Faculty of Manufacturing Engineering

THERMAL STABILITY EFFECT ON PHYSICAL AND FLEXURAL PROPERTIES OF HYBRID GLASS/JUTE FIBER REINFORCED EPOXY COMPOSITES

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DECLARATION

I declare that this thesis entitled "Thermal stability effect on physical and flexural properties of hybrid glass/jute fiber reinforced epoxy composites" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Mohd Fadli bin Hassan

Date : 25/9/2007

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering .

Signature : .....

Name : Prof Madya Dr. Noraiham binti Mohamad

Date : 25/9/2017

DEDICATION

I dedicate this thesis to my family for nursing me with affections and love and their dedicated for success in my life. Thank you. My love for you all can never be quantified.

ABSTRACT

Introduction of natural fibers with partial replacement of synthetic fibers in tooling materials could lead to new venture in composite tooling industries.This is due to the environmental concern on the recyclability limitation of synthetic fiber made composites as well as their potential in weight and cost reduction.The primary goal of this research is to fabricate a green hybrid glass/jute fibre reinforced epoxy composite for potential tooling material via vacuum infusion technique and evaluate the thermal cycle effect on its flexural properties. In the first stage, the processing parameters of the vacuum infusion technique; i) supply pressure, ii) soaking time and iii) the utilization of flow media (with or without) were optimized by response surface methodology for maximum flexural properties of the hybrid glass/jute fibre reinforced epoxy composites.The flexural strength of ~195 MPa and flexural modulus of ~13412 MPa were achieved at optimum parameters of 100 kPa pressure and 120 minutes soaking time with the utilization of flow media during the vacuum infusion process. In the second stage, the hybrid glass/jute fiber reinforced epoxy laminated composite was prepared with the optimum process paramaters and exposed to 50 times thermal cycles at three different temperature; i) room temperature, ii) 120 °C and iii) 200 °C and tested for flexural properties. The reduction in flexural properties of around 40% was recorded composites exposed to 200 °C thermal cycles when compared with those at room temperature and at 120 °C. It was resulted from partial degradation of natural fibers at 200°C. The composites which exposed to thermal cycle at 120 °C showed stable flexural properties as well as physical properties even at 50 thermal cycles. The findings indicate that the hybridization between glass and jute fiber exhibit promising potential to be used as tooling materials with weight reduction of almost 25%.

ABSTRAK

Pengenalan gentian asli melalui penggantian sebahagian daripada gentian sintetik ke dalam bahan acuan membawa kepada suatu cubaan baru dalam industri acuan komposit. Hal ini disebabkan kebimbangan terhadap isu alam sekitar bagi had kitar semula gentian sintetik dalam penghasilan komposit di samping potensinya dalam penjimatan berat dan kos. Matlamat utama kajian ini adalah untuk menghasilkan komposit epoksi diperkuat gentian hibrid kaca / jut mesra alam untuk potensinya sebagai bahan acuan melalui teknik infusi vakum dan mengkaji kesan kitaran haba ke atas sifat lenturannya. Pada peringkat pertama, parameter pemprosesan bagi teknik infusi vakum; i) tekanan bekalan, ii) masa rendaman dan iii) penggunaan media aliran (dengan atau tanpa) telah dioptimumkan dengan kaedah permukaan sambutan (RSM) untuk sifat lenturan maksimum komposit epoksi diperkukuh gentian hibrid kaca / jut. Kekuatan lenturan ~ 195 MPa dan modulus lenturan ~ 13412 MPa telah dicapai pada parameter optimum iaitu tekanan setinggi 100 kPa dan masa rendaman selama 120 minit dengan penggunaan media aliran semasa proses infusi vakum. Pada peringkat kedua komposit epoksi diperkukuh gentian hibrid kaca / jut disediakan mengikut paramater proses optimum yang dijana dalam peringkat pertama dan didedahkan kepada 50 kali kitaran haba pada tiga suhu yang berbeza; i) suhu bilik, ii) 120°C dan iii) 200°C dan diuji untuk sifat lenturan. Pengurangan dalam sifat lenturan sekitar 40% dicatatkan bagi komposit yang terdedah kepada kitaran haba pada 200°C berbanding dengan yang berada pada suhu bilik dan pada 120°C. Ia adalah disebabkan degradasi sebahagian daripada gentian asli pada 200°C. Komposit yang terdedah kepada kitaran haba pada 120°C menunjukkan sifat lenturan dan sifat-sifat fizikal yang stabil walaupun pada 50 kitaran haba. Dapatan kajian menunjukkan bahawa penghibridan antara gentian kaca dan jut menpamerkan potensi yang meyakinkan untuk digunakan sebagai bahan acuan dengan pengurangan berat badan hampir 25%.

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ASTM	-	American Society for Testing and Materials
BFP	-	Woven Basalt prepreg
BCFP	-	Basalt and carbon fiber prepreg
CFP	-	Woven Carbon prepreg
CFRP	-	Carbon Fiber Reinforced Polymer
CTE	-	Coefficient of Thermal Expension
DGEBA	-	Diglycidyl Ether of Bisphenol A
DOE	-	Design of Experiment
DSC	-	Differential Scanning Calorimetry
FRC	-	Fiber Reinforced Composites
FRP	-	Fiber Reinforced Polymer
GFRP	-	Glass Fiber Reinforced Polymer
JRP	-	Jute Reinforced Polymer
MEKP	-	Methyl Ethyl Ketone Peroxide
MPa	-	Mega Pascal
oC	-	degree celsius
PLA	-	Polylactic Acid
PMC	-	Polymer Matrix Composite
RC	-	Reinforced Concrete

RSM	-	Response Surface Methodology
RTM	-	Resin Transfer Molding
SEM	-	Scaning Electron Microscopy
SFRC	-	Sisal Fabric Reinforced Polymer
TGA	-	Thermagravimetric Analysis
UTM	-	Universal Testing Machine
VIP	-	Vacuum Infusion Process
WA	-	Water Absorption

LIST OF PUBLICATIONS

Journals

1. N. Mohamad, M. F. Hassan, S. Y. Chang, Q. Ahsan, Y. Yaakob, H. E. Ab Maulod, "Correlation between Process Parameters with Flexural Properties of Hybrid Glass/Jute Fibre Reinforced Epoxy Composite Fabricated via Vacuum Infusion Technique", Applied Mechanics and Materials, Vol. 761, pp. 531-535, 2015

Proceedings

1. Noraiham Mohamad, Mohd Fadli Hassan, Chang Siang Yee, Qumrul Ahsan, Yuhazri Yaakob, Hairul Effendy Ab Maulod, "Correlation between Process Parameters with Flexural Properties of Hybrid Glass/Jute Fibre Reinforced Epoxy Composite Fabricated via Vacuum Infusion Technique", 3rd International Conference on Design and Concurrent Engineering 2014 (iDECON 2014), 22-23 September 2014, Avillion Legacy Melaka Hotel, Malaysia, #144.

CHAPTER 1

INTRODUCTION

1.1 Background of study

Fiber-reinforced polymer (FRP) made from glass, aramid and carbon fiber is widely utilized as construction materials in composite tooling technology. It possesses high strength and stiffness at a relatively low weight. Unfortunately the use of synthetic fiber-reinforced polymer leads to a serious disposal problem due to structure stability of thermoset matrix and synthetic fibers once the structure made is ready to be decommissioned. It is worse when simple landfill disposal of this material is becoming increasingly impossible due to problems related to environmental sensitivity. An interesting option might be where construction materials made of renewable resources that consist of natural fibers are embedded in so-called biopolymers or natural polymer, as these also involve economically and ecologically acceptable manufacturing technologies.

The idea of the combination of synthetic fibers and natural fibers is an interesting idea to counter the disadvantage of synthetic fibers. This is due to concerns about environmental awareness about the limitations of recycled synthetic fiber composites, but it is also due to the potential of such materials in cost reduction.

Hybridization of two or more different continuous fibres in a matrix is a versatile approach to improve strength or stiffness of structural composites (Matthews and Rawlings, 1999). Performance of a hybrid composite is a combination of weighed amounts of the individual components, of which balances between the strength and weakness of the

individual components (Al-Mosawi et al., 2012b). The selection of suitable components is determined by the desired properties required for the final products. Despite the excellent performance of synthetic fibres such as high strength and stiffness (Yuhazri et al., 2014) as well as good chemical resistance (Jennise et al., 2014), issues on production cost and disposal of after-use products of non-biodegradable materials are crucial. Therefore, the utilization of either solely natural fibres or in-hybridization with synthetic fibres has attracted the attention of scientists and technologists. Natural fibres such as banana, cotton, coir, sisal and jute have found their applications in consumer products, low-cost housing and other civil structures (Gowda et al., 1999). It has been observed that natural fibre composites have compatible electrical resistance, good thermal and acoustic insulation properties as well as good resistance to fracture (Gowda et al., 1999). Furthermore, the use of green composites offers several advantages such as light weight, low production cost and low thermal mass (Cicala et al., 2009, Arrakhiz et al., 2013, Yuhazri and Sihombing, 2010).

In addition, the most widely used fiber for fiber reinforced composite is called E-glass or electrical glass. E-glass is low cost, high density, low modulus fiber that has good corrosion resistance. However, glass fiber with superior mechanical properties known as S-glass or structural glass is used for higher-strength fiber for filament wound pressure vessels and solid rocket motor castings (Campbell, 2004).

As other part of reinforcement for hybrid laminated composites, jute fibers possess huge potential as fibrous reinforcement in polymeric composites. The fibers are extracted from jute plant Corchorus, from the Malvaceae family. Jute fiber extracted from bast or skin of plant, is off-white to brown in colour and measured 1-4m long. The fiber thickness varies between 40 and 80 μm which leads to a variation in the tensile strength between

1000 and 480MPa. In addition, jute fibers can withstand up to 100°C (Chand and Fahim, 2008).

1.2 Problem statement

In aerospace industry, production tooling made of synthetic fiber (carbon fiber or glass fiber) reinforced thermoset composite is facing difficulties to be disposed or recycled. Most of the production tooling in the market produces by wet hand layup technique or high quality prepreg. Tooling components by wet hand layup technique are heavy and bulky where prepreg are not cost effective. Therefore a vacuum infusion technique was utilized in this study. This technique is proven by several studies to be an efficient technique in producing high performance composites at high production rate and low cost. In addition, the uses of synthetic fibers as tooling materials are very expensive, thus increasing the overall cost of composite products. The hybridization of natural fiber and synthetic fiber in these tooling materials could lead to new venture in tooling industries. These new generation hybrid green composites offer several advantages such as light weight, low production cost and low thermal mass (Cicala et al., 2009, Arrakhiz et al., 2013, Yuhazri and Sihombing, 2010) as well as having high potential to be biodegradeble.

For tooling manufacturer, thermoset resins such as epoxy is widely used as matrix phase in the fabrication of mould tool for composite parts. Rao et al., (2011) also stated the epoxy is most commonly used polymer matrix with reinforcing fibers for advanced composites applications. Epoxy resin is more viscous than polyester with curing temperature up to 180°C. The shrinkage of epoxy is smaller than that of polyester, which is by 1-5%. Generally epoxy is stiffer and stronger and posseses to maintain its properties to higher temperature compared to polyester (Matthews and Rawlings, 1999).

This study initially fabricates the hybrid composite (glass / jute fibre) via vacuum infusion technique. This technique is common for the production of synthetic fiber based composites however; the application of this technique to prepare natural fiber based composites is limited. This technique offers lower resin to fiber ratio and produces stronger and lighter composites (Yuhazri and Sihombing, 2010). However, the process parameters need to be optimised to ensure appreciable amount of impregnated resin to fibers for better wetting.

In the industries, the tooling material subjected to thermal cycling in service. Thermal cycling is defined as alternate heating and cooling of materials. Low thermal cycle means the time taken for completion of the cycle is large enough to cool the component. On the other hand, high thermal cycle means time involved is in milliseconds and the heating and cooling is influenced by the thermal inertia of the system under consideration (Agbadua et al., 2011). During heating and cooling, the material experiences expansion and contraction. Therefore, the dimension of the material changes when subjected to thermal cycling.

Tooling material is subjected to repeated thermal cycling during in service and is likely to induce distortion on the tooling due to the difference in thermal mass and coefficient of thermal expansion. Despite the potential of these green composites, studies on thermal effect on its properties are crucial. Therefore, this study addresses the potential of hybrid glass/jute fibers reinforced composite to be fabricated via a vacuum infusion technique and evaluates its physical and flexural properties under thermal effect.

1.3 Objective of study

In this research, the main objectives are:

i. To optimize process parameter of vacuum infusion technique for fabrication of hybrid glass/jute fiber reinforced epoxy composites

ii. To determine the physical and flexural properties of hybrid glass/jute fiber reinforced epoxy composites

iii. To evaluate thermal cycle effect (temperature and number of cycle) on the physical and flexural properties of hybrid glass/jute fiber reinforced epoxy composites

1.4 Scope of study

In this research, a hybrid laminated composite of woven glass fibers / jute fibers reinforced epoxy was fabricated via a vacuum infusion technique. In the first stage, the process parameters of the vacuum infusion technique (pressure, soaking time and flow media) were optimized through a response surface methodology (RSM). Two level factorial design for three independent variables (pressure (X_1), soaking time (X_2) and flow media (X_3) were used to design the experiment using response surface methodology (RSM). The optimum parameters were determined from flexural properties as well as physical properties and support by several analyses. The testing was conducted on 7 plies hybrid laminated composites at constant stacking sequence and orientation. In the second stage, the hybrid laminated composites were produced using the selected optimum parameters and tested for their performance under thermal cycle effect (temperature and number of cycles). The observations were supported with several analyses (SEM, TGA etc). Tested samples of the hybrid laminated composite were investigated for fracture