# Assessment of mechanical behavior of Kevlar/polyester composites after thermal shock conditioning

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Unsaturated polyester resins are the most widely used thermoset resins, offering a good balance of mechanical, and chemical-resistance properties at moderate or ambient temperatures, also at relatively low cost. Their poor impact resistance, inferior hot/wet mechanical properties and high shrinkage on curing preclude their utilization for high performance applications [1, 2]. The principle aramid fiber for composite reinforcement for high performance composites will remain Kevlar. The interface-sensitive properties are weaker in polyaramid-reinforced composites than in their glass or graphite counterparts. 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 [3]. The interfacial adhesion between fiber and matrix has a dominating effect on the overall performance of a composite. The short beam shear (SBS) test is performed here to assess the interfacial bond strength. This characterization is valid where only the bonding level is a variable [2]. The bond between a fiber and the surrounding polymer can be weakened by exposure to active environments [4]. The fiber/matrix interfacial debonding may be reflected in the short beam shear test.

The present investigations aim to study the effects of temperature, sub-zero temperature and combined effects of thermal shock on interlaminar shear strength (ILSS) of Kevlar 49/polyester composites. These aerospace materials frequently experience this type of active thermal shock environment during their service life. Unfortunately, there is a paucity of experimental data in this area. It is a 3-point SBS test, which generally promotes failure by interlaminar shear and the results may be useful for the estimation of interfacial bond strength at the fiber/matrix interface.

Kevlar 49 fibers (Scott Bader Company Ltd., UK) and polyester (Scott Bader, Crystic 471 PALV and Catalyst Butanox M-50) were used for the investigation. The SBS specimens of Kevlar composites were fabricated by the wet lay-up method. The specimens were treated in a thermal shock environment with a 160 °C temperature change by two separate routes; for one lot of specimens, it was from 80 °C temperature to −80 °C temperature and for the other lot it was from −80 °C temperature to 80 °C temperature. The −80 °C temperature was maintained in a saturated mixture of solid carbon dioxide in acetone. The first batch of samples were exposed to the 80 °C temperature environment for various times (5, 10 and 20 min) and then immediately plunged in to the liquid bath for 5 min. The second batch of samples use first kept in the liquid bath for the same time intervals and then exposed to the 80 °C temperature condition for 5 min. The 3-point bend tests were conducted almost instantaneously to avoid any reversible recovery to occur.

The ILSS values were calculated as follows,

$$\mathrm{ILSS} = 0.75 p/bt$$

where $p$ is maximum load, $b$ is width of specimen, and $t$ is thickness of specimen.

Fig. 1 shows the effect of thermal shock on the ILSS values of the thermally conditioned specimens. The trend of reduction in ILSS values is reflected here. The deterioration of ILSS value is more noticeable for the 5 min conditioning time. There are two opposite effects acting upon the specimen. The post curing strengthening phenomena are developed because of conditioning at the 80 °C temperature. These may lead to improved interfacial bonding at the fibre/matrix interface. The thermal shock may adversely affect the interface by weakening the physical and mechanical bonding at the interface. This might dominate over the post-curing hardening effects and thus, consequently be reflected in the reduction of ILSS values. The noticeable reduction of ILSS value for 5 min conditioning time may be due to less post-curing effect. This is because of reduced conditioning time. The variation of ILSS values of thermally shocked specimens is plotted against the −80 °C temperature conditioning time in Fig. 2. Here also the data indicate the trend of reduction of ILSS values. There is also an exception noticeable at 20 min conditioning. This improvement in ILSS value may be for the development

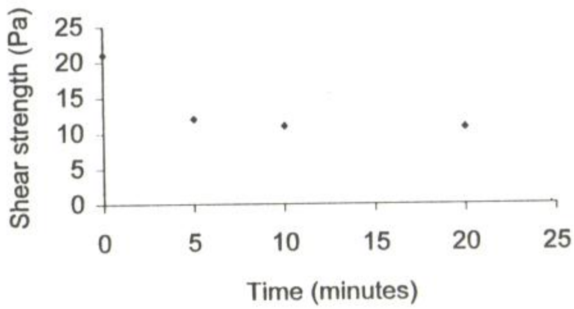


*Figure 1* Temperature and thermal shock effects on shear strength of Kevlar/polyester composites.

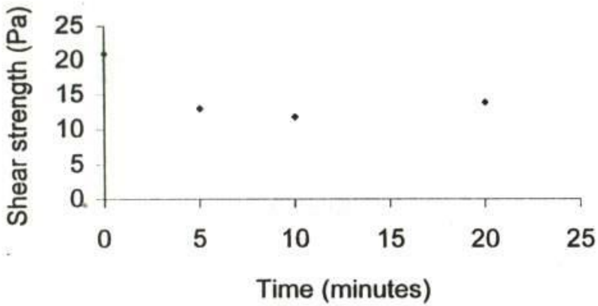


*Figure 2* Sub-zero temperature and thermal shock effects on shear strength of Kevlar/polyester composites.

of a greater amount of shrinkage compressive strength for longer conditioning at −80 °C temperature. This may be helping to introduce more mechanical interlocking at the fiber/matrix interface. This might start suppressing the debonding effect of thermal shock environment.

It may be concluded that this type of complex environmental conditionings results in damage to the interfacial bonding for Kevlar/polyester composites. This debonding phenomenon could be related to the different thermal coefficients of expansion and/or contraction for polyester matrix and Kevlar reinforcement.

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