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Inter laminar shear strength behavior of acid, base and silane treated E-glass fibre epoxy resin composites on drilling process

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ABSTRACT

In this present work siliconized e-glass fibre reinforced epoxy resin composite has been prepared and compared with acid and base treated e-glass fibre epoxy composites to know the significant advantage of silane treatment on fibre. The composites were fabricated by laying 20, 30 and 40vol% of e-glass fibre into epoxy resin matrix. The e-glass fibre woven mat was surface treated by an amine functional coupling agent 3-Aminopropyletrimethoxysilane (APTMS). The fibres were surface treated by aqueous solution method and thermo assisted to create silinol groups. Similarly for acid treatment H_2SO_4 and base treatment NaOH with 1N concentration was used for surface treating the fibres. Effectiveness of silane treatment on glass fibre was compared by inter laminar shear strength test according to ASTM D 2344. Drilling process with varying diameter drill bit and varying cutting speed was applied to check the composites for their delamination resistance while machining. Maximum improvement of 15%, 12.5% and 9% (20, 30 and 40vol %) on ILSS was achieved for siliconized e-glass fibre reinforced epoxy composites. The scanning electron microscopy images revealed that no fibre pull out was present on fractured surfaces of composites which contains siliconized e-glass fibre. Similarly better dimensional accuracy was achieved on drilling process for composites contains siliconized e-glass fibre.

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1. Introduction

Glass fibre reinforced epoxy resin composites are used widely in automobiles, wind mills and other engineering applications. Polymers could be strengthened by addition of fibre and particles [1]. The fibre toughened polymer composites are highly preferable in aero and automobile applications due to high strength to weight ratio, ease of processing and more reliable. Epoxy resins are more attractable because of its excellent adhesion, insulation, chemically inactive properties and readily available nature. In order to improve tensile, flexural and other mechanical properties fibre addition is a common method and efficient way too [2–4]. Fibre volume is directly proportional to strength of composite but adding more layers of fibre leads the composites to delaminate. The adhesion between the fibre and resin could be governed by surface modification of fibre. To improve the bonding between fibre and resin and to reduce delamination issues fibres were treated with acid (H_2SO_4) and base (NaOH). When surface treatment process carried out on fibres leaching is a common issue which may reduce the dimensions of glass fibre. Reduced size of glass fibre gives reduction in cross sectional area hence stress concentration could be increased while external load applied [5]. The silane treated fibres could be more attractable since they cover fibres as a cap and ensure reaction site (NH_2) on fibre. The induced reaction site enhanced better adhesion between fibre and resin via chemical route. The silane surface treatment process could be done by aqueous solution method with an amino functional coupling agent. 3-Aminopropyletrimethoxysilane could be used as a coupling agent where NH_2 reaction site could be reacted with epoxide group and forms covalent bonds [6]. Siliconized E-glass fibre provides better adhesion with epoxy resin hence mechanical properties like tensile strength, flexural strength, impact strength and inter laminar shear strength could be improved [6]. Ramamoorthi et al. [7] reported that silane treatment of natural fibre in poly lactic acid improved mechanical properties due to physico-chemical interaction of fibre to matrix. When external load applied these surface modified fibres transfer load from matrix and reduce stress concentration on matrix. Singha A.S et al. [8] reported that silane treated Grewia optiva

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fibres give excellent thermal stability and mechanical properties than other surface treatments. The properties like swelling and water uptake were decreased than acid and base treated fibres. Jinchun zhu et al. [9] confirmed that among all chemical treatments on fibre surface, silane treatment gives better results because of improving adhesion between fibre and matrix. Machining of composites at high speed and feed also a major key functional area in structural engineering where delamination is a crucial issue [10–12]. Drilling on composites could be an essential process when composites preferred for structural applications. Drilling at high speeds and traverse feed fibre delamination could be occurred due to poor bonding strength of fibres with matrix. B.V.Kavad et al. [13] reported that drilling at high speeds, delamination occurred due to buckling effect and poor bonding strength of fibres. Mervin A Herbert et al. [14] reported fibre delamination issues on carbon fibre reinforced polymer matrix composites. The drilling process parameters like drill speed, feed, tool material and poor bonding strength of fibre greatly affects the fibre laminates. Katlay sevar et al. [15] reported that silane surface treatment on fibre improved mechanical and machining properties of glass fibre reinforced epoxy composites. From earlier studies it could be seen that the silane treatment on fibre surface improves mechanical and machining properties of fibre reinforced polymer matrix composites.

2. Experimental procedures

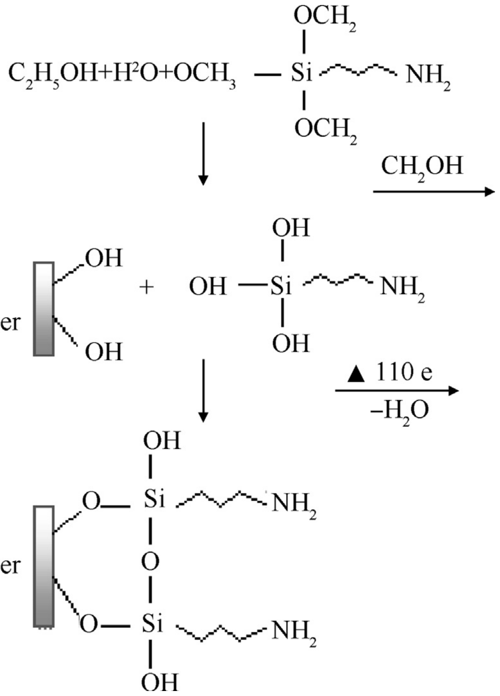
2.1. Materials

In this present study liquid diglycidyl ether of Bisphenol-A type epoxy resin (Huntsman India Ltd. Mumbai, Araldite LY556) with an equivalent weight per epoxide group of 195 g/mol, viscosity of 12000 cps and density of 1.2 g/cm^3 was used. Triethylenetetramine (TETA, Huntsman India Ltd. Mumbai., HY951), a low viscosity aliphatic amine with viscosity of 20cps and density of 0.98 g/cm^3 was used as a curing agent. E–Glass fibre continuous woven mat (0–90°) with density of 2.54 g/cm^{3}and GSM of 600was used. Surface modifier 3-Aminopropyltrimethoxysilane (APTMS) was purchased from Sigma Aldrich. NaOH of molecular weight 40 g/mol and H_2SO_4 of 98.07 g/mol (Merck India ltd) were taken for surface treatment process.

2.2. Sample preparation

2.2.1. Preparation of siliconized E-glass fibre

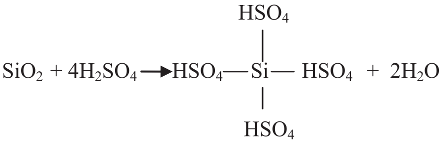
The siliconized e-glass fibre was prepared by hydrolysis process; in this the fibres were immersed in a specially prepared ethanol – water – silane solution [16]. A 95% of ethanol and 5% of water were taken and mixed gently for 10 min. Required amount of silane coupling agent generally 2 wt% concentration was added drop by drop to get homogeneous mixture followed by 5 min gentle stirring. Fibres were immersed in ethanol water solution for 10 min. The surface treated fibres were separated from aqueous solution by decanting excess solution manually. The surface treated fibres were washed briefly with ethanol to remove excess silane and dried at 110 °C for 10 min in oven to remove moisture and to form Si–O–Si structure [17]. Scheme 1 shows condensation reaction between ethanol-water to silane and silanol groups to e-glass fibre [6].



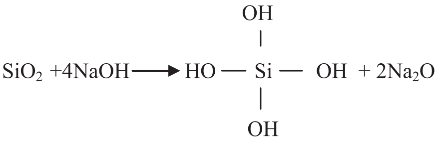
Scheme1. Structure of condensed siliconization reaction of 3-aminopropyletrimethoxysilane on e-glass fibre.

2.2.2. Preparation of acid and base treated E-glass fibre

The acid and base treatments of fibre were performed by general dipping method [5,18]. Sulphuric acid (H_2SO_4) of 1N was prepared based on molecular weight calculation. The prepared solution was poured in a glass vessel and e-glass woven mats were immersed thoroughly and soaked for 1 h. The acid treated fibres were separated by decanting the acid solution. Base treatment of fibre also performed by same method with 1N of NaOH. Equations (1) and (2) describe the reaction between fibre to acid and fibre to base.



$$\mathrm{SiO_2 + 4H_2SO_4 \longrightarrow HSO_4 - \overset{HSO_4}{\underset{HSO_4}{Si}} - HSO_4 + 2H_2O} \qquad (1)$$



$$\mathrm{SiO_2 + 4NaOH \longrightarrow HO - \overset{OH}{\underset{OH}{Si}} - OH + 2Na_2O} \qquad (2)$$

2.2.3. Preparation of composite

A variable quantity of 20, 30 and 40 volume % of acid, base and silane treated e-glass fibres were laid along with epoxy resin at room temperature by hand layup process. Curing catalyst (TETA) was added by 1:10 weight ratio to cure samples. The entrapped air bubbles were removed by cotton roller and excess resin was wiped out manually. Gravity force is used to get uniform thickness of composites. The curing was done at room temperature for about 24 Hrs and post cured for 2 days [19]. Scheme 2 shows reaction between epoxy and siliconized e-glass fibre. The designation and composition of hybrid composites used in this study are presented in Table 1.

2.2.4. Specimen preparation

The prepared e-glass fibre reinforced epoxy composite sheets were taken out from mould then cleaned and dried in room temperature for 1 h. All composites were visually inspected for surface defects before specimen making process. Specimens of suitable dimensions according to ASTM D 2344 were cut by abrasive water

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