The Influence of Filler Loading on Mechanical Properties of Rice Husk Reinforced High Density Polyethylene

By

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CERTIFICATION OF APPROVAL

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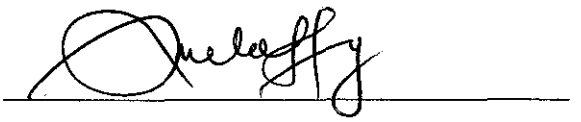
Approved by,



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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and the original work contained herein have not been undertaken or done by unspecified sources or persons.

TUAN MOHD FAIZIE BIN TAN YUSOFF

ABSTRACT

The aim of this project was to investigate the influence of varying filler loading on composite mechanical properties. The filler used in this research was rice husk and the matrix was high density polyethylene (HDPE). The particle size of the filler was 0.5 mm. Particulate size of rice husks were compounded together with the matrix polymer and moulded into dog-bone shaped specimens using an injection moulding machine. In the sample preparation, rice husks were prepared using four different filler loadings which were 0, 5, 10 and 15 wt.%. The effect of the coupling agent on the mechanical properties was also investigated by incorporating 2% maleated polyethylene (MAPE) at three different filler loadings which were 5, 10 and 15 wt.%. From the microstructure observation, the surface characteristic of filler was changed when it has been dried in an oven during filler preparation process. After the drying process, the surface of rice husk appeared to be smoother than before the drying process and the ridges were less visible from the surface. Results obtained from tensile test showed that tensile strengths of the composites decreased with increasing filler loading. With the addition of compatibilizing agent, tensile strength of the composites was improved as much as 14% as filler was incorporated into the matrix at 5 wt.%. For the flexural strength, it was observed that flexural strength increases gradually with increase in filler loading. Flexural strength decreased by 16 % as 5 % filler loading added to the composite. However the flexural strength of the composites increased gradually as filler content increased to 10 and 15 wt. %. Microstructural observation of the tensile fractured surfaces of samples without added compatibilizing agent showed poor compatibility of the filler–matrix as evidenced by filler debonding and pull-out. In the case of the composites with compatibilizing agent, the interfacial bonding between the filler and the matrix polymer was stronger, resulting in fracture at the filler itself and not at the interface.

ACKNOWLEDGEMENTS

First and foremost, thank god for His grace and mercy throughout the progress of Final Year Project. I would like to acknowledge my family for always being there to provide financial and moral support. I would also like to record my gratitude to Assoc Prof Dr Puteri Sri Melor Binti Megat Yusoff, my Final Year Project's supervisor. She has been abundantly helpful, and has supported me in numerous ways, from the very early stage of this project until I have finished this project for this semester. She also introduced me the aspects needed to do my FYP and the methods which are to be used to analyzed the project so that the needed result can be obtained. Besides, I would like to express my special thanks to the lecturers and others who have directly and indirectly contributed to the project by giving valuable information on how to conduct and improve the project. Without such assistance from these people, this Final Year Project might not be as successful as it is.

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NOMENCLATURE

RHF Rice Husk Fiber

SLF Rice Straw Leaf Fiber

SSF Rice Straw Stem Fiber

WSF Rice Whole Straw Fiber

WF Wood Fiber

HDPE High-density Polyethylene

MAPE Maleated Polyethylene

PE Polyethylene

PP Polypropylene

SEM Scanning Electron Microscope

CHAPTER 1

INTRODUCTION

1.1 Background Of Study

In recent years, natural fibers have been widely used as reinforcing fibers in thermoplastic polymer composite materials. Natural fiber reinforced thermoplastic composites have recently gained importance in various applications as building materials and automotive components. The fibers offer advantages of large quantity, annual renewability, low cost, renewability, competitive specific mechanical properties, reduced energy consumption, and environmentally friendliness [1]. The addition of fibers to the polymer matrix is a fast and cheap method to modify the properties of the base polymer [2]. Each fiber adds its own characteristics to the host matrix and consequently, changes the properties of the composite. The natural fibers used to reinforce thermoplastics mainly include wood, sisal, jute and flax [3].

Rice husk fiber can also be considered as important potential reinforcing filler for thermoplastic composite. Rice husks are an agricultural industrial residue produced as by products during the rice milling process [2]. Rice husk is the outer covering of paddy and accounts for 20-25% of its weight [4]. In the last few years, rice husk fiber has been studied due to their large availability. Global paddy production reached 628 million tons in 2005 with an additional one percent increase in 2006 [4]. The U.S. rice production in 2006/07 was at 10 million tons [1]. In fact, as consequence of the large production of rice, approximately 600 million tons/year [3], there is a large amount of rice husk waste.

Production of rice is dominated by Asia, where rice is the only food crop that can be grown during the rainy season in the waterlogged tropical areas. Most paddy is produced by China (31%) followed by India (21%). Assuming a husk to paddy ratio of 20% [2],

and an ash to husk ratio of 18% [3], the total global ash production could be as high as 21,000,000 tons per year. Figure 1.1 shows the 20 highest rice paddy producing countries in 2002.

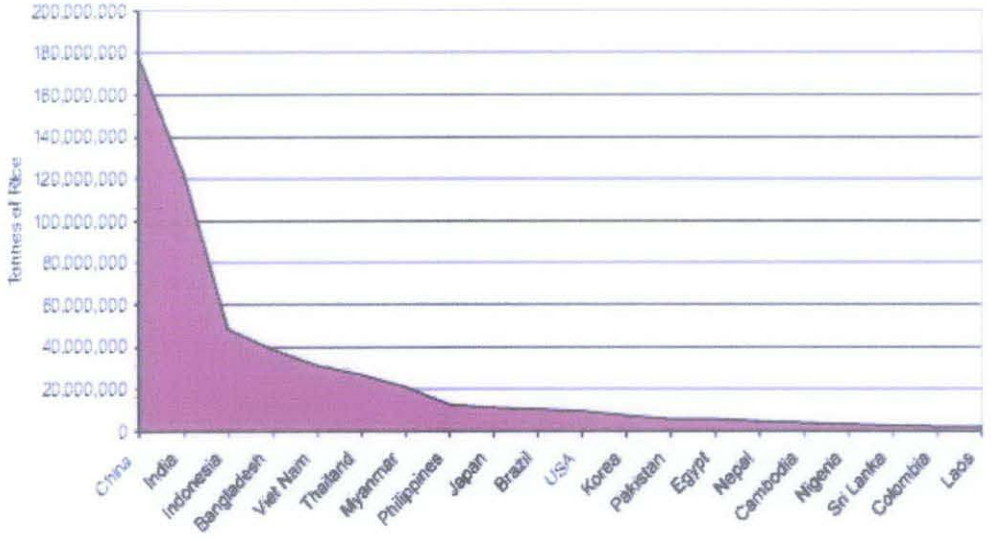

Figure 1.1: The 20 highest rice paddy producing countries in 2002 [3]

1.2 Problem Statement

Most of the rice husks are either used as a bedding material for animals, are burned or used for land filling. Rice husk biomass waste is very much abundant in many countries around the world. This waste material can be found elsewhere and often times we can see piles of rice husks at the back of the rice mill where they are stacked for disposal or some are thrown and burned on road sides to reduce its volume [4].

The burning process of this substance pollutes the environment with silica [2] and therefore this is not the better way to get rid of the huge amounts of rice husks produced every year. Therefore, the use of rice husks and its derivatives in the manufacturing of thermoplastic polymer composites is attracting much attention and has become one of the most important aspects of industry to overcome the problem of environmental pollution. However, the characteristics and mechanical performance of rice husk filled

composites require further study before the composites can be used as an alternative material.

1.3 Objective

The objective of this research is to study the influence of varying the filler loading on the mechanical properties of the thermoplastic composites as the composition of the filler are varied through tests conducted using established standards.

1.4 Scope of Study

In this investigation, rice husk was used as filler in high density polyethylene matrix (HDPE). The filler that was used in this study was rice husk which in size of 0.5 mm. The matrix polymer that was used was high density polyethylene (HDPE). The composites were prepared using three different filler loadings which were 5 wt%, 10 wt% and 15 wt% with and without the use of coupling agent. Maleated polyethylene (MAPE) coupling agent was used to study its effect on the composite mechanical properties. The mechanical testing that was performed includes tensile and flexural testings. The effect of the filler loading on the mechanical properties was studied through tensile and flexural tests. The morphology of the composites fracture surface was examined in order to study and understand the fibre-matrix adhesion of the composites.

CHAPTER 2

LITERATURE REVIEW

A recent research was conducted to investigate the effect of compatibilizing agents on mechanical properties. Han-Seung Yang [5] performed this study using rice-husk flour as the reinforcing filler and polypropylene as the thermoplastic. The different levels of filler loading and compatibilizing were used to prepare the samples. The tensile test was conducted on the samples at the different crosshead speeds and temperatures. As the filler loading increased, the composite made without any compatibilizing agent showed decreased tensile strength and more brittleness, but other mechanical properties were greatly improved by incorporating the compatibilizing agent. Another research by Keneer TJ [6] showed that maleated coupling agents can increase the compatibility and improved the matrix fiber adhesion through the interaction between the anhydride group of coupling agent and the hydroxyl groups on the natural fibers.

Other research by Han-Seung Yang [7] was to examine the possibility of using lignocellulosic materials as reinforcing fillers and to determine testing data for the physical, mechanical and morphological properties of the composite according to the reinforcing filler content in respect to thermoplastic polymer. In this study, polypropylene as the matrix and rice-husk flour as the reinforcing filler were used to prepare a particle-reinforced composite. In the sample preparation, four levels of filler loading (10, 20, 30 and 40 wt.%) were designed. In the tensile test, six levels of test temperature (-30, 0, 20, 50, 80 and 110 °C) and five levels of crosshead speed (2, 10, 100, 500 and 1500 mm/min) were designed. From the results obtained, tensile strengths of the composites slightly decreased while the tensile modulus improved as the filler loading and crosshead speed increased. Also, the tensile strength and tensile modulus of the composites decreased as the test temperature increased because the thermoplastic

polymer was softened at these increasing temperatures and the composite showed more ductility. From the morphology study, it's revealed that as the filler loading increased more filler particles and increased numbers of holes where filler particles have pulled out traces.

Previous research has mainly focused on rice husk fiber reinforced thermoplastic composites. Research by Fei Yao [1] was to study the influence of various rice straw fiber components on mechanical properties of the reinforced HDPE composites using both virgin and recycled HDPE materials. Influences of different rice straw components, and compatibilizers on various properties of rice-straw based polymer composites were also investigated. Untreated rice straw was used in this study to obtain the elementary properties of rice straw-based HDPE composites. Five kind of reinforcing materials including rice husk fiber (RHF), rice straw leaf fiber (SLF), rice straw stem fiber (SSF), rice whole straw fiber (WSF) and wood fiber (WF) were used in this study. From the results, they showed that fiber reinforced virgin HDPE (VHDPE) had relatively larger storage modulus and loss modulus but reduced tensile and impact strength. The trend was more obvious at the higher fiber-loading fiber. Rice straw fibers can work well with both VHDPE and RHDPE as reinforcing filler. Also, different components of rice straw had no significant influence on mechanical properties of composites [1].

Silvia Luciana Fávaro [3] studied the mechanical and morphological properties of composites, prepared with modified and unmodified post consumer high density polyethylene (HDPE) matrixes and modified and unmodified rice husk fibers as the reinforcement phase. Composites were obtained from post consumer high density polyethylene (HDPE) reinforced with different concentrations of rice husk. PE and rice husk were chemically modified to improve their compatibility in composite preparation. Rice husk was mercerized with a NaOH solution and acetylated. The chemically modified fibers were characterized by FTIR and 13C NMR spectroscopy. From the results, the incorporation of rice husk fibers into the PE matrix increased the tensile and flexural modulus of the composite prepared with 10 wt% of acetylated rice husk fiber and unmodified polyethylene matrix appreciably. This composite presented an increase of 35% in Izod impact strength [3] comparatively to that of the pure matrix. SEM

photomicrographs demonstrated the interfacial interaction between acetylated rice husk fibers and unmodified PE and the better phase compatibility afforded by acetylation. The modification of PE did not improve its interaction with modified and unmodified fibers, which explains the poor mechanical properties of its composites.

The use of rice husk as a filler not only limited reinforced with thermoplastics but also can be used to reinforce with waste tire rubber. The study by D. Garcia [8] was to evaluate the effects of amount and average size of rice husk particles on the sintering process. Waste tire rubber and rice husk with different average size particles were used as raw materials for obtaining plates by sintering technique. It is anticipated that the use of both residues in the production of new materials could reduce the environmental problems associated to their accumulation. The tensile test was performed on this rice husk–rubber composite to study their mechanical properties. As a general trend, an increment in rice husk content enhances the elastic modulus, decreases the tensile strength and the strain at break, whatever the particle size used. At low strains, the higher stiffness of the rice husk produces an increase in the global stiffness of the composite.

2.1 Theory

2.1.1 Rice Husk

The exterior of rice husk is composed of dentate rectangular elements, which themselves are composed mostly of silica coated with a thick cuticle and surface hairs. The mid region and inner epidermis contain little silica [10]. Table 2.1 shows the properties of rice husk.

Table 2.1: Rice husk's properties [10]

Property	Range
Bulk density, kg/m³	96 - 160
Length of husks, mm	2 – 5
Hardness (Mohr's scale)	5 – 6
Ash, %	22 – 29
Carbon, %	~35
Hydrogen, %	4 – 5
Oxygen, %	31 – 37
Nitrogen, %	0.23 – 0.32
Sulphur, %	0.04 – 0.08
Moisture, %	8 - 9

Paddy on an average consists of about 72 % of rice, 5 % – 8 % of bran, and 20 % – 22 % of husk 4 [10]. It is also estimated that every tone of paddy produces about 0.20 t of husk and every tone of husk produces about 0.18 t to 0.20 t of ash [10], depending on the variety, climatic conditions, and geographical location.

2.1.2 Injection Molding

The schematic of an injection molding machine is shown in Figure 2.1. Most injection molding machines is of the reciprocating Archimedian screw type in which the polymer is melted in a barrel.

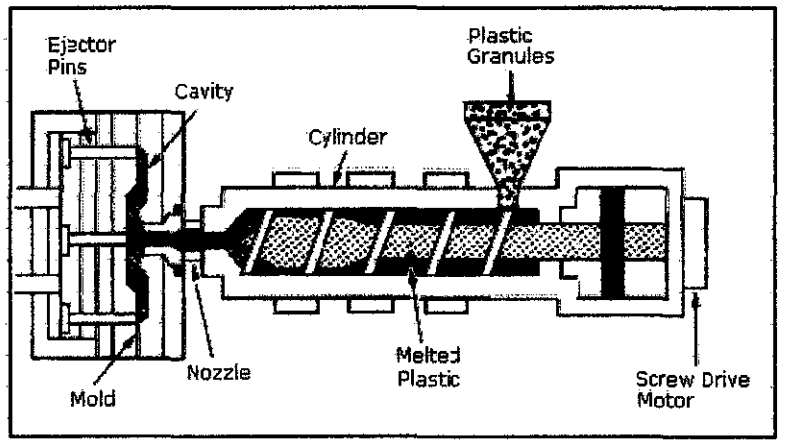

Figure 2.1: The parts of injection molding [11]

The material which is in form of granules is fed into the barrel through a hopper and falls on to one end of the screw. The polymer melts and further heating is obtained from mechanical work as the screw turns through the viscous melt. At the forward end, the shank of the screw has a larger diameter so that the channel defined by the flights is shallower and the work done on the material intensifies.

As material is fed forward the screw is allowed to move backwards along the barrel axis and a charge of homogenized melt gathers at the front end of the barrel. When sufficient material is present to fill the mold cavity plus the runner system the screw is thrust forward, propels the melts into the mold via a nozzle that is held tightly against the entrance to the mold.

The material in the mold must now be allowed to cool until it is sufficiently solidified. The force on the screw is maintained for a significant fraction of the cooling time so that thermal shrinkage of the melt can be combated and the mold is keep topped up. Once the material in the gate has frozen, the holding pressure can be released and the screw

can start to turn again and prepare the next charge. Further cooling time must be allowed to elapse before the molding has solidified sufficiently to be ejected [11].

2.1.3 Stress-Strain Diagram

A tensile test is used to determine a variety of mechanical characteristics of material. The specimen is mounted in a test machine and gradually loaded in tension in increasing increments. The total elongation over the gauge length is measured at each increment of the load and this is continued until failure of the specimen takes place. The loads (stress) are observed and the changes in length (strain) are recorded and plotted in stress-strain diagram. Figure 2.2 shows a typical stress-strain diagram [12].

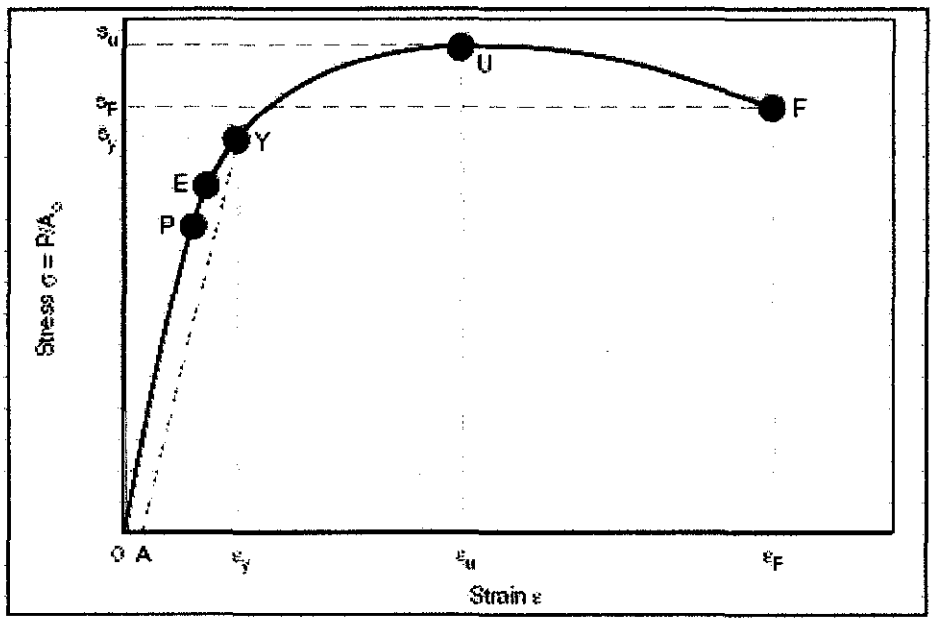

Figure 2.2: A typical stress-strain diagram [12]

Refers to Figure 2.2, point P is called the **proportional limit** where stress is proportional to strain. The slope of the line P is the modulus of elasticity. Point E is the **elastic limit**. At this point, if a part is loaded to a stress level below point E, no permanent deformation will be sustained. During the tension test, many materials reach a point where the strain begins to increase rapidly without a considerable increase in stress. This point is called the **yield point** which is represented by point Y.

The ultimate or **tensile strength** is represented by point U. This is the maximum stress that can be withstood by a part. Point F is where the part **ruptures**. Rupture is the point at which specimen material breaks into two parts [12].

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

The project work in developing rice husk reinforced thermoplastic composites is shown in Figure 3.1.

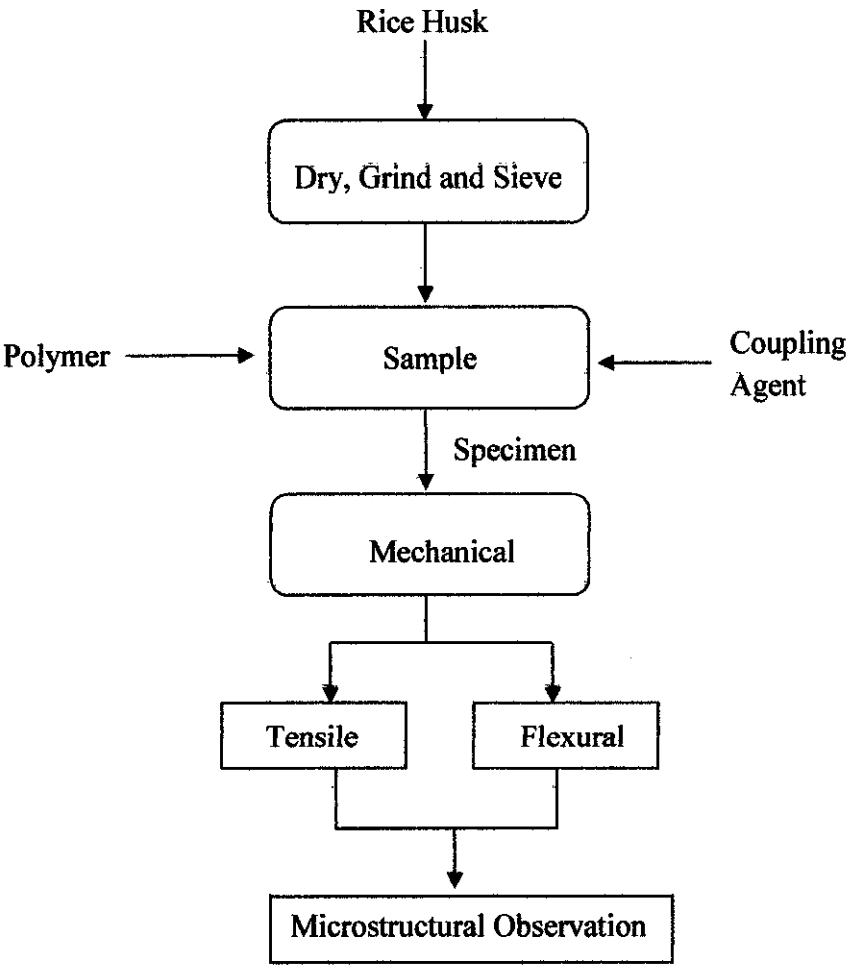

Figure 3.1: Procedure Identification

3.2 Materials

3.2.1 Natural Fiber

The filler that was used in this study was rice husk. This filler is obtained from local sources. The appearance of used filler is shown in Figure 3.2.

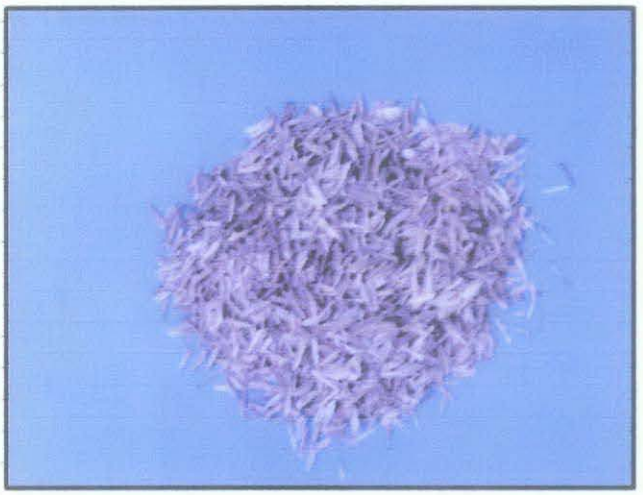

Figure 3.2: The natural filler that employed in the study

3.2.2 Reinforcing Filler

High density polyethylene (HDPE) was obtained by Polyethylene (PE) Malaysia Sdn. Bhd., Kerteh, Malaysia. HDPE was used as the matrix of the composite. The properties of HDPE can be referred in Table 3.1.

Table 3.1: HDPE properties [13]

Properties	Melting Temperature	Melt index	Tensile Strength	Flexural Modulus
HDPE	134°C	10g/10min	19-30 MPa	0.7 - 1.7 GPa

3.2.3 Coupling Agent

Maleated polyethylene (MAPE) was used as a coupling agent. MAPE was ordered from Sigma-Aldrich Corporation. 2 wt% of the coupling agent is incorporated in the composites. Table 3.2 shows the properties of MAPE.

Table 3.2: MAPE properties [13]

Properties	Melting Temperature	Density (at 25 °C)	Viscosity (at 140 °C)
MAPE	107°C	0.92 g/mL	500 000 cps

3.3 Filler Preparation

Rice husk was dried in an oven at 80°C for 24 hours. The initial size of overall rice husk was 3 mm. The filler was then has been grinded and sieved using Rocklabs Type B.T.R.M Model 1A. In order to obtain a specific particulate size of 0.5mm, the grinded rice husks were sieved using Endecotts EFL2000 Sieve Shaker Set together with MaTest Sieve Type 0.5 mm. The composition of the composite material is shown in Table 3.3. Four samples for each tensile and flexural test were prepared for each formulation.

Table 3.3: Material formulations

Materials	Matrix (wt.%)	Filler Loading (wt.%)	Coupling Agent (wt.%)
HDPE-Rice Husk	95	5	-
HDPE-Rice Husk	90	10	-
HDPE-Rice Husk	85	15	-
HDPE- Rice Husk	93	5	2
HDPE-Rice Husk	88	10	2
HDPE- Rice Husk	83	15	2

3.4 Experimental Procedures

3.3.1 Injection molding

Matrix polymer and reinforcing filler was mixed and moulded into dog-bone shaped specimens according to ISO 527-2, type 1B specimen. The composite samples were prepared using an injection molding Tat Ming Engineering Works Ltd, Model ME20 III with an injection pressure of 80 bar and temperatures of 120°C (zone 1) and 180°C (zone 2 and 3). Four levels of filler loadings (0, 5, 10 and 15 wt.%) were used during the moulding process of the specimens. The other set of three filler loadings (5, 10 and 15 wt.%) were added with coupling agent into the mixture. All the composite formulations are injection molded and specimens are produced for subsequent mechanical testing.

3.5 Characterization

3.5.1 Mechanical testing

The tensile tests were conducted according to *ISO 527-2* standard using a Universal Tensile Testing Machine, LLOYD Instruments LR5K. The crosshead speed that used was 5 mm/min. Five specimens were prepared for each formulation.

The flexural testing was performed according to *ISO 178* standard. The flexural modulus was determined using an Universal Tensile Testing Machine, LLOYD Instruments LR5K. The crosshead speed employed is 2 mm/min. At least five specimens of each formulation were tested. The most commonly used specimen size for this ISO standard is 10mm x 4mm x 80mm.

3.5.2 Electron microscopy

The fractured surface of the composites and morphology was studied using a scanning electron microscope SEM-XRAY, Leo 1430VPSEM, High Tech. Instrument Sdn. Bhd. The microstructure observation was carried on fracture and non fracture surface of specimen.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Microstructure Observation

Microstructural observation has been performed by scanning electron microscope (SEM). SEM examination on the filler surface before and after drying, gives further insight on the rice husk morphology and the modification due to the drying process. Figure 4.1 and 4.2 show the surface microstructure of rice husk before drying and after drying respectively.

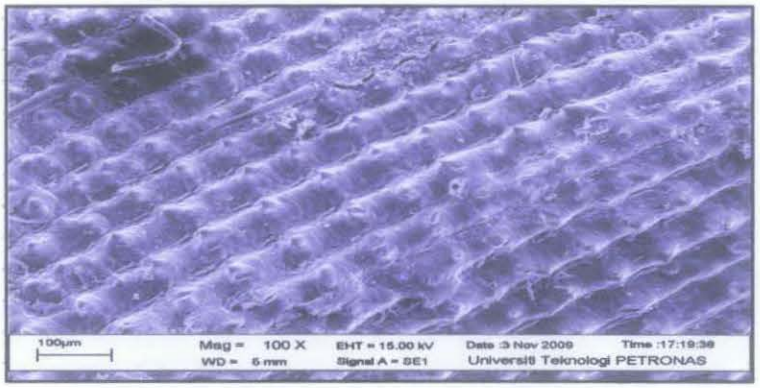

Figure 4.1: Surface of rice husk before drying

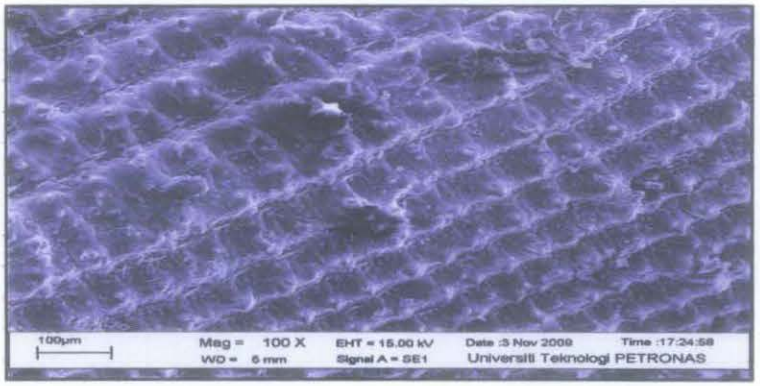

Figure 4.2: Surface of rice husk after drying

From the observation on surface of rice husk before drying process, the surface was characterized by ridges and appeared rough. From the previous study [3, 14] the outer surface of rice husk was highly ridged, and the ridged structures had a linear profile. Thus, dry grinding produced segments of rice husks with epidermal surfaces predominating [14]. After the drying process, the surface of rice husk appeared to be smoother than before the drying process. The ridges were less visible from the surface. The high temperature used during the process of drying may have affected the surface morphology.

4.2 Sample Observation

The rice husk filler and matrix polymer were mixed at four different filler loadings and moulded into dog-bone shaped specimens using injection moulding. The weight of each sample is 13 gram. The test sample has the basic shape of a tensile dog bone, 150 mm long, with the center section 10 mm wide by 4 mm thick by 80 mm long as prescribed by ISO 3167. Figure 4.3 shows the appearance of dog bone shaped specimen without reinforcement.

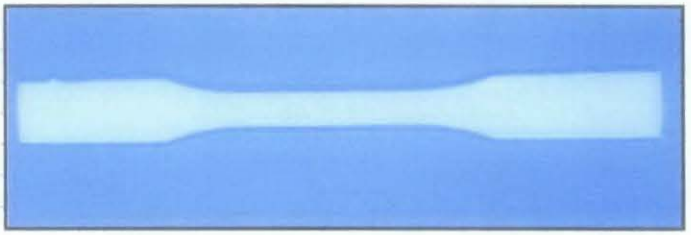

Figure 4.3: A dog bone shape specimen

Resulting samples from the injection molding process can be differentiated based on their color. Sample color turned darker as the content filler increased indicating a successful incorporation of fillers.

4.3 Tensile Properties

Figure 4.4 shows the tensile strength for the tested materials. Five samples were prepared for each formulation. The figure shows the comparison in tensile strength for composites with varying filler loading with and without compatibilizing agent.

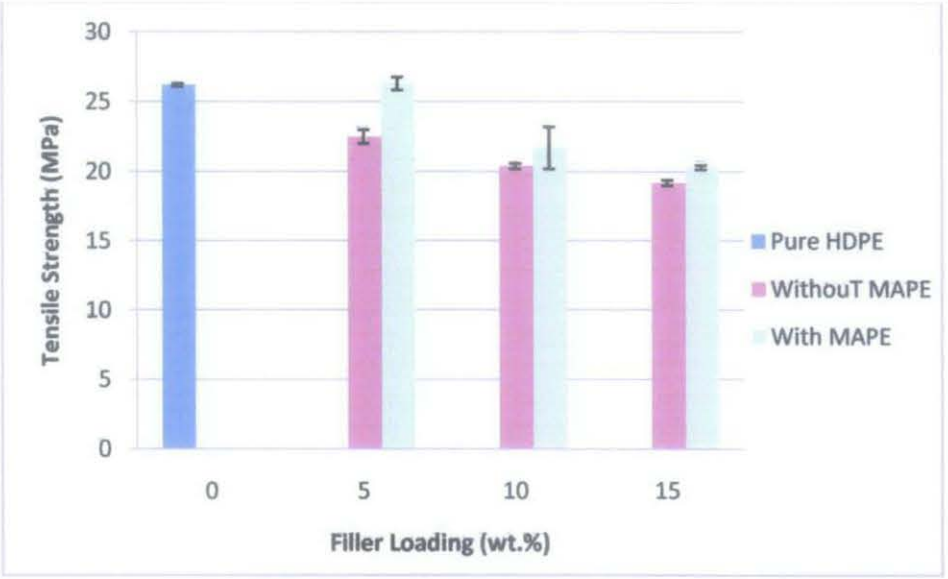

Figure 4.4: Comparison of tensile strength between composites with and without compitibilizing agent.

Composites without compatibilizing agent showed a decreased of 14% in their tensile strength as filler was incorporated into the matrix at 5 wt.%. The tensile strength decreased by another 4% and 5% as the filler contetnt increased to 10 and 15 wt., respectively.

The tensile strength decreased with increasing filler loading due to the poor interfacial bonding between hydrophilic filler and hydrophobic matrix polymer [5]. For irregularly shape filler, the strength of the composites decreases due to the inability of the filler to support stresses transferred from the polymer matrix [7] while poor interfacial bonding causes partially separated micro-spaces between filler and matrix polymer, which obstructs stress propagation when tensile stress is loaded and induce increased brittleness [7]. The results achieved same with the previous researches which indicated

that the tensile strengths of the composites decreased with increasing filler loading [5, 7].

The addition of compitibilizing agent has shown to improve the tensile strength of the composites. At 5 wt.% filler content, the tensile strength of the composites was 26.3MPa as compared to 23.8 Mpa at similar filler laoding but without compitibilizing agnet. The difference is amounting to 11 %. Similar improvement in tensile strength was seen for composites at 10 wt.% and 15 wt.%, although the amount of increament was lower at 6% and 5 %, respectively.

The mechanism of compatibilizing agent is shown in Figure 4.5. The compatibilizing agent chemically bonded with hydrophilic filler and blended by wetting in the polymer chain [6]. The compitibilizing agent chemically bonded with hydrophilic filler and blended by wetting in polymer chain [5].

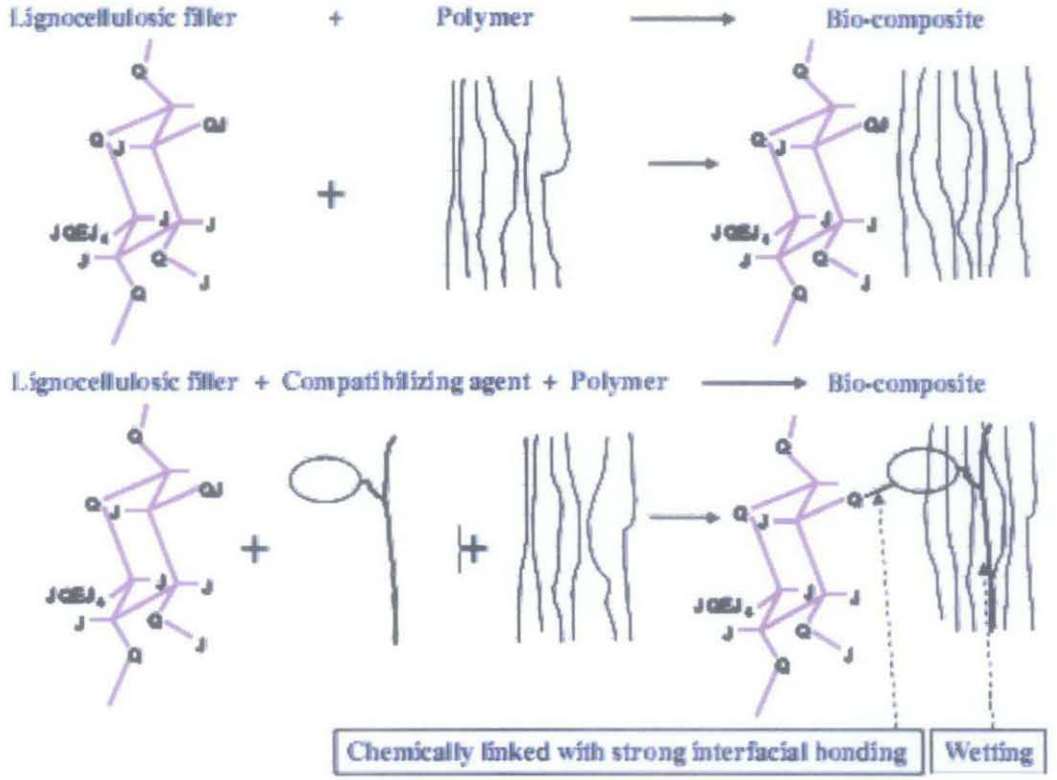

Figure 4.5: Mechanism of compatibilizing agent between hydrophilic filler and hydrophobic matrix polymer [6]

With the addition of compitibilizing agent, tensile strength of the composite significantly improves. This finding is supported by previous studies that have been performed [5, 6]. From the previous study, tensile strength of composite improved up to the same level of that of pure polypropylene [5].

4.4 Flexural Properties

Figure 4.6 shows the flexural strength for the tested materials. Five samples were prepared for each formulation. The figure shows the comparison in flexural strength for composites with varying filler loading with and without compatibilizing agent.

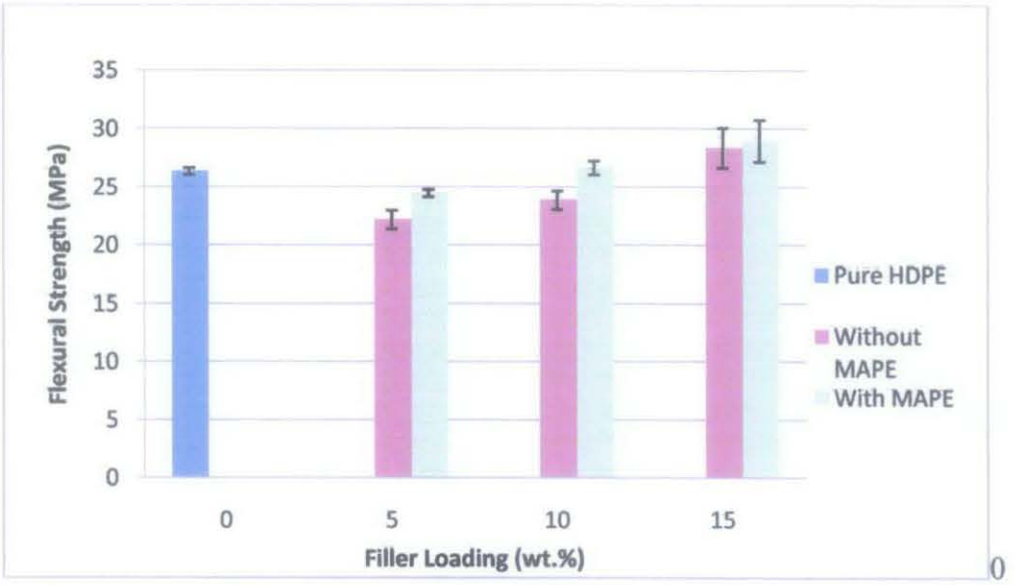

Figure 4.6: Comparison of flexural strength between composites with and without compitibilizing agent.

Results showed that flexural strength of both composites, with and without compitibilizing agent, reduced as 5 wt.% of rice husk filler was incorporated into the HDPE matrix. The reduction is 16 % and 7 % for 5 wt.% composites without and with compitibilizing agent, respectively. However the flexural strength of the composites increased gradually as filler content increased to 10 and 15 wt. %, both for without and with compitibilizing agent. At 15 wt.% filler content, the composite's flexural strength

was 8 % and 10 % higher compared to the pure HDPE, for those without and with compitibilizing agent, respectively.

Flexural loading causes multiple forces which are tensile, compression and shear to develop within the composites [15]. The presence of the filler inside the composites aids in absorbing and transferring the multiple forces developed within the composites. This causes the composites able to withstand greater load [15]. With increasing amount of filler, higher amount of forces and load can be tolerated by the composites. The forces are able to be distributed to the fillers present inside the composites resulting in higher flexural strength at higher filler loadings.

4.5 Morphological study

4.5.1 Fracture surface without compitibilizing agent

The tensile fracture surfaces of the composites at 5, 10 and 15 wt.% filler loadings without compatibilizing agent are shown in Figure 4.7, Figure 4.8 and Figure 4.9 respectively. At 5 wt.% filler loading (Figure 4.7) a few filler particles were clearly seen at the tensile fracture surfaces, with the main component being matrix polymer. At this filler loading, the composite fractured with large amount of plastic deformation indicating ductile failure [7]. At 10 wt.% filler loading (Figure 4.8) the filler particles have pulled out traces. However the matrix polymers still dominate the sample fracture surface. At 15 wt.% filler loading (Figure 4.9) more filler particles were seen rather than matrix polymer. The large amount of poorly bonded interfacial area between filler and matrix polymer causes brittle deformation of the composite. The numbers of holes on the fracture surface also increased. It was observed that some cavities were seen where the filler has been pulled-out. The presence of these cavities means that the interfacial bonding between the filler and the matrix polymer was poor and weak [5]. Poorly bonded interface and the brittleness of the filler have resulted in lower tensile strength values.

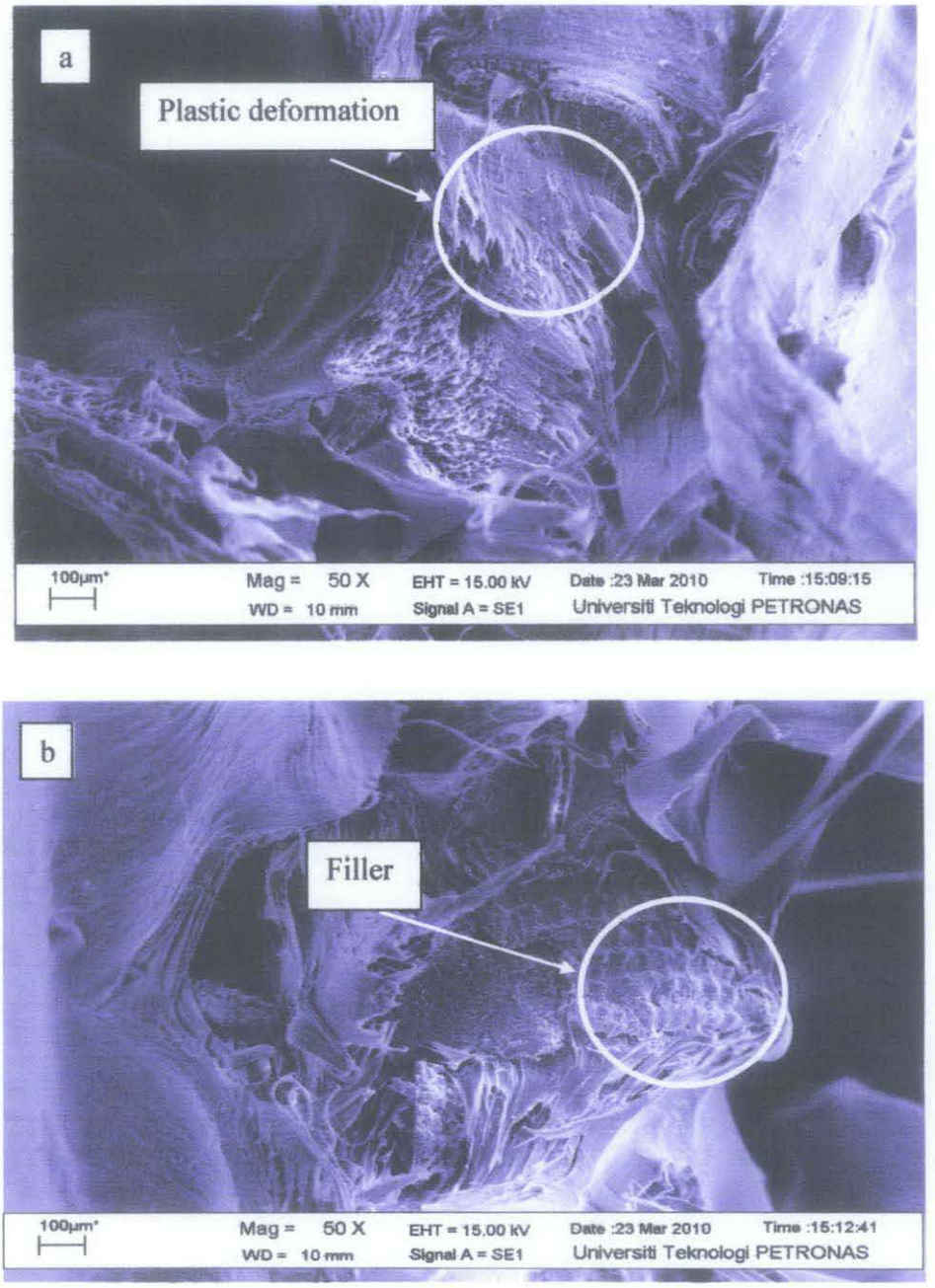

Figure 4.7: SEM micrographs of the tensile fracture surfaces at 5 wt.% filler loading without compitibilizing agent; *(a) magnification = 50 X (b) magnification = 50 X.*

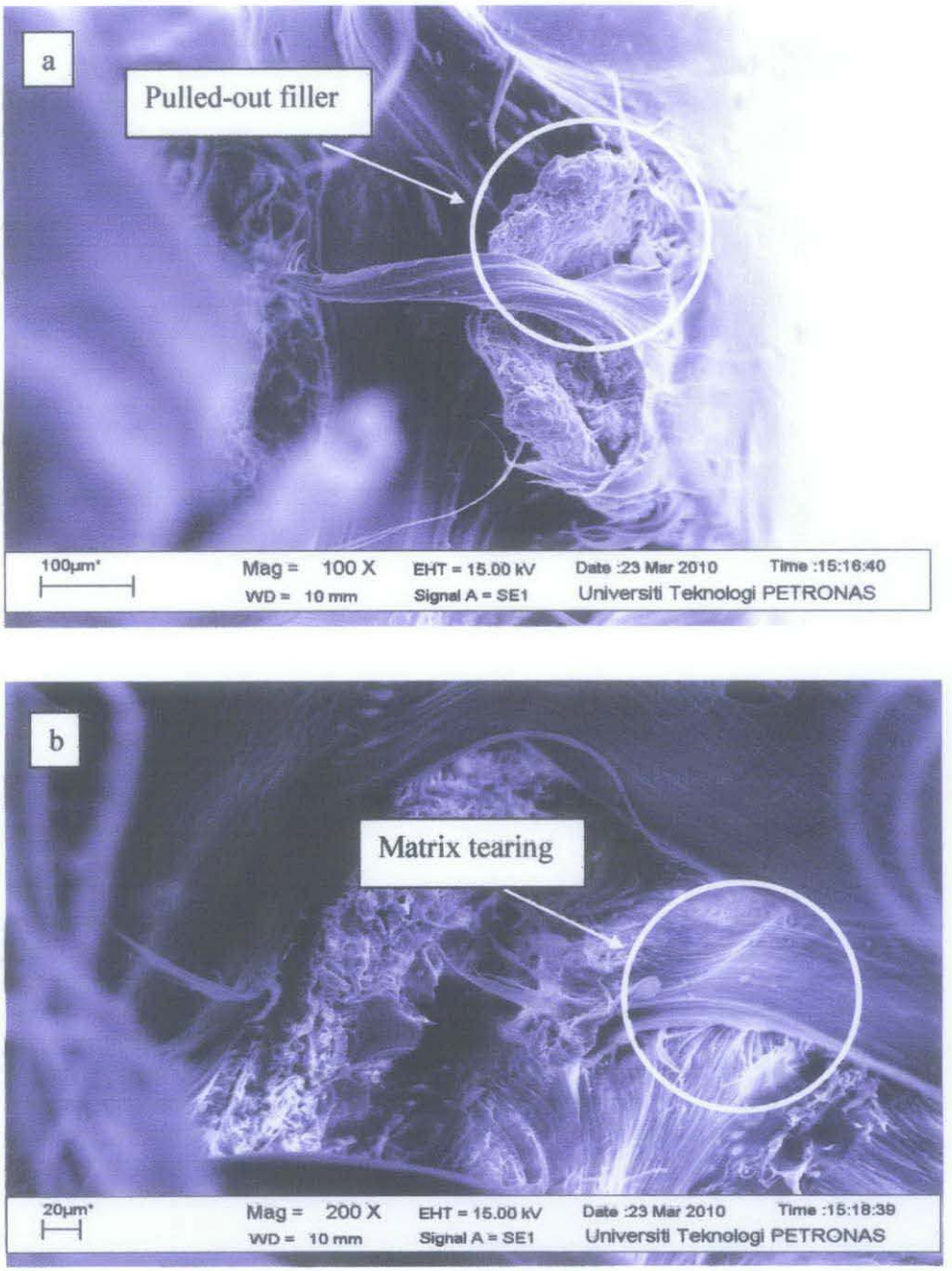

Figure 4.8: SEM micrographs of the tensile fracture surfaces at 10 wt.% filler loading without compitibilizing agent; *(a) magnification = 100 X (b) magnification = 200 X.*

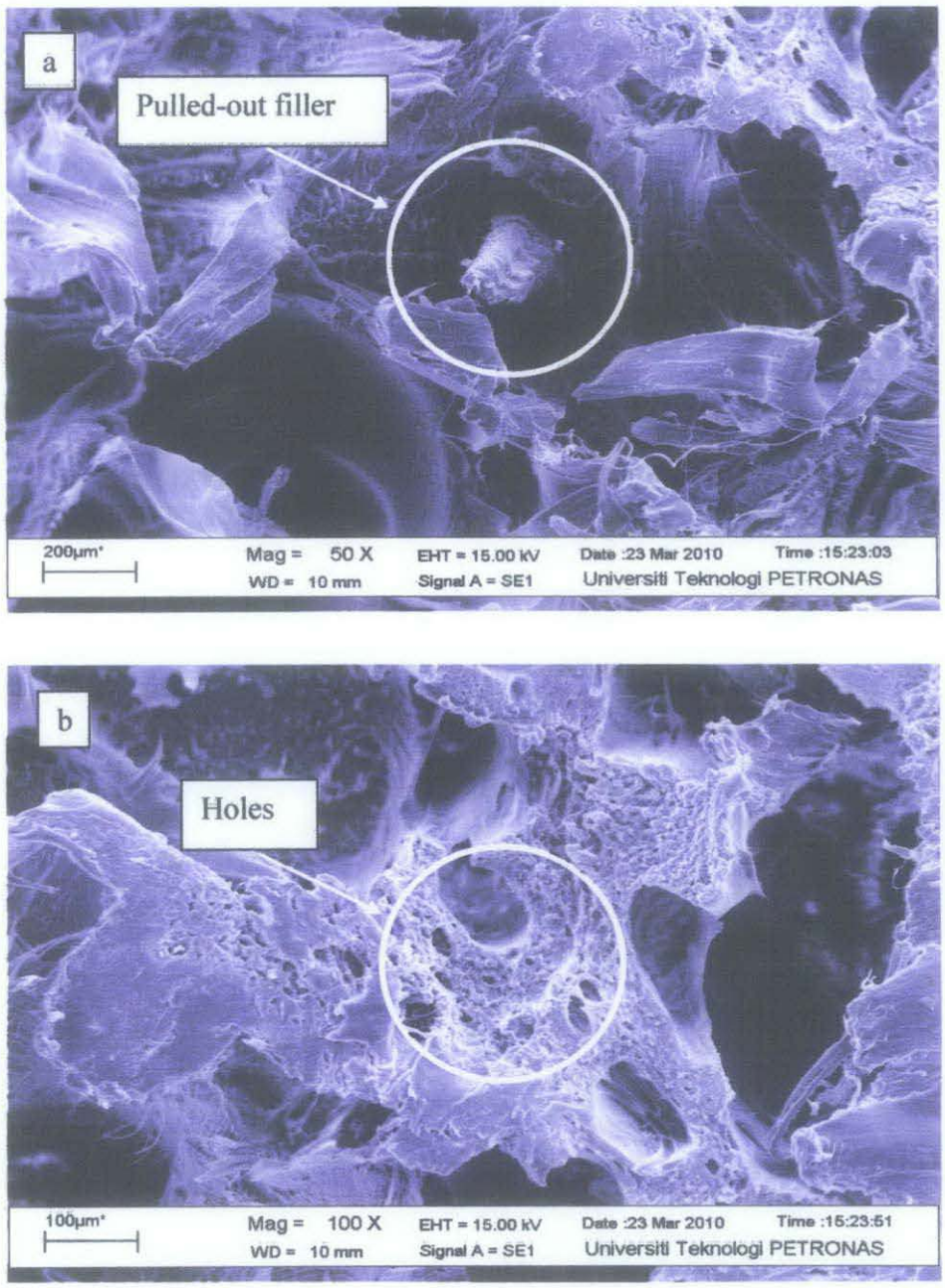

Figure 4.9: SEM micrographs of the tensile fracture surfaces at 15 wt.% filler loading without compitibilizing agent; *(a) magnification = 50 X (b) magnification = 100 X.*

4.5.2 Fracture surface with compitibilizing agent

The tensile fracture surfaces of the composites at 5, 10 and 15 wt.% filler loadings adding with compatibilizing agent are shown in Figure 4.10, Figure 4.11 and Figure 4.12 respectively. For all filler loadings, it can be observed that the rice husk filler has been pulled-out from the fracture surface. In the case of the composite made with compatibilizing agent, the interfacial bonding between the filler and the matrix polymer is strong, and the fracture occurred not at the interface but at the filler itself. This characteristic of the composite with compatibilizing agent causes brittle deformation of the composite when tensile stress is applied. Improved interfacial bonding leads to improved tensile property, which is reflected in the increased strength and modulus of the composite made with compatibilizing agent. Few traces where filler particles have been pulled-out are to be seen, while fractured filler particles are to be seen

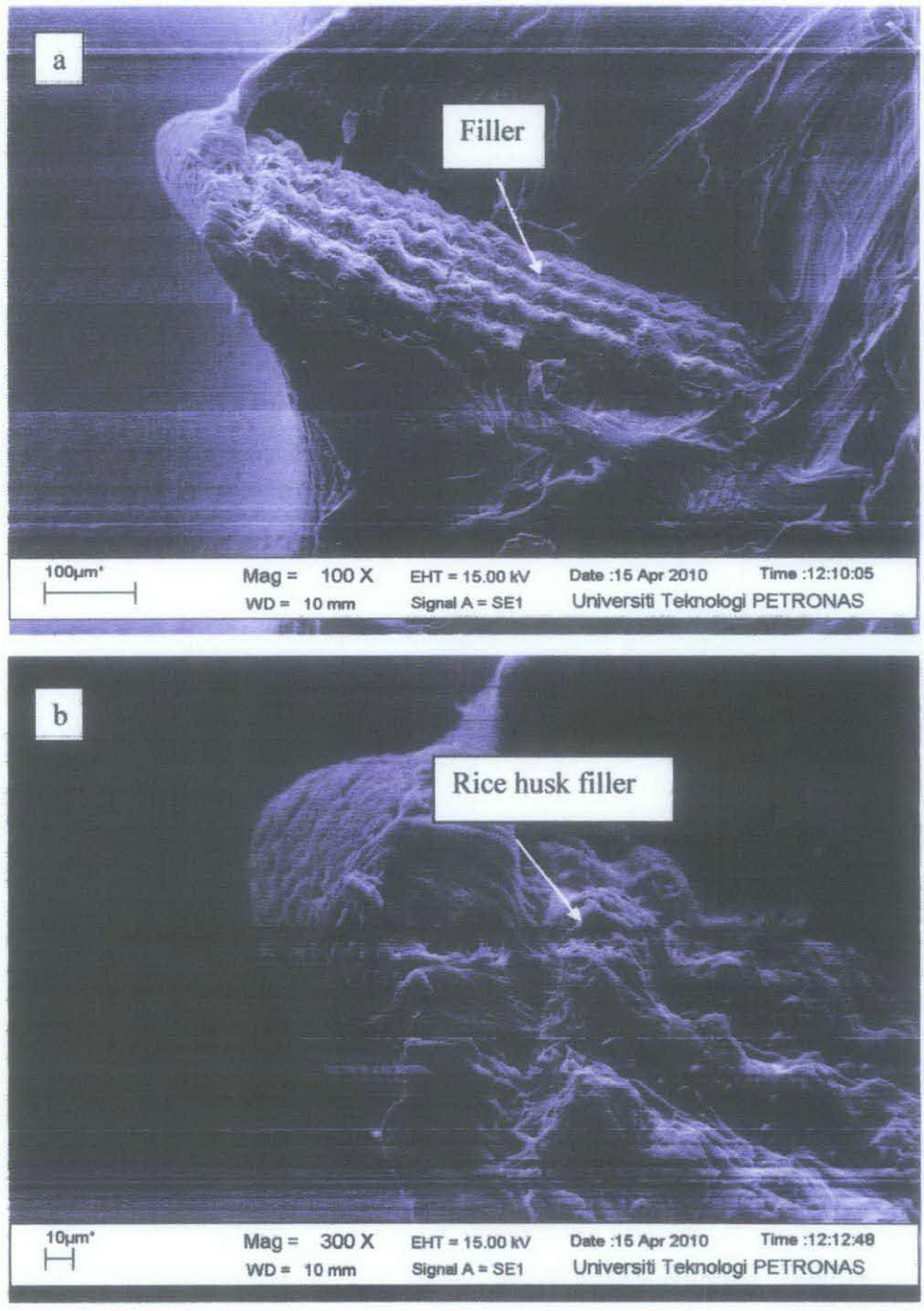

Figure 4.10: SEM micrographs of the tensile fracture surfaces at 5 wt.% filler loading with compitibilizing agent; *(a) magnification = 100 X (b) magnification = 300 X.*

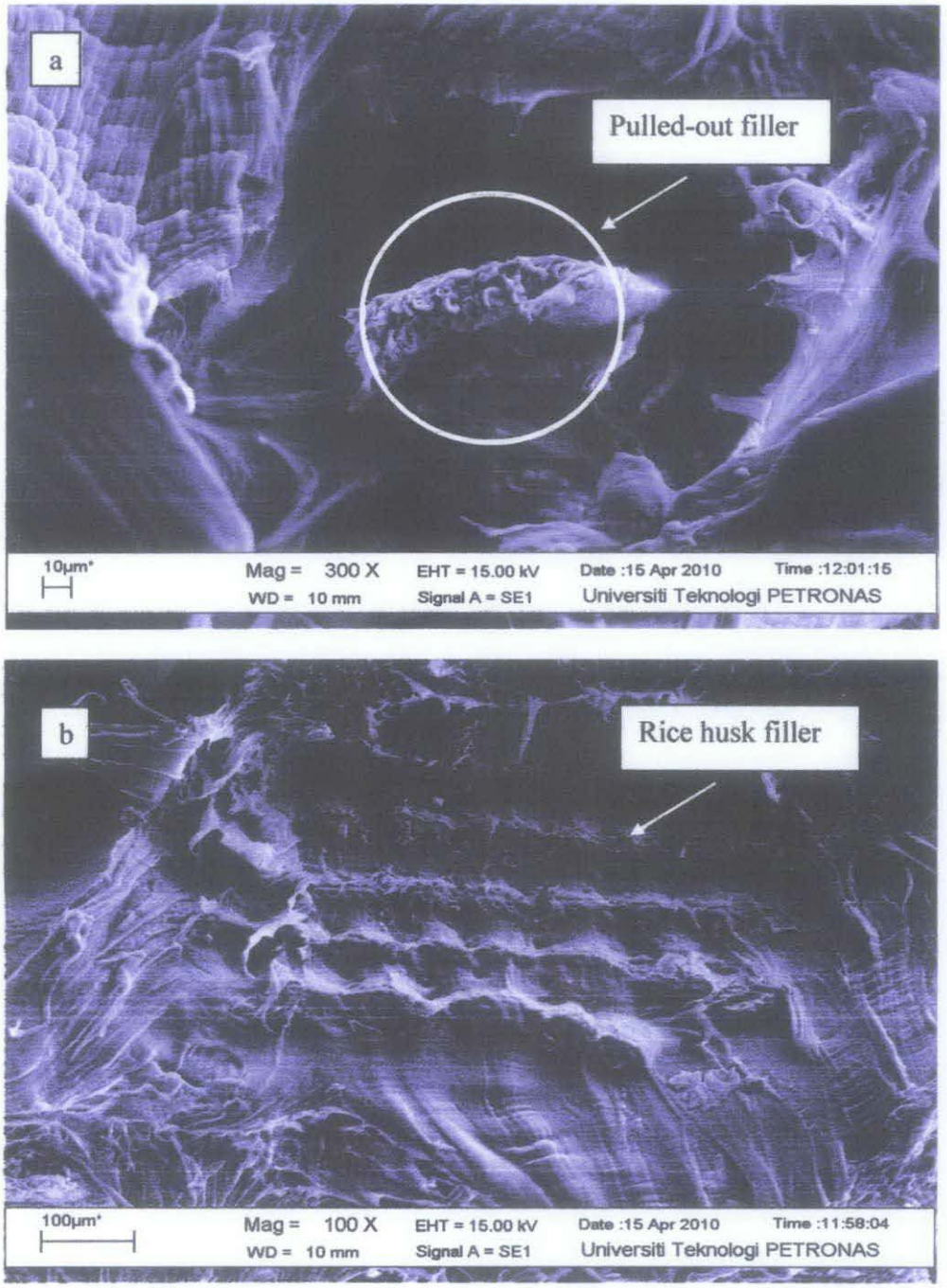

Figure 4.11: SEM micrographs of the tensile fracture surfaces at 10 wt.% filler loading with compitibilizing agent; *(a) magnification = 300 X (b) magnification = 100 X.*

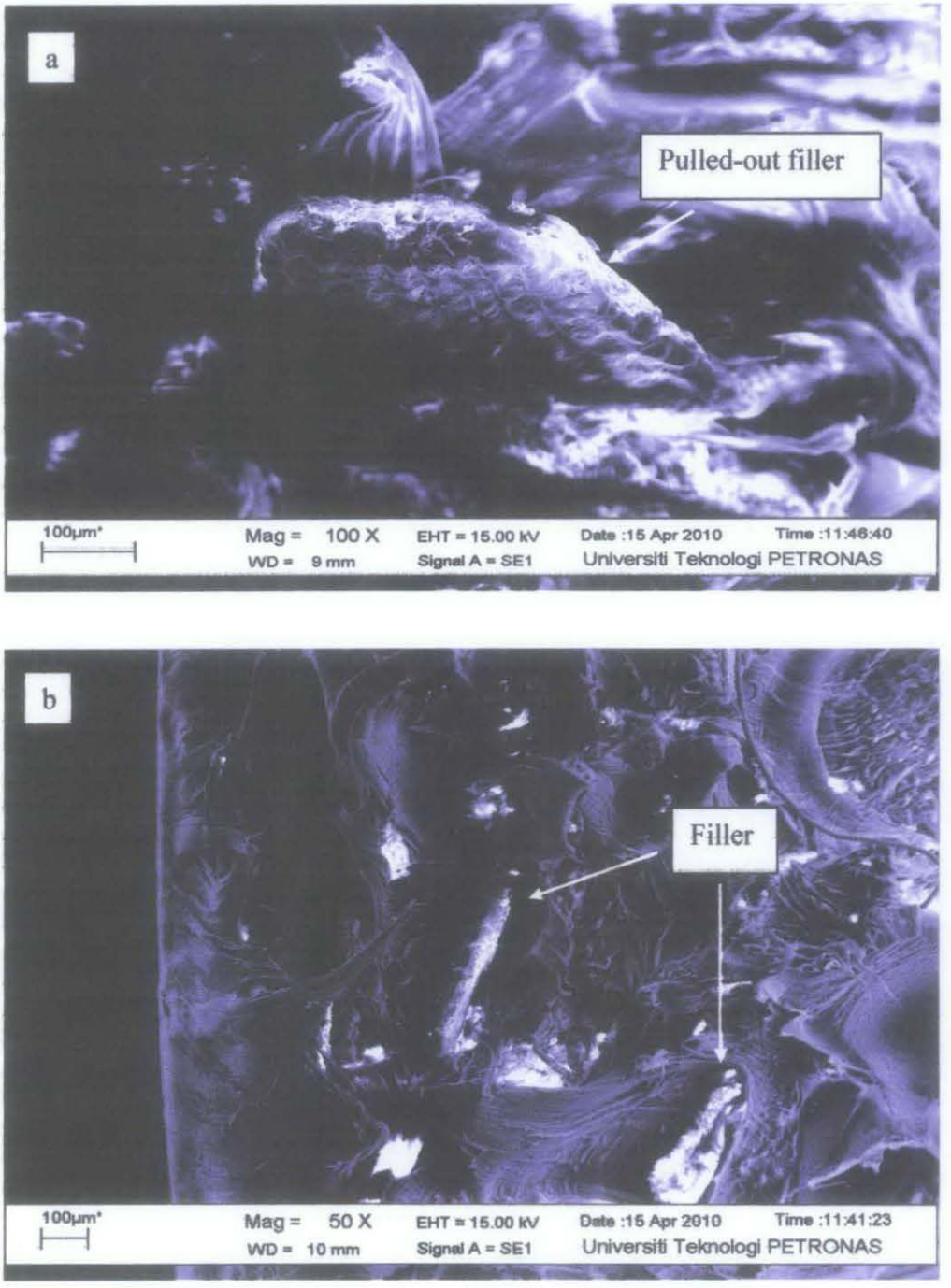

Figure 4.12: SEM micrographs of the tensile fracture surfaces at 15 wt.% filler loading with compitibilizing agent; *(a) magnification = 100 X (b) magnification = 50 X.*

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The tensile strength of the composites obtained agrees with that from previous researche. As filler loading increased, the tensile strength decreased. Tensile strength decreased by 14 % as 5 wt.5 filler was incorperated into the composite. The tensile strength decreased with increasing filler loading due to the poor interfacial bonding between hydrophilic filler and hydrophobic matrix polymer. Generally, the addition of compitibilizing agent which is maleated polyethylene improved the tensile strength of all composites at 5, 10 and 15 wt.% filler. The tensile strength of the composite at 5 wt.% filler content significantly improved up to the same level of that of pure high density polyethylene.

For the flexural strength, it is observed that flexural strength increased gradually with increase in filler loading although initially at 5 wt.% filler, the strength reduced by 16 % and 7 % for composites without and with compitibilizing agent, respectively. As filler content increased from 0 to 5 wt.% the composites showed increased in flexural strength by 8 nad 10 %, for those without and with compitibilizing agent. Incorporating compitibilizing agent increasing filler content up to 15 wt.% have shown to enhance the composite's flexural strength.

From the fracture surface morphologies, as the filler loading increased more filler particles or traces of pulled-out filler particles were seen, while the fractured filler particles were observed in samples with compitibilizing agent using scanning electron microscope. Due to strong interfacial bonding between the filler and the matrix polymer,

the fracture occurred not at the interface, but the filler particles themselves and the composites were more brittle in nature.

5.2 RECOMMENDATION

For the further study, it is suggested to study the effect of varying compitibilizing agent on the mechanical properties of composites. The composites can be prepared using similar type of filler and at similar filler loading. For the compitibilizing agent, varying content should be used namely 2 %, 4 % and 6 %. The objective of the study is to find the optimum level of compitibilizing agent content on the mechanical properties and to find the optimum level of compitibilizing agent that will result the optimum mechanical properties of composites.

Another recommendation is to study the effect of filler particle size on mechanical properties of rice husk reinforced high density polyethylene. The rice husk filler can be prepared at three different filler particle sizes for example 250, 500 and 750 microns. The composites of HDPE with varying filler particle size will be extruded before going into the injection molding process. For the mechanical testing, the samples will be tested for their tensile, flexural and impact properties. From this study, it can determine the optimum particle size that can result in optimum mechanical properties of the composites.

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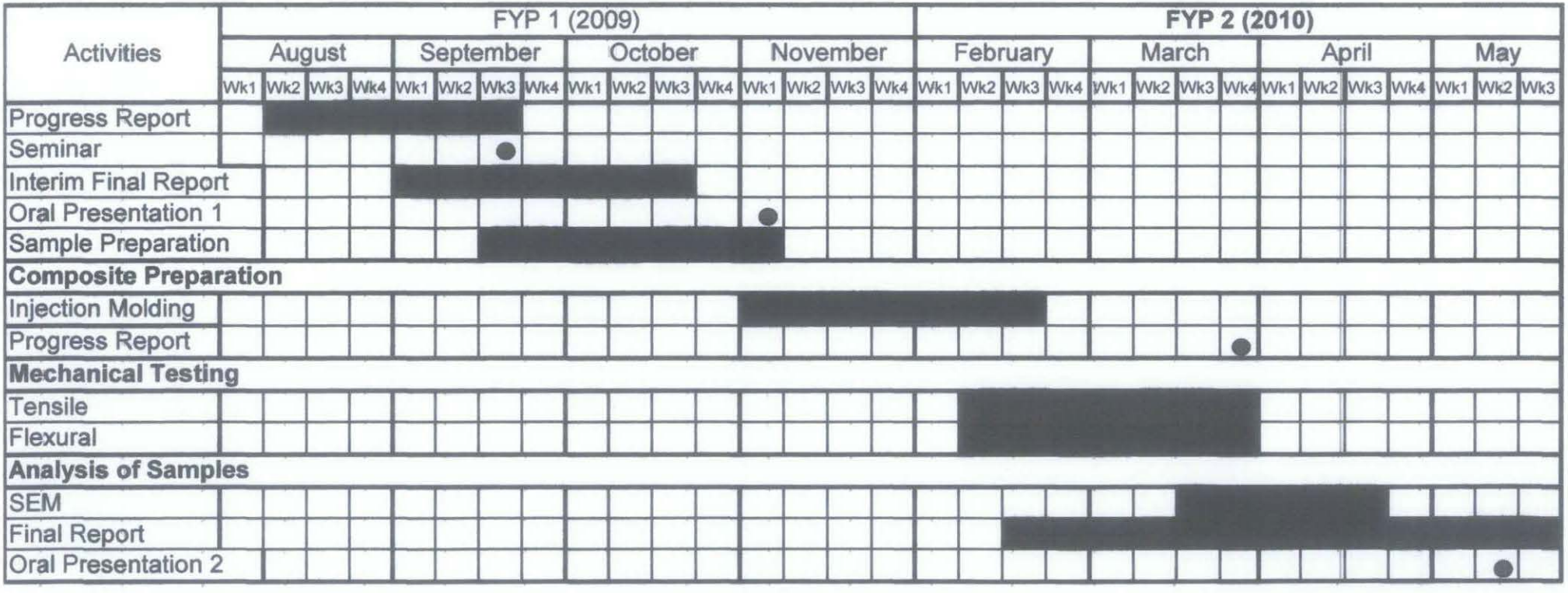
APPENDICES

APPENDIX A

GANTT CHART

Final Year Project

Title: The Influence of Filler Loading on Mechanical Properties of Rice Husk Reinforced High Density Polyethylene



APPENDIX B

RAW DATA FOR TENSILE TEST

Tensile Test without MAPE

Nv gnngv ,Filler Content	Sample	Stiffness (N/m)	Young's Modulus (MPa)	Load at Maximum (N)	Extension at Maximum (mm)	Tensile Strength (MPa)	Percentage Strain at Maximum	Work to Maximum (J)
5 wt.%	1	88762749.10	110953.44	937.37	3.31	23.43	6.61	3.04
	2	2923542.78	3654.43	988.80	4.28	24.72	8.55	3.59
	3	1694832.96	2118.54	853.75	5.36	21.34	10.72	3.77
	4	1350794.39	1688.49	867.13	4.82	21.68	9.64	2.99
	5	46577554.85	58221.94	1012.31	4.33	25.31	8.65	2.35
10 wt.%	1	3754173.28	4692.72	803.85	4.22	20.10	8.45	2.81
	2	1593411.00	1991.76	812.05	3.82	20.30	7.63	2.55
	3	5122515.58	6403.14	812.74	4.19	20.32	8.38	2.91
	4	2161585.87	2701.98	812.80	3.96	20.32	7.93	2.74
	5	5772825.30	7216.03	788.86	4.58	19.72	9.17	3.02
15 wt.%	1	26587033.31	33233.79	784.31	5.23	19.61	10.47	3.46
	2	2689683.44	3362.10	793.99	4.43	19.85	8.85	3.66
	3	3080817.01	3851.02	799.61	4.41	19.99	8.83	2.66
	4	1765760.40	2207.20	798.48	4.02	19.96	8.04	2.65
	5	1161610.69	1452.01	748.65	3.86	18.72	7.71	2.91

Tensile Test with MAPE

Filler Content	Sample	Stiffness (N/m)	Young's Modulus (MPa)	Load at Maximum (N)	Extension at Maximum (mm)	Tensile Strength (MPa)	Percentage Strain at Maximum	Work to Maximum (J)
5 wt.%	1	1474324.31	1842.91	1066.94	4.19	26.67	8.39	3.73
	2	3906362.62	4882.95	1056.07	4.01	26.40	8.01	3.60
	3	3318632.49	4148.29	1027.87	3.22	25.70	6.45	2.68
	4	5290191.94	6612.74	1054.49	4.08	26.36	8.16	3.58
	5	52772411.02	65965.51	1006.30	3.62	25.16	7.24	3.07
10 wt.%	1	101975209.85	127469.01	803.60	3.13	20.09	6.26	1.95
	2	3405002.99	4256.25	894.51	4.57	22.36	9.14	3.41
	3	20240715.23	25300.89	813.65	4.02	20.34	8.03	2.78
	4	1695632.32	2119.54	818.69	4.62	20.47	9.24	3.22
	5	2215592.78	2769.49	812.48	4.49	20.31	8.97	3.03
15 wt.%	1	6271523.28	7839.40	727.87	3.52	18.20	7.04	2.03
	2	4127736.93	5159.67	762.93	4.07	19.07	8.13	2.50
	3	4127736.93	5159.67	762.93	4.07	19.07	8.13	2.50
	4	1235182.30	1543.98	795.42	4.05	19.89	8.10	2.56
	5	1136027.39	1420.03	760.79	5.00	19.02	10.00	3.13

APPENDIX C

RAW DATA FOR FLEXURAL TEST

5 wt.% Filler Loading Without MAPE for Flexural Test

Time (s)	Load (N)	Deflection before Compensation (mm)	Compressive Stress (MPa)
158.52	27.54	0.02	0.64
166.86	29.08	0.02	0.67
175.21	29.64	0.02	0.68
183.55	29.94	0.02	0.69
191.89	31.58	0.02	0.73
200.24	33.02	0.02	0.76
208.58	33.56	0.02	0.77
216.92	35.05	0.02	0.81
225.27	35.62	0.02	0.82
233.61	36.52	0.02	0.84
241.95	37.01	0.02	0.85
250.30	37.73	0.02	0.87
258.64	38.63	0.02	0.89
266.98	39.37	0.02	0.91
275.33	40.09	0.02	0.92
283.67	40.59	0.02	0.94
292.01	41.54	0.02	0.96
300.36	42.19	0.02	0.97
308.70	42.57	0.02	0.98
317.04	43.19	0.02	1.00
325.39	43.35	0.02	1.00
333.73	42.89	0.02	0.99
342.07	43.18	0.02	1.00
350.42	43.26	0.02	1.00
358.76	43.12	0.02	0.99
367.10	43.05	0.02	0.99
375.45	43.66	0.02	1.01
383.79	43.89	0.02	1.01
392.13	43.56	0.02	1.00
400.48	44.21	0.02	1.02
408.82	44.22	0.02	1.02
417.16	44.61	0.02	1.03
425.50	44.87	0.02	1.04
433.85	44.82	0.02	1.03
442.19	44.43	0.02	1.03
450.53	45.12	0.02	1.04

10 wt.% Filler Loading Without MAPE for Flexural Test

Time (s)	Load (N)	Deflection before Compensation (mm)	Compressive Stress (MPa)
197.02	30.10	0.00	0.69
205.23	30.73	0.00	0.71
213.44	31.91	0.00	0.74
221.65	31.96	0.00	0.74
229.85	32.54	0.00	0.75
238.06	33.73	0.00	0.78
246.27	33.99	0.00	0.78
254.48	35.23	0.01	0.81
262.69	36.12	0.01	0.83
270.90	37.15	0.01	0.86
279.11	38.73	0.00	0.89
287.32	39.49	0.00	0.91
295.53	40.09	0.01	0.92
303.74	39.93	0.01	0.92
311.95	40.15	0.01	0.93
320.15	39.23	0.01	0.90
328.36	38.38	0.01	0.88
336.57	39.49	0.01	0.91
344.78	39.01	0.00	0.90
352.99	39.09	0.00	0.90
361.20	39.73	0.00	0.92
369.41	39.08	-0.01	0.90
377.62	38.05	-0.01	0.88
385.83	39.08	-0.01	0.90
394.04	39.50	-0.01	0.91
402.25	40.16	-0.01	0.93
410.45	40.50	-0.01	0.93
418.66	41.01	-0.01	0.95
426.87	41.55	-0.01	0.96
435.08	41.46	-0.01	0.96
443.29	41.19	0.04	0.95
451.50	41.22	0.02	0.95
459.71	41.18	0.01	0.95
467.92	40.45	-0.01	0.93
476.13	40.09	-0.01	0.92
484.34	39.97	-0.01	0.92

15 wt.% Filler Loading Without MAPE for Flexural Test

Time (s)	Load (N)	Deflection before Compensation (mm)	Compressive Stress (MPa)
197.24	43.47	6.55	0.99
206.20	44.64	6.84	1.02
215.17	44.96	7.14	1.03
224.13	45.63	7.44	1.04
233.10	47.24	7.74	1.08
242.06	48.56	8.04	1.11
251.03	48.87	8.34	1.11
259.99	50.07	8.64	1.14
268.96	51.47	8.94	1.17
277.92	51.83	9.24	1.18
286.89	52.89	9.53	1.21
295.85	54.54	9.83	1.24
304.82	54.57	10.13	1.24
313.78	55.01	10.43	1.25
322.75	55.03	10.73	1.25
331.71	54.57	11.03	1.24
340.68	54.34	11.33	1.24
349.64	54.32	11.63	1.24
358.61	54.05	11.92	1.23
367.58	54.34	12.22	1.24
376.54	54.18	12.52	1.24
385.51	54.73	12.82	1.25
394.47	55.52	13.12	1.27
403.44	55.99	13.42	1.28
412.40	56.47	13.72	1.29
421.37	56.73	14.02	1.29
430.33	56.69	14.32	1.29
439.30	57.31	14.61	1.31
448.26	56.84	14.91	1.30
457.23	56.27	15.21	1.28
466.19	56.30	15.51	1.28
475.16	55.72	15.81	1.27
484.12	54.65	16.11	1.25
493.09	53.92	16.41	1.23

5 wt.% Filler Loading With MAPE for Flexural Strength

Time (s)	Load (N)	Deflection before Compensation (mm)	Compressive Stress (MPa)
132.79	30.53	4.40	0.73
140.60	32.33	4.66	0.77
148.41	31.58	4.92	0.75
156.22	33.59	5.18	0.80
164.03	34.24	5.44	0.81
171.84	35.74	5.70	0.85
179.66	36.06	5.96	0.86
187.47	35.97	6.22	0.86
195.28	37.10	6.48	0.88
203.09	37.64	6.74	0.90
210.90	38.22	7.00	0.91
218.71	38.64	7.26	0.92
226.52	39.25	7.52	0.93
234.33	40.31	7.78	0.96
242.14	40.18	8.04	0.96
249.96	40.67	8.30	0.97
257.77	41.43	8.56	0.99
265.58	41.40	8.82	0.98
273.39	41.57	9.08	0.99
281.20	42.77	9.34	1.02
289.01	42.99	9.60	1.02
296.82	43.51	9.86	1.03
304.63	42.44	10.12	1.01
312.44	43.97	10.38	1.05
320.26	44.05	10.64	1.05
328.07	43.12	10.91	1.03
335.88	41.17	11.17	0.98
343.69	41.42	11.43	0.98
351.50	41.84	11.69	1.00
359.31	41.99	11.95	1.00
367.12	43.19	12.21	1.03
374.93	44.05	12.47	1.05
382.74	44.57	12.73	1.06
390.56	45.03	12.99	1.07
398.37	44.11	13.25	1.05
406.18	44.05	13.51	1.05

10 wt.% Filler Loading With MAPE for Flexural Strength

Time (s)	Load (N)	Deflection before Compensation (mm)	Compressive Stress (MPa)
211.59	41.46	7.02	0.96
219.42	42.78	7.28	0.99
227.26	44.53	7.55	1.03
235.10	45.33	7.81	1.05
242.93	45.76	8.07	1.06
250.77	46.56	8.33	1.08
258.61	47.84	8.59	1.11
266.44	47.62	8.85	1.10
274.28	47.30	9.11	1.09
282.12	46.89	9.38	1.09
289.95	48.29	9.64	1.12
297.79	48.95	9.90	1.13
305.63	48.66	10.16	1.13
313.46	48.41	10.42	1.12
321.30	48.47	10.68	1.12
329.14	48.66	10.94	1.13
336.97	46.90	11.20	1.09
344.81	46.90	11.46	1.09
352.65	47.53	11.73	1.10
360.48	49.86	11.99	1.15
368.32	49.08	12.25	1.14
376.16	49.39	12.51	1.14
383.99	49.74	12.77	1.15
391.83	50.14	13.03	1.16
399.66	49.34	13.29	1.14
407.50	49.51	13.55	1.15
415.34	50.44	13.82	1.17
423.17	49.04	14.08	1.14
431.01	48.86	14.34	1.13
438.85	49.75	14.60	1.15
446.68	50.20	14.86	1.16
454.52	49.95	15.12	1.16
462.36	47.58	15.38	1.10
470.19	47.10	15.64	1.09

10 wt.% Filler Loading With MAPE for Flexural Strength

Time (s)	Load (N)	Deflection before Compensation (mm)	Compressive Stress (MPa)
213.49	52.10	7.08	1.21
221.70	53.45	7.36	1.24
229.91	53.95	7.63	1.25
238.12	54.94	7.90	1.27
246.33	56.29	8.18	1.30
254.54	57.20	8.45	1.33
262.76	56.81	8.73	1.32
270.97	56.73	9.00	1.31
279.18	56.67	9.27	1.31
287.39	57.57	9.55	1.33
295.60	58.39	9.82	1.35
303.81	57.39	10.09	1.33
312.02	58.03	10.37	1.34
320.23	58.11	10.64	1.35
328.44	57.46	10.91	1.33
336.66	56.76	11.19	1.32
344.87	56.32	11.46	1.30
353.08	57.72	11.74	1.34
361.29	58.26	12.01	1.35
369.50	58.18	12.28	1.35
377.71	58.17	12.56	1.35
385.92	58.19	12.83	1.35
394.13	57.16	13.11	1.32
402.34	58.12	13.38	1.35
410.56	58.15	13.65	1.35
418.77	57.23	13.93	1.33
426.98	56.86	14.20	1.32
435.19	57.72	14.47	1.34
443.40	58.46	14.75	1.35
451.61	55.88	15.02	1.29
459.82	55.53	15.29	1.29
468.03	55.37	15.57	1.28
476.24	55.32	15.84	1.28
484.46	53.35	16.12	1.24
492.67	53.08	16.39	1.23