Multi layers glass fibres reinforced epoxy composite: Dynamic mechanical analysis

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Received: 18 March 2016, Revised: 20 September 2016 and Accepted: 21 September 2016

DOI: 10.5185/amp.2017/810
www.vbripress.com/amp

Abstract

In present work, epoxy based glass composite is prepared using hand lay-up method followed by static compression with varying numbers of woven glass layers. Dynamic mechanical properties of prepared glass composites are studied in terms of storage modulus (E'), loss modulus (E"), damping (Tanδ) and glass transition temperature (T_g) as a function of temperature. The results indicated that value of E' and T_g increases whereas value of Tanδ decreases as increase in temperature. In addition, value of T_g obtained from Tanδ curve is found lower than that obtained from peak of E" curve. The present glass composites are suitable for constructions, automobiles and aerospace industries due to its better dynamic mechanical properties and thermal stability.

Keywords: Glass fibre, polymer matrix, hand lay-up method, dynamic mechanical properties, applications.

Introduction

Glass fibre is the most widely used reinforcement material for polymer based matrix due to its advantages such as low weight, high specific strength, high stiffness and long life. Glass fibre reinforced polymer composite (GFRPC) is consisting of glass fibre as reinforcement and polymers as a matrix. Polymers may be either thermosets or thermoplasts. It has been used in various engineering applications such as automobile, aircraft, spaceship, piping, military, and sea vehicle industries **[1-5]**.

DMA has become the most sensitive and successful thermo mechanical technique to characterize the interfacial interaction between fibres and matrix of fibre reinforced polymer composites **[6]**. Many studies have been presented on the dynamic mechanical properties of natural fibre reinforced polymer composites (NFRPCs) and GFRPCs **[7-10]**. Saha *et al.* **[11]** studied the dynamic mechanical properties such as storage modulus, loss modulus and damping of uni-directional glass fibre reinforced polymerized methyl methacrylate composite. The glass transition temperature was found to shift towards higher temperature due to incorporation of glass fibers into matrix material. The dynamic mechanical properties of short jute fibre reinforced polypropylene composite was reported by Rana *et al.* **[12]**; loss modulus and glass transition temperature was found to increase with increase in fibre content in composites. Ray *et al.* **[13]** studied the dynamic mechanical analysis of jute fibre reinforced vinylester composite. The tests were carried out in nitrogen atmosphere, using three-point bending mode at 1 Hz frequency within temperature range of 30-210°C. They reported that storage modulus and glass transition temperature were found to increase with increase in fibre content due to proper stress transfer at fibre-matrix interface. However, the value of storage modulus suddenly decreased in temperature range of 110-170 °C.

In present communication, dynamic mechanical properties i.e. storage modulus, loss modulus and damping of prepared glass fibre reinforced epoxy composites are studied at 1 Hz frequency within temperature range of 25-200°C. The purpose of the present study is to develop a composite material having a better dynamic mechanical properties and thermal stability using multi layers of woven glass fibres into a new grade of epoxy resin (Araldite Klear 4+) as a matrix.

Experimental

Materials

Glass fibres are used as reinforcement and epoxy resin as a matrix in this work. Woven glass fibre was purchased from Goodgripp (India) Agency, Kolkata, India whereas epoxy and corresponding hardener were purchased from Bakshi Brothers/Universal Enterprise Kanpur, India. Epoxy resin (Araldite Klear 4+) and corresponding curing agent (Hardener Klear 4+) are mixed in ratio of 10:8 to make the matrix as recommended by the suppliers.

Fabrication of composites

The composites are fabricated by reinforcing woven glass fibres into epoxy matrix by hand lay-up technique followed by static compression. A stainless steel mould having dimensions of 300 × 200 × 3 mm^3 is used to maintain the required thickness of the composites. A releasing agent is used to assist easy removal of the composite from the mould after curing. The cast of each composite is cured under a load of 50 kg for 24 hours before it is removed from the mould. The specimens for DMA are cut as per ASTM standard using a diamond cutter. The composites manufactured with varying numbers of layers of woven glass fibres are designated as G3 (3 layers of glass fibre), G6 (6 layers of glass fibre), G9 (9 layers of glass fibre) and G12 (12 layers of glass fibre).

Dynamic mechanical analysis

The dynamic mechanical properties of prepared glass fibre reinforced epoxy composite are studied using the dynamic mechanical analyzer (Seiko instruments DMA 6100). The composites are cut into samples having dimensions of 50 mm × 13 mm × 3 mm as per ASTM D 5023. The dynamic mechanical properties are determined at 1 Hz frequency using 3point bending test as a function of temperature. Experiments are carried out in the temperature range 25–200 °C with heating rate of 10°C/min in nitrogen atmosphere. The dynamic mechanical properties such as storage modulus, loss modulus and damping of prepared glass composites are studied in present work.

Results and discussion

Storage modulus (E')

Storage modulus is defined as energy stored by materials during one cycle of oscillation. It determines the load bearing capacity and stiffness of materials. **Fig. 1** shows the variation of storage modulus of multi-layer glass composites as a function of temperature at 1 Hz frequency. It can be observed that the storage moduli of glass composites are very close to each other in glassy region because at high temperature the fibres don't contribute much to impart stiffness to materials. Storage moduli of glass composites increase with increase in numbers of woven glass fibre layers in epoxy matrix. In the glassy region, increase in values of storage modulus follows the order: G12 > G9 > G6 > G3. The highest value of *E'* for glass composite G12 can be explained by the facts that addition of high strength glass fibres restrict the movement of polymer chain as results increase in value of *E'*. In all cases, the storage moduli are found to decrease with increase in temperature due to loss in stiffness of fibres at high temperature **[14]**. In transition region, it can be observed that all glass composites have a gradual fall in value of *E'* with increase in temperature. In rubbery region, increase in storage modulus follows the same order as in glassy region. It can be observed that the glass composite G12 has the maximum value of storage modulus as compared to all other glass composites. However, glass composite G3 has its lowest value which shows increases in molecular mobility in epoxy matrix due to rise in temperature **[15]**. In addition, it can be also observed that values of *E'* are closer to each other in rubbery region than that of glassy region.

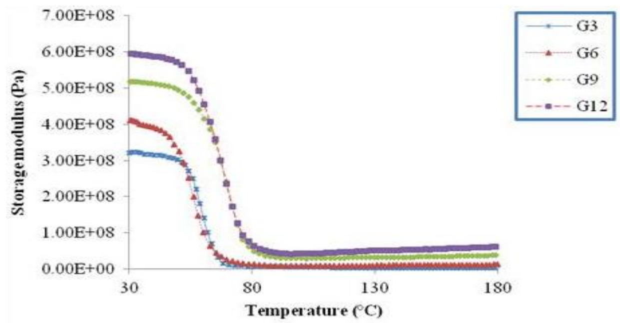

Fig. 1. Variation of storage modulus of glass composites with temperature.

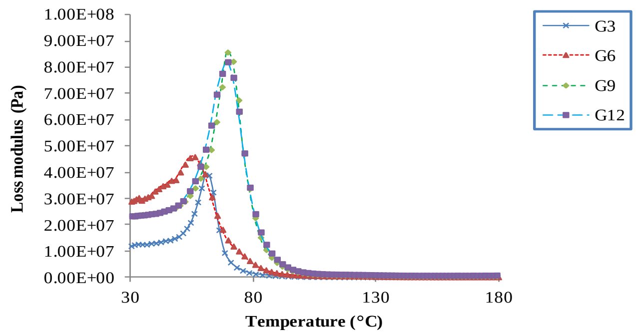

Fig. 2. Variation of loss modulus of glass composites with temperature.

Loss modulus (E'')

Loss modulus presents the viscous response of the materials which depends upon motion of molecules in the composites **[16]**. T_g is defined as a point where material changes from glassy to rubbery state. It can be obtained from either peak of *E''* or Tanδ curve. The variation of loss modulus of glass composites as a function of temperature at 1 Hz frequency is shown in **Fig. 2**. In glassy region, loss modulus curve for glass composite follows the order: G6 > G9 > G12 > G3. It can be seen that the value of ***E''*** increased up to T_g and then decreased with increase in temperature. The peak of loss modulus curve for glass composite follows the order: G9 > G12 > G6 > G3 as shown in **Table 1**. The value of T_g for the glass composites which is obtained from peak of loss modulus curve is given in **Table 1**. The values of T_g obtained from loss modulus curve for glass composites follows the order: G12 > G9 > G3 > G6. The higher value (69.58 °C) of T_g for glass composite G12 is due to maximum loading of high strength woven glass fibres, which shows better thermal stability than all other glass composites.

Table 1. Peak height and glass transition temperature (°C) from loss modulus and tan delta curve.

Composites	Peak height of loss modulus curve	Peak height of Tan delta curve	T_g from Loss modulus curve	T_g from Tan delta curve
G3	3.91 E+7	0.60	60.32	68.24
G6	4.60E+7	0.54	56.14	71.85
G9	8.58 E+7	0.58	69.48	76.26
G12	8.21 E+7	0.51	69.58	76.35

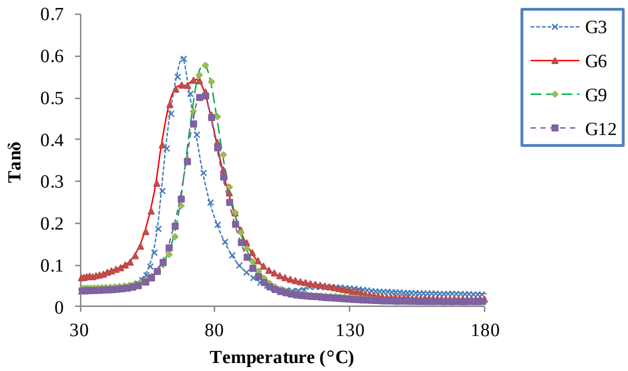

Fig. 3. Variation of Tan δ of glass composites with temperature.

Damping (Tanδ)

Damping or *Tanδ* is the ratio of loss modulus and storage modulus which is related to impact resistance of the materials. Damping depends upon adhesion between fibres and matrix. Poor fibre-matrix adhesion associated with high damping and vice versa. This fact can be explained that poor fibre-matrix adhesion increases the mobility of polymer chain turns into increase in damping. Lower value of damping shows good load bearing capacity of composite. At 1 Hz frequency, the variation of *Tanδ* for glass composites as a function of temperature is shown in the **Fig. 3**. The glass composite G3 has the highest peak of *Tanδ* curve, which shows better damping as compared to all other glass composites. The peak of *Tanδ* curve for glass composites follows the order: G3 > G9 > G6 > G12 as shown in **Table 1**. The lower value of *Tanδ* is found for glass composite G12. The lower value of *Tanδ* shows improved load bearing capacity due to good adhesion between fibres and matrix **[16]**. The value of T_g for the glass composites, obtained from peak of *Tanδ* curve is given in **Table 1**. The T_g obtained from *Tanδ* curve for glass composites follows the order: G12 > G9 > G6 > G3. The shifting of T_g towards higher temperature (76.35 °C) is found for glass composite G12. This is due to decrease in mobility of polymer chain by addition of glass fibres.

Conclusion

Dynamic mechanical properties of glass fibres reinforced epoxy composites are investigated at 1 Hz frequency and following conclusions are obtained. Storage modulus and glass transition temperature are found to increase with increase in numbers of layers of woven glass fibres in epoxy matrix. The glass composite G12 displayed the highest value of storage modulus and glass transition temperature but lower value of damping than all other glass composites. The improved dynamic mechanical properties of glass composites show a great possibility in the applications such as automobile, bridges, aerospace, boats and buildings.

Acknowledgements

The authors would like to thanks the Head of Mechanical Engineering Department of Motilal Nehru National Institute of Technology Allahabad for their support in allowing us to perform the tests. The study is partially supported by Cumulative Professional Development Allowance Fund for teachers from Motilal Nehru National Institute of Technology Allahabad.

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