Thermo-Mechanical Behaviour and Shape Memory Characteristics of Carbon Fibre Reinforced Epoxy

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Abstract Summary: In this study, the thermo-mechanical behaviour, shape memory characteristic and the mechanical properties such as tensile strength, Young's modulus, impact energy and hardness of the carbon fibre reinforced shape memory epoxy composite have been investigated.

Introduction: The shape-memory polymers (SMPs) being evolved intensely and represent a fast growing branch of smart materials research. The global research interest in these materials has been rapidly growing, because of their inimitable advantages of good manufacturability, high shape deformability, large recoverability, good biodegradability, and an easily tailorable glass transition temperature (Tg) [1, 2]. Once the SMPs are reinforced with fibres, significant improvements in the mechanical properties have been identified [3]. Furthermore, the researches have investigated the effect of glass fibre reinforcement on the shape memory behaviour [4]. Our preliminary investigations was focused to analyse quantitative and qualitative mechanical behaviours and dimensional stability of the glass fibre reinforced shape memory polymer composites (SMPC) [5]. This paper presents the experimental investigations on thermo-mechanical behaviour and mechanical properties of SMP epoxy and its woven carbon fibre composite. Moreover, the shape fixity and shape recovery behaviour of the shape memory polymer composite also presented.

Material and Experimental Methods: In order to prepare the test specimens, multiple laminations of prepreg epoxy containing 0/90 woven carbon fibre mesh has been cured under vacuum bagging. Shimadzu fourier transform infrared spectrophotometer (IRAffinity-1S) and Jeol benchtop scan electron microscope (JCM-6000) has been used to determine the material structure. TA instruments dynamic mechanical analyzer (DMA Q800) with single cantilever clamp has been used to investigate the thermo-mechanical behaviour of the material. MTS Insight Electromechanical Testing Systems has been used for the tensile testing under ISO 527-5:2009 test conditions. The ability of the material to absorb shock and impact energy has been tested by using Instron Dynatup Drop Weight Impact Testing Instrument (8200). Barcol Impressor Hand-held portable hardness tester (GYZJ-934-1) has been used to determine the hardness of the SMPC.

Results and Discussion: The cured epoxy predominantly contained the functional groups of carbon, oxygen and hydrogen. According to the SEM results the top and bottom surfaces of the prepared specimens are consisted with voids having length up to 1.8mm and width up to 705μm. Further, spaces between layers has been identified at some locations, which might have caused local bending to initiate the delamination during the tensile failure. The maximum gap between two layers, which was identified during the SEM observations is 32.4μm. The SMP composite comprising a 32.6% mass fraction of carbon fibre exhibited a tensile strength of 517 MPa and Young's modulus of 42 GPa. The energy required to fracture the material subjected to impact load is 1.97J and the hardness of the SMP composite in Barcol Impressor scale is 56 which is approximately 39 in Brinnell and 44 in Vickers scales.

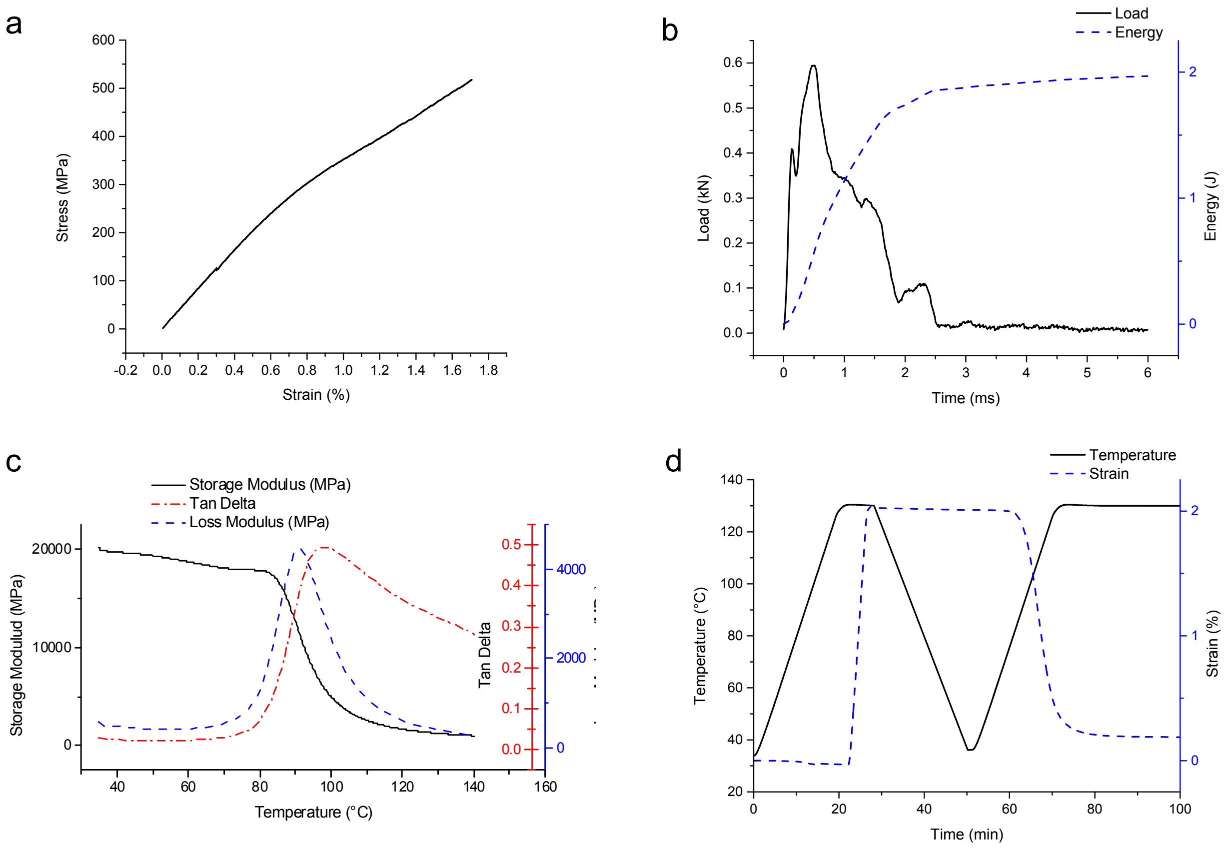

Fig. 1 Mechanical properties and thermomechanical behaviour (a) Tensile stress versus strain (b) Impact load, energy versus time (c) Storage modulus, loss modulus and tan delta verses temperature (d) Temperature strain verses time under DMA strain rate mode.

According to the tan delta curve, the glass transition temperature (Tg) of the material is 98°C. Exceptionally the SMP composite has not exhibited any spring back effect after the programing phase of the DMA strain fixity experiments. The strain recovery has been started at 73°C and the strain is recovered up to 0.189% at 130°C. Accordingly, shape fixity ratio of the SMPC is almost 100% and the shape recovery ratio is 90.55%.

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