SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal-Fluids)"

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Date : …………………………....

MODELLING OF PALM FIBRE POLYPROPYLENE COMPOSITE FOR RANDOMLY DISTRIBUTED FIBRE REINFORCEMENT

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DECLARATION

" I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

Signature : ……………..…………….

Author : YUVARAJAN A/L KARATHIHAYAN

Date : …………………………...

Specially dedicated
to my beloved parents and brothers

ACKNOWLEDGMENT

Praise to God almighty for His grace in providing me the strength and ability in bringing this research to completion.

I would like to extend my sincere gratitude and appreciation to my project supervisor, Dr.Sivakumar Dhar Malingam, for his devotion and effort in providing me with the guidance needed to accomplish this research.

Last but not least, I would also like to thank my family and friends who provided me with motivation and support at times of difficulty and was always there for me. Their contribution is much appreciated.

ABSTRACT

This research presents the development of a Finite Element Analysis (FEA) model for prediction of oil palm empty fruit bunch (OPEFB) fibre reinforced polypropylene. Previous studies regarding natural fibre reinforced fibres have only used mechanical and chemical testing in order to characterize the material behavior. Thus there was a need to develop FEA model that is capable of simulating behavior of these natural fibre reinforced polymer composites. The tensile FEA model of the 30 % OPEFB fibre reinforced polypropylene is developed using commercial FEA software package, ANSYS Release 14. The model was developed by using data from tensile test. The tensile test was conducted by using samples that conform to ASTM D3039 standard and the test was done on a universal testing machine (INSTRON 5585. Studies have conducted on different types of elements with ANSYS. Shell 181 element showed the best overall correlation and also has a low computation time. Solid element, Plane 182 also shows good correlation with experimental result.

ABSTRAK

Kajian ini membentangkan pembangunan model Analisis Unsur Terhingga (FEA) untuk ramalan polypropylene diperkuat serat tandan kosong kelapa sawit (OPEFB). Kajian terdahulu mengenai serat serat semula jadi bertetulang hanya menggunakan ujian mekanikal dan kimia untuk mengkaji ciri-ciri bahan tersebut. Oleh itu, terdapat keperluan untuk membangunkan model FEA yang mampu simulasi ciri-ciri polimer diperkuat serat semula jadi .Model tensil FEA bagi komposit polypropylene yang diperkuat dengan 30% serat OPEFB dibangunkan dengan mengunnakan pakej perisian FEA komersial iaitu ANSYS Release 14. Model ini telah dibangunkan dengan menggunakan data daripada ujian tensil. Ujian tensil yang telah dijalankan, menggunakan sampel yang menepati standard ASTM D3039 dan ujian itu dilakukan dengan menggunakan mesin ujian universal (INSTRON 5585). Kajian telah dijalankan ke atas pelbagai jenis elemen-elemen yang sedia ada dalam perisian ANSYS. Shell 181 menunjukkan korelasi terbaik keseluruhan dan juga mempunyai masa pengiraan yang terendah.. Elemen Plane 182 juga menunjukkan korelasi yang baik dengan eksperimen

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

With the problem of environment and sustainability at large, there has been many developments of green technology where the field of material science and engineering has been developing biocomposites to play its part. Biocomposites as materials are coupled with natural resources have seen increasing research interest. Biocomposites poses a challenge where the many combinations of materials offer a wide variety of properties as well as characteristics. The characteristics and properties of biocomposites vary typically due to the influence of natural fibres type, the effect of environmental conditions where the fibres are sourced, the methods involved in treating the fibres and the alterations made to the fibre matrix.

The scarce availability of non-renewable resources has made a tremendous impact on the dependence of renewable resources. The emergence of products based on renewable plants has surged in recent times. Natural fibres are sourced from various types of plants grown commercially are shown in Table 1.1. The fibres produced from the plants are grouped into six types; bast fibres, grass fibres, core fibres, leaf fibres, reed fibres, and all other types eg. wood and roots (Omar et al.2012).

Table 1.1: Commercially available fibre source

Fibre source	World production (10^3 ton)
Bamboo	30000
Jute	2300
Kenaf	970
Flax	830
Sisal	378
Hemp	214
Coir	100
Ramie	100
Abaca	70

Utilisation of natural fibres in modern engineering provides advantages such as low weight, low density, recyclability and biodegradability (Khalid et.al 2008) which allows for a better way of managing these biofillers. Natural fibres on their own possess mechanical properties that can justify their utilisation for much application. However by coupling them with plastics which exhibit high plasticity load bearing applications could be applicable.

In Malaysia oil palm empty fruit bunch (EFB) which is the waste product of palm oil processing of almost 30 million tonnes per year is abundantly available (Hassan et al.1997). Recent researches involving utilisation of EFB as reinforcement matrix in polymers have been conducted in which the mechanical properties were studied (Yusoff et al.2010). These studies were done by altering the preparation of the fibre and its matrix (Arbelaiz et al.2005).EFB bio-composites are assessed on their mechanical properties through tensile tests and flexural tests (Yusoff et al.2010). Studies regarding the effect of chemical modification on mechanical properties (Rozman et al.2003) and also hybrid bio-composites (Jawaid et al.2012) were also done. EFB fibres are produced from the fruit bunch of oil palm they are processed by first shredding it the conveying the shredded EFB through a hammer mill to produce the strands of fibre. The Oil Palm fruit bunch and its fibre are shown in Figure 1.0. The properties of untreated EFB fibres are found in Table 1.2.

Table 1.2: Properties of EFB fibres

Properties	
Diameter (µm)	250 - 610
Moisture content (%)	2.2 – 9.5
Tensile Modulus (MPa)	71
Young's Modulus (MPa)	1703
Elongation of break (%)	11

Figure 1.1: Empty fruit bunch and the processed fibre (Rozman et al.2003)

The growing pace in adapting EFB fibres as reinforcement in polymers is bottlenecked by manual methods in predicting its properties. Finite element analysis (FEA) could prove useful in the current scenario as the FEA would allow for much more advanced data extraction. FEA could give insights on the stress distribution in the biocomposite structure which otherwise will be impossible with conventional testing. This allows researchers to save time and money on making prototype. However there is lack of codes which are suitable to simulate biocomposites with discontinuous fibre reinforcement. The approach of using material models which are designed for metals could offer an alternative but the model should be validated with actual experiment data. Currently there are various commercial FEA codes available such as Abaqus, Ansys, and NASTRAN-PATRAN.

1.1 PROBLEM STATEMENT

The large waste of by-products such as bio-mass, fronds, and empty fruit bunch (Rozman et al.2003) are produced every day. In an effort to diversify the use of by-products, fibres produced from empty fruit bunch (EFB) is currently undergoing extensive research ,as this fibre can be used as a replacement for non-organic composite fillers in polymer composites. Many researches had been done on the structural performance of EFB fibre reinforced epoxy (Yusoff et al.2010) and EFB reinforced Polypropylene (Rozman et al.2003) but these have only consisted of mechanical testing and there is still lack of FEA modelling done in order to determine the performance of these structures. FEA modelling allows reduction in terms of research and time consumption besides fewer experiments are required to be conducted. Moreover FEA model will also be able to show the distribution of stress and strain of a final product during the design stage. Hence FEA model has to be developed in order to aid researches on natural fibre reinforced composite

1.2 OBJECTIVES

The goal of this research in order to solve the problem statement given previously is to model a suitable finite element model in order to study stress distribution in discontinuous fibre arrangement in polypropylene. The major concern of the research is the correlation of data gathered from the experiment and the data produced by the FE analysis.

The objectives of the research are:

1. To develop a finite element model using finite element software.
2. To simulate and examine the stress distribution using finite element software.
3. To validate the finite element model with experimental work.

1.3 SCOPE

1. Development of finite element model for randomly distributed palm fibre reinforced polypropylene composite for tensile loading.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

This literature study emphasises on the review of structural performance of oil palm EFB fibre composite materials, specifically the tensile properties of the composite. Studies regarding finite element analysis (FEA) validated by experimental work carried out by researchers globally are reviewed. Besides that, scholarly work in relation to the preparation and treatment of fibre as well as standards used in mechanical testings are reviewed

2.1 OIL PALM EMPTY FRUIT BUNCH FIBRE

Oil palm empty fruit bunch fibre (OPEFB) also called lignocellulose fibres are composed of cellulose and hemicellulose in a lignin matrix as shown in figure 2.1. The compositions of lignin, cellulose and hemicellulose differ from breeds of oil palm, soil and plantation location. The mechanical properties which attribute the oil palm fibre such as tensile strength, flexural strengths, and rigidity are dependent on the alignment of the cellulose fibrils (John and Thomas, 2008). Cellulosic fibrils align themselves parallel to each other and form crystalline structure and a small quantity of amorphous regions. Figure 2.2 shows the transverse cross section of OPEFB fibre cell wall structure. The OPEFB fibre consists of two main walls, the secondary wall consists of three sub-secondary (S1, S2, and S3) wall layers where the layers consist of different cellulose fibril orientation (Khalil et al.2006).OPEFB fibres are found in thread-like bundles where after processing the fibres are turned into long and short singular strands in the lengths of 50-60mm and 10-30 mm respectively (Hassan et al.2010).

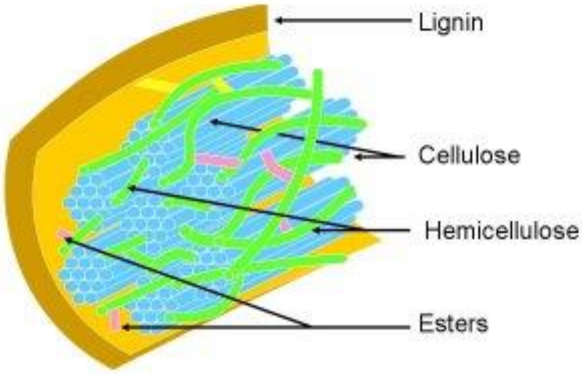

Figure 2.1: Arrangement of lignin, cellulose, and Hemicellulose (Source:http://lignofuel.wordpress.com)

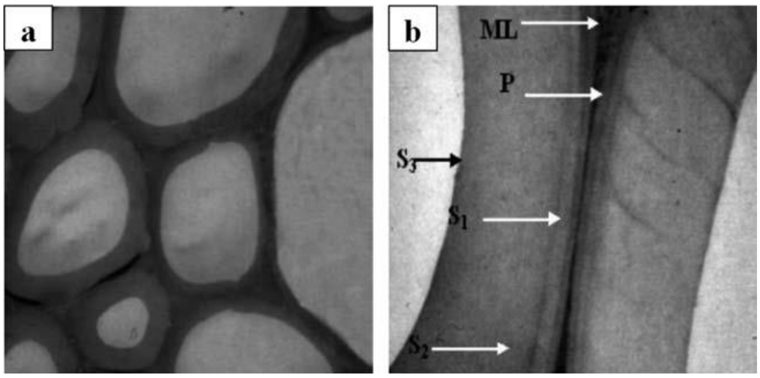

Figure 2.2: Transverse section of OPEFB fibre cell wall structure (ML, middle lamella; P, primary wall; S1, S2, and S3, secondary wall sub layers)(Source: Hassan et al.2010)

2.2 POLYPROPYLENE COMPOSITES

Polypropylene is used widely due to its properties such as low density, good surface hardness, and good mechanical properties (Perez et al.2012). However polypropylene (PP) alone is not sufficient for applications that require high stiffness and mechanical strength. In order to overcome these insufficiencies polypropylene based composites gained interest and is commonly used in home appliances, automotive industry and other industries. The mechanical properties of the composites especially those composites reinforced with natural fibre still lack good data of their mechanical properties (Perez et al.2012). Glass fibre reinforced polypropylene, carbon fibre reinforced polypropylene and the newer carbon nanotube reinforced polypropylene composites are some of the common composites of polypropylene with inorganic fillers. Research on these composites have been done on their mechanical properties such as Mariana an Silvia (2012) who have studied the effect of enhancing adhesion between the glass fibre and the PP matrix on the mechanical properties of the composite. Rahmanian et al.(2012) conducted study on the effect on tensile strength, flexural strength and impact properties of carbon nanotube coated glass and carbon fibre reinforced polypropylene composite. Natural fibre reinforced polypropylene has properties which make it important as a renewable and environmentally friendly substitute to non-organic fillers such as glass fibres and carbon fibres. Natural fibres are low in cost, biodegradable, have low density and have high specific strength (Pankaj et al.2012). Tensile and fracture behaviour of PP and wood flour (WF) composite was conducted by Ezequeil et al (2012). In the experiment, samples with different weight content of wood flour were produced. Tensile test conducted showed that the pure PP composite was far more superior having higher tensile strength compared to PP/WF composites which had failed at a lower tensile strength. Besides, the tensile strength reduces as the weight content of WF increases.

Comparative studies between oil palm empty fruit bunch (OPEFB) fibre and oil palm derived cellulose in their mechanical studies have been carried out by Khalid et al. (2008) In the study tensile strength, flexural strength and impact strength of both fibre and cellulose filled PP in different loading contents were compared, where the study showed that PP has decreasing if not the same tensile strength when loaded with the fibre and cellulose.

2.3 FIBRE LOADING IN COMPOSITES

Short discontinuous fibres are usually produced by adding certain amount of fibres into the matrix, where any amount of fibre loading other than the specific fibre content will lead to detrimental effects on the mechanical properties of the composite. Fibre loading refers to the volume fraction or weight fraction of the fibre content in a sample of composite. Fibre loading is determined either by using volume fraction or weight fraction.

Weight fraction of the fibre is given is by the weight of fibres to the sum of weight of both fibre and matrix.

$$W_T = W_f + W_m$$ *Equation 1*

Weight Percentage (%) $= \dfrac{W_f}{W_m}$ *Equation 2*

Where;

W_T = Weight of total fibre and matrix composition

W_f = Weight of fibre content

W_m = Weight of matrix content

The Volume fraction of fibres can be found from the weight fraction of the sample. The equations for the conversion are given by;

$$V_m = \frac{W_m}{\rho_m}$$ *Equation 3*

$$\frac{V_f}{V_m} = \left(\frac{W_f}{W_m}\right) \bullet \left(\frac{\rho_m}{\rho_f}\right)$$ *Equation 4*

Where;

V_f = Volume of fibre in the content

V_m = Volume of matrix in the content

ρ_f = Density of fibre , in the case of polypropylene is given by Jawaid et al.(2010) as 0.7 – 1.55 g/cm^3

ρ_m = Density of the matrix, in the case of polypropylene is given by Rozman et al.(2003) as 0.903 g/cm^3

W_f = Weight of fibre content

W_m = Weight of matrix content

In the work by Ramli et al. 2011 study of the effect of fibre loading and coupling agents on mechanical, thermal and interfacial properties were done. From the study it was determined that overall the 30% by weight fibre loading offered best tensile strength compared to other percentages of fibre loading.

2.4 COUPLING AGENT

Coupling agent allows for a better adhesion between fibre and the PP matrix. In many research involving the investigation of mechanical properties of natural fibre reinforced PP or other polymers, coupling agents such as meleated polypropylene (MAPP) and maleic anhydride (MAH) are used. The MAH is present also in MAPP. The methodology involving the use of these coupling agents differs in the sense of interchanging the components (MAH< MAPP) to treat composite. When the fibres are treated with a coupling agent, the MAH is used and should the PP is to be treated or grafted as the process is named then MAPP is used. MAH reacts with the lignocellulosic hydroxyl group making them form a covalent bond with the polar acid base in PP. In a study conducted by Rozman et al (2003) studies were carried out to investigate the effects of MAH as the coupling agent on various fibre weight gain in EFB fibre reinforced with PP composite. The weight gains in the fibres are caused by absorption of maleic anhydride by the fibres thus it is analogous to higher percentage of weight gain means higher amount of MAH used. The result of the study in respect to flexural test concludes that the 20% weight gain of fibre at all filler size (mesh 60, mesh 80and mesh 120) offers the best flexural strength to the composite.

MAPP is produced by grafting MAH and PP by using peroxides at desirable temperatures and is applied as a coupling agent in composites by adding a certain weight percentage of MAPP during sample production. MAPP improves the adhesion between fibre and matrix by improving wetting of the fibre with the PP matrix by causing the fibre surface to become hydrophobic and also by allowing covalent bonds between fibre and matrix to develop. (Park et al. 2006) In a published work by Khalid et al. (2006) the effect of MAPP as coupling agent on mechanical properties of EFB fibre and cellulose polypropylene composite (shown as Cellulose in Figure 2.3 and Figure 2.4) was carried out. The research was carried out by using samples with 30% weight fibre and cellulose weight loading with variable MAPP content on mechanical tests. Figure 2.3 and Figure 2.4 show the results from the tensile and flexural test respectively, it can be concluded that 2% MAPP addition as coupling agent offers the best solution for tensile strength while 2% addition in flexural test offers best solution for fibre matrix adhesion other than no coupling agent being added.

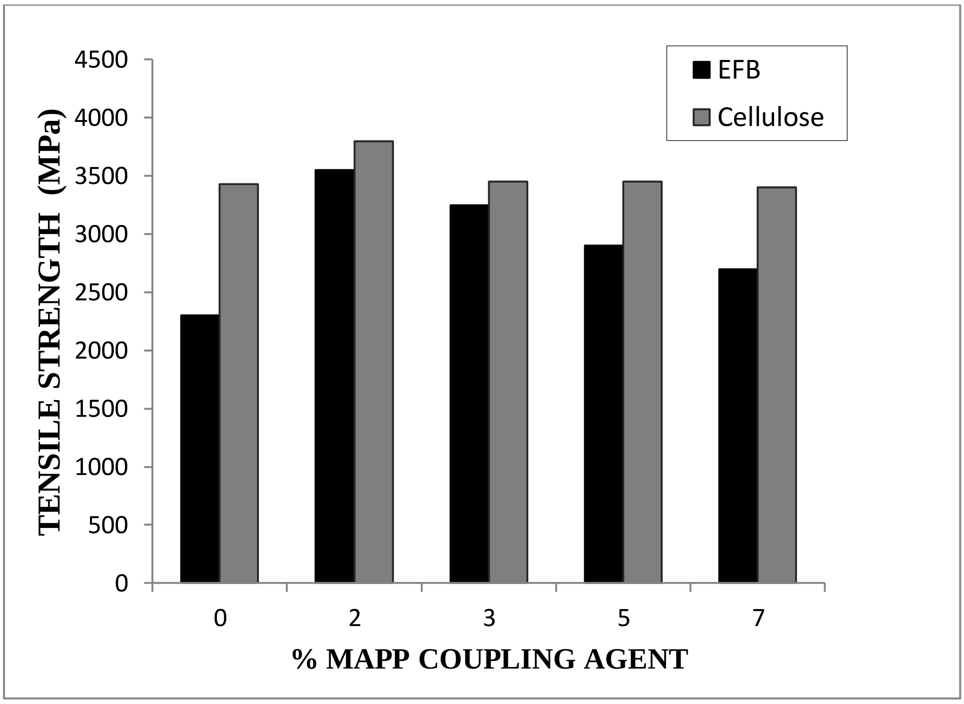

Figure 2.3: Effect of MAPP on composite tensile strength at 30%wt filler loading (Khalid et al. 2006).

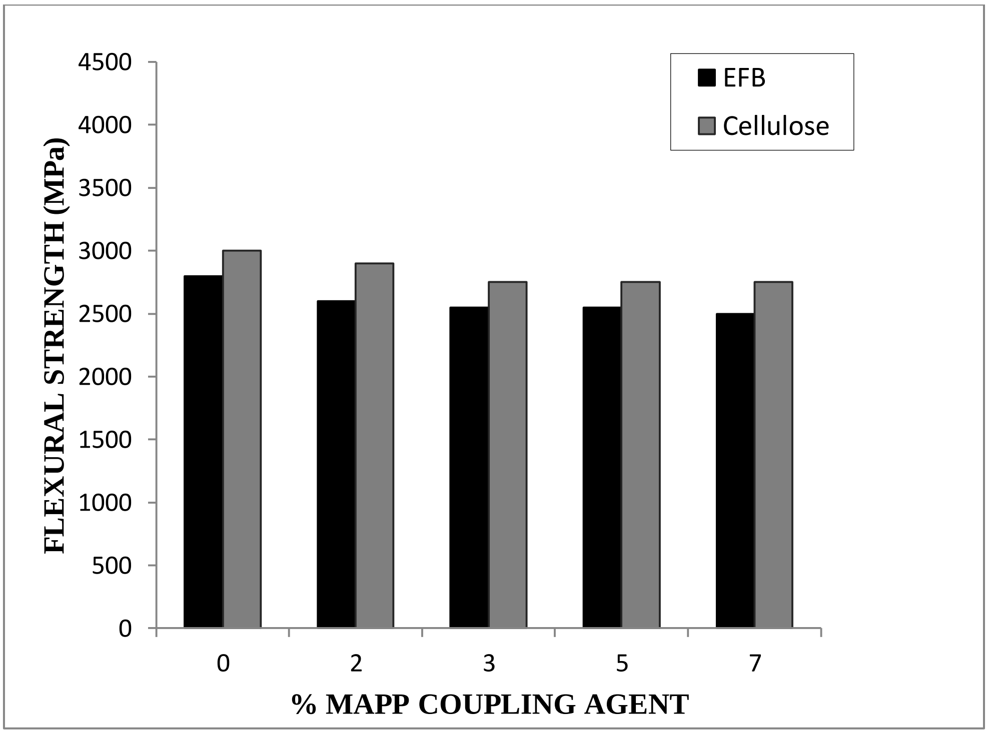

Figure 2.4: Effect of MAPP on composite flexural modulus at 30%wt filler loading (Khalid et al. 2006).

2.5 ALKALINE TREATMENT

Alkaline treatment is done on fibres in order to create better compatibility with the PP matrix. In the work of Bedzki and Gassan (1999) alkaline treatment towards cellulose based reinforcement in thermoplastics was done. It was found that removal of lignin and hemicellulose improved the tensile characteristics of the fibre due to the capability of fibrils arranging themselves better for stress distribution of tensile stress. The alkaline treatment also increases the surface roughness of the fibre which improves the mechanical bonding. (Asumani et al.2012) In the works of Bachtiar et al.(2010) the flexural strength was improved compared to untreated fibre by immersing the sugar palm fibre in a solution of 2.5% NaOH for 1 hour. Izani et al.(2012) treated oil palm EFB fibre with 2% NaOH by immersing the fibres in the solution for 30 minutes, treatment by boiling in hot water for 30 minutes and also did a combination treatment by immersing the fibre in 2% NaOH and then boiling the fibres in hot water for another 30 minutes. The study concluded that soaking in NaOH for 30 minutes had favourable tensile strength compared to other treatment methods. Table 2.1 shows the summary of mechanical properties before and after the treatment.

Table 2.1: Mechanical properties of treated and untreated fibres (Izani et al.2012)

Treatment	Untreated	Water Boiling	NaOH soaking	NaOH & Boiling
Fiber Diameter (μm)	180-440	330-340	230-380	180-305
Maximum Stress(MPa)	52	49	64	42
Young's Modulus (MPa)	2407	2763	2625	1890
Elongation at Break (%)	10	7	10	9