{\zeta}(\sigma)$ functions

$$\varepsilon_i^p(\sigma, t) = S_{ik}^p \sigma_{k0} \overline{\xi}\left(t\right) \overline{\zeta}(\sigma). \tag{2}$$

Both functions are obtained experimentally from creep and strain recovery tests at different stress levels.

Results show, that the time - dependent response of the neat matrix and both composite systems is close. It indicates that the viscoelasticity in both composite systems is mainly controlled by the viscoplasticity of the matrix rather than the fiber - matrix debond growth. The stress dependency of the viscoplastic strain of both composite systems is very similar. However, it is larger than for neat resin. It can be explained by local stress concentrations between the fibers in composite. Our conclusion is that the fiber/matrix interface properties does controls the final failure of the composite in shear, but do not affect the development of the viscoelastic strain of composite.

Acknowledgment

The presented work is also a subject of the Nordic Co-operation Network, supported by Nordic Council of Ministers.

References

[1] Schapery R. A., (1997), Mechanics of Time-Dependent Materials, 1, No.2, 209-240.

[2] Megnis M. and Varna J., (2003), Mechanics of Time-Dependent Materials, in press.