UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PERFORMANCE ANALYSIS OF MINERAL FIBRE REINFORCED POLYETHYLENE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) (Hons.)

by

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This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing (Manufacturing Process) (Hons.). The member of supervisory is as follow:

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(PROF. MADYA IR. DR. SIVARAO SUBRAMONIAN)

ABSTRAK

Kapas batu adalah salah satu contoh daripada serat mineral. Kapas batu juga merupakan sejenis serat bukan organik yang dihasilkan dengan proses letupan stim, dan diikuti dengan proses penyejukan. Amphibolite adalah bahan utama dalam kapas batu. Selain daripada itu, kapas batu juga merupakan salah sejenis bahan penebat. Ciri-ciri untuk kesemua bahan penebat adalah konduktiviti haba yang rendah, biasanya lebih rendah daripada 0.1 W/Mk. Polietilena (PE) adalah polimer termoplastik yang terdiri daripada rantaian panjang etilena monomer. Polietilena dibahagikan kepada polietilena ketumpatan rendah dan polietilena ketumpatan tinggi. Daripada penyelidikan yang dilakukan oleh para penyelidik, didapati bahawa hanya beberapa orang penyelidik sahaja yang menyelidik tentang batu kapas sebagai pengisi, tiada juga daripada mereka yang menggunakan kapas batu sebagai pengisi untuk komposit matriks polimer serta menganalisis ciri-ciri mekanikalnya. Oleh situ, kajian saya bertujuan untuk menyiasat ciri-ciri mekanikal komposit polietilena ketumpatan tinggi berisi kapas batu dengan pelbagai nisbah berat kapas batu, iaitu dari 0 – 40 wt%. Ujian-ujian mekanikal seperti ujian tensile, ujian flexural dan ujian shore hardness digunakan untuk menyiasat ciri-ciri mekanikal komposit polietilena ketumpatan tinggi berisi kapas batu, manakala scanning electron microscopy (SEM) digunakan untuk mengaji struktur mikro tersebut. Software CES EduPack digunakan untuk membantu mencadangkan produk untuk komposit polietilena ketumpatan tinggi berisi kapas batu menurut ciri-ciri mekanikalnya. Daripada keputusan ujian, didapati bahawa specimen berisi dengan 20 wt% kapas batu mempunyai prestasi yang paling bagus dalam ujian tensile, manakala specimen berisi dengan 40 wt% kapas batu mempunyai prestasi yang paling bagus dalam ujian flexural dan ujian shore hardness.

ABSTRACT

Stone wool is one of the examples of mineral fibre. It is an inorganic fibrous substance produced by steam blasting, and followed by cooling. Amphibolite is the main component of stone wool. Besides, stone wool is also an insulating material. The feature of all insulating materials share is their low thermal conductivity factor λ, usually lower than 0.1 W/Mk. Meanwhile, polyethylene (PE) is a thermoplastic polymer consisting of long chains of the monomer ethylene. PE is classified into low density polyethylene (LDPE) and high density polyethylene (HDPE). Review passed work by other researchers, it is found that only few researchers do research on the stone wool as reinforced fibres, and none of them used stone wool as reinforcement for polymer matrix composite (PMC) and analyze its mechanical properties. Thus, my study is aiming to characterize the mechanical properties of stone wool reinforced HDPE with various stone wool weight ratio, which is between 0 – 40 wt%. Mechanical tests such as tensile test, flexural test, and shore hardness test are used to characterize the mechanical properties of the stone wool reinforced HDPE, while scanning electron microscope (SEM) is used to study the microstructure. Software CES EduPack is used to propose products for stone wool reinforced HDPE composite according to its mechanical properties. From the results, the 20 wt% stone wool loaded specimen has the best performance in tensile test, while the 40 wt% has the best performance in both flexural test and shore hardness test.

DEDICATION

To my beloved parents and siblings.

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LIST OF ABBREVIATIONS, SYMBOLS, NOMENCLATURES

Al_2O_3	- Alumina
ASTM	-American Standard Test Method
AWPEX	- Apatite-wollastonite particulate reinforced polyethylene
BN	-Boron nitride
CMC	- Ceramix matrix composites
CTDIC	- Cardinal derivative of toluene diisocyanate
EL	-Elongation
Fe	-Ferum
FRC	-Fibre Reinforced Composite
GPa	-Giga Pascal
HDPE	- High density polyethylene
HDPE-r	- Recycled high density polyethylene
LDPE	- Low density polyethylene
MMC	- Metal matrix composites
MPa	-Mega Pascal
NaOH	-Sodium hydroxide
PE	- Polyethylene
PEMA	- Polyethylene grafted with maleic anhydride
PMC	- Polymer matrix composites
rpm	-Revolutions per minute
SEM	- Scanning electron microscope
SFFT	- Single fibre fragmentation test
SRPE	- Sand reinforced polyethylene
SS	-Sago starch
TCP/HDPE	- Tri-calcium phosphate-high density polyethylene
UTS	-Ultimate tensile strength

β	-Beta
℃	- Degrees Celcius
ρ	- Density
ε_p	-Flexural strain
σ_p	-Flexural Strength
l_f	-Final gauge length
g	-Gram
in	- Inches
kg	- Kilogram
kN	-Kilo Newton
L	- Length of the lower support
P_p	- Load applied to the planar surface of the specimen
m	-Mass
µm	-Micrometer
P_{max}	-Maximum load
E	-Modulus
>	- More than
A_o	-Original cross sectional area
l_o	-Original gauge length
%	- Percent
±	-Plus or Minus
ε	-Strain
σ	-Stress
S_u	-Tensile strength
d	-Thickness of the specimen.
v	- Volume
wt%	-Weight percent
b	-Width of the specimen

CHAPTER 1

INTRODUCTION

1.1 Background

Composite is a material made from two or more constituent materials with different chemical and physical properties. When the constituent materials are combined, a composite material which has characteristics different from the individual components will be produced. Examples of typical engineering composite materials are polymer matrix composite (PMC), metal matrix composite (MMC) and ceramic matrix composite (CMC). The polymer matrix in a polymer matrix composite consists mainly of thermoset or thermoplastic resin.

According to Rassiah et al. (2011), polymer is a long chain of repeated atoms and produced by joining the molecules which are known as monomers. In other words, polymer is a high molecular weight compound consisting of many repeated small segments. By using two different types of reactions, all modern polymers can be created: poly-condensation as well as poly-addition. They can all produce linear or branched polymers. The strong covalent bonds formed between the molecules are primary bonds. On the other hand, the secondary bonds which are an order of magnitude weaker than the covalent bonds are also formed.

Besides, stone wool is a natural material that formed from one of the earth's most abundant material, and this material are spun into wool from rock at a temperature of about 1600 ℃ followed by stream of air or steam. Some of the rock wool produced by some advanced techniques that spinning molten rock on high speed spinning wheels like the process prepared cotton candy. The final product is a mass of fine, and intertwined fibres with a typical diameter of 6 to 10 micrometers. Heat temperature that stone wool can withstand is in the range between 700℃ - 850℃.Stone wool itself has some very good properties and can act as insulator and means in build fire protection.

1.2 Problem Statement

Polymeric composite, is a combination among polymer with another material as separate phases and this combination can obtain unique level of properties. Various researches have been done on different fibre or particulate reinforced polymer composites from the past. And the results usually show that, fibre of particulate reinforcements help to increase the properties of the composites. However, there has been little investigation based on the stone wool reinforced composite, and furthermore the matrix used is not polymer but ceramic. There is lack of information on the stone wool reinforced polymer composite and its properties. Thus, this study is aiming on characterizing the stone wool reinforced HDPE composite, by using different mechanical test (tensile test, flexural test, shore hardness test) and scanning electron microscopy (SEM).

1.3 Objectives

The objectives of this study are to:

a) Characterize the stone wool reinforced HDPE composite;

b) Propose product for the stone wool reinforced HDPE composite.

1.4 Scope

This study is mainly focusing on the characterization of the stone wool reinforced HDPE composite with different stone wool weight ratio (%), which is between 0 to 40 wt%. The composites are manufactured using hot press moulding technique. Tensile test, flexural test, shore hardness test and scanning electron microscopy (SEM) are carried out in this study. Tensile and flexural and shore hardness test are carried out to determine the mechanical properties of the specimens. Their microstructure are observed using SEM. Other filler weight ratio of stone wool and test will not be discussed. Product is then proposed for stone wool reinforced HDPE composite based on its mechanical properties.

1.5 Composite

Composite is usually defined as a combination of two or more components differing in form or composition. In such a manner, the properties and structural performance are superior to those of the constituents acting independently. In other words, a proper combination of materials into composites gives rise to properties which transcend those of the constituents, as a result of the principle of combined action (Akovali, 2001). Composites enable us to make better use of their virtues, as well as helping us to minimize the effects of their deficiencies.

Most of the materials of biological origin are generally composites. This is why the composite concept is said to be not invented by human. For example, bone achieves its combination of strength as well as lightness by combining crystals of apatite with fibres of protein collagen. Meanwhile, wood contains cellulose fibres surrounded by hemicelluloses and lignin. Nowadays, composites are produced to optimize material properties: chemical, physical, optical, acoustic as well as mechanical properties. There has been an increasing demand for the materials that are stronger, stiffer and lighter in aeronautic, civil engineering and in various structural applications since the early 1960s.

Composites consist of a reinforcing material (also known as reinforcement and filler) embedded in a matrix. Dating back to 4000 B.C., the oldest composite is the addition of straw to clay to make bricks for building. In this combination, the straws are the reinforcing fibres while the clay is the matrix. Another example is reinforced concrete, where the concrete itself is brittle and has no useful tensile strength. By reinforcing steel rod (rebar), necessary tensile strength is imparted to the composite. Incorporating dispersed phase into the matrix helps to increase the strength and to improve overall properties. The matrix can be an engineering material such as ceramic, metal or polymer, thus the combinations are known as ceramic matrix composites (CMC), metal matrix composites (MMC), and polymer matrix composites (PMC).

Matrices in composites are generally of low modulus, while reinforcing elements are typically 20-150 times stiffer and 50 times stronger. Composites are usually used for their structural properties, where the most commonly use reinforcing component is in fibrous or particulate form. Hence, the definition above can be restricted to such systems that contain a continuous/discontinuous fibre or particle reinforcement, all embedded in a continuous phase known as matrix. A reinforcement phase usually exists with substantial volume fractions, usually 10% or more.

There are three common types of composites can be described as:

a) Particle strengthened composites;
b) Discontinuous fibre reinforced composites;
c) Continuous fibre reinforced composites.

Functions of each component are different: in particle-strengthened composites, the main load is bear by the matrix, and the motion of dislocations in the matrix is obstructed by the small dispersed particle; and the load is distributed between the matrix and particles. While in fibre reinforced composites (FRC), the main load is bear by the fibres, and the function of the matrix is mainly to load distribution and its transfer to the fibres. There is another group of composites in addition to these types of composites: laminar composites, where the reinforcing agents are in the form of sheets bonded together and are often impregnated with more than one continuous phase in the system.

1.5.1 Polymer Matrix Composite (PMC)

Polymer matrix composite (PMC), consists of long or short fibres (the dispersed phase) in a polymer matrix (continuous phase). The reinforcement of PMC can sometimes be in particles form as well. The reinforcement in a PMC is strong and stiff, and they have high specific strength (strength-to-weight ratio) and specific stiffness (stiff-to-weight ratio) as compared to ceramic matrix composite (CMC) in which the reinforcement is mainly used to improve fracture toughness. In addition, PMC have also improved fatigue resistance as well as higher creep resistance.

The function of the polymer matrix in PMC is to bond the fibres together as well as transferring loads between them. Thus, the PMC is usually designed so that the mechanical loads subjected to the PMC structure are supported by the reinforcement. By themselves, the fibres in PMC have little structural value, they have stiffness in their longitudinal direction but no transverse stiffness of strength, while for the polymer matrix, it is less strong and less stiff, but is tougher and often more chemically inert than the fibres (Kalpakjian and Schmid, 2010).

The percentage of fibres in PMC usually ranges from 10 to 60%. However, the highest practical fibre content is 65%, but higher percentage generally gives poorer structural properties. Besides, when more than one type of fibre is used as reinforcement in a polymer matrix, the composite is known as “hybrid”. Usually, hybrids have better properties than the single fibre composite and expensive.

1.5.2 Metal Matrix Composite (MMC)

The first focused efforts to develop metal matrix metal matrix composite (MMC) originated in the 1950s and early 1960s in order to extend the structural efficiency of metallic material while retaining their advantages (Miracle and Donaldson, 2001). The basic attributes of metals reinforced with hard ceramic particles or fibres are:

a. Improved strength and stiffness;
b. Improved creep and fatigue resistance;
c. Increased hardness, wear and abrasion resistance.

These properties of MMC give potential for exploitation in a range of engine and pump applications such as compressor bodies, connecting rods and etc. The advantages of a metal matrix over a polymer matrix are higher elastic modulus, toughness, ductility and higher density (Kalpakjian and Schmid, 2010). Matrix materials in MMC are usually aluminium, aluminium-lithium alloy, magnesium, titanium and copper.

A wide range of manufacturing methods has been used on a laboratory or development scale, however, at this stage relatively little can be said about large scale production processes for MMCs. Techniques that have been described in detail are:

a. Unidirectional solidification of eutectics or other constitutionally-appropriate alloys;
b. Liquid-metal infiltration, often under vacuum, of pre-packed fibre bundles or other preforms;
c. Liquid-phase infiltration during hot pressing of compacts consisting of matrix alloy sheets wrapped or interleaved with arrays of reinforcing wires;
d. Hot pressing or drawing of wires pre-coated with the matrix alloy;
e. Co-extrusion of prepared composite billets.