

COMPARATIVE STUDY ON VIBRATION PERFORMANCE AND  
MECHANICAL PROPERTIES BETWEEN NATURAL AND SYNTHETIC  
SILICA BASED POLYSILOXANE

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## **CHAPTER 1**

### **INTRODUCTION**

#### **1.0 General Introduction**

People have dreamed of machines, which would free them from unpleasant, dull, dirty and dangerous tasks and work for them as servants, for centuries if not millennia. One of way most to reduce unwanted vibration is to stop or modify the source of the vibration. One of the approaches to protecting a device from steady state harmonic disturbance at a constant frequency is a vibration absorber. The vibration will occurs through source of the machine, transmitter and the final stage of the machine. The vibration in the machine can affects the quality of the machining process and also effects to the users. Damping is often present in devices and has the potential for destroying the ability of a vibration absorber to protect the primary system. In addition, damping is sometimes added to vibration absorber to prevent resonance or to improve the effective bandwidth of operation of a vibration absorber. Also, a damper by itself is often used as a vibration absorber by dissipating the energy supplied by an applied force.

Composite materials are engineered materials made from two or more constituent materials with significantly different physical or chemical properties and which remain separate and distinct on a macroscopic level within the finished structure. From chemical aspect, composites are mixtures of chemicals. They are composed of two or more materials. Usually, the result of embedding fibers, particles, or layers of one

material in a matrix of another material, composites are designed to exploit the best properties of both components to produce a material that surpasses the performance of the individual parts.

Polysiloxane or polymerized siloxane is basically silicones which are mixed inorganic-organic polymers, where the specific terms of polysiloxane is any polymeric structure that contains repeating silicon-oxygen groups in the backbone, side chains or cross links regardless of the substitution on the silicon atom. Siloxane are one of the most rapidly expanding areas of materials research and coating development. Siloxane binders and coating system offer significant improvements in ultraviolet light, heat, chemical and oxidation resistance and longer term protection from corrosion and degradation (Mowrer *et al.*,2003). The wide industrial use of polysiloxane rubbers arises from the combination of interesting presented by these elastomer that include many benefits such as good weatherability, good electric isolating, resistance to oil, solvents, etc (Lachelle, 2011).

Inorganic filler can be natural and synthetic natures where contains silica based. Silica or silicone dioxide,  $\text{SiO}_2$  occurs commonly in nature as sandstone, silica sand or quartzite which has good abrasion resistance, electrical insulation and high thermal stability (from  $-100$  to  $250^\circ\text{C}$ ). The application of silica is wide in this industry, which had been used as glass production, investment casting, coatings, silicone production and also filler material.

## 1.2 Problem Statement

This research explores the viability of polysiloxane filled silica as a vibration absorbent in power tools. Even though, great progress has been made in power tools, vibration still cannot be avoided especially vibration exposure indirectly affects towards to human comfort. Vibration exposure can be felt on handle of power tools when human handle the machine and this situation had to overcome by designed, adding or placing an absorber on the system. The selection of material extremely needed upgrading specially for absorber such as the use of rubber, but there was a limitation or restraint on the material especially in range of properties towards life expectancy.

In this study, the percentage of polysiloxane composite filled silica should be identified. The properties of polysiloxane also should be identified to know their performance instead of fabricate the polysiloxane composite filled silica either it can absorb the vibration in the power tools or not, either it can reduce the amount of vibration or increase the vibration when apply this composite to the power tools. All the statements above will contribute the study of polysiloxane filled silica to the vibration performance. Properties of polysiloxane which is highly flexibility perhaps can absorb external disturbance caused vibratory excitation towards occurring vibration exposure towards power tools system.

## 1.3 Objectives

The objectives of this study are:

- 1) To fabricate of Polysiloxane filled silica for absorber application using compression moulding process. In order to achieve the main objectives, following objectives should be initially done:
- 2) To determine the influence of mechanical properties of polysiloxane to the both natural and synthetic silica.
- 3) To analyze the effects of polysiloxane and silica via vibration analysis this conducted on hand arm vibration power driven tools.

## 1.4 Scope of Study

The scopes for this study are:

- 1) The silica was then varied into two types which are amorphous silica that derived from rice husk, while the other is filled with synthetic amorphous silica
- 2) Compression moulding process is use to produce polysiloxane filled silica as an application of a vibration absorber.
- 3) The compression process will undergo only at 65°C with certain curing profile.
- 4) Different percentage of silica from 0% - 20% of weight will be varied as to obtain the most optimum compound to be a good vibration absorbent.
- 5) The scope of testing for mechanical test is Tensile Test ASTM D412
- 6) Vibration test will undergo to the hand arm of power driven tools according to the vibration test ISO 8662 P4.
- 7) Between the two panel filled silica, the influence of vibration analysis will be analyzing based on which are able to minimize the vibration most before and after applying the polysiloxane filled silica.

As for testing the physical properties, the particle will be tested for density and X-Ray Density Test which can identify SiO<sub>2</sub> powder.

## 1.5 Important of Study

In the study, an isolator of Polysiloxane filled silica will be successfully fabricated using the compression moulding technique. Absorber produce by Polysiloxane filled silica play an importance role on development of material used wherein it is expected that an absorber of Polysiloxane reducing the level of vibration occurrences. Hand arm power tools such as grinder and drills are known to transmit comprehensive levels of vibration in a wide frequency range to operator's hand arm. The direct contact between human body and source of the vibration will reduce by adding vibration absorbent material through the hand arm power tools.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

Preparation of right material to the silicone rubber will produce a good vibration absorber into the tools application. Further information were found in many research review to extract the information gathered as a guidance in intis study. The silicon rubber compounds have characteristics of both inorganic and organic materials and offer a number of advantages not found in other organic rubbers

#### **2.2 Composite**

Composite are the result of embedding high strength, high stiffness fibers of one material in one surrounding matrix of another material (Schwartz,1997) .Commonly composites component consist of bulk phase knows as matrix material. It is classified as metal, ceramic and polymer matrix. The major classes of structural composites that exist today can be categorized as polymer matrix composites (PMCs), metal matrix composites (MMCs), ceramic matrix composites (CMCs), carbon – carbon composites (CCCs), intermetallic composites (IMCs) or by hybrid composites (Schwartz, 1997). Another component are reinforcement, it can be exist in varies of type and shape. A reinforcing phase or component in composites can be particulate, whiskers, short or continuous fiber. The main purpose of reinforcing phase is to

improve the toughness, while at the same time maintaining the advantage of matrix behavior or properties, some example of reinforcement materials are glass, carbon, organic, boron, ceramic and metallic. Lastly composite component is interface. Interface occupies very large area per unit volume in composites. Interface region is important in determining the ultimate properties of composites. Most commonly, composite materials have a bulk phase, which is continuous, called the matrix and one dispersed, non-continuous, phase called the reinforcement or filler, which is usually harder and stronger. The advantages of the composites include:

- a) Weight reduction where high strength or stiffness to weight ratio
- b) Tailorable properties where the strength of stiffness can be tailored to be in the load direction
- c) Redundant load paths (fiber to fiber)
- d) Longer life, no corrosion
- e) Lower manufacturing costs because of lower part count
- f) Inherent damping
- g) Increased (or decreased) thermal or electric conductivity

Meanwhile, the disadvantages of the composites include:

- a) Cost of raw materials and fabrication
- b) Possible weakness of transverse properties
- c) Weak matrix and low toughness
- d) Environmental degradation of matrix
- e) Difficulty in attaching
- f) Difficulty with analysis

### **2.2.1 Polymer**

Most polymers are composed of long sequences of identical repeated units, the few exceptions being some naturally occurring and structurally complex polymer such as protein and nucleic acids. The overall chemical composition of a polymer and its distribution of molecular weights are major factors affecting its structure and properties. The effects of temperature and added solvents on polymer conformational

rearrangement, as related to the segmental motilities of various groups and chain sequences of different size in the polymer, are important both for understanding structure property relationship and for characterization. Transitions such as melting, glass transition, secondary transition can be well defined experimentally as functions of temperature, frequency, and solvent type and content (Gottfried, 2001).

A major categorization is into the classes of thermoplastic and thermosetting polymers. Thermoplastic polymer can melt or soften so that they flow and can be formed from one shape into another. In concept, this procedure could be repeated indefinitely. However, in practice, the polymer is subjected to degradation at high temperatures, limiting the number of times it can be processed and still retain useful properties (Arif *et al.*, 2011). Thermoplastics also can be dissolved, if a suitable solvent can be found. In both cases, after melting and cooling and after dissolution and precipitation, the thermoplastic material is nominally unchanged in its chemical composition.

Thermo sets are polymers cross-linked into one giant molecule. After cross-linking into a three dimensional network structure, it cannot be melted or dissolved, but only swollen by suitable solvents to form gels. It can be destroyed thermally, chemically, or mechanically into compounds of composition and structure different from the starting material. Thermoplastics may be converted into thermo sets, but it is cannot go in the reverse direction. A vulcanized rubber tire is a good example which it can be burned or ground up, but it cannot be returned to a mobile melt state capable of flow to fill a mould (Adrian, 2006).

### **2.2.2 Polymer Matrix Composite (PMCs)**

Polymer matrix composites are the most commonly used of the advanced composite materials. These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with a resistance to corrosion. The organic polymer matrix can be thermosetting or thermoplastic and gains its strength from fibers or applied filler. Although the goal is to ensure a microstructure where the fibers are well-wetted, uniformly distributed and correctly aligned, manufacturing methods often depend on the type of matrix being used.

For thermosetting matrices, the preferred methods of fabrication include liquid resin impregnation. The resin is rolled or sprayed on the fibers. The fibers can



be in a mat or distributed in a mold. The curing agent is mixed with the resin immediately before application, filament winding produced when bundles of fibers (tows) are drawn through a resin bath and wound into a mold; resin transfer molding is made fibers. These fibers are placed in a die and mixed with a pre-catalyzed resin. Lastly method is consolidation of resin molding compounds made when resins are mixed with chopped fibers and hot press molded (Wang, 1998).

Thermoplastic resins are fashioned into composites through: injection molding method using which are pellets of polymer are fed into a heated barrel and injected into a mold, while hot press molding of thermoplastics made when prepared sheets are stacked and hot pressed to form laminated structures (Rothon, 2002).

Resin systems such as polyethylene and polyesters have limited use for the manufacture of structures on their own, since their mechanical properties are not very high when compared to, for example, most metals. However, they have desirable properties, most notably their ability to be easily formed into complex shapes (Advani *et al.*, 2012). Materials such as glass, fiber and boron have extremely high tensile and compressive strength but in 'solid form' these properties are not readily apparent. This is due to the fact that when stressed, random surface flaws will cause each material to crack and fail well below its theoretical 'breaking point'.

To overcome this problem, the material is produced in fiber form, so that, although the same number of random flaws will occur, they will be restricted to a small number of fibers with the remainder exhibiting the material's theoretical strength. Therefore a bundle of fibers will reflect more accurately the optimum performance of the material. However, fibers alone can only exhibit tensile properties along the fiber's length, in the same way as fibers in a rope. It is when the resin systems are combined with reinforcing fibers such as glass, carbon and aramid, that exceptional property can be obtained. The resin matrix spreads the applied load to the composite between each of the individual fibers and also protects the fibers from damage caused by abrasion and impact. High strengths and stiffness, ease of moulding complex shapes, high environmental resistance all coupled with low densities, make the resultant composite superior to metals for many applications (Sperling *et al.*, 2006). Since Polymer Matrix Composites combine a resin system and reinforcing fibers, the properties of the resulting composite material will combine something of the properties of the resin on its own with that of the fibers on their own.

### **2.2.3 Matrices**

In composites system, matrices are a main medium body and dominant phase for the system. Commonly it classified as metal, ceramic or polymer matrices. The roles of matrices are protecting the reinforcement from environment effect and also transfer load to reinforcement (Rothon, 2002). The function of the matrix in a composite is to hold the filler in the desired position, and to provide a path for introducing external loads into the fillers. Since the strengths of matrix materials are generally lower than filler strengths by an order of magnitude or more, it is desirable to orient the fillers within a composite structure so that they will carry the major external loads.

Although the success of composites is largely due to this ability, the strength and other properties of matrix materials cannot be ignored. Matrix material properties can significantly affect how a composite will perform, particularly with respect to in-plane compression, in-plane shear, resistance to impact damage, and other inter laminar behavior, and especially when exposed to moisture and elevated temperatures.

### **2.2.4 Reinforcements**

The reinforcement is the dimensionally controlled constituent (fixed geometry) that can either be particles, fiber or flakes. A strong, inert woven and nonwoven fibrous material incorporated into the matrix to improve its metal glass and physical properties. Typical reinforcements are asbestos, boron, carbon, metal glass and ceramic fibers, flock, graphite, jute, sisal and whiskers, as well as chopped paper, macerated fabrics, and synthetic fibers (Sawyer and Grubb,1987). The primary difference between reinforcement and filler is the reinforcement markedly improves tensile and flexural strength, whereas filler usually does not. Also to be effective, reinforcement must form a strong adhesive bond with the resin.

In many cases the reinforcements have unique properties that contribute significantly to the properties of the composite. Particle reinforcements can be

considered point bodies in which the size as measured by the radius is the critical dimension. The important dimension for the fiber reinforcement is its length or the length to diameter ratio. For flakes the area or areas to thickness control the properties of the composite. The most common form of reinforcement for polymer matrix composites is fibers. The fibers carry the majority of the load and contribute to most of the stiffness in polymer composites since the matrix stiffness is usually only a very small fraction (1/10 to 1/100) of the reinforcement stiffness (Flinn and Trojan, 1990).

Reinforcements for the composites can be fibers, fabrics particles or whiskers. Fibers are essentially characterized by one very long axis with other two axes either often circular or near circular. Particles have no preferred orientation and so does their shape.

Whiskers have a preferred shape but are small both in diameter and length as compared to fibers. Figure 2.1 shows types of reinforcements in composites.

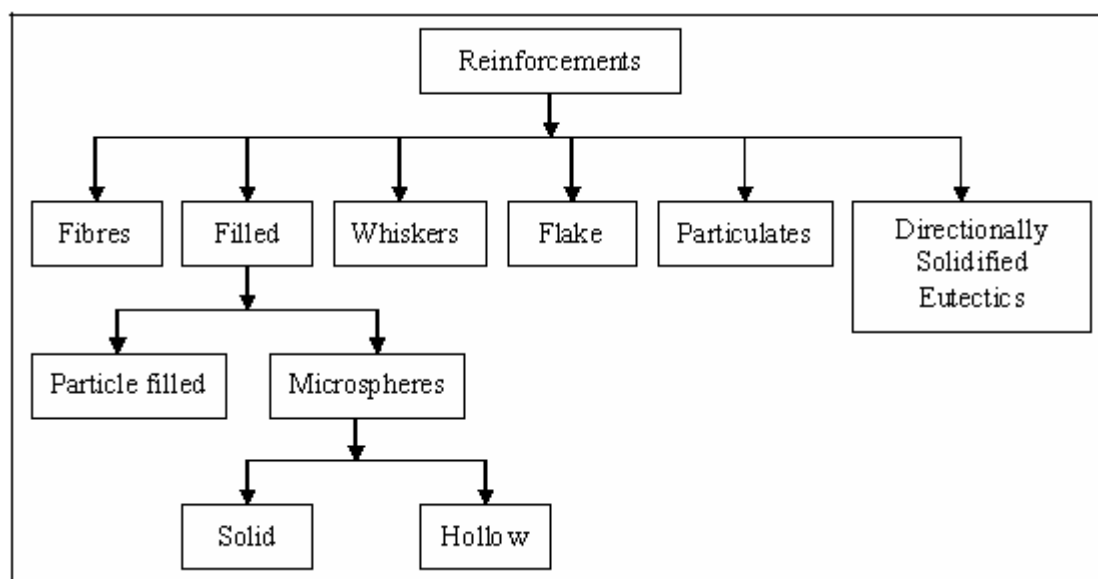


Figure 2.1: Type of Reinforcements in Composites (Schwartz,1998)

Reinforcing constituents in composites, as the word indicates, provide the strength that makes the composite what it is. But they also serve certain additional purposes of heat resistance or conduction, resistance to corrosion and provide rigidity. Reinforcement can be made to perform all or one of these functions as per the requirements (Schwartz,1998 ).

### 2.2.4.1 Fiber Composite

Fibers are the important class of reinforcements, as they satisfy the desired conditions and transfer strength to the matrix constituent influencing and enhancing their properties as desired. In general, the properties of a reinforced composite depend strongly on the direction of measurement. The design of a fiber reinforced structure is considerably more difficult than that of a metal structure, principally because of the difference in its properties in different directions. Most fiber-reinforced composites are elastic in their tensile stress-strain characteristics. Another unique characteristic of many fiber – reinforced composites is their high internal damping. This leads to better vibrational energy absorption within the material and result in reduced transmission of noise and vibrations to neighboring structures (Bitten, 1987). An advantage attributed to fiber-reinforced composites is their noncorroding behavior. However, many polymeric matrix composites are capable of absorbing moisture from the surrounding environment, which creates dimensional changes as well as adverse internal stresses within the material.

Glass fibers are the earliest known fibers used to reinforce materials. Ceramic and metal fibers were subsequently found out and put to extensive use, to render composites stiffer more resistant to heat (Ebelewe, 2000). Fibers fall short of ideal performance due to several factors.

The performance of a fiber composite is judged by its length, shape, orientation, and composition of the fibers and the mechanical properties of the matrix. A fiber reinforced composite (FRC) can be divided into three components such as:

- a) Continuous fiber-reinforced
- b) Discontinuous aligned fiber-reinforced
- c) Discontinuous random-oriented fiber-reinforced

Figure 2.2 below shows the types of fiber-reinforced composite material consists of three types of fiber reinforced composite materials.

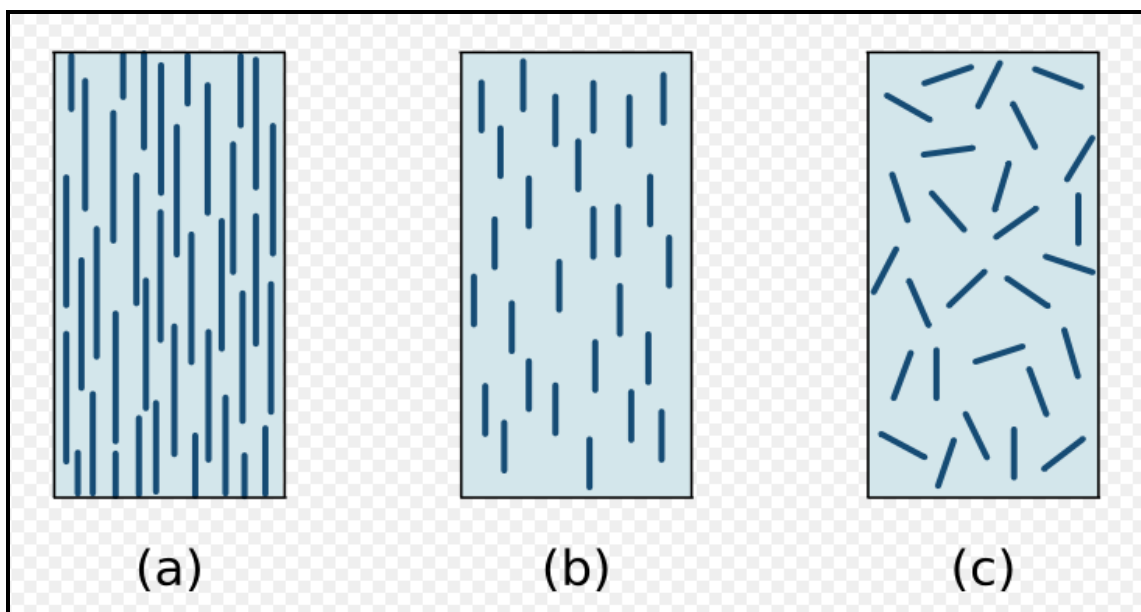


Figure 2.2: Types of FRC, a) Continuous fiber-reinforced, b) Discontinuous aligned fiber-reinforced c) Discontinuous random-oriented fiber-reinforced  
(Schwartz,1997)

Natural fibers from cellulosic waste going through the process refining, blending and compounding to formed a high strength fiber composite material in a polymer matrix. Fiber reinforced composite is high-performance fiber composite achieved and made possible by cross-linking cellulosic fiber molecules with resins in the FRC material matrix through a proprietary molecular re-engineering process, yielding a product of exceptional structural properties by Flinn & Torjan (1990).

#### 2.2.4.2 Particulates Composite (filled polymer)

Particulate composites are made by blending silica flour, glass beads, even sand into a polymer during processing. Particulate composites are much less efficient in the way filler contributes to the strength. There is a small gain in stiffness, and sometimes in strength and toughness, but it is far less than in fibrous composite. The main reason for using particulate fillers more focused on their behavior that good wear resistance can control thermal expansion and this fiber is a low cost.

Usually, the finer the particulates are, the better properties of the reinforced polymer will be. Basically, there are two types of particulate composites, which are the larger particle composite and dispersion-strengthened. Larger particles can be defined that the particle and matrix cannot be treated on the atomic or molecular level. This type involves large particles that are harder or stiffer than the matrix itself. While as for dispersion strengthened composites, it is containing 10-100 nm particles, with the matrix endure the major portion of the applied load and also the small particles hinder dislocation motion, limiting plastic deformation to occur.

Injection molding is one of the manufacturing methods using particulate composites instead of reducing the cost applying mass production in injection molding process. Figure 2.3 shows the particulate composite.

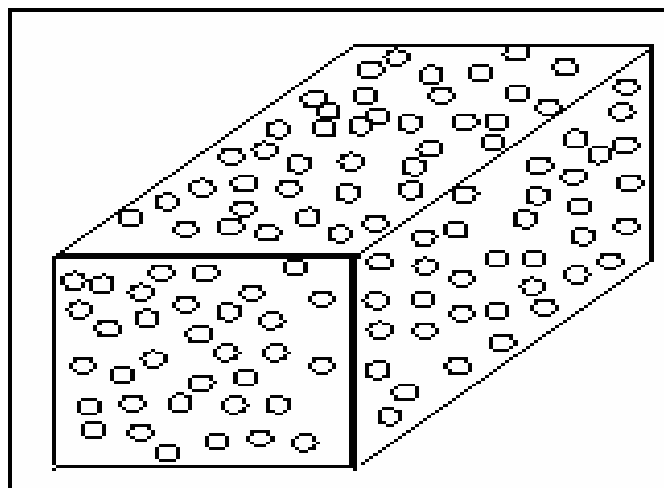


Figure 2.3: Particulate Composite. (Ebelewe, 2000)

Three-dimensional reinforcement in composites offers isotropic properties, because of the three systematical orthogonal planes. Since it is not homogeneous, the material properties acquire sensitivity to the constituent properties, as well as the interfacial properties and geometric shapes of the array. The composite's strength usually depends on the diameter of the particles, the inter-particle spacing, and the volume fraction of the reinforcement. The matrix properties influence the behaviour of particulate composite too.

Properties of the particulate reinforced composite depend on concentration, size, distribution, shape and orientation. The various geometrical characteristics of particles of the dispersed phase may be influence the properties of composites. (Flinn & Torjan, 1990).

Figure 2.4 shows the characteristics of particles that influence properties of composites.

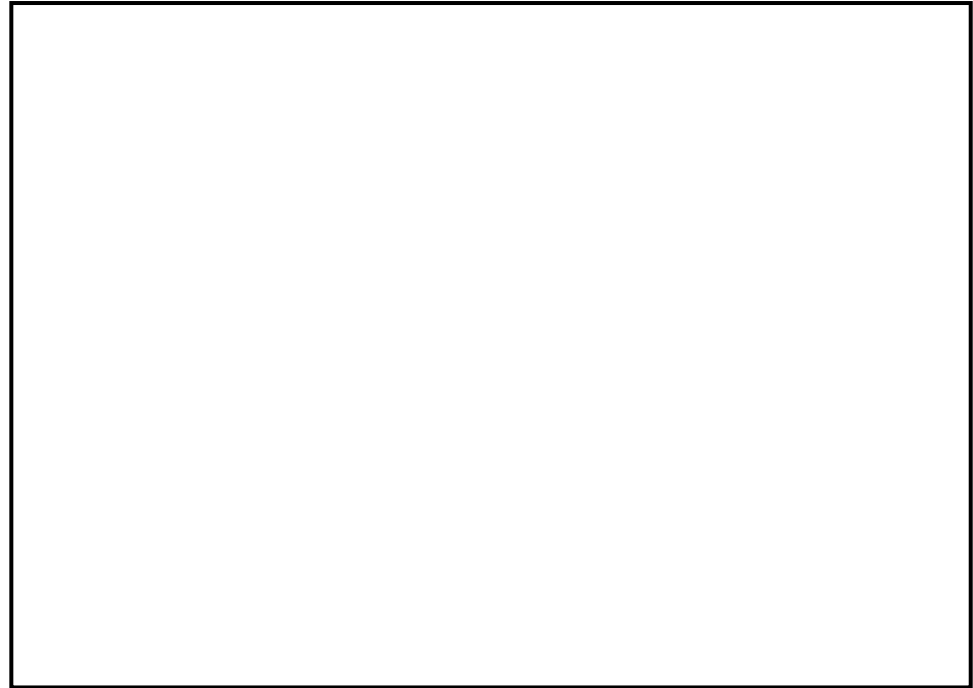


Figure 2.4: Characteristics of Particles that Influence Properties of Composites. (Chou, 2010)

### 2.3 Polysiloxane

Polysiloxane are relatively cheap materials that have received special attention as precursors of silicon oxycarbide glasses (Siqueira *et al.*, 2007). In the rubber industry, they use polysiloxane rubber from the combination of interesting properties that elastomer include excellent thermal and oxidative stability, good weatherability, good electric isolating properties, a wide interval of temperatures of use, resistance to oil, solvents, acids and fungi (Sereda,2007). Another important aspect of this rubber is versatility of their synthesis processes that allows the incorporation of different chemical structures in the chains in proportion large enough to promote interesting changes in the properties of elastomers.

In this study, polysiloxane used is an elastomeric (silicone rubber) polymer type. During manufacture, heat may be required to vulcanize (set or cure) the silicone into its rubber-like form. The modification of main chain in silicone rubber by

blending polysiloxane with other organic polymer or inorganic fillers are needed in order to improve the properties of low elastic modulus. It usually bounded to oxygen as either SiO<sub>2</sub> or SiO<sub>4</sub>. Table 2.1 shows the various classes that can be defined based on the substituent group on the polymer chain prior to the silicone designation.

Table 2.1: Various Classes that can be defined based on the Substituent Group on the Polymer Chain Prior to the Silicone Designation

No	Types	Classification
1	FMQ	Silicone rubber having both methyl and fluorine substituent groups on the polymer chain
2	FVMQ	Silicone rubber having fluorine, vinyl, and methyl substituent groups on the polymer chain
3	PMQ	Silicone rubber having both methyl and phenyl substituents groups on polymer chain
4	PVMQ	Silicone rubbers having methyl, phenyl, and vinyl substituent groups on the polymer chain
5	MQ	Silicone rubbers having only methyl substituent groups on the polymer chain such as dimethyl polysiloxane
6	VMQ	Silicone rubber having both methyl and vinyl substituent groups on the polymer chain

### 2.3.1 Room Temperature Vulcanizing

Silicone can be divided into high temperature vulcanization and room temperature vulcanization (RTV). Room temperature vulcanizing can be divided into groups which are RTV-1 and RTV-2. As for RTV-1, it is the term of room temperature vulcanizing for one component and term for RTV-2 is room temperature vulcanizing for two components. RTV silicones are used for their ability to withstand stress and temperature extremes. Usually, RTV system is widely used as silicone sealants and adhesives. RTV's with clear elastomeric functions as material that act static or dynamic parts, such as gaskets, prototypes and mould making aids. RTVs are also



used to moulded parts, such as electrical insulators for medium and high voltage. RTV systems are condensation curing. The curable composition is formed by mixing two components or in the case of one component system (RTV-1) it is ready to use and it will cure after its application out of the packaging. The major part of the curing system is a polydimethyl siloxane (PDMS) polymer with terminal hydroxyl groups and reinforcing filler. As additives it contains a cross linker, usually a functional silane, and a catalyst in many cases in tin complex (Jerschow , 2003).

The benefits of Room-Temperature Vulcanizing Silicone sealants and adhesives are one part, solvent less for 100% silicone, moisture cure system, chemical resistance, water resistance instead of very resistant to liquid, water and soaps. Besides, it also extreme temperature stability and also can provide flame resistant. Properties of RTV also very good adhesion to glass, organic fibers, metal and very good tear strength.

The curing system are classified by the chemical nature of the split products formed during the condensation process, when the functional silane is incorporated into the polymer network splitting off the condensation products.

As they form split products during their cure, such materials exhibit shrinkages with increasing degree of curing. The characteristic of a condensation curing system are:

- i) The reaction is isothermal
- ii) The volatile alcohol, oxime, amine, etc is formed as a condensation product
- iii) A mass loss occurs due to volatilization of the split product, like alcohol, which results in a chemical shrinkage of the cured rubber in the range of 0.2-2 %, linear. It depends on the concentration of reactive groups
- iv) In most system the curing reaction reverts at temperature exceeding 90°C if the reaction is incomplete
- v) Retardation of cure occurs if there is a lack of moisture in the rubber or the ambient atmosphere

The major part of the curing system is a polydimethyl siloxane (PDMS) which is the polymer with terminal hydroxyl groups and reinforce filler. The reaction is isothermal and such system cure in the presence of air moisture (Jershow, 2002).

Polymers, fillers, softener and some additive are normally contained in the rubber base, while crosslink and tin catalysts, as well as extenders and dyes or pigments in

the curing agent. As for RTV-2 or room temperature for two components, which is applied in this study, is to obtain the stable system. It is imperative to split up the rubber constituents into two components in such way that unwanted reactions will not occur during storage. One of the main application of two components RTV system mould making. The curing agent is a liquid or paste which is incorporated into the mould making base. Once mixing in the system will cure, if enough moisture is present in the ambient air or the mix itself (Jerschow, 2002).

### 2.3.2 Mechanical Properties of Polysiloxane

In general, the mechanical properties of polysiloxane elastomers are inferior to those of other organic elastomers, such as natural rubber. Polysiloxanes are known for their useful properties, such as flexibility, permeability to gases, low glass transition temperature,  $T_g$ , about 146K and low surface energy. Polysiloxane also have a much higher permeability to gases than other polymers.

Polysiloxane are so flexible because they show two types of flexibility: torsion flexibility and bending flexibility. Torsion flexibility is the ability of the atoms to rotate around a chemical bond. It considers that the bond length and angles remain unchanged throughout the process. As for bending flexibility occurs when there is a large hindrance between non-bonded atoms where there are unfavorable torsion angles (Jones *et al.*, 1995).

One polymer derivative of siloxane that has unusually high permeability is polydimethylsiloxane (PDMS). PDMS also has other unusual properties. These includes low internal pressure, low bulk viscosity, low temperature coefficient and low excess volume upon mixing.

Figure 2.5 shows the example of polysiloxane chemical bonding, polydimethylsiloxane. Polydimethylsiloxane is the basic and most commonly available silicone.

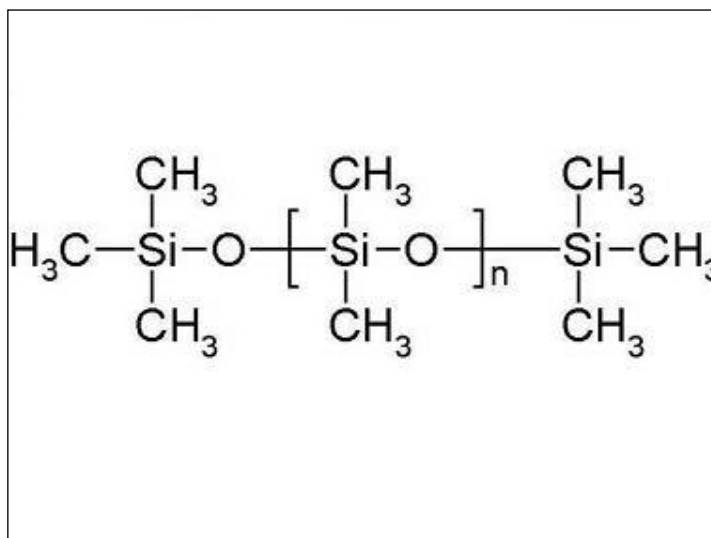


Figure 2.5: Polydimethylsiloxane Chemical Bonding  
( Hou, 2005)

Elastomers generally have too low of an elastic modulus to serve as a matrix for rigid structural composites. This silicone rubber has a good performance of the resistance to high and low temperature but poor mechanical damping properties. The polysiloxane backbone differs greatly from the basic polyethylene backbone, yielding a much more flexible polymer. Because the bond lengths are longer, they can move farther and change conformation easily, making for a flexible material.

Polysiloxanes are generally recognized as the newest generic class of high performance protective coating types based on inorganic siloxane and organic-inorganic siloxane hybrids. Recent advances in siloxane chemistry and formulation technology have led to the development of ambient temperature curable polysiloxane coating system with significant advantages compared to traditional inorganic and organic coatings, (Mowrer, 2003).

The epoxy siloxanes have very high solids, excellent temperature resistance and good resistance to chemical lining applications. Semigloss highly weatherable topcoats have also been formulated using this technology. The versatility of siloxane extends to adhesives, sealants and composites. For example, an epoxy siloxane adhesive has been developed with improved temperature resistance for use on chemical and fire resistance composite pipes (Mowrer, 1997). Phenolic siloxane resin binders have been developed for use in composite fire resistant piping. The phenolic binder provides improved flexibility and resistances to cracking compared

to conventional phenolic composites yet still the requirement for hydrocarbon fires (Kejimen *et al.*, 2000).

The siloxane bonds (-Si-O-Si-) that form the backbone of silicone, dimethyl polysiloxane are highly stable. At 433 kJ/mol, their binding energy is higher than that of carbon bonds (C-C), at KJ/mol. Thus, compared to common organic polymers, silicone rubbers have higher resistance and chemical stability and provide better electrical insulation.

According to this study, refer to the vibration performance of polysiloxane filled silica; one of the characteristic in silicone rubber is good in vibration absorption. The loss modulus ( $\tan \delta$ ) of silicone rubber is generally low, making it suited for use as a vibration absorber. Products with enhanced vibration absorption performance, however, absorb vibration consistently over a wide temperature range, from -50°C to 100°C (Hua, 2005). Loss modulus ( $\tan \delta$ ) is expressed by the following equation 2.1.

$$\text{Tan } \delta = G_2 / G_1 \quad (2.1)$$

where  $G_1$  is storage modulus and  $G_2$  is loss modulus. The larger of the value of  $\tan \delta$  depends on the greater ability of a particular material to absorb energy such as vibration. Figure 2.6 shows the temperature dependence of vibration absorption for rubber.

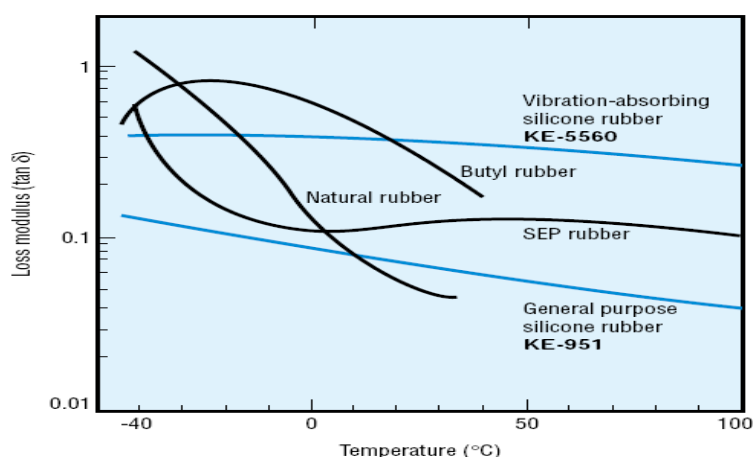


Figure 2.6: Temperature Dependence of Vibration Absorption of Rubbers

(Hua, 2005)

### 2.3.3 Fabrication of Polysiloxane

Most of the fabrication processes employed for monolithic materials, such as uniaxial pressing, isostatic pressing, injection molding, extrusion and slip casting can be used for particulates and whisker-reinforced composites. In this study, the fluid processing involves. For those involving fluid processing techniques are generally preferred is slip casting.

The term polysiloxane can include silicone but it is used herein in its broadest sense, that is, any polymeric structure that contains repeating silicon-oxygen groups in the backbone, side chains or crosslink regard less of the substitution on the silicon atom.

In early 1960's, silicone based coating formulations were developed for the application of coatings for exhaust stacks, heat exchangers, boilers, ovens and furnaces, mufflers, cookware and aircraft components. Then, significant advance were introduced about ambient cure binders based on the hydrolysis of trialkoxysilane. These binders are capable of providing long term resistance to heat in excess of 760°C. (Law, 1978). Besides, the development of siloxane hybrids coating also discover by some researchers. The first specification and earliest example of hybrid organic-inorganic coating is TT-E-490 consist of Enamel, Silicone Alkyd Copolymer). It was replaced by MIL-E-24635 consist of Enamel, Silicone Alkyd Copolymer, which these binders used as a weatherable topcoat on ships. Besides, it also used for the protection of tanks, chemical process equipment, bridges and other steel structures (Keijman *et al.*, 2000)

Further progress was made with the commercialization of patented, improve epoxy siloxane hybrids. These coatings combined the corrosion resistance of an epoxy with the weatherability of polyurethane in one coating and now widely used in construction, industrial maintenance and marine applications (Mowrer, 2003).

The single coat of epoxy siloxane provides comparable resistance to corrosion and better resistance weathering compared to the 2-coat epoxy/urethane systems. The 2-coat epoxy siloxane system has equivalent resistance to corrosion compared to the 3- coat which consist inorganic zinc silicate (IOZ), epoxy and urethane system.

Luciano Sereda carried out the test on 0, 10 and 30 percents of silica weight percentage of rice husk ash with poly(methylvinylsiloxane) to find the influence of silica and black rice husk ash as a filler on the diffusivity and solubility of gases in silicone rubbers. It was discovered that interaction between the hydroxyl groups

located in the surface of commercial silica particles with the polymer matrix promoted the formation of physical crosslinks that enhanced the modulus of the rubbers. As a result, black rice husk ash (BRHA) displayed the better reinforcing properties. The reinforcement provided by the BRHA filler was inferior to that commercial silica.

Prior to the development of application in rice husk, other researcher found that the improvement of the flexural strength and modulus up to 100% in Chemical Matrix Composites (CMC'S) compounds filled rice husk ash (Siqueira et al, 2007). Besides, using RHA as reactive filler through pyrolysis of silicone based polymer composites, it generates uniform material without microscopy defects based in SiOOC or SiC.

Arif *et al* performed a study to examine the hydrophobicity improvement of high voltage insulator based on epoxy polysiloxane and rice husk ash compound, namely, a Bisphenol a (DGEBA) epoxy resin, Metaphenylene-Diamine (MPDA) as curing agent and 325-mesh Rice Husk Ash (RHA) as filler. The sample were installed in the special chamber, then were exposed to pollutant at their surface to improve the hydrophobicity of polymeric insulation materials (Arif et al., 2011). As a result, researcher found that polydimethyl siloxane (PDMS) treatment of filler can improve the hydrophobicity of insulator material compared without use PDMS.

In another series of test, Ishak and Bakar evaluated the potential of rice husk ash as fillers for epoxidized natural rubber (ENR) where ENR is known to possess unique characteristics of being able to be reinforced with several types of fillers. The physical testing of the ENR involves the determination of tensile, tear and hardness properties. The comparison between two fillers also determined in their study that White Rice Husk Ash (WRHA) contains 96% silica content meanwhile Black Rice Husk Ash contains only 54% silica content and the rest 44% is a carbon content(Ishak and Bakar, 1994). WRHA exhibits the best overall vulcanizates properties as compared to BRHA with regard to tensile strength and tear strength.

Mohammed studied the effect of frequency and amplitude of vibration on void formation in dies poured from polyvinyl siloxane impression. The frequency and amplitude of vibration were determined in his study to study the effect on the

formation of voids on the cast surface poured polyvinyl siloxane impression with a mechanical model vibrator. The vibrator was set at low frequency and high frequency and 30 impressions were poured in dental stone for 5 steps of amplitude. On that study, the dies poured from polyvinyl siloxane impression with high frequency of vibration (6000 cycles/min) and step 3 amplitude (0.40 mm) produced significantly fewer voids compared with steps 4 and step 5 where the amplitude are 0.45 mm and 0.80 mm. To minimize voids, it is suggested that silicone impression may be poured with a mechanical vibrator.

From the development of the polysiloxane composite filled silica, many researcher try to find the best result instead of the combination between silicone rubber and silica will be a composite material which composite materials containing fibers whether they are short staple fibers, whiskers or fibers in continuous filament form such as roving or textiles provide considerable flexibility in the design of structures. The addition of reinforcing fibers such as rice husk silica will provide equal mechanical properties of the siloxane rubbers. The result obtained from the testing will emerged the research field in silicone rubber development.

## **2.4 Silica as Filler**

Filler are widely used to improve the properties of rubbers. In this study, the effects of silica were observed to promote the improvement of their mechanical properties, hardness, compression and elongation into the rubber formulations. The reinforcement properties depend on the nature and amount of particles of fillers incorporated and on the shape and size distribution of the particles. There are three crystalline forms of silica which are quartz, tridymite, cristobalite and there are two variations of each of these (high and low). Silica is a group IV metal oxide, which has good abrasion resistance, electrical insulation and high thermal stability. It is insoluble in all acids with the exception of hydrogen fluoride (HF).

### **2.4.1 Rice Husk Silica**

Rice husk is an abundant material, produced in many countries around the world containing approximately 20-25 wt.% of silica. Rice husk silica obtained from burning husk, in principle, be used as reinforcing agents in different rubbers. The use of rice husk in the white rice husk ash and black rice husk ash varieties for the reinforcement of elastomers, verifying that the mechanical properties of epoxidized natural rubber were inferior to those composite prepared with commercial fillers (Ishak and Bakar, 1995). The applications that widely used of rice husk ash are:

- i) Aggregates and fillers for concrete and board production.
- ii) Economical substitute for micro silica / silica fumes
- iii) Absorbents for oils and chemicals
- iv) Soil ameliorants (An ameliorant is something that helps improve soil drainage, slows drainage, breaks up soil or binds soil, feeds and improves structure etc.)
- v) As a source of silicon
- vi) As insulation powder in steel mills
- vii) As repellents in the form of "vinegar-tar"
- viii) As a release agent in the ceramics industry
- ix) As an insulation material for homes and refrigerants

Preparation of amorphous superfine silica from rice husk is the most attractive utilization method at present. Superfine silica can be widely used in electronics, ceramic, plastics, rubber and photoelectric material industries, such as thixotropic agents, thermal insulators and composite fillers (Zhang *et al.*, 1997; Sridhar *et al.*, 1998; Payá *et al.*, 2002; Patricio *et al.*, 2005). The content of amorphous silica in rice husk is the highest in all gramineae plants. Several authors have concluded that rice husks are an excellent source of highgrade amorphous silica. (Pramod and Musti, 1981; Kazuhiro *et al.*, 2001; Kalapathy *et al.*, 2003). Indeed, rice husk has been used as raw material for the production of a series of silicone-based materials, including silicon carbide, silica, silicon-nitride, reinforced polymer composite, cements and other silicon-based materials (Siqueira *et al.*, 2009).

#### **2.4.1.1 Properties of Rice Husk**



Rice husk ash is a black residue which contains approximately 85-90 wt. % of silica, 10-15 wt. % of carbon, small amounts of alkalis and other trace elements (Krishnarao *et.al.*, 1995). The silica is porous and has abundant hydrophilic Si-OH groups, therefore absorbing much moisture. By heating at higher temperature, the unburned carbon can be removed from the ashes, but this leads to the crystallization of the ash from amorphous silica into cristobalite or tridymite (Haslinawati *et al.*, 2009). Many methods have been developed to produce pure silica from rice husk ash. The process of producing rice husk not only producing silica powder but it help reducing pollution problem by converting agriculture waste to the useful waste.

Previous research by Haslinawati *et al.*, 2009, were reported the raw materials, rice husk were supplied by BERNAS Sdn.Bhd at Tanjung Karang, Malaysia. The raw material was prepared to produce rice husk powder using some procedures. In order to removes clay and rock impurities, the rice husk were washed using water and subsequently dried in oven at 120°C for 24 h. The dry process is important to remove water content. Then, The rice husk was heated at 800°C for 2 h for complete combustion and then being sintered at various temperature (1000 - 1400°C) for 2 h with heating cooling and cooling rate is 2°C. from the result obtained, she discuss that silica of rice husk ash is amorphous form at low temperature 700°C and 800°C while crystalline silica occurred at temperature above 900°C.

The use of RHA in the production of high-performance and high-durable concrete has been presented in previous research review. The findings were as follows:

- i) Substantial reduction in mass loss on exposure to hydrochloric solutions (Mehta and Folliard, 2002, Sugita et al, 1997, and Wada et al, 2000).
- ii) Considerable reduction in alkali-silica and sulfate expansions, (Mehta *et al.*, 2002, and Wada *et al.* 2000).
- iii) Higher frost resistance of non-air entrained RHA concrete compared to similar mixtures of silica fume concrete (Mehta and Folliard , 2002)
- iv) Higher compressive strength (Wada et al, 2000). ,
- v) Higher resistance to chloride ion penetration of RHA concrete with 10% cement replacement compared to normal concrete (Gjorv *et al.*, 1998, Sugita *et al.* , 1997)

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