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Thermal and mechanical behaviour of Glass epoxy layers – An Experimental and Theoretical approach

Manoj kumar Yadav

Department of Mechanical Engineering, MUMBAI University, Mumbai-400305
Email: manojyadav@viva-technology.org

Abstract: *The objective of this research work is to investigate the thermo mechanical behavior of glass- epoxy hybrid laminates. Material properties and coefficient of thermal expansion (CTE), exposed to temperature variation, along the principal directions were measured and characterized as temperature function. A theoretical method was proposed, by applying these characterized properties to the classical lamination theory, to predict the change of CTE for a general laminate. The coefficients of thermal expansion of the laminate were measured and compared with those predicted from the experimental results, it is observed that the proposed method is in good agreement with the experimental result*

Keywords—*Thermal mechanical analysis; Glass-epoxy hybrid laminate; Coefficient of Thermal expansion;;Materialcharacterization*

I. INTRODUCTION

Composite materials have their significant place in the field of Aerospace, Aeronautics, Defence, Civil and Marine for their superior behavior such as the unification of modulus and strength, drop in mass and flexibility over design. Glass, Carbon, Kevlar, Natural fibers and other types of fibers have undergone many investigations. However to attain novel properties, several investigators have applied the hybridization technique [1]. Acquiringproperties that cannot be achieved by single fiber reinforcement is possible by hybridization [2]. Glass-Kevlar hybrid composites are currently used as structural materials. Besides, low CTE of a composite can facilitate precise alignment and dimensional stability to structures. Understanding of CTE is indispensable to describe the performance and end use application of composite materials [3] and also to be considered in many engineering designs [4]. Numerous investigators studied the CTE of unidirectional composites [5, 6]; some investigated the fiber orientation effect on CTE [7-9].

Since the material is anisotropic, composite materials experience complexity during manufacturing process. One such complexity is due to unknown parameters, such as development of complex stress states, that is, Thermal Distortion resulting from differences in thermal expansion [10].. The basic properties and CTEs of Glass-Kevlar/epoxy were measured and characterized as temperature function. The changes of CTEs were predicted by applying these functions in Classical lamination theory.

II. MATERIAL AND METHOD

Glass-Kevlar is a plain weave fabric of 320 gsm, in which Kevlar fiber runs in warp direction and Glass fiber through the weft. The lamina is 0.283 mm thick. A total of 11 layers (0.689 kg) were arranged in the same sequence (0, 90), through hand lay-up and fabricated using vacuum bag molding. The fiber contributed to 59.21%, epoxy resin (LY556) to 37.11% and Hardener(HY951) to 3.68%. Vacuum pressure of 14 psi was applied for 20 hours and cured at 120 degree Celsius for 2 hours. The fabricated laminate dimension was 400*400*3 mm3. Specimens were prepared according to ASTM standard D638 and D696-16 for temperature tensile test and determining CTE respectively. Fig.1. shows the plain weave fabrics, fabricated laminate and coupon specimen for determining the basic properties and CTE. Fig. 2. shows, the schematic of testing equipment for measuring the basic properties and Dilatometer. Uniaxial tension test were performed at room temperature to 100 degree Celsius.. Modulus was calculated from the stress strain curves obtained from the tests at different temperatures. CTEs were measured from dilatometer with temperature ranging from room temperature to 100 degree Celsius.

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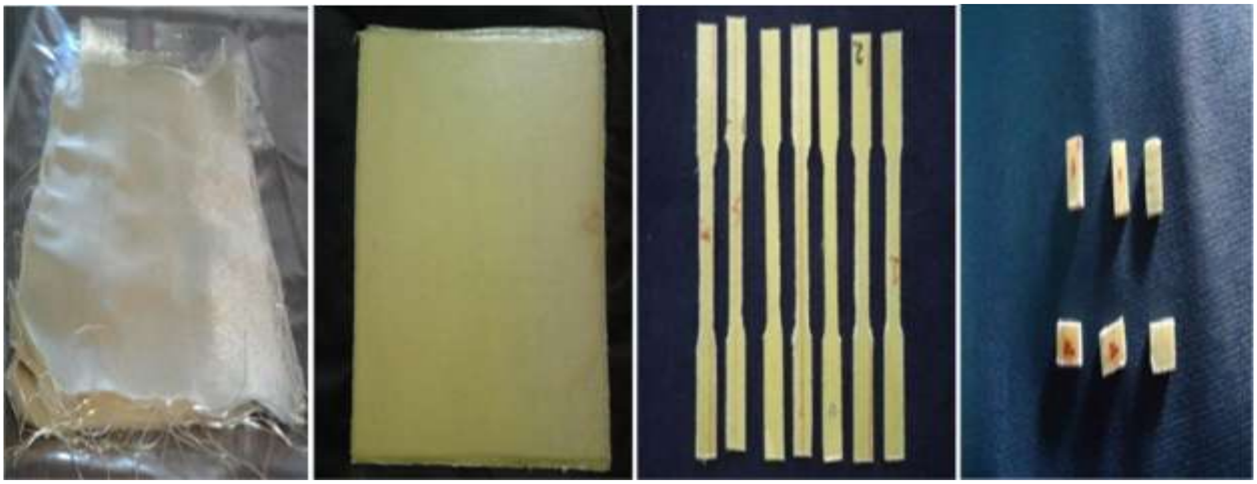

FIGURE 1. (a) Glass-Kevlar plain weave fabrics; (b) Fabricated Laminate; (c) Specimen for tensile test; (d) Specimen for determining CTE.

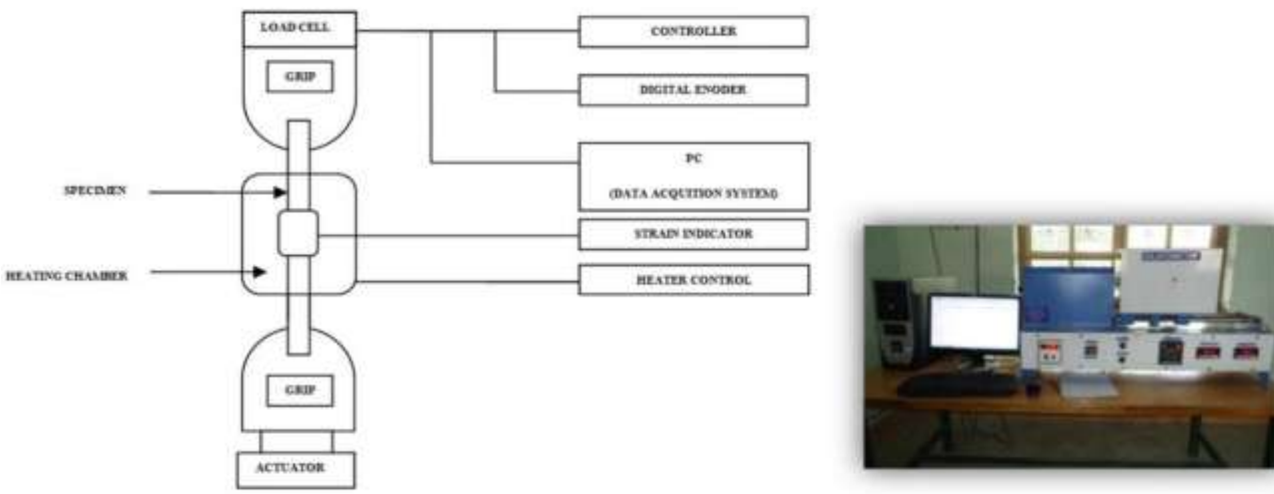

FIGURE1.2(a) Schematic of the uniaxial tension test setup; (b) Dilatometer.

III. ANALYTICAL FORMULATION

The formulation is derived from Classical lamination theory, where the following assumptions are made

[1] Each lamina is orthotropic

[2] Each lamina is homogeneous

c. A line straight and perpendicular to middle surface remains straight and perpendicular to middle surface during deformation (xyyx0)

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d. A straight line in Z-direction remains of constant length (εz=0)
e. A laminate is thin and is loaded only in-plane (σz=τxy=τyz=0)

f.Displacements are continuous and small throughout the laminate

g. Each lamina is elastic

h.No slip occurs between the lamina interfaces Considering the equations 4.7 to 4.24 derived by Jones [11], Equation 4.22and 4.33 [11] can also be written in the form, 1 and 2 are the CTEs in the fiber and transverse direction respectively. It should be noted that the values of [A'], [B'], Q and {α} are dependent on temperature.

IV. RESULTS DISCUSSION AND CONCLUSION

Fig. 3 to 6 shows the young's modulus in longitudinal (E1) and transverse (E2) directions, shear modulus (G12) and Poisson's ratio (γ12) obtained at different testing temperatures respectively.

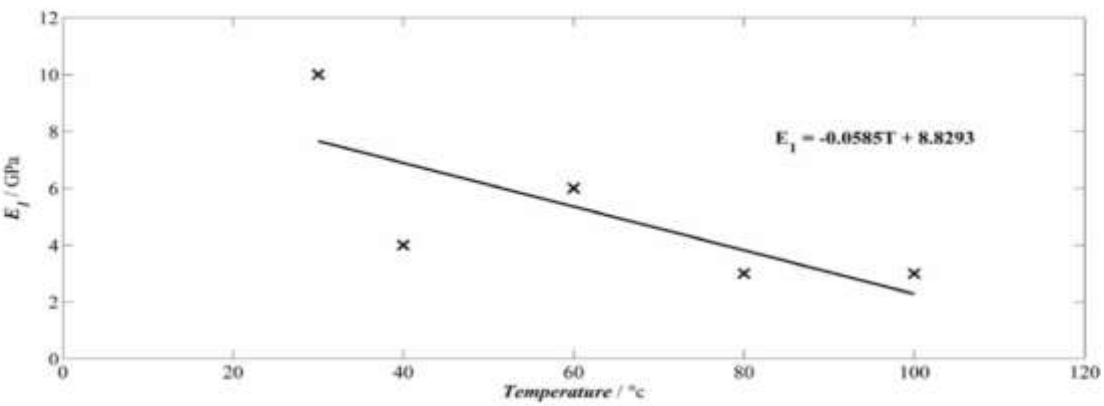

FIGURE. 3.Variation of Young's Modulus in Longitudinal direction with Temperature.

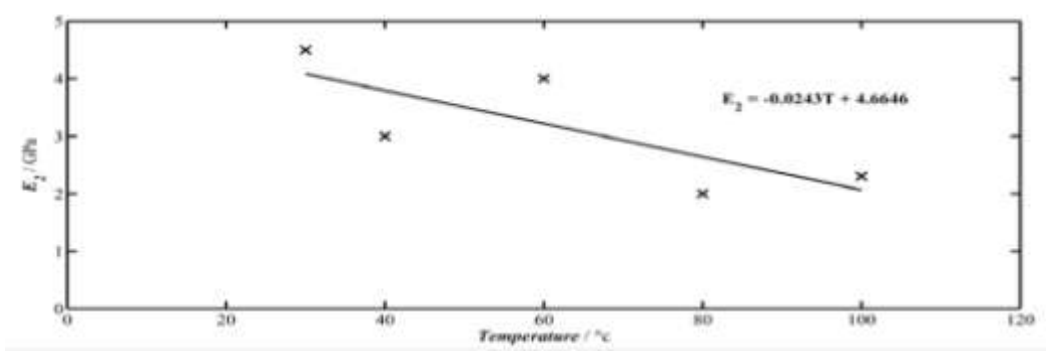

FIGURE. 4.Variation of Young's Modulus in Transverse direction with Temperature.

Young's modulus in longitudinal (E1) and transverse (E2) directions, shear modulus (G12) and Poisson's ratio (γ12) that are obtained through testing, were fitted as Temperature linear functions, for the ease of simple formulations given by equations (17) to (20).

E10.0585T 8.8293 (30˚C to 100˚C) (17)

E20.0243T 4.6646	(30˚C to 100˚C)	(18)
G120.169T 57.82	(30˚C to 100˚C)	(19)
120.0023T 0.3613	(30˚C to 100˚C)	(20)

Application of heat, the properties begin to drop initially and the variation is linearly decreasing. On the other hand, if the room temperature is eliminated, the graph would be different for shear modulus and young's modulus. Eliminating the room temperature, the modulus in the longitudinal direction, that is, the Kevlar fibre would not show that much response to the temperature variation, whereas the transverse modulus, that is, the Glass fibre would show variation. This shows the dominating character of Kevlar, when subjected to temperature variation. On viewing the so called matrix dominant characteristics, such as the transverse modulus and the shear modulus, a peculiarity is observed. Though there is a decrease in the transverse modulus, the shear modulus shows a meagre variation as the temperature varies. This is because of pure Hybridization. As a laminate, the properties were at its best, except for the drop in property on the transition from room temperature to an incremental temperature. But the laminate shows a sustainable character as it enters a hot region, especially as nearing to its cure temperature.

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