UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## Faculty of Mechanical Engineering

# COMPRESSION MOLDED KENAF/POLYPROPYLENE (K/PP) COMPOSITE: DETERMINATION OF IMPACT PROPERTIES USING DESIGN OF EXPERIMENT (DOE) ANALYSIS

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**Master of Science in Mechanical Engineering**

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**LOH XIAO HUI**

**A thesis submitted**
**in fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering**

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**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2017**

## DECLARATION

I declare that this thesis entitled "Compression Molded Kenaf/Polypropylene (K/PP) Composite: Determination Of Impact Properties Using Design Of Experiment (DOE) Analysis" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any degree.

Signature : …………………………...…
Name : …………………..……...
Date : …………….………….

**APPROVAL**

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature :…………………………………….
Supervisor Name :…………………………………….
Date :…………………………………….

**DEDICATION**

To my beloved family and family-to-be

# ABRTRACT

Natural fiber is an attractive replacement material for synthetic fiber as it owns countless advantages outlined by researchers. Industry field is adopting natural fiber as application where matching them with suitable polymer. In this study, kenaf/polypylene (K/PP) composite will be tested on Izod impact strength (ASTM D256) by varying fiber weight and length and subjected under various impact angles. Maleic anhydride-grafted-polypropylene (MAPP) will be premixed with polypropylene (PP) using internal mixer to enhance surface contact between fiber and matrix. Hardness and density test will also be conducted to identify physical properties of samples. Microstructure observation will be carried out to visualize bonding surface between fiber and matrix. Next, design of experiment (DOE) analysis will be used to identify the relationship between these factors outlined. From Izod impact test outcome, higher fiber length did helps to improve impact properties of composite as well.But, stress distribution of fiber at shorter length at lower impact angle is more significant. Therefore, sample with fiber length 1 cm and loading 30 wt.%was determined as best sample which can present good impact properties at different impact angles. Microstructure of sample shows fiber has good surface coverage with addition of MAPP into PP. Lastly; prediction of impact behavior for K/PP composite can be done by applying formula obtained through factorial analysis generated by Minitab software.

# ABSTRAK

Serat semula jadi dilihat sebagai pengganti gentian sintetik kerana ia memiliki banyak kelebihan yang dinyatakan oleh penyelidik. Bidang industri sedang menggunakan serat semula jadi dan dipadankan dengan polimer mengikuti aplikasi produk. Dalam kajian ini, kenaf/polypylene (K/PP) komposit akan diuji kekuatan impak Izod (ASTM D256) dengan mengubah kandungan serat dan panjangnya untuk diuji dengansudut impak yang berlainan. Maleic anhydride-campuran-polipropilena (MAPP) akan pracampur dengan polipropilena (PP) dengan menggunakan pengadun dalaman untuk meningkatkan kawasanpersentuhan permukaan antara serat dan matrik. Ujian kekerasan dan ketumpatan komposit juga akan dijalankan untuk mengenal pasti ciri-ciri fizikal sampel. Pemerhatianpermukaan ikatan antara gentian dan matrik akan dilakukan melaluigambaran mikrostruktur. Seterusnya, reka bentuk eksperimen (DOE) analisis akan digunakan untuk mengenal pasti hubungan antara faktor-faktor yang digariskan . Daripada hasil ujian Izod, serat yang lebih panjang tidak semestinya dapat menjamin untuk mempunyai kekuatan yang tinggi juga. Tetapi, agihan daya daripada serat panjang adalah lebih baik berbanding dengan serat yang lebih pendek pada sudut lebih rendah. Justeru itu , sampel dengan panjang gentian 1 cm dan kandungan 30 wt.% telah dipilih sebagai sampel terbaik yang boleh membentangkan ciri-ciri kesan baik pada kesan yang berbeza sudut Microstructure sampel pertunjukan serat mempunyai liputan permukaan yang baik dengan penambahan MAPP ke dalam PP. Akhirnya,. sifat K/PP komposit dapat diramal dengan menggunakan formula yang diperolehi melalui analisis faktorial yang dijana oleh perisian Minitab.

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| | | |
|---|---|---|
| ºC | - | Temperature |
| ° | - | Angle |
| wt.% | - | Weight percentage |
| g | - | Weight |
| µm | - | Length |
| mm | - | Length |
| cm | - | Length |
| m | - | Length |
| J/m | - | Impact energy |
| $kJ/m^2$ | - | Impact strength |
| MPa | - | Pressure |
| $kg/cm^2$ | - | Pressure |
| $g/cm^3$ | - | Density |
| s | - | Time |
| rpm | - | Rotational speed |

# LIST OF PUBLICATIONS

Conference:

- Loh, X.H., Ahadlin, M. & Zulkefli Selamat, M., 2015. Study on Fiber Length And Composition Of Kenaf-Polypropylene (K-PP) Composite for Automobile Interior Parts. *World Virtual Conference on Advanced Research in Mechanical and Materials Engineering*, 2014.
- Loh, X.H., Ahadlin, M. & Zulkefli Selamat, M., 2015. Examining Effect of Mechanical Properties of Kenaf/Polypropylene (K/PP) Composite Using Design of Experiment (DOE) Analysis. *3rd International Conference on Mechanical Engineering Research,* 2015.

Publication:

- Loh, X.H., Ahadlin, M. & Zulkefli Selamat, M., 2015. Study on Fiber Length And Composition Of Kenaf-Polypropylene (K-PP) Composite for Automobile Interior Parts. *Applied Mechanics and Materials*, 695, pp.36–39.
- Loh, X.H., Ahadlin, M. & Zulkefli Selamat, M., 2016. Mechanical Properties of Kenaf/Polypropylene Composite: An Investigation. *Journal of Mechanical Engineering and Sciences (JMES)*, Volume 10, Issue 2, pp. 2099-2111.

Awards:

- Ahadlin, M., Loh,X.H., Zakaria, N.F., Said., Z.A.,& Zulkefli Selamat, M. UTeMEX Research and Innovation Expo 2015, Silver Award. Natural Kenaf Fiber Composite for Automotive Internal Component.

## CHAPTER 1

## INTRODUCTION

Nowadays, people started to have awareness on protecting environment to avoid rapid earth aging process. Many disasters have occurred recent years in different country and take away million lives including human and various species of animals. Non-government organizations (NGO) have raise their voice to all nations to spread the concept and practice to recover back and slowing down earth aging process. Therefore, prevention steps are taking by many state governments to reduce harmful activities which will affect ecology and environment. Now, researchers also contribute to protect green earth by replacing synthetic raw materials with natural materials. For example, natural fiber which can be used into many applications such as automotive, packaging, sports and leisure, construction and so on.

There are two main types of natural fiber which are animal fiber and plant fiber. In this research, the fiber used is natural plant fiber. Natural fiber form plant is a good replacement candidate for synthetic fiber as they are more environmental friendly, sustainable and renewable. Besides that, natural fiber also have numerous advantages compare to synthetic fiber; which are low tool wear, low density, cheaper cost, availability, and biodegradability. Therefore, natural fibers become more popular in industries because it will help to save cost and maintain product quality at the same time.

Kenaf, or it scientific name *Hibiscus cannabinus* is comes from flowering plant family. Kenaf is unique because its stem can be fully used to produce product based on different requirements. This is because outer part of kenaf's stem can be used as bast fiber and the middle part of it can be used as core fiber which has different requirements in manufacturing field. For instance, bast owns higher mechanical strength compare to core fiber. The strength of kenaf bast fiber is enhanced by cellulose arrangement on the layers of wall.Hence, manufacturers can choose either they want to used bast or core in their product to eliminate wasting of another useful part.

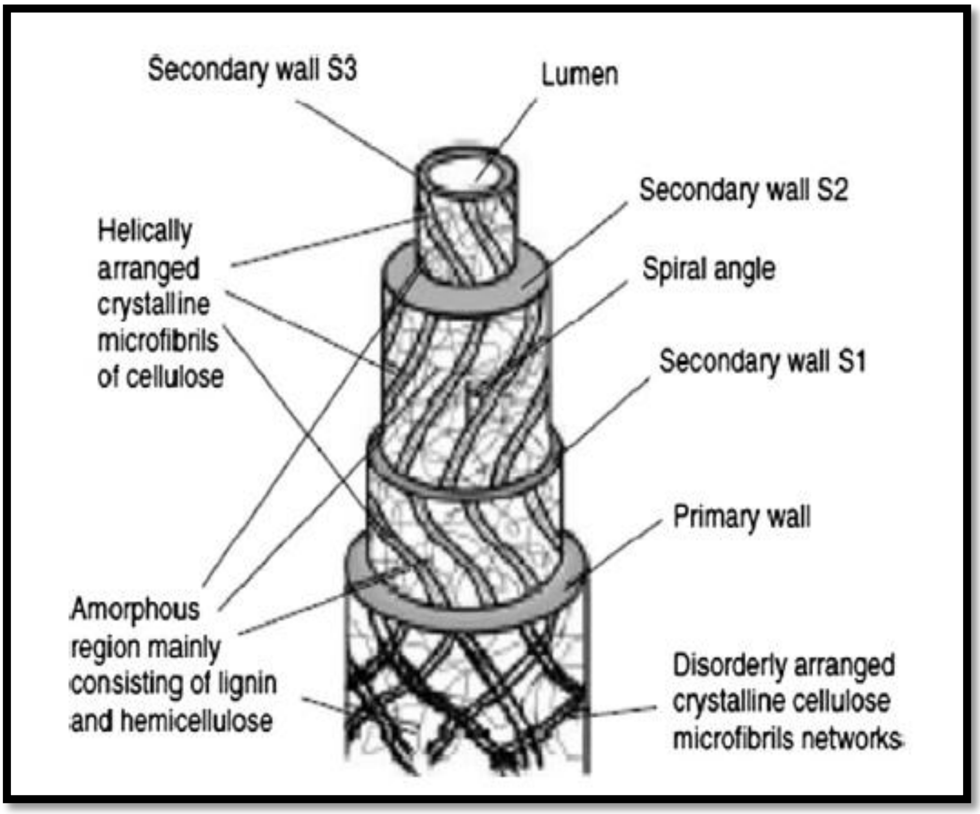


Figure 1.1: Schematic picture of cell wall in natural plants (Akil et al. 2011)

As shown in Figure 1.1, primary cell wall is normally very thin (<1μm), but the secondary wall is composed of three layers. Therefore, secondary cell wall is the thickest and it is also major contributor to the overall properties. The secondary layer is formed by microfibrils, which contain larger quantities of cellulose molecules. Composition of chemical content of kenaf stem will be displayed in Table 1.1.

Table 1.1: Microfibril size and chemical content of kenaf stem (Akil et al. 2011)

| | Bast | Core |
|---|---|---|
| Fibril length h, L (mm) | 2.22 | 0.75 |
| Fibril width, W (μm) | 17.34 | 19.23 |
| L/W | 128 | 39 |
| Lumen diameter (μm) | 7.5 | 32 |
| Cell wall thickness (μm) | 3.6 | 1.5 |
| Cellulose (%) | 69.2 | 32.1 |
| Lignin (%) | 2.8 | 25.21 |
| Hemicellulose (%) | 27.2 | 41 |
| Ash (%) | 0.8 | 1.8 |

## 1.1 Background of Study

Kenaf fiber has high potential to be used as composite reinforcement in biocomposite material. It is made up of an inner woody core and an outer fibrous bark surrounding the core. Natural fiber as reinforce materials with bio polymer matrix composite has great potential that has not been fully explored and understood yet. Natural fiber polymer composites have raised great interests among material scientists and engineers in recent years. This due to the need for developing an environmentally friendly material, and partly replacing currently used glass fiber for composite reinforcement. In addition, glass fiber can cause acute irritation of the skin, eyes, and upper respiratory tract. Concerns have been raised for long-term development of lung scarring (i.e., pulmonary fibrosis) and cancer. When released, glass fiber does not degrade and results in environmental pollutions and threatens animal life and nature significantly.

Additionally, new environmental regulations and uncertainty about petroleum and timber resources have triggered much interest in developing composite materials from natural fibers. NFPC attracts a lot of markets due to the advantages of the natural fibres as their availability, low cost, carbon neutrality regarding the environment, applicability to the available processing machines of thermoplastics and good mechanical properties. Through the optimum utilization of a renewable resource will provide positive image for sustainability of 'green' environment.

## 1.2 Problem Statement

Nowadays, applications of natural fiber composite in daily life product are getting familiar. Studies on various combinations of natural fiber and filler were carried out by researchers worldwide. Throughout understanding from previous findings, there are some questions that are not yet answered. For instance, fiber length of composite produced was approximately 0.5mm. This is due to sample preparation process was completed by internal mixer which will reduce fiber length during mixing and pelletizing. Optimum fiber length is playing an important role to transfer stress to filler; or in other words, higher properties composite. Once the optimum combination obtained, surface bonding between fiber and filler have to take into account in order to secure composite impact properties. Next, prediction of composite behavior can be done by adopting design of experiment (DOE) analysis based on experiments' finding.

## 1.3 Objectives

1. To investigate the impact properties of short kenaf fiber (1 cm, 2 cm and 3cm) reinforced with polypropylene (PP) as a matrix with varying fiber weight fraction i.e. 0 wt.%, 10 wt.%, 20 wt.% , 30 wt.% and 40 wt.%.
2. To analyze the microstructure on surface bonding of Kenaf/Polypropylene (K/PP) composite for further behavior observation.
3. To generate formula on predicting Kenaf/Polypropylene (K/PP) composite by using design of experiment (DOE) analysis

## 1.4 Scope

In this research, compression moulding technique will be used to prepare the kenaf /polypropylene (K/PP) composite specimens for impact test in accordance to the ASTM D256. Polypropylene will be premixed will maleic anhydride-grafted-polypropylene (MAPP) using internal mixer to maximize bonding between matrix and fiber. Specimens will also undergo hardness and density test according to ASTM D2240 and D792 respectively.Inspection of composite is an urgent problem and microstructure observation represents an ideal answer only when a comprehensive study is carried out. Scanning electron microscopes (SEM) and Dino-Lite digital microscope of the investigated samples are used to evaluate the fibre distribution. Next, analysis of experimental data by using Minitab software will give brief explanation of composite behavior.

# CHAPTER 2

# LITERATURE REVIEW

During early age of human generation, raw materials were collected from natural to be used in daily routine. For case in point, straw was added into clay to make wall for shelter by ancient Egyptian. Latterly, textiles were produced from harvest cotton. Years back later, enlarging interest of natural fiber was expanded from daily life to automotive industries. In 1941, Henry Ford and his research workerscommenced their first "soybean car" at an annual community festival. Soybean car was created from combination of steel frame and plastic body which contains of diverse ingredients including soybeans, wheat, hemp, flax and ramie. This car was anidea of merging agriculture and automobile industries which was generate by Henry Ford with help of Lowell E. Overly aided with his supervisor; Robert A. Boyer. Henry presumed that plastics panel of car can safeguards passenger rather than ordinary car; which was made from steel. He also able to handle shortage of metal at that time by finding replacement material obtained from renewable resources (Benson Ford Research Center 2011).

As for latest trend of development, replacements material for synthetic fiber isconcentrated on natural fibers. Besides that, immeasurable advantages of natural fibers over conventional material used in same sector are noticed by researchers. Precisely, attentions on natural fibers aregiven by manufacturers and researchers since many possible combinations can be done based on their product's requirements. Therefore, Table 2.1 below are illustratingseveralwell-known car manufacturers which was already introduced certain vehicle parts in their automotive with natural fiber composite (Jamrichov; & Akov 2013).

Table 2.1: Car Manufacturers with natural fiber composite as part of their products(Jamrichov; & Akov 2013)

| Automotive Manufacturer | Model Application |
|---|---|
| AUDI | A2, A3, A4, A6, A8, Roadster, Coupe: Seat backs, side and back door panels, boot lining, hat rack, spare tyre lining. |
| BMW | 3,5,7 series: Door panels, headliner panel, boot lining, seat backs, noise insulation panels |
| CITROEN | C5: Interior door panelling |
| FIAT | Punto, Brava, Marea, Alfa Romeo 146, 156 |
| FORD | Mondeo CD 162, Focus |
| LOTUS | Eco Elise: Body panels, spoiler, seats, interior carpets |
| PEUGEOT | 406: Seat backs, parcel shelf |
| RENAULT | Clio, Twingo: Rear parcel shelf |
| ROVER | 2000 and others: Insulation, rear storage shelf/panel |
| SEAT | Door panels, seat backs |
| TOYOTA | Brevis, Harrier, Celsior, Raum: Door panels, seat backs, spare tyre cover |
| VOLKSWAGEN | Golf, Passat, Bora: Door panel, seat back, boot lid finish panel, boot liner |
| VOLVO | C70, V70: Seat padding, natural foams, cargo floor tray |

In addition, European Union (EU) had amendedan act named directive 2000/53/EC approved by the European Parliament and Council in 18 September 2000 regarding end-of-life vehicle. This act aims to help reduce waste and rebirth certain recyclable components