PROPERTIES OF GLASS FIBRE EPOXY LAMINATED COMPOSITES WITH ELECTROSPRAY OF DIFFERENT CARBON NANOTUBES CONCENTRATIONS

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DECLARATION

This research project entitled “Properties of Glass Fibre Epoxy Laminated Composites with Electrospray of Different Carbon Nanotubes Concentrations”. Was submitted by Putri Nur Salsabila Binti Roslan, in partial fulfilment of the requirements for the Masters of Science, School of Materials and Minerals Engineering, University Sains Malaysia.

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LIST OF ABBREVIATIONS

Al_2O_3	Aluminium Oxide
ASTM	American Society for Testing and Materials
B_2O_3	Boron trioxide
CaO	Calcium Oxide
CF	Carbon fiber
C-glass	Calcium Aluminoborosilicate
CMC	Ceramic matric Composite
CNTs	Carbon Nanotubes
CVD	Chemical Vapour Deposition
EDP	Electrospray Deposition
E-glass	Soda Lime Borosilicate
Fe_3O_4	Ferric Oxide
FRP	Fiber Reinforced Polymer
GF	Glass fiber
ILSS	Interlaminar Shear Strength

MWCNTs	Multi walled carbon nanotubes
NMP	N-Methyl-2-Pyrolidone
PMC	Polymer Matrix Composites
RTM	Resin transfer molding
S-glass	Magnesium Aluminosilicate
SWCNTs	Single walled carbon nanotubes
UV	Ultra Violet
VARTM	Vacuum assisted resin transfer molding

LIST OF SYMBOLS

Cm	Centimeter
P	Density
G	Gram
Hz	Hertz
Hr	Hour
MPa	Mega Pascal
kV	Kilovoltage
%	Percent
Wt %	Weight percentage

SIFAT- SIFAT LAMINAT KOMPOSIT GENTIAN KACA DAN EPOXY DENGAN ELEKTROSEMBURAN BERSAMA JUMLAH PENGISIAN KARBON NANOTIUB YANG BERBEZA

ABSTRAK

Laminat komposit digunakan secara meluas dalam industri aeroangkasa dan sebagainya kerana modulus spesifiknya dan kekuatan spesifik yang tinggi. Namun, keretakan interlamina atau kegagalan delaminasi adalah cabaran dalam komposit berlamina. Oleh itu, tujuan kajian ini adalah untuk membaik pulih interlamina dalam laminat gentian kaca komposit. Penggunaan nanotiub karbon iaitu 0.5% berat dan 0.8% berat dengan menggunakan kaedah elektrosembur. Teknik pengacuan pemindahan resin dibantu vakum (VARTM) digunakan bagi menghasilkan laminat gentian kaca komposit. Dalam kajian ini, mod ketahanan belahan, lenturan dan pecahan isipadu serat digunakan untuk menguji dan menganalisis sifat komposit. Laminat gentian kaca dengan nanotiub 0.5% berat bagi ketahanan patah mod I ketahanan patah yang tinggi berbanding komposit yang lain. Untuk lenturan, didapati kekuatan lenturan dan kekakuan gentian kaca berlamina dengan 0.5% berat karbon nanotiub meningkat hingga 7.12% dan 2.34% kekuatan lenturan berbanding dengan sampel komposit gentian kaca berlamina. Walau bagaimanapun, 0.8% berat CNT dalam komposit berlamina menurun pada ketangguhan lenturan dan patah masing-masing sekitar 54. 98% dan 4. 66%. Ini disebabkan oleh salutan CNT yang tebal di permukaan gentian kaca. Tarikan kuat antara nanotiub menyebabkan pergumpalan berlaku. Tambahan pula, gelembung bagi laminat komposit 0.8% berat tinggi iaitu hampir 0.02% berbanding komposit berlamina dengan 0.5% iaitu 0.01%. Ringkasnya, laminat gentian kaca dengan 0.5% berat CNT menunjukkan daya tahan lentur dan patah yang lebih tinggi.

PROPERTIES OF GLASS FIBRE EPOXY LAMINATED COMPOSITES WITH ELECTROSPRAY OF DIFFERENT CARBON NANOTUBES CONCENTRATIONS

ABSTRACT

Laminated composite materials are used extensively in aerospace and other applications due to their high specific modulus and high specific strength. However, interlaminar fracture or delamination damage is the challenge in laminated composites. Therefore, the aim of this study is to improve the interlaminar of the laminated composites. The electrospray method was used to disperse the carbon nanotubes on the glass fiber. A vacuum-assisted resin transfer molding (VARTM) method was used to produce laminated glass fiber/epoxy with multi-walled carbon nanotube (MWCNT). The mode I fracture toughness, flexural, and fiber volume fraction was used to test and analyzed the properties of the composites. It is found that the mode I fracture toughness for laminated glass fiber with 0.5 wt % has high fracture toughness compared to the other composites. The flexural strength and modulus of laminated glass fiber- 0.5 wt% improved up to 7.12 % in flexural strength and 2.34 % in flexural modulus in comparison to control samples. However, laminated composites decrease in both flexural and fracture toughness when incorporate 0.8 wt % of CNT about 54.98% and 4.66% respectively. It might due to the thicker coating on the woven which can create agglomeration between nanotubes and lead to stress concentration. This can decrease in mechanical properties of the composites. In support, the void content of the laminated glass fiber-0.8 wt % has high values which are near to 0.02% compared to both control and 0.5 wt % CNTs laminated composites which are 0.01 %. In summary, laminated glass fiber when incorporating 0.5 wt % of CNTs was found to exhibit higher flexural and fracture toughness.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Technological development today is based on materials advances. Much of the research focuses primarily on meeting customer needs through the development of new material. The discovery and innovation of advanced compounds contribute to different applications in different fields such as aerospace, automotive and marine, with the necessary technical properties and the ability to improve the economic benefits.

Composite materials offer a combination of two or more materials that cannot be obtained from fibers or matrix when they are stand-alone. Here, the fibers are embedded in the matrix of other materials and the interface between them is different. The combination of fiber and matrix gives the highest quality material. Technological applications have used fiber-reinforced composite materials that have been widely used for decades.

Advanced composite materials such as a fiber-reinforced polymer (FRP) are composed of polymeric matrix and fibers as a reinforcing material with high strength and elastic modulus (Masuelli, 2012). Fibers are usually made from glass or other natural fibers such as metal, carbon, paper, and wood. FRP material applications continue to grow and are established as key and secondary components in the aerospace industry for large aerospace industries such as Airbus and Boeing. Fiber-reinforced composites have outstanding strength-to-weight ratios, which surpass other materials. For a number of purposes, manufacturing light weight parts is important to industries like shipping, infrastructure, and aerospace. Lightweight composites are easy to handle and install, can reduce project costs and help ensure compliance with standards and regulations. For example, carbon fiber-reinforced composites are 70 percent lighter than steel and 40 percent lighter than aluminum (Lab, 2020).

Most composite manufacturers used glass fiber reinforced polymers (GRP). Adding high-strength fibres to a polymer matrix can improve mechanical properties such as ultimate tensile strength, flexural modulus and resistance to temperature. Desirable properties can be achieved with the right composition and orientation. In comparison, the mechanical properties of GRP composites were similar to those of steel, which was more rigid. Composites with mechanical properties have been developed. However, the main challenges that must be met when using conventional glass fiber laminate composites are their interaction between the matrix and glass fiber (Zeyu et al, 2015). If there is poor adhesion between the fiber and the matrix, the glass fiber will not function well as a reinforcing material. The weak interaction of fibres with matrix decreases composite interfacial stability, resulting in ineffective transfer of load from matrix to the fibres. In the end, it produces negative effect on the properties of composites (Maslinda et al., 2017).

Composites require a proper laminate design to ensure that they can withstand the stresses of all operating conditions without affecting performance. Parameters such as fiber orientation, layer thickness, and stacking sequence are considered to improve the properties of composites and their properties are determined early in the design of the laminate. However, there is one limiting factor which is high cost of the polymer for commercial use. The addition of fillers improved the properties of the composite and also reduced the cost of products and manufacturing. Laminated GF reinforced composites are used in various fields. One of them is in the shipping and plumbing industry due to its excellent environmental resistance, high damage resistance to impact testing, high rigidity, and specific strength. However, developing carbon nanotubes using electrospray reinforced glass fiber laminate composites presents some challenges. This is delamination due to low interlaminar strength.

Many efforts have been made to improve the performance of epoxy laminate composites that strengthen glass fibers (Rathnakar and Shivanand, 2013). The use of nanofillers give positive effect because of their nanoscale size. However, the inclusion of multi-walled carbon nanotubes in nanocomposites has been a challenge for researchers. This is because when multiwalled-carbon nanotubes (MWCNTs) is in high concentrations, it is difficult to divide the MWCNT aggregate into individual CNTs. This is because the interaction of van der Waals forces between the CNTs is stronger.

The role of CNT is very important compared to other fillers due to their excellent functional and structural properties such as high mechanical strength, high electrical properties, and high filler ratio (Mittal et al., 2015). In addition to the intermediate level load transfer mechanism of laminated composites, the CNT and polymer matrix interface bonds also play an important role. Embedded MWCNTs in laminated composites can improve the adhesion between fiber and matrix (Ayyagari et al, 2020). Accurate information about the mechanical behavior of composite materials is important for many industrial applications.

Therefore, in this study, the properties of glass epoxy laminated composite was determined by electro-spraying of CNTs on the glass fiber. The preparation material of laminates glass fabrics with an epoxy resin matrix was used. The different concentrations of CNT could give a positive result of the composites. This is because the CNT gives the interfacial adhesion. Due to its nanoscale, they have a large surface area and give an interface for stress transfer. The dispersion of CNT on the glass surface is assisted by electrospray deposition. The presence of carbon nanotube deposits on the surface will result in significant improvement and strengthening of the properties of the glass fiber laminated composites. The relationship between the load density of the MWCNTs and the interlayer share strength is practical to improve the performance of the composite. Double Cantilever Beam is used to determining fracture toughness. The flexural test is used to determine the flexural strength and flexural modulus. A resin burns off method was used to determined fiber volume fraction.

1.2 Problem statement

Laminated composite materials are commonly used in various fields, especially in many technical areas in which they used E-glass fiber and carbon fiber because of their high-performance continuous fiber. One of the most popular materials used as reinforcement is glass fiber. It was embedded with the polymer matrix like epoxy resins, polyamide, vinyl ester, polyamide, and also phenolic which they have high chemical resistance, cheaper cost, excellent insulating performance, and high tensile strength (Soojin, 2010). But, the reinforcement development mostly relies on the interphase strength and stability of polymer and fiber. Poor interaction between the smooth surfaces of the glass fibers with the polymeric matrix causes poor adhesion between the fibers of the interface matrix.

Fiber/ matrix adhesion is poor causes the effectiveness reinforcing mechanism of fibres in the fiber reinforced composite (FRP) is not achieved. Fibre breaking, matrix microcracking and fiber separation from the matrix are the failure of fibre reinforced materials that are exposed. Under extreme environmental conditions, such as high temperatures and humidity, degradation of the bonding phase can easily occur (Etcheverry et al, 2012). Fiber strength and modulus, interface bonding between fiber/matrix, chemical stability and matrix stress transfer can influenced the mechanical behavior of composites laminates and criteria good stress transfer to occur (Erden et al., 2010).

The primary challenge for the composite laminated fibre is interlaminar fracture or delamination damage. This is because these factors will weaken the laminate strength and thus lead to failure. The primary factors that cause FRP composite fracture are load speed, stress concentration, temperature and thermal shock (Maleque, 2013). Delamination damage is the result of interlaminar shear stress caused by low velocity impact and occurs when the interlaminar stress reaches the interlaminar strength limit. The geometry and the loading parameter trigger interlaminar stress, whereas the interlaminar strength depends on the properties of the materials.

Glass fiber and epoxy interfacial adhesion can improve with the addition of MWCNTs on the woven glass. The presence of MWCNTs on the woven glass fiber surfaces is estimated to increase the interface bonding, damage tolerance, and stress transfer which may give the positive result to the composites. In recent years, there are several methods and processing approaches were established of fiber-reinforced polymer composites (FRPs) by incorporate nanofillers. For example, interleaving bucky papers at certain laminar interfaces, direct attachment of nanofillers on the fiber surface, dispersing nanofillers in the matrix, and manual spreading or spraying nanoparticles on prepregs to further improve the strengthening of matrix-reinforcement interphase (Ragavendhra et al., 2014). But, there are difficulties researchers overcome the properties of CNTs when dispersing in the epoxy matrix. This is due to strong van der Waals forces which make them agglomerate rather than form into separate CNTs which resulted in poor dispersion. Plus, when the higher concentration of CNTs, the tendency of CNTs agglomeration is high and faster.

In this study, electrospray techniques were used to analyze and investigate well-dispersed carbon nanotubes. The fabrication of the laminated glass fiber with the addition of different concentration of MWCNTs were fabricated. Their mechanical properties compared to their influence on the development of fiberglass epoxy composites composite properties. The effect of fiber volume fraction and void content of the samples were observed.

1.3 Research Objectives

The objective of this research are:

i) To investigate fracture toughness of laminates glass fiber epoxy composites with different concentrations of carbon nanotubes.