Effect of thermal shock on modulus of thermally and cryogenically conditioned Kevlar/polyester composites

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The interfacial adhesion between fibre and matrix has a dominating effect on the overall performance of a composite. The matrix shear yielding, interfacial debonding or some combination of both may be reflected in the short beam shear (SBS) test. The bond between a fibre and the surrounding matrix can be weakened by exposure to active environments. But Kevlar 49 has been specifically engineered for polymer reinforcement and is intended more for the aerospace industries, primarily to achieve significant weight reduction without compromising performance [1, 2]. It is generally believed that the polymer is likely to be tough if homogeneous yielding occurs. Even brittle crack propagation in polymers usually involves localised viscoelastic and plastic energy-dissipating processes taking place in the vicinity of the crack tip [3]. Brittle thermoset resins, such as unmodified epoxy and polyester, may undergo only a limited extent of deformation prior to failure. The propagation of the debonding cracks may involve breaking of the primary and secondary bonds between the fibre and the polymer matrix. It should be noted that multiple matrix cracking may represent a significant source of toughness.

The present experiment aims to study the effect of thermal shock on the modulus of thermally and cryogenically conditioned Kevlar/Polyester composites. The SBS laminated composites were treated in a thermal shock environment with a 160^0C temperature change by two separate routes; for one batch of specimens, it was from 80^0C temperature to -80^0C temperature and for the other batch it was from -80^0C to 80^0C temperature. The thermal conditioning was carried out at 80^0C for 5, 10 and 20 minutes and then the conditioned specimens were immediately exposed to the -80^0C temperature for 5 minutes for each stage of the thermal conditioning. The cryogenic treatment was performed at -80^0C temperature for the same time periods and then the composites were exposed to the 80^0C temperature environment for 5 minutes. The modulus values were calculated as follows,

$$\text{modulus} = pL^3 / 4bdt^3$$

where p maximum load, b width of specimen, d deflection, t thickness and L span length of specimen.

Fig. 1 shows the effect of thermal shock on modulus values of the thermally conditioned specimens. The reduction of modulus value is more noticeable for the 5 minutes conditioning time. The specimen, although supporting less load, can sustain a large deflection permitting the absorption of more energy. Thermal conditioning for longer times may help in generating better fibre/matrix adhesion either by mechanical interlocking and/or by surface chemistry phenomena. The thermal shock may degrade the interfacial bond by debonding the interface. The post-curing strengthening phenomena of the thermal conditioning could dominate over the adverse effect of thermal shock for longer conditioning times at 80^0C temperature. Thus, a remarkable improvement is observed in the modulus values. The most largest increase in modulus achieved for the 20 minutes conditioning time could be related to improved adhesion chemistry at the interface. The weakening effect of thermal shock predominates at 5 minutes conditioning because of the reduced post-curing time.

The variation of modulus values of thermally shock conditioned composites is plotted against cryogenic conditioning time in Fig .2. A deterioration of modulus values is observed with increasing conditioning time. A slight improvement is noticeable at 20 minutes conditioning. This exception may be attributed to the development of a greater amount of shrinkage compressive stress for longer period of cryogenic conditioning. This stress might start suppressing the debonding effect of the thermal shock environment. The cryogenic conditioning may not be helpful to promote the bonding at the fibre/matrix interface by surface chemistry phenomena. Thus, the damaging effect of thermal shock is reflected here.

It is reasonable to conclude that the post-curing strengthening effect of thermal conditioning for longer duration counteracts the damaging aspect of thermal shock. The debonding effect of the thermal shock is noticeable for the cryogenically conditioned Kevlar/polyester composites. The thermal conditioning results in developing better adhesion at the fibre/matrix interface. The cryogenic conditioning for longer periods may contribute in the improvement of fibre/matrix interface by mechanical principles only.

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References

1. U.GAUR, C.T.CHOU and B.MILLER, in proceeding of the 2nd International Conference on Interfacial phenomena in composite materials, Leuven, Belgium, September 1991, edited by I.Verpoest and F.Jones (Butterworth-Heinemann, Oxford 1991) p.41.

2. B.C.RAY, J.Mater. Sci. Lett., in press.

3. BOR Z. JANG in “Advanced Polymer Composites : Principles and Applications” (ASM International, Material Park, OH, 1994) p.145.

Figure Captions

Figure 1 Effect of thermal shock on modulus of thermally conditioned Kevlar/polyester composites.

Figure 2 Effect of thermal shock on modulus of cryogenically conditioned Kevlar/polyester composites.

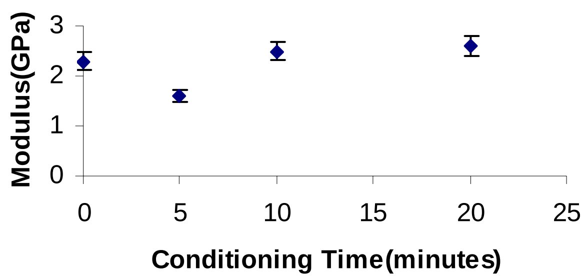

Figure 1

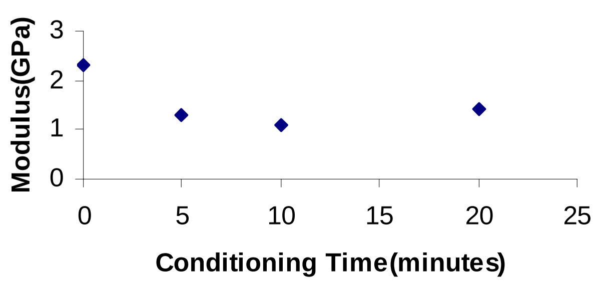

Figure 2