Effects of Temperature on Impact Fracture Behavior of Pultruded Glass Fiber-Reinforced Poly(vinyl ester) Composite

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INTRODUCTION

Pultrusion is an automatic and continuous process for the manufacturing of fibre-reinforced plastics (FRPs) with high production rate. Both thermoset and thermoplastic polymers can be used in the pultrusion process. There have been some recent interest on modeling and die inlet flow of the pultrusion process.[1-3] As pultruded FRPs have found wide ranged applications as structural components, it is important to assess their impact behaviour. Among factors that have influence on the impact characteristics, temperature and impact speed are known to have dominant effect. The objective of the present investigation is to identify the influence of temperature on the impact behaviour of a pultruded glass fibre reinforced poly(vinyl ester) composite.

EXPERIMENTAL

The pultruded composite used in this work was poly(vinyl ester) resin reinforced with 70 wt% of continuous E-glass fibre. Transverse three-point-bending-beam impact test was carried out using a Fractovis instrumented drop-weight impact tester (Ceast, Italy). The specimens were simply supported with a span of 46.4 mm. The impact force-time event was stored in a PC, from which other impact variables, such as the impact energy, velocity etc. can be calculated. All samples have length, width and thickness of 80 mm, 10 mm and 4 mm respectively. Impact tests were carried out within the temperature range of 20 ^oC to 140 ^oC.

The glass transition behaviour was determined by using a Du Pont 983 dynamic mechanical analyzer (DMA). A Seiko SSC / 5200 thermal gravimetric analyzer (TGA) was used to determine the exact glass fibre content in the composite.

RESULTS AND DISCUSSION

The results from DMA show that the storage modulus of the pultruded composite decreases rapidly with increasing temperature within the temperature range between 70 to 160 ^oC. The loss modulus shows a peak at about 115 ^oC, which is the glass transition temperature (T_g) for the matrix material.

Fig. 1 shows the maximum impact force (F_{max}) and the fracture energy (E_b) against temperature. As can be seen, both F_{max} and E_b decrease with raising in the testing temperature. The fracture energy E_b quoted in Fig. 1 is the energy at the point where the force-time (F-t) curves indicate complete unloading of the impacted beam. It has been observed that all the samples being tested did not fracture at the mid-span. The failure mode changed with changing test temperature. For the samples tested at 20, 50, 80 and 100 ^{o}C, interlaminar fracture (even though the beam is one single thick layer) were seen to occur on the neutral plane of the beams, where the shear stress was maximum. The contact damage between the impactor nose and the beam upper surface was seen to be highly localized. For samples tested at 115, 130 and 140 ^{o}C, the interlaminar shear failures were not found. Instead extensive damage can be seen at the contact region on the upper beam surfaces. This may be related to the more rubbery behaviour of the poly(vinyl ester) matrix at temperatures above 115 ^{o}C. The glass fibres have a higher degree of freedom to deform under the contact force.

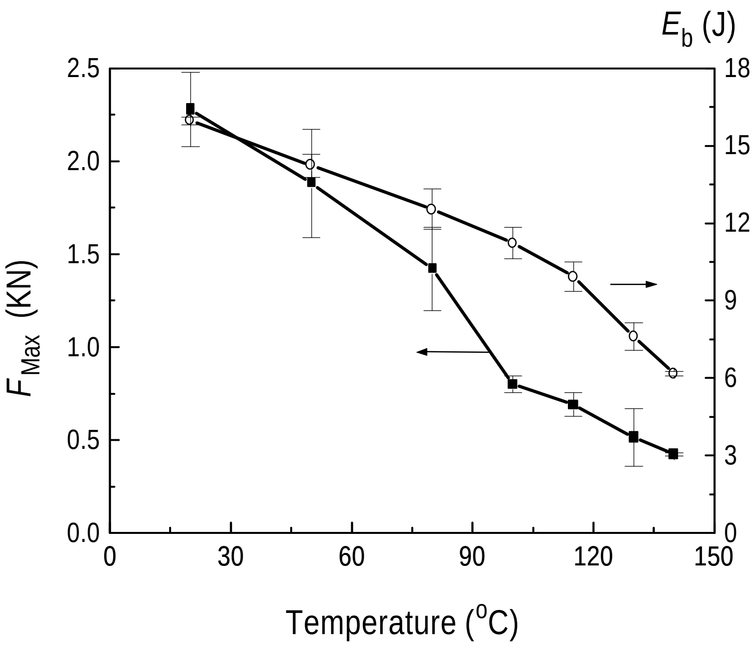

Fig. 1 F_{MAX} and E_b versus temperature

CONCLUSION

The impact damage characteristics of glass fibre reinforced poly(vinyl ester) beams are found to be highly temperature sensitive. The glass transition temperature has a significant role on the failure mode of the impacted beams. For test temperatures below T_g, interlaminar fracture on the neutral plane was the dominant mechanism. For test temperatures above T_g, due to the relaxation of the matrix phase, interlaminar fracture on the neutral plane cannot take place. Plastic bending and extensive contact deformation were the principal deformation mechanisms.

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