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DEVELOPMENT OF COCONUT SHELL POWDER REINFORCED HDPE COMPOSITES

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"I hereby, declare this thesis is the result of my own research except as cited in the references"

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DEDICATION

To my beloved mother and father, family and friends.

ABSTRACT

This project intends to develop a new material coconut shell powder -reinforced composite using high density polyethylene (HDPE) resin as the matrix material. The choice of natural fibers as the filler material is inspired by the environmental awareness to find a substitute for the slow-degradable plastic material. By combining renewable and environmental friendly coconut shell powder with HDPE thermoplastic, it is hoped that better material with great mechanical properties and highly degradable characteristic could be developed. Furthermore, the usage of coconut shell powder will reduce the manufacturing cost as this resource is not expensive and have abundant supply in Malaysia. This project involves the manufacturing route to produce coconut shell powder-reinforced composite by using internal mixer. Tensile testing is done to investigate the mechanical characteristics of composites manufactured.

ABSTRAK

Dalam projek ini, satu komposit baru hasil gabungan daripada serbuk tempurung kelapa dan HDPE(polyethylene berketumpatan tinggi) dihasilkan dengan HDPE sebagai bahan matrik. Pemilihan serat dr sumber semulajadi diinspirasikan daripada kesedaran tentang kepentingan kesejahteraan alam untuk mencari pengganti bagi plastik yang mempunyai kadar degradasi yang rendah. Dengan menggabungkan bahan dari sumber semulajadi yang mesra alam iaitu serbuk tempurung kelapa dan HDPE, adalah diharapkan suatu bahan yang mempunyai sifat mekanikal yg lebih baik dengan kadar degradasi yang memuaskan dpt dihasilkan. Tambahan pula, penggunaan serbuk tempurung kelapa sebagai bahan mentah akan mengurangkan kos pembuatan ,memandangkan bahan ini murah dan mudah didapati di Malaysia. Objektif utama projek ini adalah untuk membina kaedah bagi menghasilkan komposit gabungan HDPE dan serbuk tempurung kelapa dengan menggunakan 'internal mixer'. Kemudian komposit yang dihasilkan akan diuji melalui ujian tegangan.

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SYMBOL	DEFINITION
s	second
T	Temperature
t	Thickness
ρ	Density
g	gram
K	Kelvin
^{o}C	Degree Celcius
CO2	Carbon Dioxide
MPa	Mega Pascal
Nm	Newton Meter
Rpm	Revolution per minute

ABBREVIATIONS	DEFINITION
HDPE	High Density Polyethylene
PMC	Polymer Matrix Composites
UTeM	University of Technical Malaysia Melaka

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

To define a composite is not a simple task, especially if the definition is to include a broad and ever-increasing range of composites available in today's world. James K Wessel, in his Handbook of Advanced Materials [1], offers a few examples of composites definition:

a) Made up of distinct parts or elements
b) A macroscopic combination of two or more distinct materials, having a recognizable interface between them

Anil Kumar defines polymers as a material of very high molecular weight, which usually consists of several structural units bound together by covalent bonds [2]. These structural units are called 'monomer', which is a small molecular compound. Through chemical reaction, repeated linkage of monomers is form to obtain polymer.

Polymer matrix composites (PMC) is simply a composite that used polymeric material as it matrix material. Polymeric material has become the most common matrix material for composites. Generally, the mechanical properties of polymers are inadequate for many structural purposes, especially their strength and stiffness that are low compared to metals and ceramics. So reinforcing them would give considerable benefit even though the reinforcement (filler material) does not have exceptional properties.

Furthermore, processing of PMC does not require high temperature and high pressure. Also the equipments required for PMC processing may be simpler. This characteristic has made PMC to develop rapidly and widely used in various applications.

Examples of PMC application is in aerospace industry where PMC is used in most parts of the aeroengines.

1.2 Problem Statement

Coconut shell powder is a waste from agriculture product, often being used as a fertilizer to other plantation, or worst, is being thrown away by the agriculture industry. There is a need for development of new usage from agriculture waste, to benefit the agriculture industry as well as other industries. The development of PMC from coconut shell powder will reduce agriculture waste, and increases its value.

PMC have various advantage, its properties are usually superior to its parent materials. This means that materials with considerably low mechanical properties might perform better mechanical properties if combine together in a suitable processing method.

The slow degradation of plastic presents myriad problems. In addition to safety and environmental questions, technological and economic hurdles have complicated plastics recycling efforts. Each type of plastics have different melting temperature, meaning that one recycling process only compatible with one type of plastic. Unfortunately there are hundreds of types of plastics. Because of this, the recycling rate of rate plastics is low compared to paper recycling. Moreover, the recycled plastics will have smaller markets because of health concerns. For example, food manufacturer may not use recycled plastic for their packages unless the recycled plastic is clean. Cleaned recycled plastics require additional treatment, which will increase its recycling process cost.

1.3 Problem Identification

As society begins to recognize the importance of utilizing renewable bioproducts that are beneficial to the environment, focus is beginning to return to agricultural materials. Agricultural crop fibers such as flax, hemp, coconut shell, coir, jute, and sisal have the potential to act as replacements for glass fiber reinforcements in polymeric composites.

In general, natural fibers offer moderate mechanical properties, but, in some aspects, the properties of natural fibers can surpass those of E-glass. The low density (ρ) of natural fibers makes them competitive and even superior to E-glass in terms of specific strength (σ/ρ) and specific modulus (E/ρ).

Furthermore, public awareness of the recycling problem of plastics has been increased lately, leading to search for a degradable material with better properties to replace plastics. The used of carbon fibers, however, proves to be very advantageous as it exhibit superior mechanical properties, the only drawback is the high cost of the material. Natural fiber reinforcements offer value-added properties such as the beneficial environmental impact of these renewable resources, less abrasive nature of the fibers for reduced tool wear, and less skin irritation for workers.

By combining HDPE with natural fiber (coconut shell), we hope to develop a highly biodegradable material or at least increase the degradation rate of HDPE while increasing its mechanical properties. This could lead to several other benefits such as low cost, highly renewable (abundant resources of coconut shell) and minimizes safety and health concerns as coconut shell is not harmful to human and environment.

1.4 Objective of study

This project is carried out to develop new material by combining coconut shell powder and HDPE resin in laboratories scales. HDPE resin is the matrix material and coconut shell powder is the filler material. Internal mixer is used as the mixing method and specimen is obtain via hotpress and roll mill. Specimen is cut using specimen cutter. After manufactured, the test specimens undergo tensile testing to characterize its mechanical properties. Analysis is carried out based on the testing results.

CHAPTER 2

LITERATURE REVIEW

2.1 High Density Polyethylene (HDPE)

Polyethylene is used more than any other thermoplastic polymer. There is a wide variety of grades and formulations available that have an equally wide range of properties. In general, the outstanding characteristics of polyethylene are toughness, ease of processing, chemical resistance, abrasion resistance, impact resistance, low coefficient of friction and near-zero moisture absorption

HDPE is more rigid and harder than lower density materials. It also has a higher tensile strength four times that of low density polyethylene, and it is three times better in compressive strength. The extremely high molecular weight of HDPE combined with its very low coefficient of friction provides and excellent abrasion resistant product preventing gouging, scuffing and scraping.

HDPE have high impact resistant compared to other thermoplastics and maintains excellent machinability and self-lubricating characteristics. Other than that, HDPE possess good chemical resistance of corrosives as well as stress cracking resistance (with the exception of strong oxidizing acids at elevated temperatures). Certain hydrocarbons cause only a light surface swelling at moderate temperature.

Moisture and water (including salt water) have no affect on HDPE. It can be used in fresh and salt water immersion applications.

HDPE has variety of applications in our life from food cutting board that we have in our kitchen to radiation shielding in radiation risk zone. Its corrosion resistant capability made it a perfect protective covering for walls and various equipments that operates in environment with high level of moisture.

2.2 Coconut Shell Powder

Coconut Shell powder is made from the most versatile part of the coconut – the shell which is organic in nature. Since it has good durability characteristics, high toughness and abrasion resistant properties, it is suitable for long standing use. The shell is similar to hard woods in chemical composition although lignin content is higher and cellulose content is lower.

Advantages of natural fibres include low specific weight, which results in a higher specific strength and stiffness than glass. This is a benefit especially in parts designed for bending stiffness. Furthermore, it is a renewable resource, the production requires little energy, and carbon dioxide is used while oxygen is given back to the environment. Coconut shell powder is producible with low investment at low cost, which makes the material an interesting product for low-wage countries.

In terms of health and safety issues, natural fiber possess environmental friendly processing, with no wear of tooling and no skin irritation. Thermal recycling is possible for materials manufactured using natural fiber, unlike materials from glass which causes problems in combustion furnaces. Natural fiber also has good thermal and acoustic insulating properties.

2.3 Previous Research

A vast amount of research in polymer matrix composite (PMCs) has been done either by trying to combine new elements or improving existing PMCs with chemical treatment or by establishing better manufacturing route. And since the cost of elements such as metal is expensive and non renewable, some of the focus of PMCs has turned to the application of natural fibers; fibers from plants especially as reinforcing matrix.

Sapuan S.M. et al (2003) have done the research on coconut shell powder as reinforcing fiber for epoxy resin. His study, as shown in Figure 2.1, reported that the tensile and flexural properties increases as the filler content increases, albeit the maximum composition manufactured was only 15% of filler content.

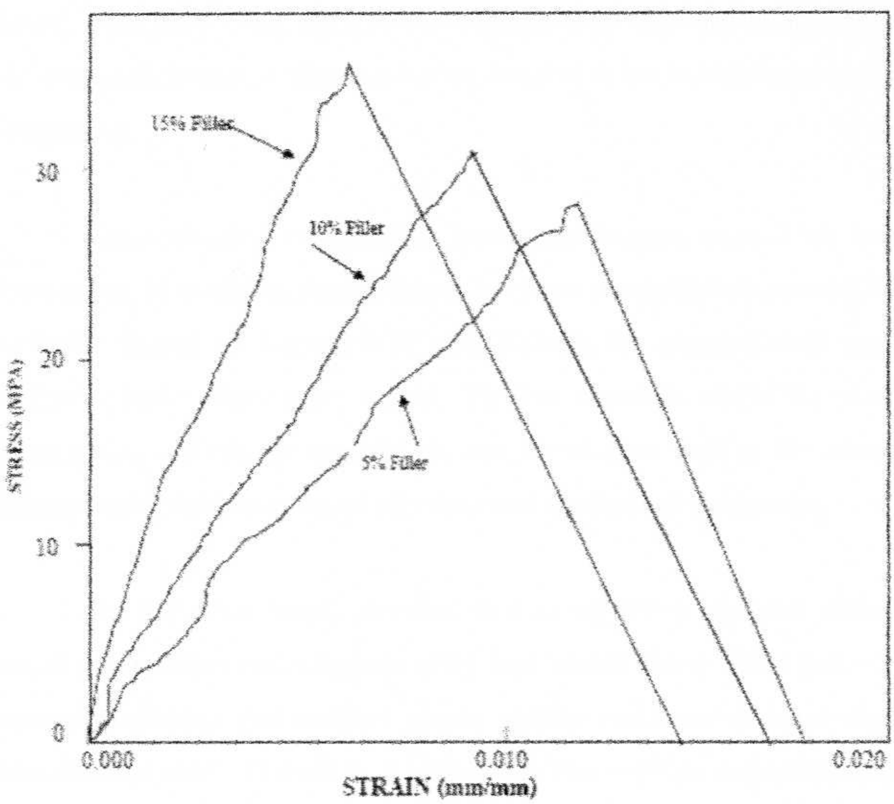

Figure 2.1 : Tensile strain vs strain for epoxy/coconut shell powder composites

Epoxy is thermosetting resin, which is non recyclable but have better mechanical properties than High Density Polyethylene (HDPE).But because HDPE is thermoplastic polymer, it might have increased recycleability characteristics if combine with coconut shell powder to produce PMCs.

Other natural fiber that has been receiving attention from researcher includes jute, sisal, bird feather and wood. Wood-plastic composites are currently used widely in construction industry, following its high strength and lightness characteristics. But recent research (Stark N.M., 2004) has indicates a concern about wood-plastic weather degradation. After accelerated weather degradation, the surface of 50% wood filler HDPE composites shown greater extent of oxidation than pure HDPE (100% HDPE), indicating that the wood filler itself contributing to the increase of weather related damage. In natural fiber composites, this is something to be concern of, as most natural fibers, especially from agricultural sources has high moisture absorption properties. Moisture accelerates surface oxidizing, leading to surface damage and loss of strength in composites.

Since weather degradation have significance impact on wood filled HDPE composites, it would be interesting to see how coconut shell powder filled HDPE might performs. Based on Sapuan S.M et al (2003), the coconut shell powder filled epoxy performs better than pure epoxy. Further research might be needed for weather degradation analysis as we still do not know how well is the coconut shell powder against wood flour in terms of physical and mechanical properties.

On the other hand, Johnson D.A et al(1999) reported different behaviour in wheat straw filled polyethylene (PE) and wheat straw filled polypropylene(PP). Her research indicated that unfilled plastic exhibit increased weather degradation problem than filled plastics. Therefore, it is possible that weather degradation may be reduced in coconut shell powder filled HDPE as HDPE itself have better mechanical properties than PE.

Research on Seashells (Calcium Carbonate) filled HDPE composites however, does not results in any significance increase in mechanical, thermal and rheological properties than pure HDPE, as indicated in Gonzalez J. et al (2005).Even the use of coupling agent did not help to improves the results in this case. Conversely, in most cases, coupling agent does facilitate processability and improves mechanical performance of PMCs as reported by Wang M et al(2001), Sousa R.A (2003) and Abdelmouleh M. et al (2006) using silane coupling agent.Wang M et al(2001) stated that silane coupling agent aids polymer penetration into the cavities of hydroxyapatite surface during processing, enhancing mechanical interlocking between matrix and filler.

Others like Mohanty S. et al (2006) treated jute/HDPE composites with Maleic Anhydride grafted Polyethylene (MAPE) and successfully improves the characteristics of the composites. The research illustrates various aspects including the effect of treatment duration and MAPE concentration to the mechanical properties of jute/HDPE composites. It is reported that the higher the MAPE concentration, the higher the tensile, flexural and impact strength can be achieved(see figure 2.1), although flexural strength suddenly dropped at 2% of MAPE concentration. As for treatment duration, optimum mechanical properties were achieved at 3 minutes treatment duration and the properties decreased if treated in longer duration as illustrates by table 2.2.

Table 2.1: Effect of concentration of MAPE on mechanical strength of the jute/HDPE composites at 30% fibre loading (Mohanty S. et al ,2006)

Concentration of MAPE (in %)	**Tensile strength (MPa)**	**Flexural strength (MPa)**	**Impact strength (MPa)**
0	27.24	34.83 ± 1.17	51.28
0.3	32.03	39.49	54.00
0.5	36.44 ± 1.02	42.00	56.23
1.0	40.14	47,97	65.69
2.0	37.10	38.57	63.33 ± 1.44

Table 2.2 : Effect of time period variation of MAPE on the mechanical strength of the jute/HDPE composites at 30% fibre loading and 1% MAPE concentration.(Mohanty S. et al ,2006)

Treatment time (in minutes)	**Tensile strength (MPa)**	**Flexural strength (MPa)**	**Impact strength (MPa)**
3	36.27	42.15	59.77 ± 1.2
5	40.14	47.97 ± 1.30	65.69
10	26.82 ± 0.95	35.87	45.72

Barone J.R et al (2005) has used keratin fiber from chicken feathers to reinforce polyethylene, and shows that there are interaction between fiber and the polymer without the use of coupling agent. Even though in this research, the mechanical properties of composites only increased slightly compared to pure polyethylene, Barone suggested that fiber with higher modulus is used to achieve optimum increase in properties.

Apart from the use of coupling agent and treatment, each research has incorporated different manufacturing route to achieve their objectives. In terms of using natural fiber as reinforcement, Sapuan S.M et al(2003) prepare samples via open mold and then cured them for 12 hours at 40°C. Mohanty S. et al (2006) uses internal mixer with roller blades to produces jute/HDPE composites. Jute and HDPE were processed at 160 °C and 25 rpm for 10 minutes. While Barone J.R et al (2005) utilize compounding method using Brabender mixing head at 140 °C and 50 rpm to produce keratin fiber reinforced HDPE. But keratin fiber was only added to HDPE once the HDPE has melted inside the mixing head. This may be done to ensure that the fiber will mix thoroughly with HDPE.

The use of natural fibers have rapidly evolved over the last decade primarily due to the issue of the environment and the shortage of oil (plastics are primarily made from petroleum). Modem technologies provide powerful tools to reveals microstructures at different levels, and to understand the relationships between the structure and properties.