UNIVERSITI TEKNIKAL MALAYSIA MELAKA

The Compatibilizing Effect of Coupling Agent on the Morphological Properties of Banana Fibre as Reinforcement for Polymer Matrix Composites

Report submitted in accordance with partial requirements of the Universiti Teknikal Malaysia Melaka for the Bachelor of Manufacturing Engineering (Engineering Materials)

By

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS TESIS*

JUDUL: THE COMPATIBILIZING EFFECT OF COUPLING AGENT ON THE MORPHOLOGICAL PROPERTIES OF BANANA FIBRE AS REINFORCEMENT FOR POLYMER MATRIX COMPOSITES

SESI PENGAJIAN : 2007/2008

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APPROVAL

This thesis submitted to the senate of UTeM and has been accepted as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials). The members of the supervisory committee are as follow:

PN. ZURINA BINTI SHAMSUDIN
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ABSTRACT

The interest in using natural fibres as reinforcement in polymer matrix composites has increased dramatically during the last few years in regard to the environmental aspect and cost-effectiveness. This report aims in studying the rheological and morphological properties of banana fibre reinforced polypropylene (PP/BF) composite as a function of fibre loading and coupling agent concentration, followed by drawing a relationship of the two parameters on the rheological-morphological properties of PP/BF composite. To conduct this research, the primary materials involved were banana fibre as the reinforcement, polypropylene (PP) as the matrix and silane as the coupling agent used. Prior to composite processing, banana fibre processing was conducted to extract banana fibres from the pseudo-stem of a mature banana (*Musacea*) plant. Fibres with length of less than 1mm were then mixed with silane at concentration of 0, 0.5, 1 and 2wt% at fibre loading of 2, 5 and 10wt%. The mixes were later subjected to rheological testing and morphological analysis. The rheological result showed that all system exhibited pseudoplasticity and incorporation of treated fibres consequent enhanced viscosity due to improved interfacial adhesion at fibre-matrix interface. However, it is observed that silane concentration of 2wt% does not yield further enhancement in the rheological properties of the composite when compared to that of 1wt%. In the aspect of morphology, the compatibilizing effect of silane is evaluated in terms of fibre orientation and dispersion. Effect of silane concentration on the morphology does not seem to be pronounced as compared to the effect of fibre loading. Increase in fibre loading causes low shear rate and the fibre concentrated at the periphery; and vice versa. However, it is found that PP/BF 10wt% with 1wt% of silane has the most promising compatibilizing effect.

ABSTRAK

Minat terhadap penggunaan gentian semula jadi sebagai penetulang dalam komposit bermatrikskan polimer telah berkembang secara mendadak sejak kebelakangan ini disebabkan oleh aspek persekitaran dan kos efektif. Matlamat penulisan kertas kajian ini adalah untuk mengkaji sifat reologi dan morfologi komposit polipropilina bertulangkan gentian pisang (PP/BF) berfungsikan muatan gentian dan komposisi agen perangkai serta perkaitan hubungan kedua-dua parameter tersebut dengan sifat reologi-morfologi komposit PP/BF. Dalam kajian ini, bahan utama termasuk gentian pisang sebagai penetulang, polipropilina (PP) sebagai bahan matriks dan 'silane' sebagai agen perangkai. Sebelum komposit difabrikasikan, pemprosesan gentian pisang dijalankan dengan mengekstrak gentian pisang dari batang semu pokok pisang (*Musacea*) yang matang. Gentian yang berpanjang kurang daripada 1 mm dicampur dengan 'silane' mengikut komposisi 0, 0.5, 1 dan 2wt% dengan muatan gentian 2, 5 dan 10wt%. Campuran kemudian melalui ujian reologi dan analisis morfologi. Keputusan ujian reologi menunjukkan semua sistem berkelakuan pseudoplastik dan penambahan gentian yang dirawat meningkatkan kelikatan disebabkan oleh lekatan kuat pada antara-muka gentian-matriks. Namun, penggunaan 'silane' berkomposisi 2wt% tidak menunjukkan peningkatan dalam sifat reologinya apabila dibandingkan dengan yang berkomposisi 1wt%. Dari aspek morfologi, kesan kesesuaian 'silane' dinilai dari segi orientasi dan taburan gentian. Kesan komposisi 'silane' ke atas morfologi kurang ketara apabila dibandingkan dengan kesan muatan gentian. Penambahan muatan gentian menyebabkan kadar ricih yang rendah dan gentian tertumpu pada kawasan periferi dan sebaliknya. Namun, keputusan menunjukkan PP/BF dengan muatan gentian 10 wt% dan komposisi 'silane' sebanyak 1wt% mempunyai kesan kesesuaian yang memberangsangkan.

DEDICATION

For my beloved parents

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$\left(\frac{d\gamma_s}{dt}\right)$	-	Shear Rate
τ_s	-	Shear Stress
%	-	Percent
°C	-	Degree Celsius
µm	-	Micrometer
A	-	Ccross Sectional Area
AEAPTMS	-	Aminoethylaminopropyltrimethoxy silane
AMPTES	-	(3-aminopropyl) triethoxysilane
ASTM	-	American Society for Testing and Materials
cm	-	Centimeter
cm^3	-	Centimeter Cube
CMC	-	Ceramic Matrix Composite
CO_2	-	Carbon Dioxide
D	-	Die Orifice Diameter
et al.	-	Et alia (and others)
etc.	-	Et cetera
FRIM	-	Forest Research Institute of Malaysia
g	-	Gram
GMA	-	Glycidyl Methacrylate
GPa	-	Giga Pascal
H_2O	-	Chemical formula for water
HDS	-	Hexadecyltrimethoxy-silanes
HM	-	High Modulus
HT	-	High Tenacity

i.e.	-	That is
IM	-	Intermediate Modulus
Inc.	-	Incorporated
ISS	-	Interfacial Shear Strength
k	-	Constant
kg	-	Kilogram
kN	-	Kilo-Newton
KOH	-	Potassium Hydroxide
kV	-	Kilovolt
L	-	Length
LDPE	-	Low Density Polyethylene
LM	-	Low Modulus
Ltd	-	Limited
MA	-	Maleic Anhydride
MAPP	-	Maleic-Anhydride Grafted Polypropylene
mg	-	Milligram
min	-	Minute
mL	-	Millilitre
mm	-	Millimeter
MMC	-	Metal Matrix Composite
MPa	-	Mega Pascal
MPRS	-	γ-mercaptoproyltrimethoxy
MPS	-	γ-methacryloxypropyltrimethoxy
n	-	Power Law Index / Flow-Behavior Index / Flow Index
NaOH	-	Sodium Hydroxide
NF	-	Natural Fibre
OH	-	Hydroxyl
P	-	Test Pressure
Pa.s	-	Pascal-second
PF	-	Phenol Formaldehyde

PMC	-	Polymer Matrix Composite
PP	-	Polypropylene
PP/BF	-	Banana Fibre Reinforced Polypropylene Composite
Q	-	Flow Rate
rpm	-	Revolution per Minute
S_1	-	Start Point
S_2	-	End Point
Sdn. Bhd.	-	Sendirian Berhad
SEM	-	Scanning Electron Microscopy
SFRTs	-	Short Fibre Reinforced Thermoplastics
SM	-	Standard Modulus
U	-	Velocity
UHM	-	Ultrahigh Modulus
UK	-	United Kingdom
UPE	-	Unsaturated Polyester
US	-	United States
UTM	-	Universal Testing Machine
vol%	-	Percent of volume fraction
wt%	-	Percent of weight fraction
Y	-	Polymerizable vinyl group in Silane
$YR_1Si(OR_2)_3$	-	Chemical formula for Silane
γ	-	Apparent Shear Rate
Δt	-	Time Travel from S_1 to S_2
η	-	Apparent Viscosity

CHAPTER 1
INTRODUCTION

1.1 Background

In the past few decades, research and engineering interest has shifted from monolithic materials to fibre-reinforced polymeric materials. These composite materials (notably aramid, carbon and glass fibre reinforced plastics) now dominate the aerospace, leisure, automotive, construction and sporting industries. Synthetic fibres are widely used in reinforced plastics due to their excellent mechanical properties. However, these fibres have serious drawbacks in terms of cost-effectiveness and environmental effect. The shortcomings have been highly exploited by proponents of natural fibre composites (Wambua *et al*., 2003).

The primary advantages of using natural fibres as reinforcements in polymer matrix composites are low density, low cost, nonabrasive nature, high specific strength and modulus, high availability, and easy recyclability (Gañán & Mondragon, 2003; Kahraman *et al*., 2005). Clemons and Caulfield (2005) had reported that one of the largest areas of recent growth in natural fibre polymeric composites is the automotive industry, particularly in Europe, where natural fibres are typically combined with polypropylene, polyester, or polyurethane to produce components such as door, trunk liners, parcel shelves, seat backs, interior sunroof shields and headrests. Various natural fibres that have been employed significantly into automotive industry include flax, hemp, jute, sisal, kenaf, and coir (Bledski *et al*., 2002).

In tropical countries like Malaysia, bananas (*Musaceae*), which are a type of agricultural crops, are available in abundance. The total planted area of banana in Malaysia is 33,704.2 hectares (MOA, 2006). Banana fibre at present is a waste product of banana cultivation. Hence, without any additional cost input, banana fibre can be obtained for industrial purposes. Banana fibre, the cellulosic fibre obtained from the pseudo-stem of a banana plant, is a bast fibre with relatively good mechanical properties (Pothan *et al*., 2003).

There are, however, a few bottlenecks of using natural fibres in polymeric composites, such as poor wettability, incompatibility of hydrophilic cellulosic fibres and typical hydrophobic thermoplastic, high moisture absorption by the fibres as well as low processing temperature permissible (Wambua *et al*., 2003; Kahraman *et al*., 2005). The most important problem is fibre-matrix adhesion. The role of the matrix in a fibre reinforced composite is to transfer the load to the stiff fibres through shear stresses at the interface. This process requires a good bonding between the polymeric matrix and the fibres (Wambua *et al*., 2003). However, the inherent polar cum hydrophilic nature of the cellulosic fibres and the non-polar cum hydrophobic nature of polymers result in poor adhesion at the interface of the two constituents, thus, further consequent in poor mechanical properties of the natural fibre reinforced polymer composites.

In order to enhance the fibre/matrix interactions, it is possible to employ chemical treatment such as fibre surface modification or addition of coupling agents (Gañán & Mondragon, 2004). Various chemical reagents have been studied by researchers to investigate the compatibilizing effect between the matrix and fibres, such as organosilane, alkoxysilanes, maleic anhydride (MA), maleated (maleic-anhydride-modified) polypropylene (MAPP), isocyanates, sodium hydroxide etc. Among these, it is reported that MAPP has been particularly successful as a coupling agent in cellulose-polypropylene composites (Kahraman *et al*., 2005).