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JUDUL: The Mechanical Properties and Morphology Study of the Silica-Reinforced Polyethylene (PE) Composites

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**TAJUK: THE MECHANICAL PROPERTIES AND MORPHOLOGY STUDY OF  
THE SILICA- REINFORCED POLYETHYLENE (PE) COMPOSITES**

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**“BERKHIDMAT UNTUK NEGARA KERANA ALLAH”**

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## DECLARATION

I hereby, declared this thesis entitled “The Mechanical Properties and Morphology Study of the Silica-Reinforced Polyethylene (PE) Composites” is the results of my own research except as cited in references.

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## APPROVAL

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## ABSTRACT

The objectives of this research are to study the relationship of morphology and mechanical properties of the silica-reinforced polypropylene composites and to find optimum ratio of silica to PE. In this research, polyethylene (PE) is used as the matrix of the composites, while the reinforcement is silica particle with size of 5.221 $\mu$ m. Polyethylene is used as matrix due to its lightweight, good mechanical performance, economic in fabricating and accepted to many types of filler. As we know, silica is a type of mineral fillers which is added to polymers in order to reduce cost and improve stiffness. In the sample preparation, the silica particles are compounded with PE to produce composites in the form of pellets. The mixing of matrix and filler is performed at three different fillers loading which are 20%, 30% and 40% of volume. Then, the compounding was brought to the hot press machine to produce a plate specimen and tested mechanically to investigate the strength and flexural properties. At the same time, the morphology study of fracture surface for tensile test samples will be observed under Scanning Electron Microscope (SEM). From the result, it shows that tensile modulus, flexural strength and elongation to break for flexural were enhanced by addition of silica in 20% and 30% volume to the PE. A strong filler or matrix adhesion would lead to enhance strength of particulate composites. Nevertheless, it did not show improvement in the tensile strength of the composite. For the morphology of fracture surface, it was indicated that the dispersion of the particles in the 20% was fairly good. Whereas the PE with 40% silica particles are severely agglomerated in PE matrix due to the particles are not disperse well in the matrix. It can be concluded that the shape, particle size, aspect ratio, volume fraction and specific surface area of the filler particles were affected the mechanical properties of the composite.



## ABSTRAK

Peyelidikan ini adalah bertujuan untuk menguji hubungan antara morfologi dengan sifat mekanikal yang menggunakan komposit silika-Polietena dan mencari nisbah di antara silika dan PE yang paling sesuai. Dalam kajian ini, Polietena digunakan sebagai matrik, sementara silika digunakan sebagai peneguhan. Polietena dipilih sebagai matrik kerana keringanan bahan, pelaksanaan kebaikan mekanikal, ekonomi dalam fabrikasi dan diterima oleh banyak jenis pengisi. Sebaliknya, silika adalah salah satu mineral pengisi yang diisi ke dalam polimer demi mengurangkan kos dan meningkatkan kekakuan bahan. Dalam penyediaan sampel, partikel akan dicampurkan dengan Polietena pada pecahan mengikut keberatan/ isipadu yang sesuai untuk menghasilkan komposit dalam bentuk gentelan. Pemprosesan komposit bermula dengan pengadunan Polietena dengan silika pada tiga komposisi yang berlainan, iaitu 15, 20 dan 30wt%, dalam mesin pengadun dalaman. Selepas penyemperitan, sample akan melakukan ujian kekuatan tarikan, kekuatan lenturan dan analysis morfologi. Selain itu, perbandingan sifat mekanikal antara komposit yang berbeza akan dilakukan bagi menentukan komposit yang memberikan sifat mekanikal yang terbaik. Menurut keputusan yang diperolehi, modulus ketegangan, kekuatan lenturan dan pemanjangan sebelum putus bagi lenturan dapat ditingkatkan dengan penambahan 20 % dan 30% partikel ke dalam PE. Peneguhan atau lekatan matriks yang kuat dapat membantu dalam memperbaiki kekuatan komposit zarah. Walau bagaimanapun, kajian ini tidak menunjukkan kesan pbaikan yang jelas untuk memperbaiki kekuatan tegangan bagi komposit. Bagi morfologi permukaan patah, ia menunjukkan taburan partikel yang agak baik pada 20%. Sementara bagi PE dengan 40% partikel silika, terdapat banyak gumpalan dalam matriks PE yang disebabkan oleh taburan partikel yang tidak sekata. Kesimpulannya, kajian ini mendapati bahawa bentuk, saiz partikel, nisbah aspek, pecahan isipadu dan luas permukaan khusus bagi partikel peneguhan akan mempengaruhi persembahan ciri-ciri mekanikal bagi komposit.

## **DEDICATION**

To my beloved family

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## NOMENCLATURE

ATCs	-Advanced Thermoplastic Composites
°C	-Degree Celsius
DSC	- Differential Scanning Calorimetry
E	- Young Modulus
Fg	-Figure
HDPE	- High density Polyethylene
kV	- Kilo voltage
LDPE	- Low density Polyethylene
LLDPE	- Linear low density Polyethylene
MDPE	- Medium density Polyethylene
PAI	- Polyamide-imide
PE	- Polyethylene
PEEK	- Polyetheretherketone
PEI	- Polyether-imide
PP	-Polypropylene
PPS	- Polyphenylene sulfide
pH	- Potential of Hydrogen
PMCs	- Polymer Matrix Composite
SCF	- Short carbon fiber
SEM	-Scanning Electron Microscope
SiO <sub>2</sub>	- Silica
TPO	- Thermoplastic olefin blend
UV	- Ultraviolet

# CHAPTER 1

## INTRODUCTION

### 1.1 Overview of project

Based on the estimation of Professor Roger Rethon, around 15 million tones of mineral fillers are used in all polymer type worldwide (Anon, 2005). The types of fillers to be used in polymer will affect the performance, properties and processing characteristics of thermoplastics. One of the main roles of using filler in the polymer is to improve the properties of the composite. There are many types of fillers occur in the world such as silica, mica, calcium carbonate and others. The choosing of silica for this research due to the characteristic itself such as dimensional stability, thermal conductivity, electrical insulation, moisture resistance and low cost when mixing with polymer matrix to form a composite.

When silica particles added into polymer matrix to form a composite, they play an important role in improving electrical, mechanical and thermal properties of the composites. Apart from that, inorganic fillers are commonly added in thermoplastic olefin blend formulations to increase their stiffness, improve their dimensional stability and lower the cost of the compounds (Liu *et al*, 2006).

According to the Wang *et al.* (2002) has declared that silica filled epoxy based materials are chosen as the most promising candidates because of their advantages such as low cost, adjustable curing temperature and curing rate by selecting a proper catalyst and good adhesion to most of the substrate. However, it is reported that the epoxy resin without silica filler cannot meet the requirement for its thermo-mechanical properties, while the addition of the silica filler will reduce the opportunity for solder bumps to contact copper pad during reflow. Therefore, the filler size and concentration have been carefully chosen to enhance the thermo-mechanical properties without sacrificing the bonding yield.

Currently many studies have focused on how particle size affects mechanical properties. The shape, size, volume fraction and specific surface area of such added particles have been found to affect mechanical properties of the composites greatly (Yong *et al.*, 1977).

Polyethylene is being used as the matrix of the composites, while the reinforcement used is silica in this research. Meanwhile, silica is a type of mineral fillers which is added to polymers in order to reduce cost and improve stiffness. The use of thermoplastic composites offers several advantages compared to that of the thermoset materials. These useful properties include high impact resistance, damage tolerance, low price and recyclable properties.

In this project, experiment is conducted in order to determine how the particle size, shape and volume content of silica affects the tensile strength, bending elastic modulus and bending strength. Besides that, fracture surface of the specimen will be observed after tensile test. Spherical silica particles of 5.221 $\mu$ m in diameter will disperse into a polymer matrix with various composition ratios.



The composition effects of particle sizes will be discussed on the result and discussion part.

## **1.2 Problem statement**

Generally, the silica is used as fillers in polyolefin in order to produce a superior mechanical property composite. However, silica is a polar while polyolefin is non polar thus coupling agents which are expensive is needed to improve the interaction between the two materials. Furthermore, these results in agglomeration of the filler thus increase their size and lower down the surface area without using the coupling agents. In this study, micro size of silica particle will be used in order to observe the affects for the mechanical properties of the composite.

## **1.3 Objectives**

- b) To investigate the effect of silica particles on the mechanical properties of polyethylene.
- c) To compare the strength and flexural properties with different filler loading in the composite.
- d) To observe the morphology behavior of the composite in relation to their mechanical properties.



## **4.1 Scope of study**

Throughout the entire project, the scope for this research is going to investigate the effect of the silica particles on the mechanical properties of composite when mixing with polyethylene. Apart from that, the mechanical properties of silica-polyethylene with different filler loading are going to be compared after all the samples are undergone the tensile test and flexural test. After the tensile testing, the fracture surface of the composite will be observed by using the Scanning Electron Microscope (SEM).

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction to composite material**

A composite material can be defined as a macroscopic combination of two or more distinct materials, having a recognizable interface between them. However, the definition can be restricted to include only those materials that contain a reinforcement supported by a binder material. This is because the composites are usually used for their structural properties. Therefore, composites typically have a discontinuous fiber or particle phase that is stiffer and stronger than the continuous matrix phase. Generally, the reinforcement is provided with a substantial volume fraction (10% or more) of the discontinuous phase (Michelle, 1998).

Composites can be divided into classes in various manners. One simple classification scheme is to separate them according to reinforcement forms which are particulate-reinforced, fiber-reinforced or laminar composites. Furthermore, fiber-reinforced composites can be divided into those containing discontinuous or continuous fibers (Michelle, 1998).

Reinforcement is considered to be a “particle” if all of its dimensions are roughly equal. Thus, particulate-reinforced composites include those reinforced by spheres,

rods, flakes and any other shapes that are roughly the same length in all directions. There are also materials, usually polymer which is containing particles that extend rather than reinforce the material. Basically, there are referred to as “filled” systems. These composites are not usually considered to be particulate composites due to the filler particles are included for the purpose of cost reduction rather than reinforcement. Nonetheless, the filler will also reinforce the matrix material in some cases (Michelle, 1998).

Fiber-reinforced composites contain reinforcement having lengths much greater than their cross-sectional dimensions. Such a composite is considered to be a discontinuous fiber or short fiber composite if its properties vary with fiber length. Most of the continuous fiber composites contain fibers that are comparable in length to the overall dimensions of the composite part.

Composite materials were developed because no single, homogeneous structural material could be found that had all of the desired attributes for a given application. Fiber-reinforced composites were developed in response to demands of the military aerospace community, which is under constant pressure for materials development in order to achieve improved performance. This is because fiberglass-reinforced plastics had been used successfully in filament-wound rocket motors and in various other structural applications by the end of the war. These materials were put into broader use in 1950s and initially seemed to be the only viable approach available for significant reductions in structural weight along with elimination of corrosion and crack formation in high-performance structures (Michelle, 1998).

Inexpensive fiberglass composites are used today in a wide variety of applications. More advanced fiber-reinforced composites have been limited in their commercial use because of high material cost, lack of widely distributed property and processing



data bases and the absence of rapid and efficient manufacturing techniques. Fiber composites offer many superior properties. Almost all high strength or high stiffness materials fail because of the propagation of flaws. A fiber of such a material is inherently stronger than the bulk form because the size of a flaw is limited by the small diameter of the fiber. In addition, it is found that it will not propagate to fail the entire assemblage of fibers as would happen in the bulk material even if a flaw does produce failure in a fiber when the equal volume of fibrous and bulk material are compared. Furthermore, preferred orientation may be used to increase the lengthwise modulus, and perhaps strength, well above isotropic values. When this material is also lightweight, there is a tremendous potential advantage in strength-to-weight and stiffness-to-weight ratios over conventional materials. These desirable fiber properties can be converted to practical application when the fibers are embedded in a matrix that binds them together, transfer load to and between the fibers and protects them from environments and handling (Michelle, 1998).

## **2.2 Polymer Matrix Composites**

### **2.2.1 Introduction**

Polymer-matrix composites consist of glass, carbon, or other high-strength fibers in a thermoset or thermoplastic resin. Polymer matrix composites are the best established advanced composite material because the mechanical properties of the polymers are inadequate for many structural purposes. Besides that, the processing of polymer matrix composites does not involve in high pressures or require high temperatures. Generally, polymers matrices are classification into three classes which are thermoplastics, thermosetting and rubbers (Matthews *et al.*, 2002).

The main advantages of PMCs are their low maximum working temperatures, high coefficients of thermal expansion and hence dimensional instability and sensitivity to radiation and moisture. Apart from that, the polymer matrix composite materials are strong, stiff, and corrosion resistant. This is because PMCs adopt flat, gently curved, or sharply sculpted contours with ease, providing manufacturers with design flexibility. In addition, composites offer the opportunity for parts consolidation and lower assembly costs (Norman *et al.*, 1997).

### 2.2.2 Matrix

The matrix is the “weak link” in the composite, especially because thermosetting resins do not presently exist that allow utilization of the stresses that the fibers are able to withstand. Therefore, resins may be micro crack and craze to form larger cracks through coalescence of microcracks, debond from the fiber surface and generally break down at composites strain far lower than desired when the composite is under load. Nonetheless, the matrix resin provides many essential functions which is the matrix keeps the reinforcing fibers in the proper orientation and position so that they can carry the intended loads, distributes the loads more or less evenly among the fibers, provides resistance to crack propagation and damage and provides all of the interlaminar shear strength of the composite (Michelle, 1998).

Thermoplastic is one of type's matrices which are used to form the thermoplastic polymeric composites. The use of thermoplastic composites offers several advantages compared to that of the thermoset materials. These useful properties include high impact resistance, damage tolerance, low price and recyclable properties (Huang *et al.*, 2007).



Thermoplastics readily flow under stress at elevated temperatures, so that it allows them to be fabricated into the required component and become solid and retain their shape when cooled to room temperature. Furthermore, these polymers may be repeatedly heated, fabricated and cooled and consequently scrap may be recycling, though there is evidence that this slightly degrades the properties probably because of the reduction in molecular weight.

Thermoplastics are linear polymers and they do not cross-link to form a rigid network although the chains may be branched. A branched chain is still discrete unlike the chains in a crosslink network. Thermoplastics are easily broken by the combined action of thermal activation and applied stress due to the weak van der Waals bonding between the chains in the thermoplastic. This is why the thermoplastics flow at elevated temperatures.

Nevertheless, thermoplastic matrix materials are tougher and offer the potential of improved hot or wet resistance. Because of their high strains to failure, they also are the only matrices currently available that allow, at least theoretically, the new intermediate modulus, high strength carbon fibers to use their full strain potential in the composite. In addition, because of thermoplastic matrices have an unlimited shelf life before molding and they can potentially be remolded by the application of heat and pressure, thermoplastic matrix composites also offer the possibility of lower-cost fabrication. These materials include such resins as polyetheretherketone (PEEK), polyphenylene sulfide (PPS), polyether-imide (PEI) and others, such as polyamide-imide (PAI), which is originally molded as a thermoplastic but is then postcured in the final composite to produce partial thermosetting characteristics (Michelle, 1998).

Apart from that, thermoset is also another type of matrices which is mixed with fibre