EVALUATION OF TENSILE PROPERTIES OF NATURAL SAND PARTICLE REINFORCED POLYMER COMPOSITE

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project report and in my opinion this project is satisfactory in terms of scope and quality for the award of Diploma in Mechanical Engineering.

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Name of Supervisor: DR. AHMED NURYE OMAR
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I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any diploma and is not concurrently submitted for award of other diploma.

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ABSTRACT

Nowadays, reinforced plastic composites are replacing metals which are being used for many years. This is due to the fact that reinforced plastics have high strength to weigh ratio, low cost compared to metals, and high resistance to corrosion. However, the production of the composites nowadays is very challenging to meet the market requirement. Though natural sand is abundant in the world and very cheap, there are not many studies regarding the mechanical properties of natural sand particle reinforced composites. The objective for this thesis is to determine the tensile properties of natural-sand particle reinforced polymer composite and to validate the experimental results against theoretically calculations. To perform this, first we needed to prepare samples. The samples were prepared with mix and heat method. A few samples were produced by varying the sand weight percentage in the composites. Six samples were produced with 5%, 10%, 15%, 20%, and 30% sand percentage by weight. Next, the samples were tested with 3-Point Bending Testing Machine and Universal Tensile Testing Machine to obtain the respective value of flexural and tensile properties of the composite samples. After that, the values obtained were compared against theoretical values which were obtained from calculation. The results obtained were in fair agreement with the experimental values. Both experimental values of the elastic modulus and ultimate tensile strength were relatively low compared to theoretical ones. There may have a lot of reason for this, but we believe that the primary reason is due to the fact that there is a critical point where the elastic modulus or ultimate tensile strength is at its lowest. In conclusion, the result is satisfying as the trend is similar although the values between theoretical and experimental are not exactly same.

ABSTRAK

Pada zaman ini, komposit plastik yang diperkukuh semakin banyak mengganti logam yang telah digunakan sejak banyak tahun lalu. Hal ini demikian kerana komposit plastik mempunyai ciri-ciri seperti nisbah kekuatan yang tinggi kepada nisbah berat, lebih murah dan mempunyai daya ketahanan yang tinggi terhadap hakisan. Walau bagaimanapun, produksi komposit tersebut merubakan cabaran yang besar untuk memenuhi pasaran. Objektif tesis ini adalah untuk menentukan ciri-ciri ketegangan komposit polymer yang ditambah dan dikukuh oleh pasir semula jadi serta membuat perbandingan antara nilai pengiraan dengan nilai sebenar yang didapati melalui eksperimen. Untuk memulakan eksperimen ini, kita kena menyediakan sampel. Cara yang digunakan untuk menyediakan sampel ialah ‘heat and mix method’. Beberapa sampel telah disediakan mengikut purata pasir yang diletakkan ke dalam komposit. Sampel yang disediakan ialah 5%, 10%, 15%, 20%, 30% purata berat pasir yang terdapat dalam komposit. Selepas itu, komposit tersebut akan diuji dengan ‘3 Point Bending Testing Machine’ dan ‘Universal Tensile Testing Machine’. Nilai tersebut akan diambil untuk membuat perbandingan. Nilai-nilai yang didapati melalui eksperimen adalah lebih rendah jika dibandingkan dengan nilai-nilai yang dikira. Walaupun terdapat banyak sebab yang menyebabkan keputusan yang didapati, tetapi kita percaya ini adalah disebabkan oleh titik critical di mana ‘Ultimate Tensile Strength’ atau ‘Elastic Modulus’ merupakan nilai yang paling rendah. Secara konklusi, keputusan yang didapati adalah amat memuaskan kerana trend antara keputusan theori dan keputusan eksperimen hampir sama.

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CHAPTER 1

INTRODUCTION

1.1. Introduction

This chapter introduces the background of the project; the main problem that initiated us to produce particle reinforced plastic materials; and the main and specific objectives of the research. Generally, this project is aimed to extend the composites to new era by using natural sand as a reinforcement and polypropylene as a matrix.

There are many composites in the world which can be applied in various fields of engineering. Some of the composites include polymer composites, ceramic composites, and metal composites. There are also many possible combinations of composites yet to be discovered. Currently, studies are concentrating on reinforce polymer composites because these composites have huge potential to replace metals in the automotive, aerospace, sport, and manufacturing fields.

1.2. Problem Statement

Nowadays, reinforced plastic composites are replacing metals which are being used for many years. This is due to the fact that reinforced plastics have high strength to weigh ratio, low cost compared to metals, and high resistance to corrosion. However, the production of the composites nowadays is very challenging to meet the market requirement. The reinforcements may vary according to the desired function of the composite. Many composites have been produced using fibers (short and long), and particles as reinforcements. However, though natural sand is abundant in the world and very cheap, there are not many studies regarding the mechanical properties of natural sand particle reinforced composites. The composite produced thus has to be tested for its mechanical properties before being used as replacement to metals.

1.3. Objectives of the Project

The main objectives of the project are

- to determine the tensile properties of natural-sand particle reinforced polymer composite.
- to validate the experimental results against theoretical calculations

1.4. Project Scope

- In particle reinforced plastic composites, both the plastic matrix and the reinforcements have their own mechanical properties. In this project, the tensile properties of natural sand will not be tested experimentally; rather the values will be taken from literatures.
- The natural sand particles content will be varied (5%, 10%, 15%, and 20% by weight) and the tensile properties of the final test specimens will be tested for the corresponding particle loadings.
- Since the ultimate goal is evaluation of tensile properties of natural sand reinforced plastic composites, testing of other properties (such as impact and flexural properties) will not be included in this study.
- The effect of dimensional stability of the natural-sand reinforced polymer composites due to the addition of the sand particles will not be covered in this study.

1.5. Summary

In this chapter, the problem statement, objectives, and scope of the project has been discussed to recognize the challenge, purpose and range, respectively, for evaluation of the tensile properties of natural sand reinforced plastic composites.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

In this chapter, compositions of natural sand reinforced plastic composites have been presented in Section 2.2. In Section 2.3., the previous studies related to particle reinforced plastic composites have been reviewed in order to obtain information regarding the production methods, and mechanism of evaluation of the mechanical properties.

2.2. Material Composition

Composite is a material system composed of two or more physically distinct phases whose combination produces aggregate properties that are different from those of its constituents. There are many kinds of composites in the worlds where the common material for composites are metals, polymers and ceramics. The properties of the composites vary widely which it depend the combination of the composites as well as the amount and distribution of each type of material. Composites nowadays are very important because it can achieve combinations of properties which normally not attainable with single material alone. Polymer (plastic) composites are advantageous than the other composites due to the fact that they have high ratios of strength to weight ratio, high fatigue properties, low cost compared to other types of composites, high toughness, and transparent properties [1-2].

Composites can be produced by adding some reinforcements to the molten matrix or by combining two different materials. However, in this study we concentrate on reinforced composites. The reinforcement is to improve the quality of the original material through additives, which the additives normally are in fiber or particle forms. There are many materials that can be used as particle reinforcements such as carbon, metal, glass particle, sand etc. Of all types of reinforcements, natural sand particles are selected for this study because of their low cost compared to other reinforcements, their abundances. For the plastic matrix, polypropylene is selected.

2.2.1. Polymer Matrix

Polymer is a chemical compound or mixture of compounds consisting of repeating structural units created through a process of polymerization. Figure 2.1 shows example of the molecular structure of polymers. There are many types of polymer in the world such as thermoplastic polymer, thermosetting plastic polymer, rubber polymer, etc. [1-2]. For this project, thermoplastic polymer which is polypropylene has been chosen.

Polypropylene (PP), also known as polypropene, with chemical formula $(C_3H_6)_n$ is a thermoplastic polymer used in a wide variety of applications including packaging and labeling, textiles (e.g., ropes, thermal underwear and carpets), stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes. In addition, polymer which made from the monomer propylene is rugged and unusually resistant to many chemical solvents, bases and acids. The density of PP ranges around 0.855g/cm^3 during amorphous phase while 0.945 g/cm^3 during crystalline phase [1]. Polypropylene commercially is isotactic and has an intermediate level of crystallinity between that of low-density polyethylene (LDPE) and high-density polyethylene (HDPE). Polypropylene is normally tough and flexible, especially when copolymerized with ethylene. This allows polypropylene to be used as an engineering plastic, competing with materials such as Acrylonitrile Butadiene styrene ABS. [3-4].

The melting point of polypropylene occurs at a range, around 130–171 °C [3-5]. This is one of the reasons we choose polypropylene as our material for composite as it has significantly low melting point. Typical examples of polypropylene pallets are shown in Figure 2.2.

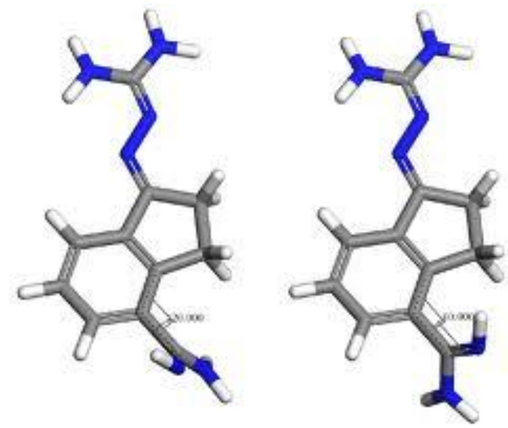

Figure 2.1: Example of molecular structure of polymer

Figure 2.2: Example of Polyethylene polymer

2.2.2. Natural Sand

Sand is a naturally occurring granular material composed of rock and mineral particles. The composition of sand is highly variable, but the most common constituent of sand is silica (silicon dioxide, or SiO_2). In terms of particle size as used by geologists, sand particles range in diameter from 0.0625 mm (or 1⁄16 mm) to 2 mm [3-5]. An individual particle in this range size is termed a sand grain.

There are many types of sand in the world, but for our cases we will choose natural sand as our material. Natural sand is the sand that is commonly used for construction. We choose natural sand because it has high melting temperature (i.e. it can withstand high temperature) and high hardness. Besides, it is very easy to get the material. The sand collected is shown in Figure 2.3.

Figure 2.3. Example of natural sand particles

2.3. Previous Researches

Effect of sand addition on the tensile properties of compression molded sand reinforced polyethylene was studied by R.R. Zahran [6]. From his experiment, Zahran concluded that sand reinforced polyethylene composite is greatly affected by the sand particles. Moreover, he stated that the mechanical properties are affected by the weight percentage of the sand particles in the composite, as well as the size of the sand particles. Figure 2.4 shows variations of tensile modulus for the composite with weight fraction. The graph shows that the finer the sand size, the higher the strength will be. However, the strength of the composite varies by the weight percentage of sand. At lower weight percentage, the strength of composite is higher than polyethylene itself while in certain high percentage, the strength of composite is lower than polyethylene. Therefore for our project, we will obtain fine sand particles which are constant variable and vary the percentage of weight of the sand in the composites.

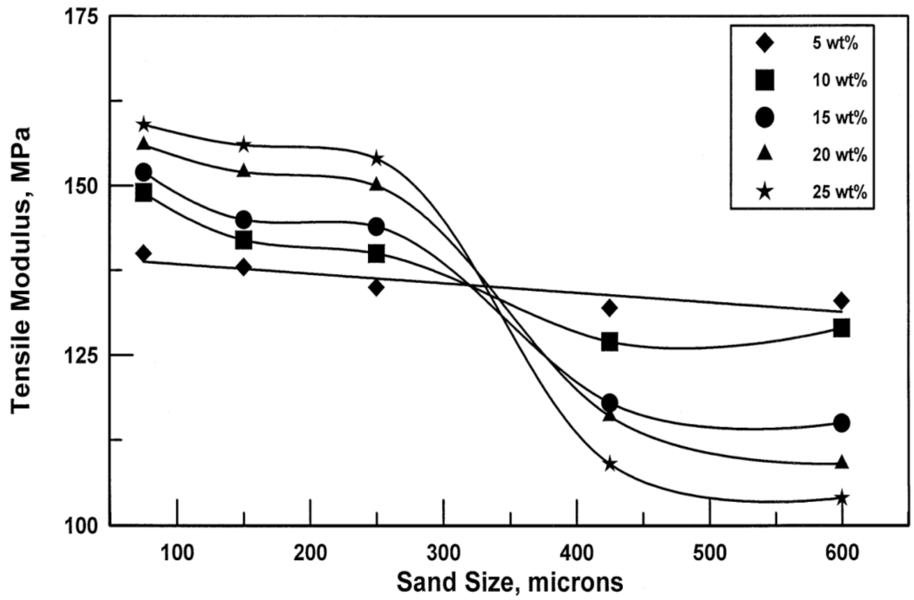

Figure 2.4 Variation of tensile modulus of sand reinforced polyethylene composites for various weight percentages [6]

In another related research by P. Herrera-Franco, A. Valadez-Gonzalez and M. Cervantes-Uc, the development and characterization of a high density polyethylene (HDPE)-sand-natural fiber (henequen fiber) composite was performed and characterized [7]. They manipulated the weight-to-weight ratio (w/w) filler contents to the thermoplastic resin and the response variables selected were the tensile and flexural properties of the composite as a function of mineral filler and/or natural fiber content and processing temperature. From their research, they conclude that the tensile strength of the HDPE-sand composite does not seem to be affected by the processing temperature, for any filler content, but the tensile modulus shows a similar behavior only at filler contents greater than 15% w/w. The flexural strength shows maximum at filler contents of 30% w/w, while the flexural modulus increases linearly. The flexural properties are not affected appreciably by the processing temperature. The HDPE-sand-henequen composite shows a more complicated behavior than the two component composites. An increase in filler content decreases the tensile strength. A similar behavior was found with an increase in the processing temperature. The processing temperature seems to have a more pronounced effect on the tensile modulus. At low temperatures the tensile modulus behavior is governed by the sand content, while at higher temperatures such behavior is governed by the fiber content. The flexural properties are also affected by the processing temperature. At low temperatures and content below 30% w/w, the flexural strength increases with fiber content and, at higher sand contents, an opposite behavior is observed. At higher processing temperatures the behavior is the same as for lower temperatures, but the flexural properties slightly decreased.

Furthermore, in other research Ahmet Samanci [8] has studied the fracture behavior of woven steel fiber reinforced and sand particle filled polymer composites. He manufactured woven steel fiber reinforced with various weight fractions and particle-filled polymer composite beams. After cure treatments, he opened initial notches on the specimens with various notch-to-depth ratios. The fiber contents he used were 2%, 4% and 6%, and the polyester content was 16.5% of the total weight of the polymer composite system. Then, he investigated mode I fracture behavior of single edge notched composite specimens using three-point bending (TPB) tests and he concluded that as the weight fractions of steel fibers increases, flexural strength of the composites increases. Moreover, as the ratio of reinforcement increases, both the flexural strength and modulus increase. More interestingly, he found out that while the fiber contents were 2%, 4% and 6%, the flexural strength was about 93%, 137% and 205% and modulus was about 96%, 129% and 154% higher than the un-reinforcement composite system respectively.

A.M. Alhozaimy, P Soroushian and F. Mirza [9] have studied the mechanical properties of polypropylene fiber reinforced concrete and the effects of pozzolanic materials. From their research, polypropylene fibers were observed to have statistically no significant effects on compressive or flexural strength of concrete, while flexural toughness and impact resistance showed an increase in the presence of polypropylene fibers.

The thermal and mechanical properties of epoxy composites reinforced by natural hydrophobic sand were investigated by G. Sui, *et. al.* [10]. From their study, G. Sui, *et. al.* indicated that a kind of Cancun natural sand could be an effective filler material for polymer composites. Their research also showed that Cancun sand has the potential for applications in cost-effective composites with enhanced mechanical and thermal properties. The enhancement of thermally conductive properties in sand particles/epoxy resin composites is also apparent. Therefore since our case is natural sand, we also believe that natural sand has huge potential as polymer reinforcement.

2.4. Summary

The state of the art related to natural sand particle reinforced plastic composites was reviewed in this chapter. The information and method to be used for the production of composites and testing of the tensile properties have been chosen and will be clarified in the next chapter.

CHAPTER 3

PROJECT METHODOLOGY

3.1. Introduction

This chapter will provide the detail explanation on the methodology that carried out for this project. Project methodology is the method that are used or proposed to strife for the result. The methodology act as a guidance or step that needs to be followed and this will ensure the project being done according to the planning. Figure 3.1 shows the flow chart for this project. The information included are establishing target specification, reviewing state of the art, proposing manufacturing method concepts, select final manufacturing method concept, sample preparation and testing, comparison with analytical results.

3.2. Research Flow Chart

Final year project is one of the most important aspects of engineering diploma in which the student will have the opportunity to gain experience in practical applications. Selection of proper project title is the first stage in the final year project. Therefore, after meeting with my supervisor we initially decided to study the tensile properties of natural fiber reinforced polymer composites.

The initial materials suggested by my supervisor were plastic polymer with natural fiber. For that, I have successfully searched and collected the material needed i.e., polypropylene for plastic and coconut fiber for natural fiber is. The plan was to differentiate the coconut fibers into single fiber and cut the fiber into an average 2cm each string. However, we faced a great threat that the technician staff of Material Lab in the Faculty of Mechanical Engineering at UMP did not agree with our idea. The reason he stated was that there were some students from Chemical Engineering Department-UMP did the experiment before and found out that the coconut fibers burned and stuck on to the walls of the injection molding machine which damaged the machine. In order to prevent the coconut fiber from burning we needed to do some chemical treatment which we did not have the capacity, time, budget and facility. Because of these setbacks we chose natural sand as reinforcement because it has high melting temperature than the suspending molten polymer.

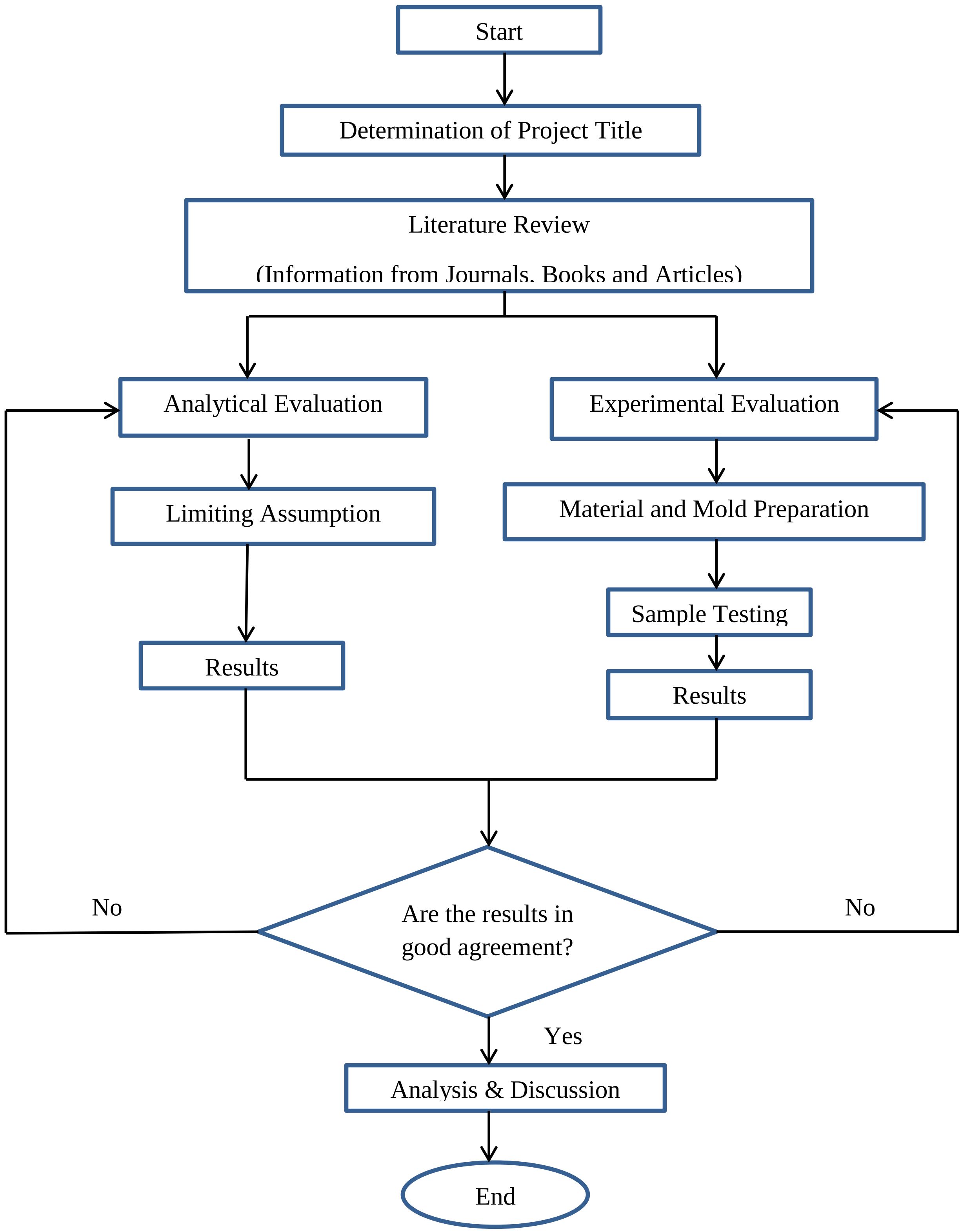

Figure 3.1 Flow Chart of the project

After deciding the title of the project, the basic information and state-of-the-art related to natural reinforced polypropylene composites were reviewed from literature (i.e. journals, books, and articles). Different methods used for production and testing the mechanical properties of the composite were studied from the previous researches to adopt in this research.

Then after understanding the techniques used to evaluate the mechanical properties of composites, analytical equation will be developed in order to predict the over properties of the composite from the tensile properties of its constituents (polypropylene and natural sand). For the mathematical calculation a lot of assumptions may be made to limit and simplify the solution. Some of the assumptions include: the shape of the sand particles is assumed to be uniform sphere and all particles have same size; the surfaces of sample are smooth and have uniform thickness; the suspending polymer is homogeneous; and the errors that arise during measuring the materials is negligible. Simultaneously, preparation of materials and mold for sample production will be performed. Once the samples are produced, they will be tested for bending and tensile by using tensile testing machine.

The results from the tensile machine testing for each sample will be put in tabular and graphical form. These results will be compared against the theoretically obtained values for both tensile stress and elastic modulus. If the two results show big difference, then both the theoretical formulas and the experimental procedures will be checked and other results will be obtained for the corrected one. Finally, the obtained results will be analyzed and documented.

3.3. Experimental Procedure

In this project, four samples were prepared using heating and mixing method. Then the samples were tested for tensile properties using tensile testing machine. These methodologies are discussed in detail in the following sub-sections.

To prepare the composite samples, two methodologies were proposed which are injection molding and heating/mixing methods. The ideal methodology for our project is injection molding. This is because injection molding is easy to use, conventionally common method for plastic reinforced composite technology. In injection molding, the materials of the composite are directly mixed together with a fixed weight ratio and then injected into the mold. However, I could not use the injection molding machine because the technician was scared and had worries about even the fine sand particles could damage the machine. Therefore, the second method which is heating the mixture of natural sand and polypropylene pellets using furnace and cooling naturally was employed in this study.

3.3.1. Composite Sample Preparation

The raw materials used in this project are natural sand as a reinforcement and polypropylene as a suspending matrix. These materials are selected because both materials can be obtained easily. Moreover, polypropylene has low melting temperature which makes it easy to mix with the natural sand. For this, first the smallest possible sand particles were selected. Conventional filter was used to take out the fry objects from the oil to filter the smallest sand. The sand which had been filtered can be considered very fine sand and is less than 0.5 mm^3 in volume. Sample of polypropylene pellets sand particles prepared are show in Figure 3.2.

(a) (b)

Figure 3.2 (a) Pellets of Polypropylene, and (b) Natural sand used for the project

The next step is mold preparation. A rectangular mold with dimensions 6 cm x 10 cm x 1.5 cm prepared as shown in Figures 3.3 and 3.4. The mold has a simple ejection system where two holes are punched in the middle and a small plate is put on top of them. The horizontal plate will be punched via the two small holes, as a result the sample will be ejected from the mold upon solidification. Some of the machineries used for preparation of the mold are shown in Appendix B and C.

Figure 3.3 A rectangular mold without covering the injection hole

Figure 3.4 A rectangular mold whose injection holes covered with loose horizontal plate

After that, we need to prepare the sample. For the sample, the weight (mass) ratio between natural sand and polypropylene were measured and mixed together in the mold. A beam balance was used to weigh the sand and polypropylene propositions for each sample. The percentage by weight and their corresponding mass of the sand and polypropylene are shown in Table 3.1. The sample is weighted as shown in table below: Then, the mixed material is put into the furnace and let the polypropylene melt. To avoid formation of pores and to produce better quality of sample, some amount of pressure applied applied by putting some weights on top of the mold during the melting process. Upon solidification, the sample is expected to mix well and is ready to be tested.

For each sample, additional 1g of sand was added to account for the sand loss. The sand loss was due to the sand that stuck to Tupperware, sand that stuck to the beam balance during weighting and the sand that were stuck to the hand.

Table 3.1 Weight of sand and Polypropylene for different weight percentages

Weight Percentage	5%	10%	15%	20%	30%
Weight of sand(g)	1	2	3	4	6
Weight of Polypropylene(g)	19	18	17	16	14

For the first sample, Ii was left open during heating and metal bar was used to stir it periodically to mix the sample well. After that, a metal plate was placed on top of it and then put some weight (metal bar stack together). After the sample was solidified, it was found out that it is hard to eject the sample out as it was stuck to the mold. After grinding away the side line and applying harder force, the sample was ejected but broken.

For the next sample (30%), aluminum foil was used to contain the mixed material first by wrapping along the mold. Then the aluminum foil was used to wrap the cover metal plate and the metal bars as well. The outcome is the sample produced was irregular in shape. But still it was accounted for testing.

Another adjustment was made after that for 1st 30% sand percentage sample. For this sample, we made a trade in by abandoning the stirring process and we just applied pressure with the metal bar hoping that it will produce smoother surface. The outcomes were much more desirable as we do produce smoother surface but the sand become more like sand coating instead of mixed with the polypropylene. For the next few samples, we practiced the steps taken for 1st 30% sample and produce similar sand coating samples to be tested. Figures 3.5 and 3.6 show the front and back views of the sample produced for 30% sand by weight.

Figure 3.5 Front view of sample prepared for 30% sand by weight

Figure 3.6 Back view of the sample prepared for 30% sand by weight

3.3.2. Sample Testing

The samples are then tested with Bending and Tensile testing Machines to obtain the elastic modulus and tensile strength, respectively.

3.3.2.1. Bending Test

First the samples cut into uniform length and width, and tested with Shimadzu AG-X bending machine. The bending machine is used to obtain elastic modulus for the samples. The machine has two supports and a load. The supports need to be distanced so that they can support both end of the sample. Next, the samples were placed on top of the supports and then control the load until it touches the samples. After that, the force and displacement calibration was set to 0. Finally, the testing was started and stops the test when the machine reached certain displacement. By that, we can calculate the elastic modulus as the force is different to achieve that displacement for different sample. The final results are auto generated from the computer. The steps were repeated until every sample has been tested. Figure 3.7 shows the 30% sand composite sample loaded on 3-point bending test machine (Shimadzu AG-X).

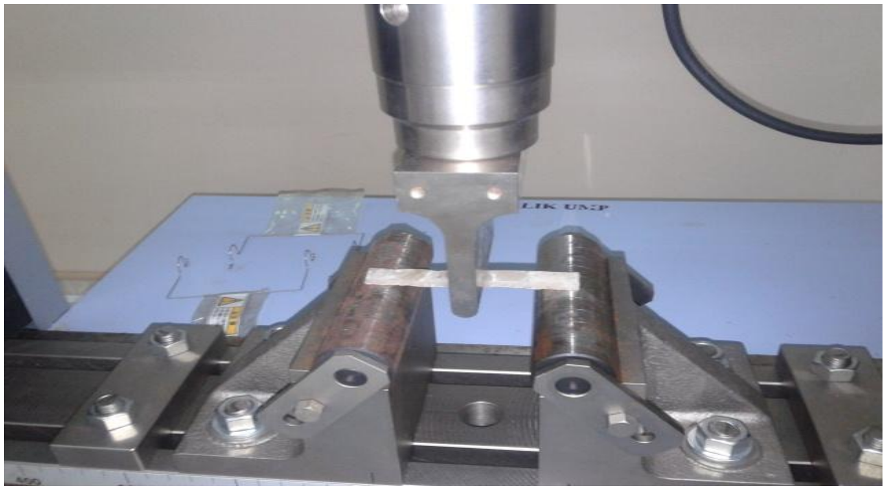

Figure 3.7 Sample (30% by wt. sand reinforced PP composite) loaded on a 3-Point Bending Test Machine

3.3.2.2. Tensile Test

After bending machine, the tensile strengths of the samples were tested using universal tensile testing machine. For tensile testing, the samples were first fixed on the clamp. Then, “start button” was pressed to run the test. The test stopped automatically after the sample broke. The data was auto generated from the integrated computer. The steps were repeated until every sample has been tested.

3.4. Theoretical Calculation

Since the second objective of this project is comparing between theoretical and experimental value of elastic modulus and tensile stress, the equations used for the calculations are outlined in this section.

3.4.1. Rule of Mixture (ROM)

Due to its simplicity, the rule of mixture (ROM) was used in this study to estimate the tensile properties of the composite samples. The values for the ultimate tensile strength and tensile modulus of natural sand and polypropylene can be obtained from literatures and suppliers. Hence, the ultimate tensile strength is 3 MPa for sand and 31 MPa for polypropylene [1-2]. Similarly, the elastic modulus of the sand and polypropylene are 15 GPa and 1.3 GPa, respectively [11-12]. Therefore, to estimate the ultimate tensile strength and elastic modulus of the composite the following formula can be used:

$$S_C = S_{ut\ sand} V_{sand} + S_{ut\ pp}(1 - V_{sand}) \quad (3.1)$$

$$E_C = E_{sand} V_{sand} + E_{pp}(1 - V_{sand}) \quad (3.2)$$

where:

S_C = Ultimate tensile strength of the composite

E_C = Tensile modulus of the composite

$S_{ut\ sand}$ and $S_{ut\ pp}$ = Tensile strengths of sand and polypropylene, respectively

E_{sand} and E_{pp} = Elastic modulie of sand and polypropylene, respectively

V_{sand} = Volume fraction of sand

However, the composite samples were produced based on weight fraction of each constituent as shown in Table 3.1. Therefore, the weight fractions should be converted to volume fractions to calculate tensile properties of the composites using Eqs. (3.1 and 3.2). First we need to find the density of natural sand and polypropylene. The densities of both materials can easily be obtained from literatures and suppliers; and their values are 905 kg/m^3 for polypropylene while the density of sand is 1922 kg/m^3 [1-2].

Generally, the space taken by the sand inside the polypropylene will affect the performance of the composite. Due to this reason, it is expected that the larger the space (the higher the volume fraction of sand), the higher the irregularities coefficient of the molecular structure of the composites and thus the material will have high hardness but lowers the tensile strength (which is similar to ceramics properties which sand resembles.. This is because irregularities in the molecular structure will make it harder for the molecule to slide on each other and thus promoting higher hardness due to additional force required causing sliding of molecule.

Thus, the volume fraction of the sand can be calculated as follow

$$V_{sand} = \frac{W_{sand} \times \rho_{pp}}{[\ \rho_{pp} W_{sand+}\ +\ \rho_{sand} W_{pp}]} \tag{3.3}$$

Where:

V_{sand} = Volume fraction of sand

W_{sand} = Weight fraction of sand

ρ_{pp} = Density of polypropylene

ρ_{sand} = Density of sand

3.5. Summary

In this chapter the methodology used, the material selection process, the equipments used, and the testing procedures for evaluation of tensile properties of natural sand particle reinforced polypropylene composites have been discussed. Data were collected for various sand particle weight fraction loadings and are ready for analysis. Moreover, the mixtures of rule equations used for the analytical calculation were outlined. Generally, the samples prepared can be considered as fair quality even though they do not meet our expectations because they are sand-coated instead of sand-mixed.

CHAPTER 4

RESULT AND DISCUSSION

4.1. Introduction

After the samples were tested for tensile and bending, the data generated by the testing machines were analyzed. Moreover, the theoretical modulus and strength values were calculated using the equations outlined in Chapter 3. Therefore, in this chapter the experimental and theoretical modulus and tensile strength values are discussed and compared to each other.

4.2. Experimental Results

4.2.1. Tensile Properties

The experimental results obtained from the tensile testing at various sand particle loadings are tabulated in Table 4.1. Two 30% by weight sand reinforced samples were produced and designated as 30% (1) and 30% (2). The first represents the sample which is mixed first then heated whereas the later represents the sample which is heated first then mixed. It can be clearly seen from the table that the tensile stress values dropped gradually from 21.62 MPa for 5% by weight sand to 8.01 MPa for 30% (2). Then the tensile stress rose to 13.59MPa for 30% (1) by weight of sand reinforcement. From the results, it can be concluded that the hypothesis “the higher the percentage of the sand particle reinforcement, the lower the ultimate tensile strength of the composite would be” is valid.

On the other hand, the tensile modulus of the composite is maximum when the concentration of the sand is minimum, and vice versa. For instance the tensile moduli obtained for 5% and 30% (2) wt sand-pp composites are 2.7 GPa to 1.3 GPa, respectively. The trend of the graph is not uniform as its value decreased to 1.7 GPa for 10% wt and increased again to 1.84 GPa for 15%.

Table 4.1 Experimental results of the tensile test for various sand particle loadings

	Sand Particle weight percentage	Tensile Stress at Yield (Slope Threshold at 0.2%) [MPa]	Maximum Load [kN]	Tensile Stress at Maximum Load [MPa]	Tensile Modulus [GPa]	Extension at Break (Standard) [mm]
1	5%	21.62	1.21	22.40	2.686	1.39
2	10%	13.80	0.73	13.82	1.682	1.66
3	15%	13.24	0.71	13.44	1.836	2.52
4	20%	10.21	0.63	10.96	1.688	0.85
5	30%(2)	8.01	0.66	8.36	1.332	0.83
6	30%(1)	13.59	0.82	14.49	2.092	1.23

The stress vs strain plot for the tensile test shown in Figure 4.1 indicates that as the percentage of the sand particles increases, the elongation of the composite also increases producing maximum value of 0.012 mm/mm for 5% reinforcement. It can be clearly seen from the graphs that the composite sample with 5% wt sand has the largest elongation before break whereas the sample with 30% (2) wt sand has the lowest, 0.012 mm/mm and 0.01 mm/mm being the respective values.

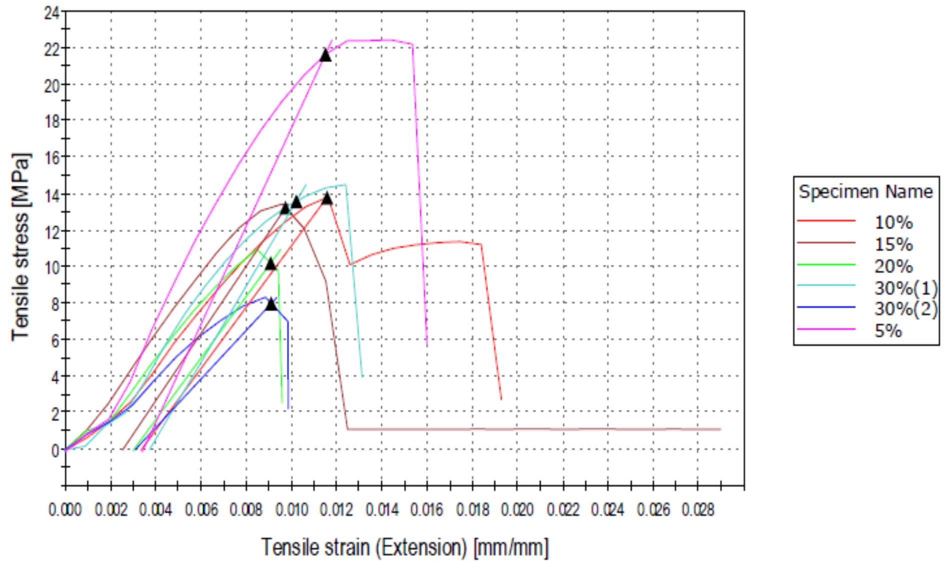

Figure 4.1 Stress vs strain diagram for tensile test

4.2.2. Flexural Properties

Similarly, the experimental results obtained from the bending test at various sand particle loadings are shown in Figure 4.2. From the figures, it can be seen that the flexural modulus tends to drop from 792 MPa for 5 % until 281 MPa for 15%, and then rose back until 943 MPa for 30% (1). In this case, the hypothesis made earlier is not valid. We believe that the primary factor that caused this phenomenon to occur is that the composites have a critical point where the elastic modulus is at its lowest. For this particular case the value will lie between 10% to 20% sand percentage. Therefore, decreasing the sand percentage before the critical point will increase the elastic modulus whereas increasing the sand percentage after the critical point will increase the elastic modulus. This argument can be supported by R.R Zahran's research [6]. The actual value of the critical point can be studied in the future. The suggestion to improve the results is the same as the suggestion given for ultimate tensile strength case.

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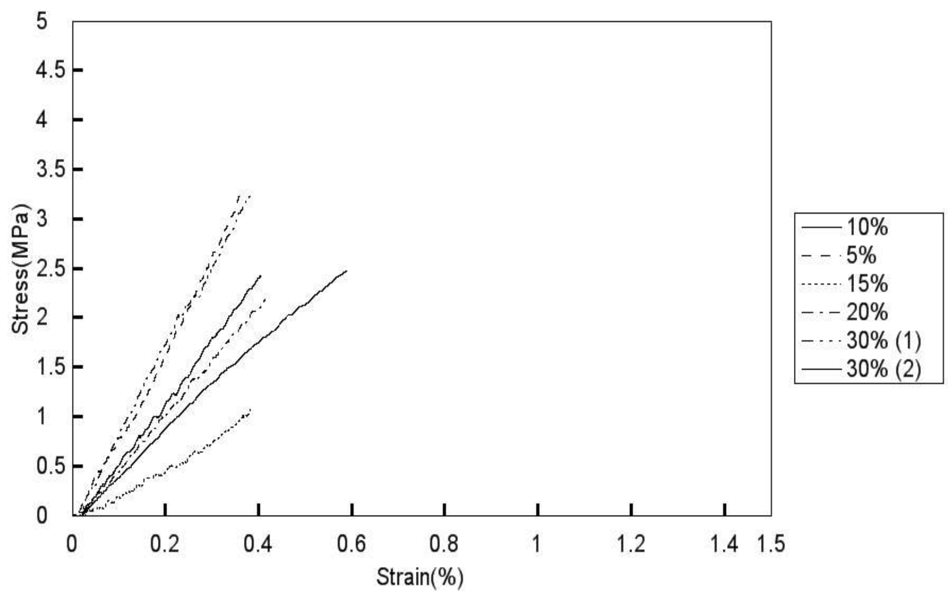
Test Report

Test Date	2013/05/13	Temperature	20 degrees
Humidity:	30%	Testing Machine	AG-X
Test Mode	Single	Test Type	3 Point Bend
Speed	0.5mm/min		

Data Processing Items

Name	Elastic
Parameters	Stress 0 - 1 MPa
Unit	MPa
10%	619.606
5%	792.245
15%	281.277
20%	548.196
30% (1)	943.251
30% (2)	483.829

(a)



(b)

Figure 4.2 Experimental results for bending test (a) Flexural modulus of the sand particle reinforced PP composite, and (b) Stress vs. strain diagram at various sand loadings

4.3. Theoretical Results

4.3.1. Volume Fraction

The volume fraction of sand increases as the weight percentage of sand increases. The results obtained for the volume fraction using Eq. (3.3) are tabulated in Table 4.2. The volume fraction of polypropylene is thus obtained by just subtracting the volume fraction of sand from 100%.

Table 4.2 Volume fraction of sand

Weight fraction of sand (%)	5	10	15	20	30
Volume fraction of sand (%)	2.41	4.972	7.672	10.53	16.79

4.3.2. Tensile Strength

By visual inspection of the samples, i have noticed the following situation for most of the samples: the sand particles are only coated on the surface of the samples with very less sand particles that are actually pierced through and taking random positions in between polypropylene particles. Therefore, I have used another formula that can be used as a reference for comparison between experiment, rule of mixture, and the current proposed theoretical results. Since it is difficult to measure the exact thickness of the sand coated region, by taking average, i guessed that the thickness of the coated surface was within the range of 0.1mm-0.5mm (i.e., 0-10% of the total thickness). The theoretical results assuming the thickness of the coating to be only 10% of the total thickness are presented. Therefore, the new formula used has the form:

$$S_{ut,coated} = 0.9(S_{ut,PP}) + 0.1(S_{ut,composite}) \quad (4.1)$$

where:

- $S_{ut,coated}$ = Estimated ultimate tensile strength of the sand coated composites in Mpa.
- 0.9 – 90% of the thickness which is polypropylene
- 0.1 – 10% of the sand thickness coating.
- $S_{ut,composite}$ = Theoretical value of the composite tensile strength obtained from the rule of mixture (ROM)

Therefore, the theoretical tensile strength values obtained using the rule of mixture, Eq. (3.1), and the current modified equation, Eq. (4.1), are tabulated in Table 4.3. From Table 4.3, we can make a hypothesis that the higher the percentage by weight of sand, the lower the ultimate tensile strength of the composite will be.

Table 4.3 Theoretical tensile strength of sand particle reinforced PP composites obtained using ROM method and Eq. 4.1

Sand weight fraction	Tensile strength using ROM (MPa)	Tensile strength using Eq. 4.1 (MPa)
5%	39.11	39.91
10%	38.16	39.82
15%	37.16	39.72
20%	36.10	39.61
30%	33.79	39.38

4.3.3. Tensile Modulus

Following similar fashion, the theoretical tensile modulus of the sand particle coated composites can be calculated using the formula:

$$E_{coated} = 0.90(E_{PP}) + 0.1(E_{composite}) \tag{4.2}$$

where:

- E_{coated} = Estimated elastic modulus of the sand coated composites in GPa.
- 0.9 – 90% of the thickness which is polypropylene
- 0.1 – 10% of the sand thickness coating.
- $E_{composite}$ = Theoretical value of the composite tensile modulus obtained from the rule of mixture (ROM)

Therefore, the theoretical tensile modulus values obtained using the rule of mixture, Eq. (3.2), and the current modified equation, Eq. (4.2), are tabulated in Table 4.4. From the calculation made above, we can make a hypothesis which states that the higher the percentage of sand, the higher the elastic modulus of the composites. Since the output of the sample mostly is sand coated instead of sand mixed, we should have another formula to estimate the elastic modulus of the sample which is same as estimating the ultimate tensile strength of the sample. I propose another formula and theoretical value which can be used as a reference for comparison and it is also modified from the formula to calculate the ultimate tensile strength of the sand coating. The formula is:

Table 4.4 Theoretical tensile strength of sand particle reinforced PP composites obtained using ROM method and Eq. 4.2

Sand weight fraction	Tensile modulus using ROM (MPa)	Tensile modulus using Eq. 4.2 (MPa)
5%	1.63	1.33
10%	1.98	1.37
15%	2.35	1.41
20%	2.74	1.44
30%	3.60	1.53

4.4. Comparison of Experimental and Theoretical Values

Comparisons of experimental and theoretical tensile modulus and strength values of sand particle reinforced PP composites are shown in Figures 4.3 and 4.4, respectively, for various sand loadings. The theoretical results were obtained using both the rule of mixture and considering the sand coating. It can be seen from Figure 4.3 that the theoretical tensile modulus values are in good agreement with the experimental values. However, the tensile modulus at higher sand concentration showed significant variation from the experiment whereas the modified theoretical values are close to the experiment at all concentrations. Even though the theoretical values are in good agreement with the experiment, their trend is opposite, i.e., the experimental modulus decreases as the sand concentration increases whereas the opposite is true for the theoretical modulus values.

On the other hand, the experimental and theoretical values for the tensile strength show significant variations as shown in Figure 4.4. However, both theoretical results could predict similar trend with the experiment, i.e., decrease in tensile strength with increasing sand concentration. The discrepancies may be due to the fact that the composite samples were produced by putting some weights on top of the mold to increase the bonding pressure. The pressure generated by such method may not be enough to create strong bond between the sand and PP, and even between PP molecules. This might result to small tensile stress. Moreover, the molecular structure (crystallinity) should also be accounted for the polypropylene part. We do not know how much the crystallinity was and it is known that the crystallinity properties of the polypropylene affects the composites tensile strength and elastic modulus and thus we could only take the average value upon prediction instead of calculating the actual value. Another reason that the theoretical tensile strength values differed from the experimental one may be irregularities in the samples. The major irregularities are uneven surfaces of the samples. These caused due lack of pressure and usage of aluminum foils during formation of the samples. Uneven surfaces cause uneven distribution of the stress at different parts.

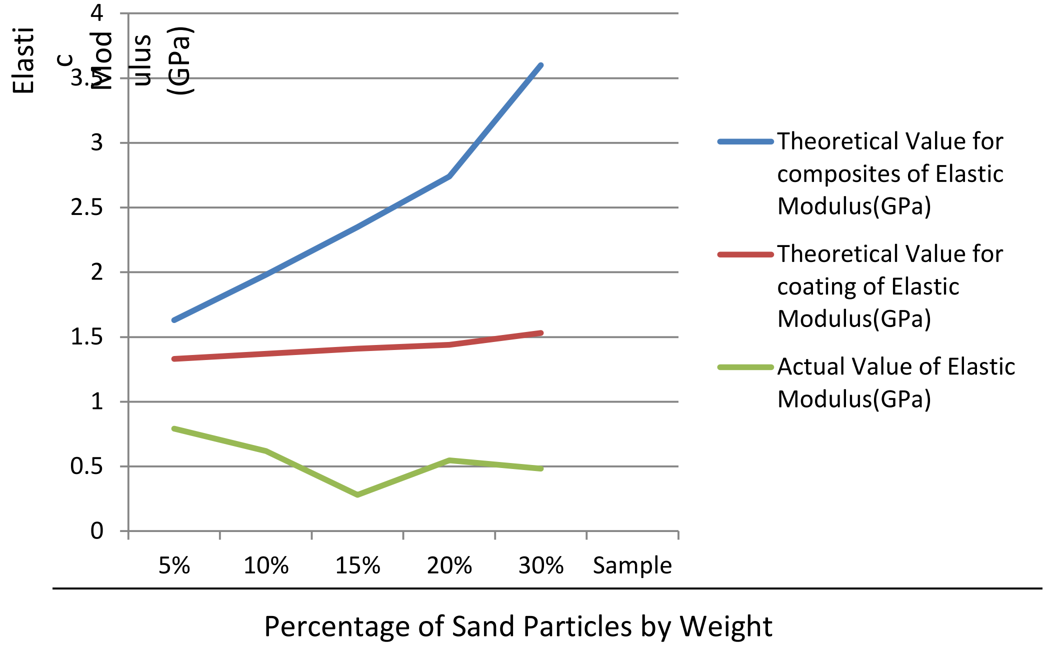


Figure 4.3 Comparisons of experimental and theoretical tensile modulus of sand particle reinforced PP composites

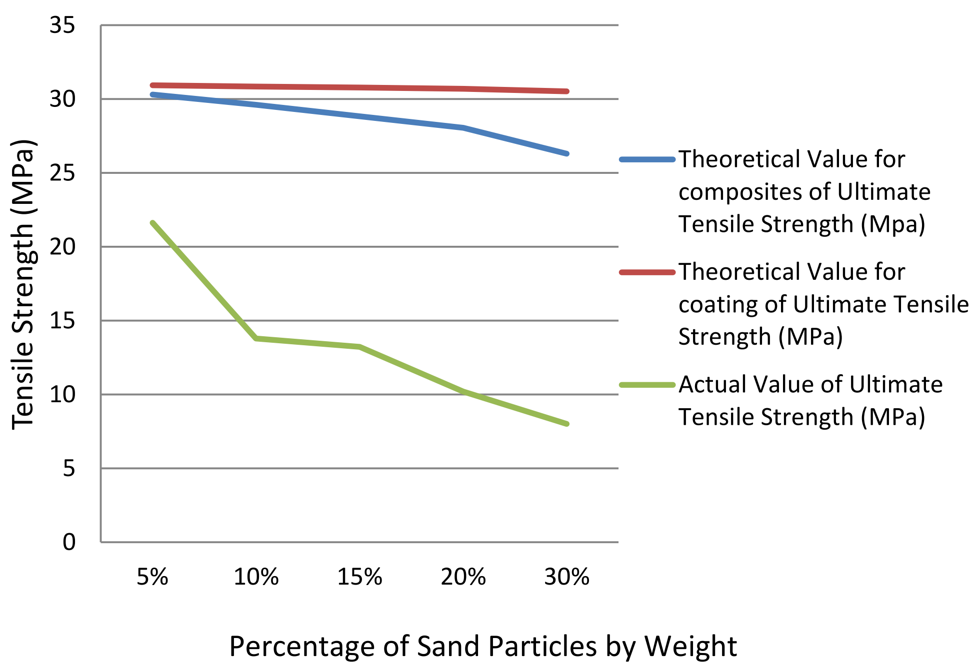


Figure 4.4 Comparisons of experimental and theoretical tensile strength values of sand particle reinforced PP composites

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

In conclusion, the results were satisfactory even though the hypothesis for ultimate tensile strength is valid while for elastic modulus is not. For ultimate tensile strength, it was clearly shown that the higher the sand weight percentage in the samples, the lower the ultimate tensile strength would be. Such phenomenon could occur due to availability of critical point where any decrease in sand concentration before the critical point would increase the elastic modulus of the composite. On the other hand, increasing the sand concentration after the critical point will increase the elastic modulus of the composite. We believe that the critical point lies between 10% - 20%. To find the exact value further research is essential.

Moreover, we have discovered a simple technique that sand can be coated on polypropylene. However, it needs proper equipment to apply enough pressure to the sample so that the surface irregularities and any porousness can be avoided. This may open a new path for studies to coating technology with sand and other non-metal materials. Furthermore, there is not much research about composites utilizing sand reinforcement. This may also contribute to future research regarding sand reinforced composites.

5.2. Recommendation for Future Work

To use mix and heat technique, some recommendations are drawn to improve the outcome of the composite sample.

1. The material should be treated with hot mixing machine before pouring to the mold in order to mix both the sand and the polypropylene well. From the experiment we found out that the viscosity of the molten polypropylene is very high, where the sand is hardly dissolve or pierce inside. By introducing hot mixing machine treatment, the sample can first be treated with mixing both materials well by increasing the temperature to reduce the viscosity of the polypropylene. From our experiment, it was found out that even though we mix both materials beforehand, when the polypropylene melted the sand particles condensed at the bottom of the mold due to gravity and only small portion of the sand particles mixed well with molten polypropylene.
2. The sand weight percentage prepared for the composite sample should be slightly higher than the calculated weight. This is to account for the sand loss during transferring the sand and any other unaware occasions. Therefore, the sand is recommended to have additional 1 or 2g to the calculated weight.
3. During heating and cooling process, high pressure should be applied to the composite samples. The pressure should be greater that 1MPa using pressing machine to avoid some irregularities and pores to the sample. Besides, before applying high pressure make sure that the mold is fully covered to prevent spill out of the molten mixture.
4. The mold should have well developed ejection system or it should have shape which will ease the ejection of the sample from the mold.
5. Injection molding is highly recommended as it solves the problems of lacking of pressure, heating the materials as well as mixing the materials.
6. From our project, we have discovered a method of plating with sand. For this we might have open a new research path for the future by introducing sand plating technology. Therefore, intensive researches can be done in this area.

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APPENDICES

Appendix A

Machineries and Equipments used for Mold Preparation

Figure A.1 Shearing Machine used to prepare the mold

Figure A.2 Grinding machine used to prepare the mold

Figure A.3 Welding machine used to perform permanent joint connecting operation for the mold.

Figure A.4 Drilling machine used to perform hole drilling operation to the mold.

Appendix B

Equipments and Materials used for Composite Sample Preparation

Figure B.1 Some of the weights used to apply pressure

Figure B.2 Weights that has been wrapped with aluminum foil

Figure B.3 Beam Balance with cover to measure sand and PP weight

Figure B.4 Vernier caliper for measuring dimensions of the sample

Figure B.5 Furnace used to mix and heat the sample

Figure B.6 Condition of the composite sample during heating inside the furnace

Appendix C :

Machineries and Equipments used for Testing the Properties of the Samples

Figure C.1 Shimadzu 3-Point Bending test machine used in this project

Appendix D

Gantt Chart for Final Year Project

Planned Progress

Project Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Introduction, briefing	■													
Preparation of material		■	■	■										
Preparation of mold				■	■									
Preparation of sample					■	■								
Tensile Testing						■								
Data Analysis							■	■	■	■				
Thesis Writing							■	■	■	■	■	■	■	■

Actual Progress

Project Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Introduction, briefing														
Preparation of material														
Preparation of mold														
Preparation of sample														
Tensile Testing														
Data Analysis														
Thesis Writing														