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Viscoelastic characterization of multifunctional composites incorporated with microencapsulated phase change materials

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Abstract

The paper reports an experimental investigation on the viscoelastic properties of glass/epoxy composites incorporated with microencapsulated phase change materials (micro-PCMs). The effects of phase-transition process on the thermo mechanical characteristics of host composite laminates were studied using dynamic mechanical analysis (DMA) technique. Variation of the storage modulus is explained by the observed changes in the apparent crosslink density. Using the loss modulus to determine the glass transition temperature (Tg), a bilinear dependency between Tg of the composite laminates and micro-PCMs concentration was identified. Glass transition relaxation in composites was studied using multi-frequency DMA scans in conjunction with the apparent activation energy. It was found that the viscoelastic properties of micro-PCMs enhanced glass/epoxy composites are inversely proportional to the weight fraction of microencapsulated fillers.

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*Keywords:*Type your keywords here, separated by semicolons ;

1. Introduction

Phase Change Materials (PCMs) are capable of storing, releasing and absorbing significant thermal energy during the solid ↔ liquid phase transition process. Due to their inherent thermal storage capabilities, PCMs have been used in several applications including wearable textiles, spacecraft protective gears, building materials, thermal storage

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structures and electronic packaging. Incorporating PCMs into Fiber Reinforced Plastic (FRP) composites will result in multifunctional material systems that possess structural properties along with the capability of storing thermal energy. However, fully utilization of such composite laminates cannot be realized before understanding the effect of embedded PCMs on the thermo-mechanical properties of the host laminates.

Although several researchers have reported on the influence of micro-sized particles on the viscoelastic properties of polymers/foams [1-3], similar studies on FRP composites incorporating microencapsulated phase change materials (micro-PCMs) are not available in the open literature. In this study, micro-PCMs were integrated into glass/epoxy composite laminates and the viscoelastic properties of the multifunctional composites over a wide range of frequency and temperature were investigated experimentally. Among thermo-physical properties, the glass transition temperature (Tg) of polymer-based composites is vital since the physical/mechanical properties of the polymer drastically change at Tg due to the activation of segmental chain motions. For the same reason, the maximum operating temperature of a polymer-matrix composite is determined by Tg. The viscoelastic properties of a composite material depend on the fiber content, presence of the additives (fillers), compatibilizer and impact modifier, fiber orientation and the mode of testing. Therefore, understanding the inclusion effect and the influence of phase transition of micro-PCMs on thermo-physical properties of composites is required.

2. Materials and Methods

2.1. Materials

The host composite laminate consisted of a plain-woven E-glass fabric (195 gm^{-2}) from Colan Australia, RenLam® LY113 epoxy resin and its corresponding amine-based hardener RenLam® HY97-1, both obtained from Huntsman Chemicals, Australia. The microencapsulated PCMs (MPCM 37) was purchased from Microteck Inc, USA, and used as received. Micro-PCMs are core-shell microcapsules containing an outer shell: melamine-formaldehyde (10-15 %·w/w) and a core material: *n*-eicosane (80-90 %·w. w) [4, 5]. The mean size of microcapsules was 18.5±1.5 μm with a melting temperature (T_m) of 37 °Cand heat of fusion (ΔH_m) of 190-200 J g^{-1}.

2.2. Preparation of micro-PCMs enhanced laminates

Micro-PCMs were added to the epoxy resin with a predetermined concentration of either 10 %, 30 % or 50 % by weight. The epoxy/micro-PCMs slurry was stirred using a mechanical mixer for 30 minat 900 rpm, then degassed. The hardener was added into the mixture at the suggested mixing ratio of 30 phr. The neight layers of resin-impregnated glass fabric were prepared via a wet hand lay-up method to achieve a fiber fraction of 60 %·w.w. Consequently, the weight fraction of micro-PCMs in the composite was 4, 12 and 20 %·w/w. Composite laminates with a cross-ply configuration were fabricated using resin impregnated plies. The laminates were vacuum-bagged and left to cure at room temperature for 24 h. The panels were subsequently post-cured according to manufacturer recommendation: 12 h at 40 °C → 2 h at 60 °C → 2 h at 80 °C → 2 h at 100 °C→ 12 h at 120 °C. In addition, glass/epoxy laminates with 0 %·w/w micro-PCMs were prepared for baseline comparison. The resultant thickness and density of the fabricated laminates are reported in Table 1.

Table 1: Thickness and density of micro-PCMs enhanced laminates

Micro-PCMs weight fraction (%·w. w)	Fibre volume fraction (%)	Density (g cm^{-3})	Thickness (mm)
0	44 ± 0.2	1.7 ± 0.0	1.23
4	43 ± 0.1	1.6 ± 0.0	1.41
12	37 ± 0.7	1.5 ± 0.1	1.51
20	33 ± 1.6	1.4 ± 0.1	1.88