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EFFECT OF LAYERING PATTERN ON MECHANICAL AND WATER ABSORPTION PROPERTIES OF GLASS/FLAX REINFORCED EPOXY

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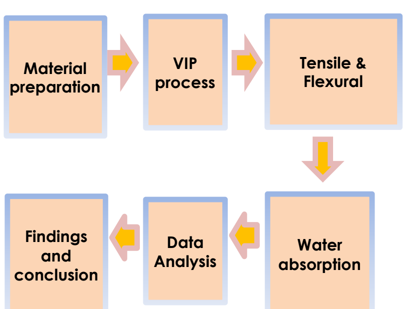
Graphical abstract



Abstract

In this present study, a new hybrid composite with epoxy as a resin and hybrid reinforcing glass and flax are used as layered mat. The composites were prepared via vacuum infusion process (VIP) comprising glass and flax fibres with the weight fraction of 57 % and 43 %, respectively. All the laminates were prepared with a total of seven plies, by varying the position of the glass and flax. The effect of stacking sequence of the laminates on the mechanical and physical was characterized by tensile, flexural and water absorption tests. The results indicated that the flexural strength and modulus were significantly dependent on the hybrid configuration in comparison to their tensile properties. The interplay hybrid laminates with sandwich-like sequence exhibited 10.5 % and 5.5 % higher of flexural strength and modulus, respectively as compared with intercalation. Physical property was observed based on water immersion for 14 days at different elevated temperatures of 40 °C and 80 °C. Result indicated that sandwich-like is better than intercalation sequences for water resistance at both elevated temperatures with the percentage of water intrusion about 4.4 % and 6.35 % at 40 °C and 80 °C, respectively. Conversely, specimens with intercalation sequence exhibited 5.1 % and 7.0 % of water intrusion at 40 °C and 80 °C, respectively.

Keywords: Glass, flax, stacking sequence, tensile, flexural, water absorption

1.0 INTRODUCTION

Composite materials are broadly used in various fields and applications nowadays due to unique properties and characteristics that cannot be realized by conventional material. Hybridization of composite laminates with natural fibres gain attention widely due to the low density materials offered, yielding relatively light weight composites with specific properties, low cost, acceptable specific properties, ease of separation, enhanced energy recovery and biodegradability [1, 2]. Flax/epoxy potentially in replacing glass/epoxy in terms of stiffness, flexural and impact properties as found by Chilali *et.al* [3]. Flax amongst the best group of industrialized fibres in terms of mechanical properties with a stifness of about 70

GPa and its specific stiffness higher than glass fibres [4]. Effect of stacking sequences of jute/glass reinforced polyester on flexural loading was studied and it was found that incorporation of glass in jute fibre composites enhances the properties of hybrid composites [5]. Empty fruit bunches (EFB) - jute reinforced epoxy with the different layering pattern has been investigated and the result indicated that the arrangement of woven jute as a skin and oil palm EFB fibre as a core leads to enhance in flexural strength and modulus [6].

Hybrid composites with different stacking sequences of glass/carbon [7], carbon/basalt [8], jute/glass [9] on the mechanical loadings significantly affected the properties of the laminates. Hemp fibre reinforced polyester was investigated on the effect of water absorption at different temperature. It was found that the composite significantly degrade at elevated temperature compared at room temperature. In addition, percentage of natural fibre loading in hybrid laminated composites significantly affected the percentage of water intrusion due to the higher cellulose contents [10]. The objectives of the present work are to investigate the effect of stacking sequences of glass/flax hybrid laminated composites on tensile, flexural and water absorption behaviour at different elevated temperature.

2.0 METHODOLOGY

All the reinforcements used are in the form of plain weave. Natural fibre of flax used is 2/2 twill weave with same warp and weft count of 7 ends/cm with the weight of approximately 200 g/m². Synthetic fibre of E-glass used in the form of woven rowing with the arial weight of 600 g/m². Epoxy resin DM15F3 (A) is cured with hardener DM15F3 (B) in the ratio of 5:1, supplied by Chemrex Corporation Sdn. Bhd, Selangor, Malaysia.

Hybrid laminates of woven glass and flax mats were prepared via VIP on a glass mould as shown in Figure 1. All the composite laminates consist of seven plies with the configurations as shown in Table 1.

Tensile test is performed according to ASTM D638-10 using universal testing machine, Instron Model 5969 with a load cell of 10 kN at a speed rate of 2 mm/min. Specimens were cut according to dumbbell shape (Type I). Five identical specimens were tested and the average result is obtained.

For the flexural test, specimens are loaded on 3-points bending with a span to depth ratio of 16:1 in according to ASTM D790-10 [11]. The test was also conducted using a load cell of 10 kN at 2 mm/min rate of loading.

Flexural strength (σ_f) and modulus (E_f) are calculated using Eqn (1) and Eqn (2)

$$\sigma_f = 3P\, max\, L/2bd^2 \quad (1)$$

$$E_f = L^3m/4bd^3 \quad (2)$$

where is P is the maximum load (N), L is the support span (mm), b and d are the width and depth of the beam tested (mm) and m is the slope of the tangent to the initial straight-line portion of the load-deflection curve (N/mm).

Water absorption test is carried out in according to the ASTM D570-98 [12]. Specimens with dimension 50 mm x 50 mm are soaked in distilled water at 40 °C and 80 °C for 14 days. Percentage of water absorption (%W) is measured every 24 hours and calculated by using Eqn (3).

$$\%W = [(W_t-W_0) / W_0] \times 100\% \quad (3)$$

Where W_t = wet weight, W_0 =the initial weight

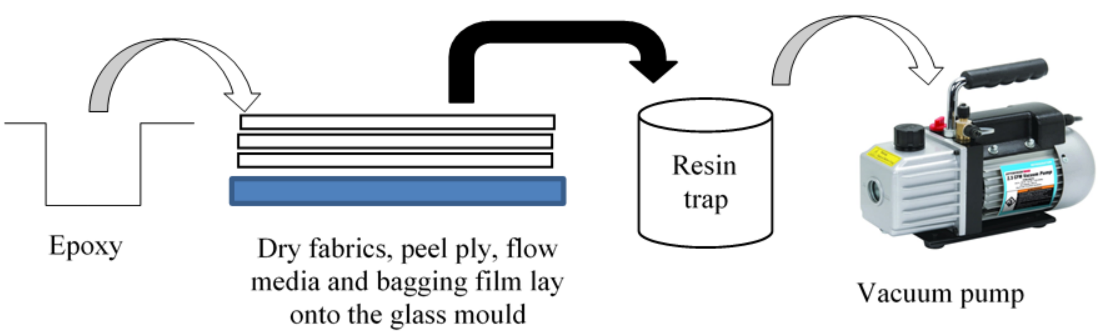


Figure 1 Schematic diagram of VIP

Table 1 Laminate stacking sequence

Symbol	Sample	Stacking sequence	Thickness (mm)	Density (g/cm³)
S1	Glass/flax (sandwich-like)	$[G_2/F_3/G_2]$	3.0	1.56
S2	Glass/flax (intercalation)	$[G/F/G/F]_S$	2.8	1.54
S3	Glass	$[G_7]$	2.9	1.89
S4	Flax	$[F_7]$	3.1	1.41

3.0 RESULTS AND DISCUSSION

3.1 Tensile Properties

Tensile strength and modulus of glass/flax reinforced epoxy laminates are summarized in Figure 2 and Figure 3. It was observed that the tensile properties of glass/flax hybrid composite are not significantly influenced by the stacking sequence between sandwich-like and intercalation sequence. Tensile strength of laminate (S1) is increased, but not significant when compared to (S2). This phenomenon can be explained due to the equivalent effect of fibre loading acting on the cross-sectional area of the hybrid laminates which is perpendicular with the direction of applied load. Although the sequences are different, but hybrid laminates were constructed with an equal percentage of fibre loading between glass and flax, which is 53 % and 43 %, respectively. Hence, the effect of stacking sequence in the present study has not significantly contributed to withstand tension load.

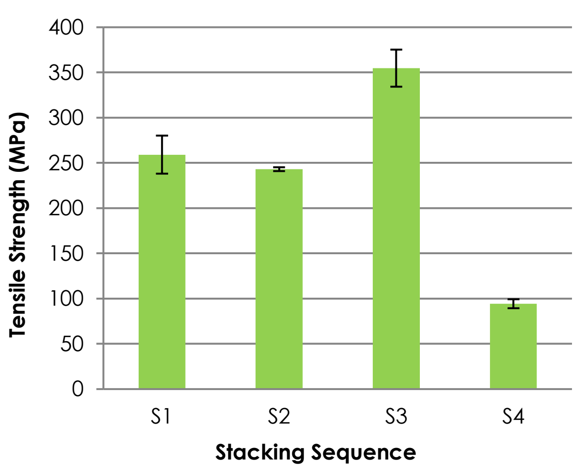


Figure 2 Tensile strength of laminates

This finding agreed with the previous study on the effect of lay-up architecture on the plain-weave flax [13] and hybrid composite laminates of glass/carbon with different sequences [7]. Dedicated laminate of glass shows higher tensile strength and modulus which opposed with flax laminate with the value of 354.7 MPa, 7.0 GPa, 94.3 MPa and 2.3 GPa, respectively.

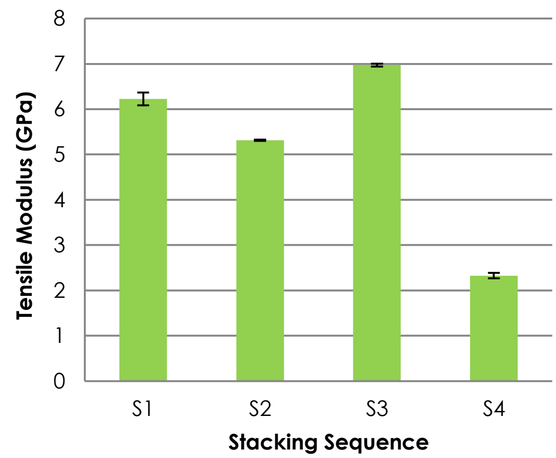


Figure 3 Tensile modulus of laminates

3.2 Flexural Properties

Hybrid composite laminates of glass/flax (S1) exhibits 10.5 % higher of flexural strength than intercalation sequence (S2) as shown in Figure 4. This pattern was similarly observed on the flexural modulus with the (S1) shows 5.3 % higher than (S2) as evidenced in Figure 5. It was revealed that the arrangement of fibre in hybrid composite structure strongly affected its flexural strength and modulus as reported by literatures [5, 6, 12, 13]. As predicted, dedicated laminate of glass fibre (S3) shows the highest flexural strength which is more than three times higher than flax laminates (S4). In terms of stiffness, sample (S1) shows the highest value of 12.19 GPa, which is better than pure glass (S3) laminates. Emergence of flax fibre as a core inside the hybrid laminates possible to reduce the brittleness of glass/flax composites. Sandwich-like sequence of hybrid laminated composites highly significant on flexural loadings and these can be explained due to the behaviour of the hybrid specimens under bending load, whereas upper and lower sides are in tension and compression modes. Two layers of glass at extreme sides of sandwich-like sequence enable the hybrid laminates to withstand higher on flexural loading since the core of natural fibre seem at neutral position, only withstand smaller load caused from bending.

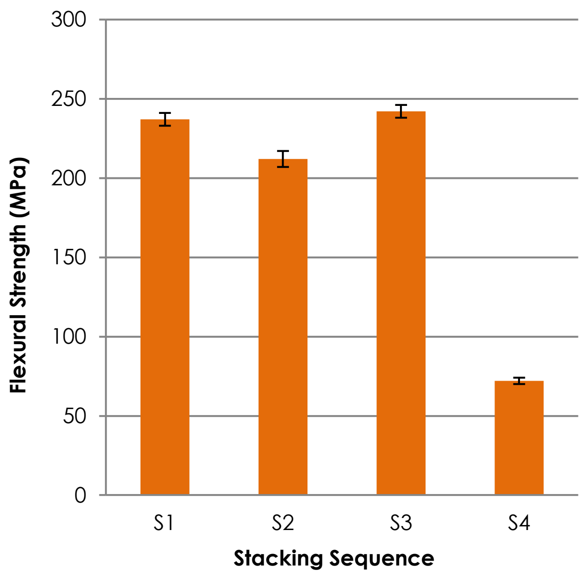


Figure 4 Flexural strength of laminates

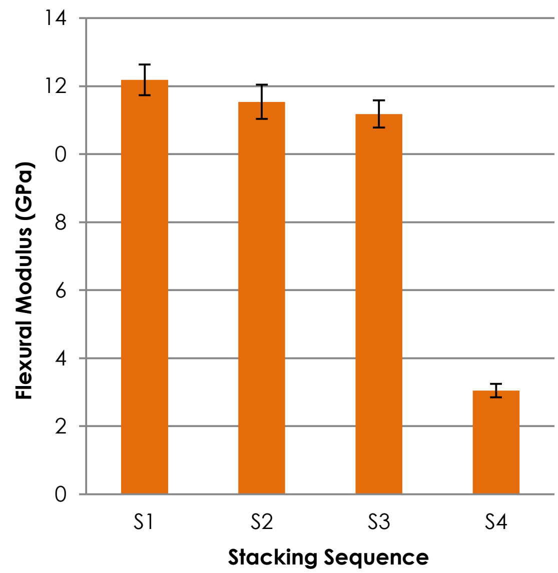


Figure 5 Flexural modulus of laminates

3.3 Percentage of Water Absorption

Glass/flax hybrid laminates with different configurations significantly affected the percentage of water uptake considered in this study. At both elevated temperature of 40 °C and 80 °C, dedicated laminate of glass (S3) shows the least overall of water uptake, while flax laminate (S4) exhibits its hydrophilic nature with the highest percentage of water immersion and this finding agreed with the previous Study [8]. Glass/flax with sandwich-like sequence (S1) shows the lower percentage of water uptake compared with intercalation sequence (S2) for both elevated temperature as shown in Figure 6 and Figure 7. At 40 °C, sample (S1) and (S2) show 4.4 % and 5.1 % of water intrusion, respectively. This similarly occurred at 80 °C with the increasing value of 6.35 % and 7.0 %, respectively. This phenomenon could be due to the lower capillary effect and low porosity possess by glass fibre whereas two layers of glass used at extreme site in hybrid laminate (S1) help in creating better intrusion barrier compared with single layer of glass (S2). In addition, water intrusion inside natural fibre is temperature and time-dependent as revealed by a previous study [16]. The higher the temperature, the percentage of water intrusion increased due to the swelling effects of natural fibres over temperature as found in previous literature [17].

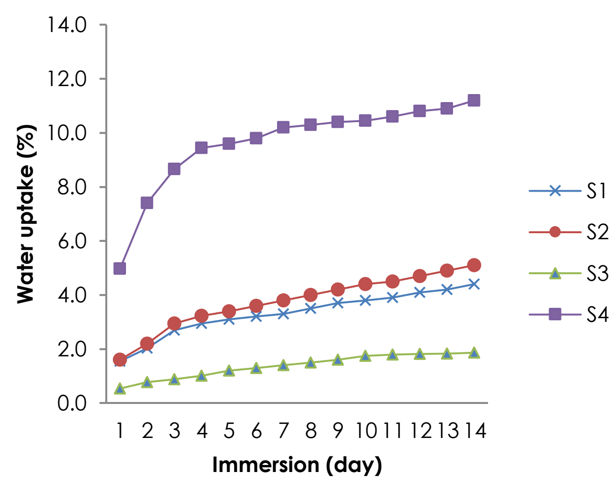


Figure 6 Water absorption at 40 °C

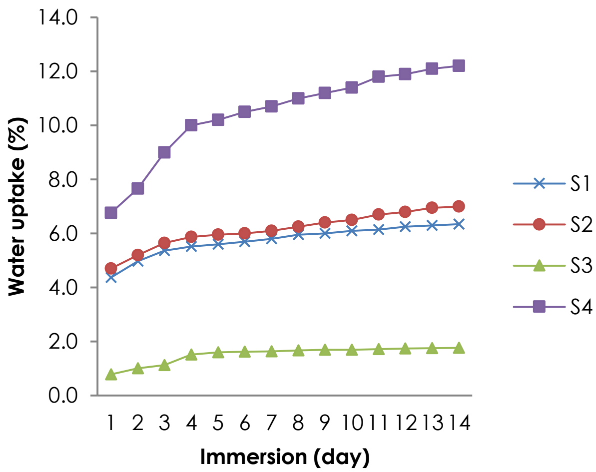


Figure 7 Water absorption at 80 °C

4.0 CONCLUSION

This study explored the possibility of incorporating flax fibre into glass fibre reinforced epoxy in creating hybrid composite laminates of glass/flax. Effect of stacking sequence was investigated on the tensile properties, flexural properties and the percentage of water immersion at different elevated temperature. It was found that tensile properties are not significantly influenced by stacking sequence. However, it is interesting to note that the stacking sequences significantly affected on the flexural properties. Flexural strength and modulus of sandwich-like sequence (S1) shows higher values than intercalation sequence (S2) with the increasing value approximately up to 10.5 % and 5.5 %, respectively. In addition, percentage of water uptake highly correlated with hybrid configuration. Sandwich-like sequence (S1) shows the least of water uptake at both elevated temperature compared with (S2). The findings of this study are very crucial in customizing hybrid composite laminates in order to achieve the desired mechanical and physical properties of the composite system. Furthermore, utilization of natural fibre is very essential nowadays towards green technology development as well as to cope with biodegradability and sustainability issues.

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