INTERNATIONAL JOURNAL OF APPLIED RESEARCH ON TEXTILE
URL: http://atctex.org/ijartex
Volume 3, Issue 2, pp 44-48, December 2015

DETERMINATION OF ADHESION BONDING IN MULTI-LAYER GLASS AND CARBON FIBRE REINFORCED EPOXY

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Received 15 May 2015, Accepted 25 December 2015

ABSTRACT

Composite materials are attracting more attention worldwide. This is because of their good mechanical properties together with their light weight and they have diverse applications. Textile composite materials are materials where a textile material is used to reinforce a resin, mainly polymeric resins. Glass, carbon, and Kevlar are commonly used textile materials for fabrication of composite materials. One of the factors affecting the performance of these materials is the way that the material and the resin are brought together, which is known as the bonding adhesion. This article determines this factor by studying the internal bonding, the effect of the number of layers, and the type of the textile fibre used. The tensile strength and the elasticity were also measured. The conclusion of this work had shown that glass fibre had better adhesion properties than carbon fibre when used to reinforce epoxy polymer.

Keywords

Composites; glass fibre, carbon fibre, epoxy, lamination, adhesion

1. INTRODUCTION

A composite material is a combination of two or more materials that gives better properties than any individual material if used separately. These materials are well known to be very good structural materials (Ruzli Zulkifli, 2009). The composite materials are characterized by their high strength and high stiffness with low weight (Valer V., Evgency V**.,** 2001) and the main constituents of a composite material are a reinforcement encapsulated in a matrix. The former provides the strength and stiffness while the later gives the body and shape. Textile materials in different forms are widely used as reinforcement materials, and there are four different matrix materials are commonly in use, and the polymeric matrix materials are the most dominant and are being widely used (F.C. Campebell, 2010). The textile materials which are characterized by their good mechanical properties, known as high performance materials, are materials made of glass, carbon, and aramid fibres. The suitability of the matrix material type for each kind of fibre depends on the bond being formed

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between both components. The properties of both components and the way that they are brought together determine the final properties of the composite (V. Srinivasan, et al ,2007).

Fibres are normally characterized by their high aspect ratio in consequence with their type, whether short fibres or continuous filaments, and these fibres can be made in different forms and structures. The way of their orientation dictates the final property of the composite. Thus the end use of the composite is determined by the structure of the fibres and their lay out in this structure (G. Wrobel, S. Pawlak, 2006). The fibre volume fraction is a factor that determines the amount of fibres in the whole composite material and so it determines the mechanical properties (Derek Hull, 1981).

Thermosetting and thermoplastic polymers are normally used as matrix materials for fabricating textile composite materials (H. Dhieb etal 2011). Different methods are also used to do so. The hand lay-up method is the most commonly and easily used method. The final composite material mechanical properties are a mix of the mechanical properties of the reinforcement, matrix, and the inter-phase between both materials. This inter-phase is determined by the adhesion which provides an interfacial contact such that mechanical force or work can be transferred easily across the interface. The mechanism of adhesion is done by forming a bond by filling-in the minute pits and fissures normally present even in very smooth surfaces (Nor Mohd., et al., 2010). Such bonds offer well distributed stress at the bonding area and resist moisture and corrosion.

Laminated composites refer to composites that are made of two or more single sheets being stacked together in different orientations to obtain certain desired properties (Fred Isley, 2013). Such composites suffer from delamination which is considered as one of the negative impacts of lamination and it is referred to as adhesion failure that causes peeling. This peeling effect is mainly determined according to the internal bond strength and tensile strength.

In this work, glass and carbon filaments made in the form of uni-directionally aligned strands were used to reinforce epoxy polymer and their internal bonding and tensile strengths were determined.

2. MATERIALS AND METHODS

Uni-directionally aligned glass and carbon filaments were used to reinforce epoxy polymer using the hand lay-up method to form different multi-layer composite materials. Typical properties of these materials are shown in Table 1.

Table 1: Typical properties of the materials used

No.	Property	Epoxy	Glass fibre	Carbon fibre
1	Density (mg/m)	1.3	0.0026	0.0018
2	Young`s Modulus (GPa)	4	76	300
3	Tensile Strength (MPa)	55	2200	2600
4	Elongation to Break (%)	5	1.9	0.75
5	Thermal Conductivity(Wm^{-1} C°)	0.1	30	1.04
6	Coefficient of Thermal Expansion	60	-	-
7	Diameter (μm)	-	11	8

Seven samples each of 25×25 cm^2 in area, of uni-directionally aligned carbon and glass strands were prepared and their weights were measured using a digital balance. A suitable amount of epoxy polymer was spread evenly on each layer of these strands. This amount is determined according to the weight of the samples, so that the fibre volume fraction composes 63% of the total volume. A rubber squeegee was used to evenly spread the resin on the layers and the sufficient amount was decided upon noticing extra resin amount coming out through the sides of the samples. The composites were laminated to make four and eight layers for each type of fibre material. These layers with the epoxy spread evenly on their surfaces, were kept in the mould, well sealed, for 24 hours under a pressure of 32.5gm/cm^2. The air bubbles were removed by thorough squeezing so as to avoid resin rich areas which will result in stress concentration regions. Then the samples were cured and post cured at 80 C° and 120 C° respectively for 2 hours each. As it is normally applied on composite fabrication, a hardener is usually used to lessen the time for solidification of the resin on both preforms (the substrate) so the resin becomes solid and the probability for evaporation to occur becomes less. The weights of these samples are shown in Table 2.

Table 2: Preforms and their composites weights for different layers

No. of layers	Preform weight (gm)		Composite weight (gm)	
	Glass	Carbon	Glass	Carbon
4	12.96	13.16	24.52	21.69
8	25.92	26.32	48.87	36.51

The composite samples for both types of fibres with their different layer numbers were tested for the internal bond (IB) and tensile stress using universal testing machine (UTM). The samples for the internal bond testing were prepared by cutting them to form an area of 5×5 cm^2 using an electronic saw to avoid edge fragmentation. Two blocks were heated at ≥200 C° and a little amount of melt glue was well distributed on the surface and then the samples were put in-between the blocks for 5-10 minutes. The samples were then removed, kept at room temperature for 24 hours and then tested using the UTM, with a constant crosshead speed rate. The tensile stress testing necessitates preparing a 20×20 cm^2 sample from each specimen and the UTM was also used to perform this test having the test length to be 16 cm. These tests were carried at standard testing conditions where the temperature range is (25 ±2) ° C and the relative humidity range is (65±2) %.

3. RESULTS AND DISCUSSION

The results of testing the internal bond and the tensile stress for four different samples retained the following values as shown in Table 3.

Table 3: The results for the internal bond and the tensile stress

Type	Sample	Internal Bond (MPa)	Tensile Stress (MPa)	Elasticity (GPa)
Glass(G1)	4-layer glass composite	30.6	140.1	8.9
Glass (G2)	8-layer glass composite	7.4	161.5	3.4
Carbon (C1)	4-layer carbon composite	14	98.1	18.6
Carbon (C2)	8-layer carbon composite	5.5	253.0	6.1

3.1 Internal Bonding

It is clear from Table 3 above that the 4-layer composite has better internal bonding between each layer compared to the 8-layer sample and this is the case for both glass and carbon reinforced composites. This indicates that delamination has a lower effect on samples of fewer number of layers and that the layers as becoming more may face surface slippage. This is also because slippage occurs between single layers and accumulates as the number of layers increases. Another reason is that the compactness of the 4-layers samples is higher than that of 8-layers sample since both samples were made using the same loading pressure. Thus, as the load increases, the compactness of layers also increases resulting in better adhesion properties between the layers.

3.2 Tensile Strength

The greater the number of layers, the greater the tensile strength is, and this is logical as far as the number of layers is considered. Comparing carbon fibre composite material to that of glass fibre, it is noticed that the 8-layer carbon fibre composite is stronger than that of glass with the same number of layers. Nevertheless, the 4-layer glass composite is stronger than that of carbon fibre with the same number of layers. This is directly related to what have been mentioned about the effect of the high internal bonding noticed with the 4-layer glass fibre composite. It is also worth mentioning that, and according to the smooth surface of carbon substrate compared to the glass, a peeling is more liable to occur for the 4-layer carbon composite. This is also clear when looking at the results of the elasticity retained by the 4-layer carbon composite which had shown the highest value.

4. CONCLUSION

This study had shown that the adhesion between glass fibre and epoxy polymer intended for fabrication of composite materials is stronger than that of carbon fibre. On the other hand, few layers of glass fibre substrates have better adhesion properties. However, surface roughness of glass fibre has also an effect on the adhesion strength. The high value of the tensile strength in both fibre types for the 8-layers is due to the number of layers and has nothing to do with the adhesion strength.

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