A Study on
Ethylene Vinyl Acetate Sawdust Polymer Composite

By

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CERTIFICATION OF APPROVAL

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Chemical Engineering Programme

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Approved by,

____

(Dr Maziyar Sabet)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2014

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 person.

AHMAD HISSAMUDDIN BIN ZULKIFLI

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ASBTRACT

Sawdust is a waste that have a lot of potential that can be explored and can be used to feed humans needs nowadays. Moreover it can be found abundantly at sawmill with low price Sawdust has a potential to be used as a material for construction, can be used to make furniture and many more. In order reveal the potential of sawdust, this research project will investigate about the characteristic of sawdust, application of sawdust and how to improve the mechanical properties of sawdust.

As for this research paper, chapter 1 will give introduction on the background of the project. Problem statement of this project will be explained to enlighten the main objective and the advantages of conducting this project. Besides, the objectives and the scope of the study will also be presented,

After that we will proceed to the second chapter which contain the idea and concept of this project in details to make sure the significance o =f this project will be deliver. This chapter will be explaining about the sawdust, Ethylene Vinyl Acetate (EVA) and Ethylene Vinyl Acetate Sawdust Composites.

In order to understand how this project are carried on, this research project also include the research methodology, the experimental approach ,procedures as well as key milestone to cover the whole journey of this experiment.

Finally in the last chapter, all result and discussions, calculations and recommendation will conclude everything that have been achieved while doing this project.

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CHAPTER 1

INTRODUCTION

1.1 Background Study

As time goes by, people start to realize the issue of natural resources being abuse by human kind for the sake of human kind necessity. One of them is wood which has been used since thousand years ago for source of fuel and construction material. Recently there has been high demand of wood all over the world due to application of wood has widely develop. The conversion of forest land because of human desires and actions lead to global ecological revolution and cause biodiversity extinction. In over a period of 5 years the world lost 100 hectares of forested lands. This situation become worst from time to time when global deforestation happens and give large impacts for the survival of lives in this planet. Carbon dioxide emission cannot be control anymore if abuses of forest keep happen from day to day besides the green environment also holds much of the responsibility to prevent floods and erosions. (Sauve,2012).

Thus,one of the solution to prevent deforestation is to reuse wood dust or also known as sawdust. Wood dust is by prodoct of wood which can found abundantly at sawmills factory.A factory produces about 600 pounds of dry residue per thousand board feet which means US industries alone produce exceed 15 million tons a year. (HARKIN, 1969). Sawdust is a low cost waste,cheap and easy to be obtained. Genarally sawdust exhibit properties of a wood.Sawdust has been used as raw material to form particle board since 1941 to replace the production of plywood due to economical problem.

Since 1990, there is development of new composite materials using natural fibres with termoplastic polymers known as wood polymer composties (WPC).WPC has several advantages which is low density, low cost, high specific properties, low toxicity and derived from renewable resource of energy. There are several examples of thermoplastic polymers with different natural fibres and one of them is wood sawdust. (Moeller, 2008)

In conjunction with green technology campaign, in this research Ethylene Vinyl Acetate has been chosen as polymer to investigate the different between sawdust composites and polymer sawdust composites in term of mechanical properties and strength.

1.2 Problem Statement

As time goes by, people realized that sawdust has a lot of potential to be recycle and reuse in our daily life because of the low range of price and it can be found abundantly at sawmills. In order to bring the sawdust to the next level and to be commercialized in industries, a research must be conducted to improve the mechanical properties and strength of sawdust. Sawdust has several disadvantages that needs attention of the researcher such as permeability, mechanical strength, porosity and many more. These kind of advantages would be a barrier in order to produce high quality of product. Thus, in this project Ethylene Vinyl Acetate will be used to form EVA sawdust composite in order to increase the mechanical properties of the sawdust. This project will investigate the effect of addition of polymer to the sawdust. While conducting the research, several important characteristics will be observed to compare EVA polymer composite with raw sawdust.

1.3 Objective

There are three objectives of this research which are:

1. To investigate application waste of wood
2. To investigate how polymer can improve properties of sawdust
3. To investigate the effects of particle size of sawdust towards properties of sawdust composites

1.4 Scope of Study

There are several scope of study in this research to make sure all the experiment that has been conducted fulfill the objective of this experiment:

1. Properties of the sawdust
2. Properties of the Ethylene Vinyl Acetate (EVA)
3. Comparison of Ethylene Vinyl Acetate sawdust composite with the raw sawdust properties.
4. Conducting an experiment to test the mechanical and physical properties towards EVA sawdust composite and raw sawdust.

CHAPTER 2

LITERATURE REVIEW

2.1 Ethylene Vinyl Acetate

Ethylene vinyl acetate also call as EVA is the copolymer of ethylene and vinyl acetate. The weight percent vinyl acetate most likely diverges from 10 to 40%, with the remainder being ethylene.

EVA is copolymer of ethylene and vinyl acetate. Its and extremely elastic material that can be sintered to form a porous material similar to rubber, yet with an excellent toughness. It is three times as flexible as low-density polyethylene (LDPE), showing tensile elongation of 750% with a peak melting temperature of 250 ^{0}F (96 ^{0}C).This material has good barrier properties, low-temperature toughness, stress-crack resistance, hot melt adhesive waterproof properties, and resistance to ultraviolet radiation. EVA has a little or no odour and it's competitive with rubber and vinyl products in many electrical applications. (Material Porous Plastic, 2014)

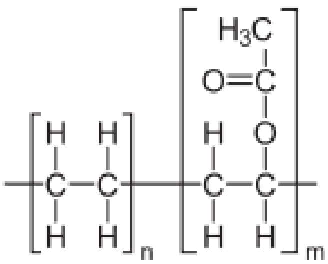


Figure 1: Chemical structure of Ethylene vinyl acetate

Besides that, EVA copolymers are versatile polymers, produces by high temperature and pressure, free radical polymerization process. They could contain only a few percent by weight of the vinyl acetate comonomer of the copolymers or up to 40 wt% and a few of techniques have been used to explain the composition of the copolymers. The increase in the ethylene content increases the crystallinity and the flexibility of the EVA copolymers. Thermal and viscoelastic studies have been carried out in relation to the peel behaviour on metal, and other technological properties determinations have been made, EVA copolymers are used as major components, for flexible, heat-sealable, and hot melt coatings with excellent water vapour and gas barrier properties which contained 18-20 % content of vinyl acetate); for repulpable hot melt adhesives; for repulpable materials in packaging for wall covering adhesives; for thermal laminating; and for alternative lamination processes to eliminate expensive solvents . They are also used as low-order, low-VIC decorative points and coatings up to 15 wt%. Other than that They are used as substitutes for PVA homopolymers acrylic polymers in several applications. Some studies have been devoted to the characterization of EVA adhesives, their rheological properties as well as the influence of wax structure and content on the performance of EVA-based hot melt coatings and adhesives .(OLABISI, 1997)

As they exhibit high versatility in hot-melt formulations, EVAs are most preferred polymers for hot-melt manufacturing. EVA based hot-melts are able to meet up a lot of specifications in applications such as packaging, bookbinding or label sticking.
They are highly flexible products, compatible with many other polymers and additives, and are easy to process. Due to its chemical structure, the EVA range:

- are highly flexible
- delivers high cohesive strength and compatibility
- ensures excellent adhesion to a wide range of substrates
- are highly resistant to rupture

Due to their high compatibility, they can be articulated in combination with both natural or synthetic tackifiers, a large range of PE waxes, modified waxes or plasticizers and their intrinsic stability can be enhanced by the right choice of antioxidant or UV/Light stabilizers. (Ethylene Copolymers Centre, 2014)

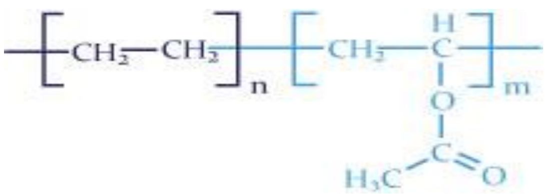


Figure 2: Structure of random Ethylene Vinyl Acetate copolymer

Ethylene Vinyl Acetate (EVA) copolymers are used in the manufacture of profile extrusions, pharmaceutical supplies, extruded tubing blow-moulded items, hospital surgical, injection-moulded mechanical goods, and hospitals surgical. EVA also applicable in toys, footwear, sporting goods and as combining agents for their resilience, flexibility and toughness which is 8-15 wt% vinyl acetate. A special Micro line polymer possesses almost 100% plastic memory. (OLABISI, 1997)

Other than that, EVA is one of the materials generally known as expanded rubber or foam rubber. EVA foam is used as padding in equipment for various sports such as ski boots, bicycle saddles, hockey pads, boxing and mixed martial arts gloves and helmets, wakeboard boots, water-ski boots, fishing rods and fishing reel handles. It is usually used as a shock absorber in sports shoes. It is used for the manufacture of floats for commercial fishing gear such as purse seine (seine fishing) and gillnets. In addition, because of its buoyancy, EVA has made its way into non-traditional products such as floating eyewear. It is also used in the photovoltaic industry as an encapsulation material for silicon cells in the manufacture of photovoltaic modules. EVA slippers and sandals are currently very popular because of their properties like light weight, easy to mould, odourless, glossy finish, and cheaper compared to natural rubber. In fishing rods, it is used to construct handles on the rod-butt end. EVA can be used as a substitute for cork in many application

2.2 Sawdust

Sawdust is the by-product of wood that can be obtained from grinding, sanding, cutting of wood. It has variety of size, from flour looked alike to grumpy grains. Sawdust also can be found from by-product of certain animals because animals like woodpecker and carpenter ant. However there are a lot of negative sides of sawdust in term of Health, safety and environmental issues.

Figure 3: Sawdust

Firstly, wood dust has potential contributor to health problem. Wood dust is usually mix with other ambient pollutants and could contribute in giving harmful effects to the others substances. For example, wood dust particles in the air of pulp mills where gases such as sulphur dioxide, chlorine dioxide, hydrogen dioxide and hydrogen sulphide and various mercaptans are encountered. Some of these gases are really soluble and may be scrubbed in upper part of respiratory tract, hence being less likely to infiltrate into the lungs. (Jacobs, 1994)

Besides, another risk appears to be involving wood dust exposures in the workplace. There has been IARC working group on the evaluation of carcinogenic risks to human which entitled “sufficient evidence in humans for the carcinogenicity of wood dust”. The overall evaluation showed that wood dust is carcinogenic to humans with the following foot-note: “This evaluation is based on the observation of a marked increase in the occurrence of cancers of the nasal cavities and paranasal sinuses among workers exposed frequently to hardwood dust. (N.Cheremisinoff, 1997)

Secondly, wood dust is and organic medium which can provide a favourable environment for the growth of microbials. Certain types of diseases associated with wood dust are actually due to microorganisms that tend to grow on the wood. So if sampling is being done to evaluate exposures to this wood, microbial sampling may also be necessary in certain situations. (McDermott, 2004)

However all those problems could be overcome by conducting proper way of handling sawdust. For example, all wasted sawdust must be well manage to prevent airbone and becomes harmful leachates in the water. Besides, personal protective equipment (PPE) also one of the important measures to make sure human being can be protected from airbone of sawdust which is very harmful.

One of the biggest contribution of sawdust in industries is production of particle board which started since 1941. Particleboard is a panel product made by compressing small particles wood while simultaneously bonding them with an adhesive. There are many types of particleboard depends to size and geometry of particles, the amount of adhesive used and the density to which panels are pressed. (Rubin Shmulsky, 2011). Particle boards newly produced from 100% sawdust can have same or even better properties than the former generation of boards.(Kharazipour,2002).

Besides particle board, sawdust concrete is one of the contribution of sawmills by product to industry. Sawdust concrete is an economically beneficial material in which sawdust (in small amounts, though, up to 10%) goes mixed with sand, and cement does with lime.The strong features of the basic components such as cement and gypsium binder sawdust and the other wood wastes,are most effectively combined in fast-hardening sawdust. Wood has nature to inflammability and decay, sawdust concrete has none of them and improved volumetric stability, strength, high hygienin properties and ease of working. (Cornelia Vasile, 2006).

2.3 Ethylene Vinyl Acetate (EVA) sawdust composites

Enviromentals regulations of all over the coutry are putting pressure on manufacturers to reanalayze then environmental impact of their products. Due to the this situation, interest in the development of new composites using natural fibres with thermoplastic polymers known as wood polymer composites (WPC) is start to develop since 1990. There are variety type of natural fibres like wood, flax, are being used being wood-like fibres the most used.

WPC composites have a few of advantages compared with their inorganic counterparts such as low toxicity,biodegradability,low cost,low density and derived from a renewable resource and enhances energy recovery.Basically WPC are neat polymers and they have qualities that the wood alone does not have. For example, WPC are more unaffected to moisture and to the invasion by insects and fungi than neat wood. WPC also can be stained, painted and finished as natural wood.

Despite all of the advantages, this type of composites presents some weaknesses that can reduce their potential use as reinforcement agents in polymers. Firstly the wood is incompatibility with polymeric matrices, as a consequence of the hydrophilic (polar) and hydrophobic characters of wood and polymers. There has been composition of PP and pine wood sawdust and it shows that the interfacial adhesion was too bad, because the surfaces of wood fibres were clean. However this lack of adhesion between both phases can be improved by means of compatibilization that can be carried out:

1. Adding Modified polymeric matrices with some polar groups which can interact which can interact with the polar groups of the wood.
2. Modifying the wood with some non-polar groups that can be linked to the polymer.

Recently there has been a lot of application using WPC and it is widely develop in various field for example for household utilities. Most current WPC application are residential deck boards, wearing surfaces, window lineal, door components and rails and balusters.

Advantages and Disadvantages of Wood Polymer Composite.

NO	ADVANTAGES	DISADVANTAGES
1	Decay and insect resistant	Dense
2	Water repellency	Heat retention
3	Uniform dimensions	Flame spread
4	Low maintenance	High initial cost

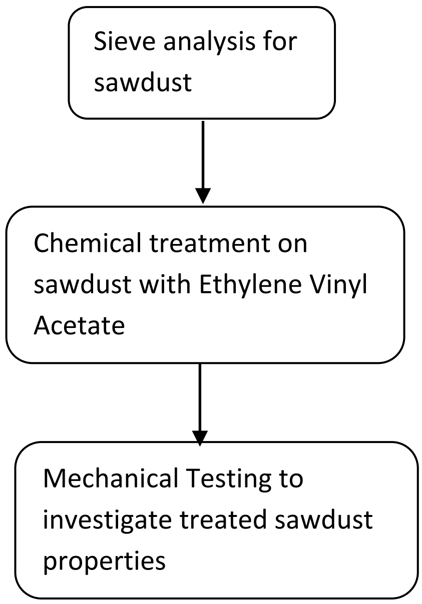
Table 1: Advantage and Disadvantge of Wood Polymer Composite

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

This project is based on research which involve experimental approach. Most of the experiment concept involve chemical, mechanical and civil engineering background. There are few mechanical testing that will be conducted on raw composites of sawdust and EVA composites of sawdust. Comparison of the two different composites are really important to investigate the effects of polymer composition towards sawdust. When the research is done, the result will be helping towards application of sawdust composition in science and technology field.



Figures 4: Schematic diagram of general experiment approach

3.2 Materials

3.2.1 Sawdust

In order to conduct this research, sawdust was purchased from Sun Nsm Lee Sawmill Sdn Bhd, local sawmill factory which located at Kampar, Perak. One Polyethylene bag of sawdust only cost RM 5. The first step of the research is to analyze the particle size of sawdust using sieve analysis. There are several series of sieves sizes which are 2.36mm. 2.00mm, 1.18mm, 0.60mm, 0.425mm, 0.30mm, 0.212mm, 0.15mm and 0.063mm. Out of all series of sieves only four sizes will be selected to undergo the next step of this research.

3.2.2 Ethylene Vinyl Acetate (EVA)

Ethylene Vinyl Acetate was obtained from MF Chemical Sdn. Bhd which located at Bukit Mertajam, Pulau Pinang. 25 kilogram of EVA was sold at RM250. Generally EVA will be mold with the sawdust based on three different ratio. Sawdust and EVA are mold using compression molding machine based on melting point of EVA which is 100 ^{o}C. These polymer composition will be mold based on testing requirement. Each testing has their own shape requirement.

3.3 Testing

In order to determine the properties of raw sawdust and chemically treated sawdust, a few of experiment test will be conducted during this research. There are:

EXPERIMENT	EQUIPMENT
Mechanical Testing • Tensile Strength • Flexural Strength	1. Tensile Machine 2. Hardness Test Machine
Dimension Stability • Water Absorption • Thickness Swelling	• Weighing Balance • Ruler
Density	• Weighing Balance

Table 2: Mechanical Testing Details

3.3.1 Mixing and Processing Procedures

For the next step of this experiment, four different particle size of sawdust (1.18mm, 0.60mm, 0.212 and 0.425mm and 0.063 mm sieve size) will be mixed with ethylene vinyl acetate (EVA) at different ratio percentage. These sizes is chosen to investigate effect of different size particle towards mechanical properties. Different ratio is important to know the best composition of polymer and sawdust mixing. Shown below are the mixtures for the composite materials

Polymer Content (%)	Ethylene Vinyl Acetate
75	25
60	40
90	10

Table 3: Mixture for the composite materials

Other than that, testing procedures require special specimen type to be tested because each test require different type of mold container. Mold container has variety of size depends on the testing machine requirement, that’s why different testing would need different total weight of composition. The composition are as follow:

Type of Testing	Total weight Composition Needed
Tensile Strength	12 gram
Flexural Strength	8 gram
Water Absorption	4 gram

Table 4 : Composition needed for testing.

After that the mixture will be compression molded to form into specimens using a compression molding machine. This machine require the melting point of EVA to make sure it melt properly and well distributed among sawdust while being molded.

3.3.2 Water Absorption

10 g of raw sawdust with sieve size of 1.18mm, 0.60mm and 0.425 were prepared for the measurement of water absorption. The samples were dried at 100 ^{o}C in an oven until a constant weight was reached. After constant weighs have reached, each sawdust is soaked into water for 2 hours in a beaker. Then, the sawdust is filtered until there is no free water content and reweight. Water absorption was calculated according to the formula:

$$\Delta M(t) = \frac{m_t - m_o}{m_o} \times 100$$

Figures 5: Formula of Water Absorption

W_f = Sample weight after soaking

W_I= Weight of sample after oven dried

3.4 Gantt Chart

No	Detail/week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Project Work Continuous															
2	Submission of Progress Report															
3	Project Work Continuous															
4	Pre-SEDEX															
5	Submission of Draft Final Report															
6	Submission of Dissertation (Soft Bound)															
7	Submission of Technical Paper															
8	Viva															
9	Submission of Project Dissertation															

Figures 6: Gantt chart

3.5 Project Flow Chart

Figure 7: Project Flow Chart

3.6 Key Milestones

There are a few of key milestone for this research project that must be followed in order to achieve the objective of the experiment.

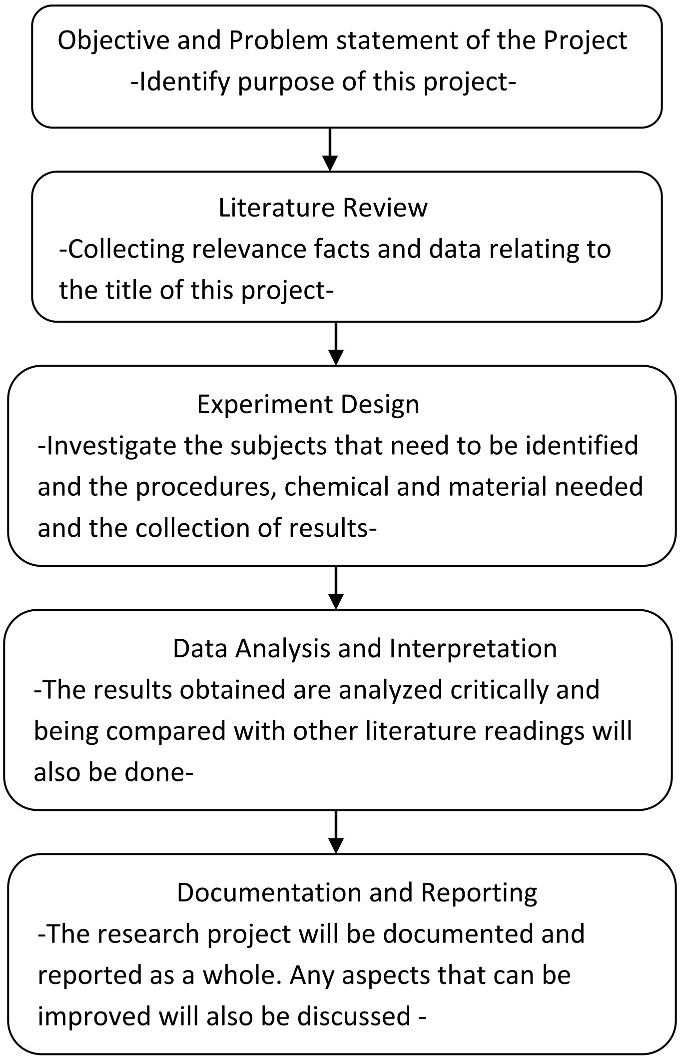


Figure 8: Key Milestone

3.7 Experiment Conducted

3.7.1 Sieve Analysis

Material and Apparatus needed

- Sawdust
- Sieving Machines

Procedure

1. Arrange all the sieving tray based on the biggest size to the smallest size.
2. Fill the upper part of the sieving machine with sawdust.
3. Put the sieving tray on the machine and set the machine for 10 minutes.
4. Switch on the machine
5. Repeat the sieving process for the second time
6. Separate the sawdust according to particle size
7. Choose particle size of sawdust from 0.425mm, 0.06mm,1.18mm and 0.2

3.7.2 Water Absorption

Material and Apparatus

1. Beaker
2. Oven
3. Sawdust
4. Distilled Water
5. Weighing balance

Procedure

1. Weigh 10 g of sawdust according to the size
2. Put the sawdust in the oven for 24 hours to remove moisture content
3. Weigh the sawdust until constant weigh is obtained

4. Pour 65ml of distilled water into three beakers containing the sawdust and left it for two hours at room temperature. Make sure all the sawdust immersed in the water
5. After two hours, filter the sawdust,
6. Weigh the sawdust
7. Calculate the amount of water absorbed by the sawdust according to particle size.

Water Absorption Sample Proportion

Sample	Percentage of EVA (%)	Percentage of Sawdust (%)	Total Weight (g)
1	60	40	4g
2	60	40	4g
3	60	40	4g
4	60	40	4g

Table 5: Water absorption for ratio 60:40

Sample	Percentage of EVA (%)	Percentage of Sawdust (%)	Total Weight (g)
1	75	25	4g
2	75	25	4g
3	75	25	4g
4	75	25	4g

Table 6: Water absorption for ratio for 75:25

Sample	Percentage of EVA (%)	Percentage of Sawdust (%)	Total Weight (g)
1	90	10	4g
2	90	10	4g
3	90	10	4g
4	90	10	4g

Table7: Water absorption for ratio for 90: 10

3.7.3 Compression Molding Machine

Materials and Apparatus needed

1. Sawdust
2. Ethylene Vinyl Acetate
3. Mold container
4. Weighing Balance
5. Wax

Operational instruction

1. Switch on main power supply. Switch ON isolator, air and water supply to be turn on for cooling purpose
2. Clean and wipe both platen, surfaces and make sure the guard door closed
3. Switch on the Control power, hydraulic pump and platen heat.
4. Setting the require temperature for platen 1 and platen 2 and let the platen heat-up to set temperature
5. Put the sample with or without mold (depend on projects) and close the safety guard
6. Close the clamp by simultaneously depressing and holding the dual “CLAMP” CLOSE” push buttons. The clamp will close at a rapid speed until “SLOWDOWN” proximity switch is actuated
7. Adjust clamp pressure adjustment to pressure required
8. If (optional) platen cooling is required, pull the “AIR” push button to activate “AIR COOLING” feature.

3.7.4 Universal Testing Machine (UTM SKN)

Materials and Apparatus needed

1. Sample
2. Ruler

Operational Procedure

1. Start up the computer system and select the NEXYGEN software, after that select “Lr Lrx Console”

2. Switch On machine power system
3. Press safe line yellow button until light off
4. Machine will starting up and at machine controller keyboard press A button to connection access
5. Display monitor at machine controller keyboard must display "Under Control of remote computer". From now the gripper frame can control from computer (console)
6. From Nexygen program, go to EDIT, select insert New Test and select sample type (plastic, rubber, metals or etc).
7. Select Tensile Setup
8. Fill in the dimension or specification of the sample
9. Insert the specimen to gripper frame
10. Select Zero "O" for zeroing the load and Stroke. Start the test by select the "Start Test"
11. The machine now under running condition and will stop automatically after fracture detected.

Flexural Test Sample Proportion

Sample	Percentage of EVA (%)	Percentage of Sawdust (%)	Total Weight (g)
1	60	40	8g
2	60	40	8g
3	60	40	8g
4	60	40	8g

Table 8: Flexural Test for ratio 60:40

Sample	Percentage of EVA (%)	Percentage of Sawdust (%)	Total Weight (g)
1	75	25	8g
2	75	25	8g
3	75	25	8g
4	75	25	8g

Table 9: Flexural Test for ratio 75: 40

Sample	Percentage of EVA (%)	Percentage of Sawdust (%)	Total Weight (g)
1	75	25	8g
2	75	25	8g
3	75	25	8g
4	75	25	8g

Table 10: Flexural Test for ratio 90 : 10

Tensile Test Sample Proportion

Sample	Percentage of EVA (%)	Percentage of Sawdust (%)	Total Weight (g)
1	60	40	12g
2	60	40	12g
3	60	40	12g
4	60	40	12g

Table 11: Tensile Test for ratio 60:40

Sample	Percentage of EVA (%)	Percentage of Sawdust (%)	Total Weight (g)
1	75	25	12g
2	75	25	12g
3	75	25	12g
4	75	25	12g

Table 12: Tensile Test for ratio 75:25

Sample	Percentage of EVA (%)	Percentage of Sawdust (%)	Total Weight (g)
1	75	25	12g
2	75	25	12g
3	75	25	12g
4	75	25	12g

Table 13: Tensile Test for ratio 90:10

CHAPTER 4

RESULT AND DISCUSSION

4.1 Sieving analysis

Sieve analysis permits the determination of the distribution of particle sizes in granular materials. Precision separation is very important in many industries, because a small amount of product can cost thousands of dollars .As for this experiment sawdust is one of the granular materials and have undergone sieve analysis in order to determine the particle size. Shown below is the overall sieve size of mash that are available in our laboratory

Table 14: Overall size of mash

No.	Mesh sieve size mm
1	2.36
2	2
3	1.18
4	0.6
5	0.425
6	0.3
7	0.212
8	0.15
9	0.063

After running the experiment four sizes of sawdust particle have been chosen .Shown below is the range of particle size that have been chosen. Range of sawdust particle are been identified by referring to the mesh sizes.

Table 15: Range of particle of sawdust

Sample	Range of sawdust particle size (mm)
A	0.063
B	0.212
C	0.425
D	1.18

4.1.2 Discussion of sieving analysis

Table above shows the range of size have been chosen. This is because these four sizes show identical difference in term of physical appearance. In order to produce the best sample of sawdust polymer composition, the best size must be chosen to get the most excellent performance in term improvement of mechanical strength.

4.2 Water Absorption Test

4.2.1 Sawdust Water Absorption Test

Water absorption is used to determine the amount of water absorbed under specified conditions. Factors affecting water absorption include type of plastic, additives used, temperature and length of exposure the data sheds light on the performance of the materials in water or humid environment. For this project two water absorption test were done. The first experiment is water absorption test towards sawdust and the second experiment was a test towards sawdust polymer composition specimen. This is the formula that had been used to calculate the percentage of sawdust.

$$\Delta M(t) = \frac{m_t - m_o}{m_o} \times 100$$

Where:

M (t) = Percentage of weight gained

M_t = Weight of sawdust after immersed in water

M_o =Weight of sawdust before immersed in water

4.2.1 Sawdust Water Absorption Test

Particle Size (Sieve Size)	Weight of sawdust before immersed in the water m_o (g)	Weight of sawdust after immersed in the water m_t (g)	Percentage of Water Absorption (%)
0.063	8.95	40.64	77.99
0.212	8.86	37.68	76.49
0.425	8.96	36.64	75.56
1.18	9.47	18.57	48.99

Table 16: Water Absorption

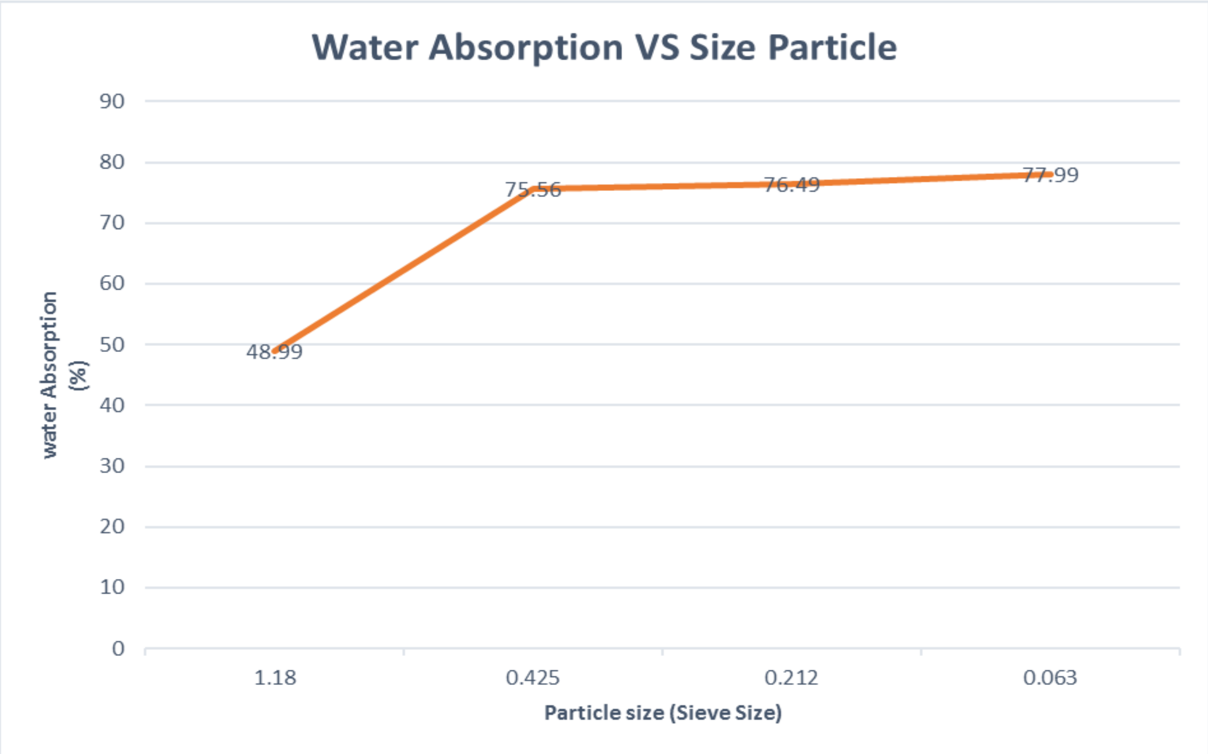


Figure 9 : Water Absorption of sawdust at different particle size graph

4.2.1.1 Discussion of Sawdust Water Absorption Test

From the graph shown above, it shows that, biggest size particle of sawdust absorb the smallest amount of water which means, the smaller particle size the higher amount of water absorption. This situation occur because smaller particle size has larger surface area for water absorption. As shown in the graph above 0.063 particle size absorb 77.99 % of water absorption wihle 1.18 particle only absorb 48.99 % of water.

4.2.2 Sawdust Polymer composition Water Absorption Test

This is the formula that had been used to calculate the percentage of sawdust:

$$\Delta M(t) = \frac{m_t - m_o}{m_o} \times 100$$

Where:

M (t) = Percentage of weight gained

M_t = Weight of sawdust after immersed in water

M_o =Weight of sawdust before immersed in water

Water Absorption Test Result

Particle Size (Sieve Size)	Weight of sawdust polymer composition before immersed in the water Wi (g)	Weight of sawdust polymer composition after immersed in the water Wf (g)	Water Absorption of sawdust polymer composition (%)
0.063	2.25	2.34	4
0.212	2.26	2.36	4.42
0.425	2.78	2.91	4.6
1.18	2.56	2.71	5.8

Table 17: Water Absorption Test Result for 60: 40 ratio

Particle Size (Sieve Size)	Weight of sawdust polymer composition before immersed in the water Wi (g)	Weight of sawdust polymer composition after immersed in the water Wf (g)	Water Absorption of sawdust polymer composition (%)
0.063	2.248	2.32	3.2
0.212	2.27	2.35	3.5
0.425	2.40	2.49	3.7
1.18	2.228	2.35	5.3

Table 18: Water Absorption Test Result for 75: 25 ratio

Particle Size (Sieve Size)	Weight of sawdust polymer composition before immersed in the water Wi (g)	Weight of sawdust polymer composition after immersed in the water Wf (g)	Water Absorption of sawdust polymer composition (%)
0.063	2.248	2.30	2.3
0.212	2.27	2.34	3.08
0.425	2.401	2.49	3.7
1.18	2.228	2.325	4.35

Table 19: Water Absorption Test Result for 90: 10 ratio

4.2.2 Discussion on water absorption towards size of particle

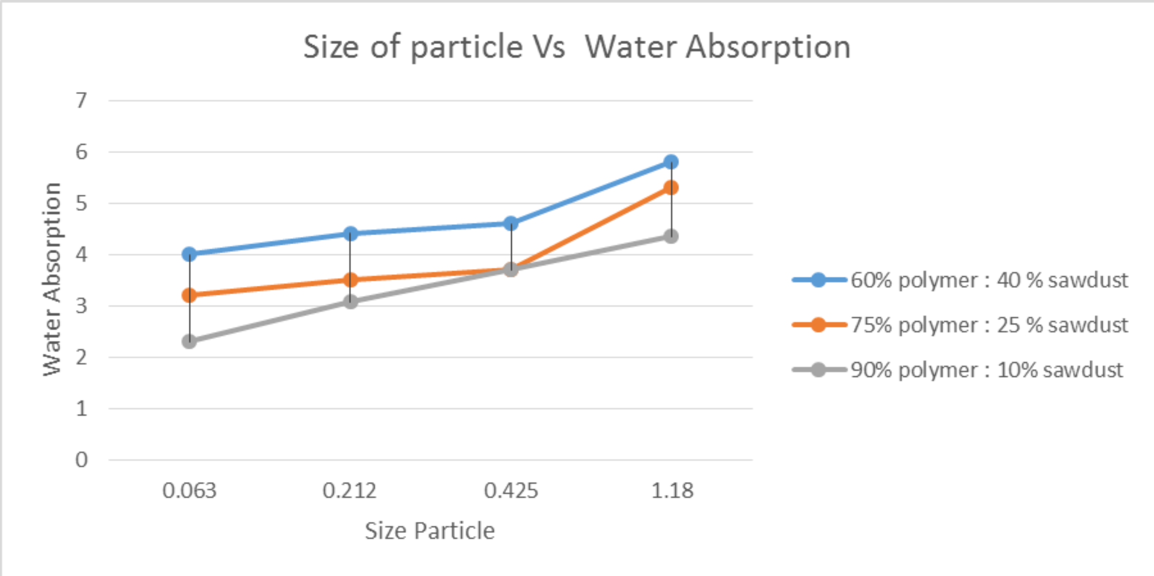


Figure10 : Graph of Size of particle Vs Water Absorption

Graph above show the result of size of particle towards water absorption. As for this experiment we have four different ranges of sizes which are 0.063mm, 0.212mm, 0.425 and 1.18mm. Generally from the graph we can see that when the large of size particle increase the rate of water absorption by the sample is increase. Sample 4 with particle size 1.18 recorded highest value of water absorption which are 5.8%, 5.3% and 4.35%. This result is in good agreement with previous research (Charoenwong & Pisuchpen, 2010). Large size of particle offer larger surface area and increase the probability of penetration of water throughout the sample. Samples with course particle are distributed randomly and so higher strength of EVA molecule cannot be bonded together and open the opportunity for the water absorption (S. Ramli, C.T. Ratnam, & S.H. Ahmad, 2013).

The smallest size particle which is 0.063 recorded the lowest water absorption percentage which are 2.3 %, 3.2 % and 4%. Smallest size particle would not be able to provide enough surface area for water absorption. However there is one sample in that graph for sample with 75% polymer recorded sudden drop at 0.425 mm size. The possible explanation is there must a defect at the sample itself which allow the penetration of the water. Besides, the matrix also might not bonded properly with reinforcement.

4.2.2.1 Discussion on water absorption towards size of particle

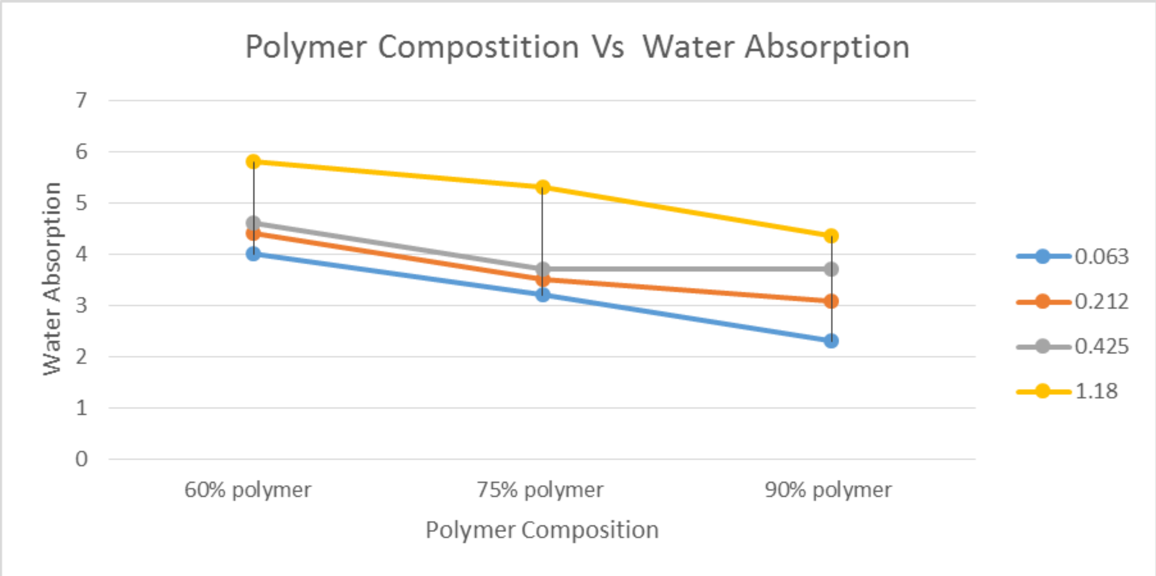


Figure11 : Graph of polymer composition Vs Water Absorption

Graph above show the result of the effect polymer composition towards polymer composition. As u can see from the graph above the graph show that, when the amount of polymer compostition increase, the percentage of water absorption will be decreased. Generally sample with 90% of polymer recorded the lowest percentage of water absorption which are 2.3 %,3.08,% and 4.03 % means this result is parallel with the previous research (Mohd idrus, Hamdan, Rahman, & Islam, 2011) . From this experiment we can see that mixing of raw sawdust with the polymer manage to enhance the mechanical properties of sawdust itself (S. Ramli, C.T. Ratnam, & S.H. Ahmad, 2013).

However there is one sample for the 90% polymer that recorded higher value than sample woth 75% polymer which is sample with 0.425mm particle size. The possible explaination for this situation is might be sample is having defect during preparation using compression molding machine. The temperature maybe is not enough for the EVA to be well mixed with the sawdust.

4.3 Thickness Swelling Determination

4.3.1 Result

Shown below is the formula used to calculate the percentage of thickness swelling for every sample

$$\% \, \textbf{\textit{Thickness swelling}} = \frac{T_f - T_0}{T_0} \times 100\%$$

Particle Size (Sieve Size)	Initial thickness T_O	Final thickness T_F	Percentage of thickness swelling
0.063	0.43	0.5	16.3
0.212	0.41	0.45	9
0.425	0.38	0.41	8
1.18	0.45	0.48	6.7

Table 20 : Percentage of thicnkess swelling 60% polymer : 40 % polymer

Particle Size (Sieve Size)	Initial thickness T_O	Final thickness T_F	Percentage of thickness swelling
0.063	0.39	0.44	12.8
0.212	0.39	0.42	7.7
0.425	0.39	0.41	5.1
1.18	0.43	0.45	4.7

Table 21 : Percentage of thicnkess swelling 75% polymer : 25 % polymer

Particle Size (Sieve Size)	Initial thickness T_O	Final thickness T_F	Percentage of thickness swelling
0.063	0.38	0.42	10.5
0.212	0.39	0.41	5.1
0.425	0.40	0.5	5
1.18	0.43	0.44	2.3

Table 22 : Percentage of thicnkess swelling 90% polymer : 10% polymer

4..3.2 Discussion of result

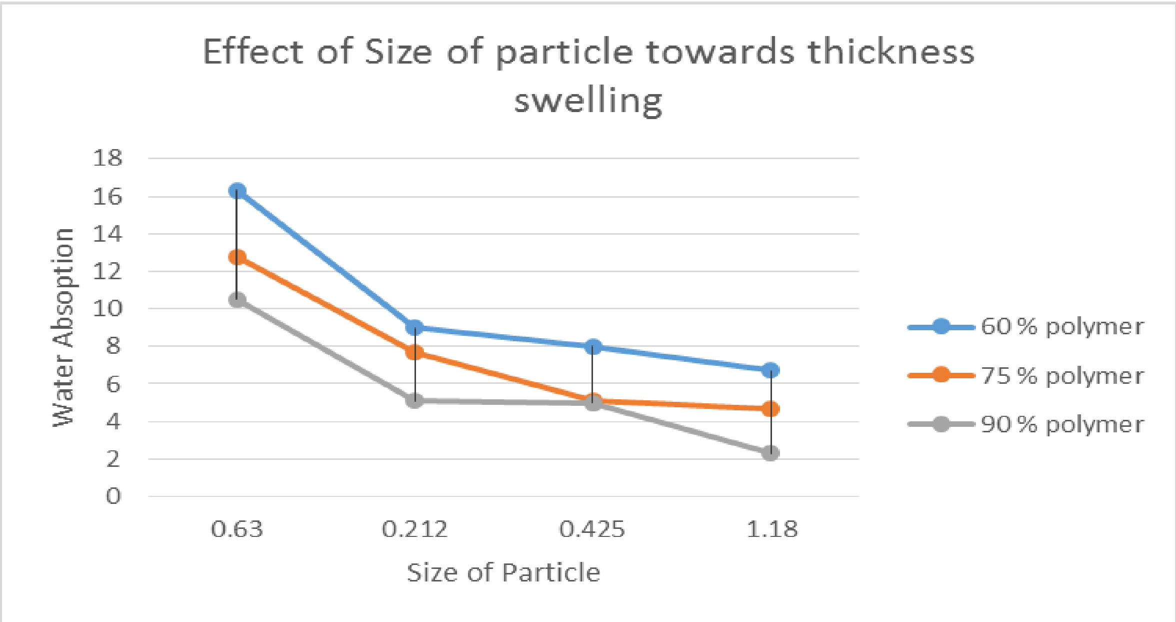


Figure 12 : Graph of Effect of size of particle towards thicnkess swelling

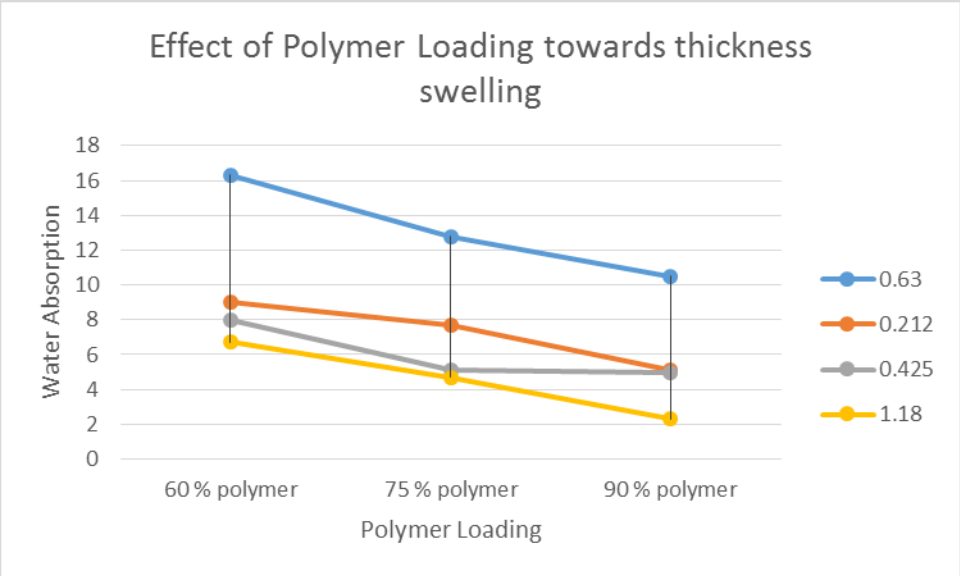


Figure 13 : Graph of Effect of size of particle towards thicnkess swelling

Graph figure 12 we can see that particles size 0.063 recorded high water absorption. The highest percentage is 16.3 % followed by 12.8% and 10.5% . This graph showed to us the smaller the size particle the higher the rate of thickness swelling. (S. Ramli, C.T. Ratnam, & S.H. Ahmad, 2013)A small particle sample offer denser packing and more unifrom particle size and that why tr packing and more unifrom particle size and that why the sample show high value of swelling. This is an expected result based on previous research (Charoenwong & Pisuchpen, 2010).

Besides that graph in figure 13 show us the effect of polymer loading towards thickness swelling. Based on the graph we can see that 90% polymer sample recorded lowest value of thickness .This graph showed to us that when the he polymer loading is increase the rate of thickness swelling will be decreasesd and it also agreed in the previous research (Mohd idrus, Hamdan, Rahman, & Islam, 2011). 1.18 mm sample manage to record the smallest value of tickness swelling. 90 % polymer loading is the sample that own the highest composition of polymer. So when the polymer composoition is high the bond between the molecules is high and prevent the swelling of the particle.

4.3 Flexural Test

The mechanical testing method measures the behavior of material subjected to simple bending loads. There a lot of mechanical testing exist and one of it is flexural test to indicate the flexural strength of the sample in this project. Flexural strength is an object's ability to bend without obtaining any major defects or can also be defined as material's ability to resist deformation under load.

As for flexural test, three different ratio of sawdust polymer composite is selected to undergo this test. For each ratio different size of particle is used to investigate the consequence towards flexural test which are:

1. 0.063 mm
2. 0.212 mm
3. 0.425 mm
4. 1.18 mm

Flexural test has two procedure which are A and B. For my project, procedure B is chosen for all ratio which means the sample being tested up to the 5% elongation. Shown below is the test report

4.3.1 Flexural test result

Sample	Particle Size	Max Load (Mpa)	Strain %	Elastic Modulus (Mpa)
1	0.063	1.992	5.818	38.774
2	0.212	2.752	5.844	86.665
3	0.425	2.95	5.783	61.435
4	1.18	2.107	5.870	41.054

Table 23: Flexural Test Ratio: 60 % Polymer and 40 % sawdust

Sample	Particle Size	Max Load (Mpa)	Strain %	Elastic Modulus (Mpa)
1	0.063	2.524	5.151	55.421
2	0.212	2.841	5.261	59.515
3	0.425	3.389	5.487	74.139
4	1.18	1.435	5.715	24.835

Table 24: Flexural Test Ratio: 75 % Polymer and 25 % sawdust

Sample	Particle Size	Max Load (Mpa)	Strain %	Elastic Modulus (Mpa)
1	0.063	2.634	5.350	42.176
2	0.212	3.663	5.320	46.874
3	0.425	3.904	5.373	47.374
4	1.18	2.358	5.417	49.845

Table 25: Flexural Test Ratio: 90 % Polymer and 10 % sawdust

4.3.2 Discussion of Effect of particle size against maximum load graph

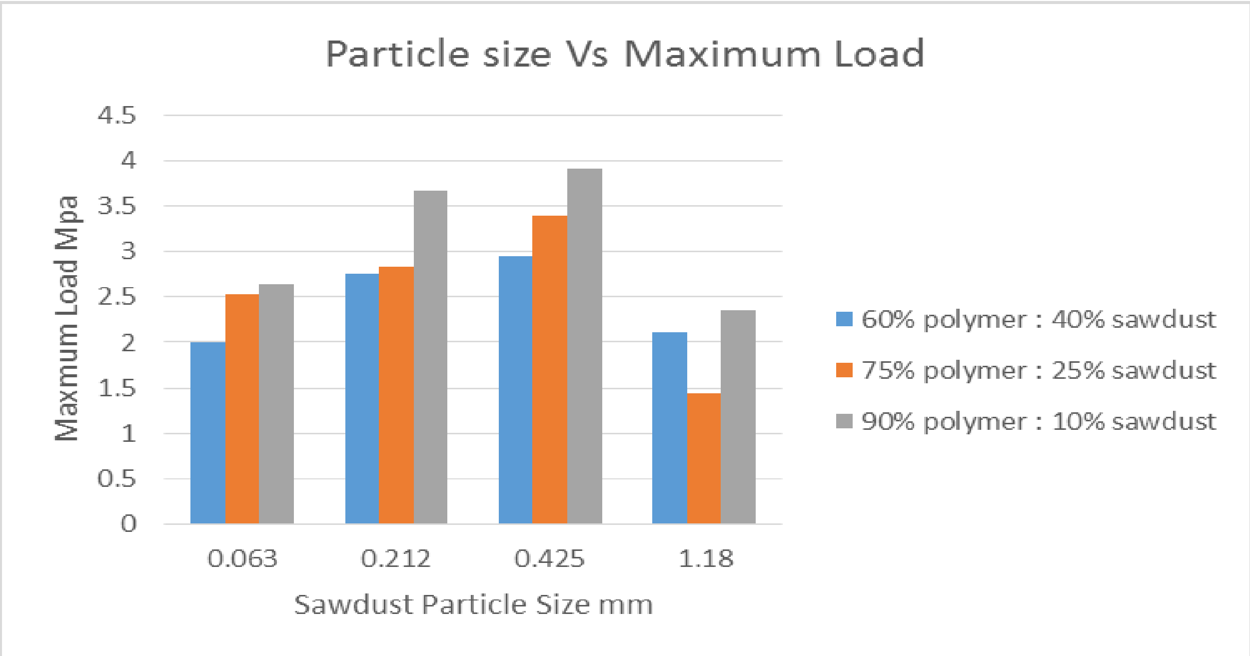


Figure 14: Particle size against maximum load Graph

Graph above show the result of particle size against maximum load that can be retained by sample before 5% strain graph which is also known as flexural strength. There are four particles sizes which are, 0.063mm, 0.212mm, 0.425mm and 1.18mm that have been tested in this experiment. Generally we can see that when the particle size is increase maximum load that can be retained by sample is increase which means the flexural strength is increase.

These result is in good agreement with previous research (Boufif, Koubaa, Perre, & Cloutier, 2009) . Sample 3 which is sample of 0.425mm sample manage to record highest value of maximum load compared to the other range of size and they are 2.95 Mpa, 3.389 mPa amt 3.904. Even though 1.18 mm sample Is the largest sample of size but this sample record the lowest value of maximum load. This kind of experiment has prove that wood particle might be having cracks and fructure surface area that increased with increasing particle size increase and that why 1.18mm recorded slowest value because this sample cannot retained max load before 5% of strain (Boufif, Koubaa, Perre, & Cloutier, 2009).

Discussion 4.3.3 Discussion of effect of polymer loading against flexural strength

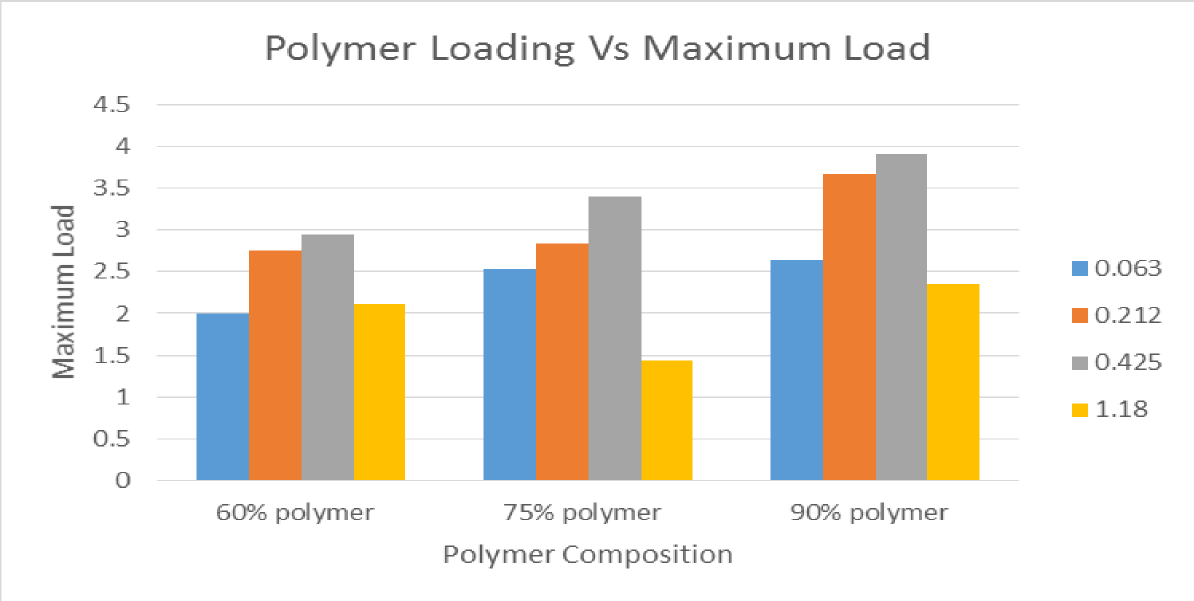


Figure 15: Polymer loading against maximum load Graph

Graph above show the result of polymer composition maximum load that can be retained by sample before 5% strain graph which is also known as flexural strength. There are three different polymer composition which is 60 %, 75% and 90%. From the graph above we can see that the higher composition of polymer recorder the highest value of flexural strength. All samples that contained 90% of polymer managed to record highest value of flexural strength which is 2.634 Mpa, 3.663 Mpa, 3.904 Mpa and 2.358Mpa (S. Ramli, C.T. Ratnam, & S.H. Ahmad, 2013).

So it is proven that chemical treatment towards sawdust has improve the tensile strength of the sawdust (Mohd idrus, Hamdan, Rahman, & Islam, 2011). Clearly, a mixing of raw sawdust with 90% of polymer manage to increase the interfacial interaction between sawdust particle and EVA. For the sample of 90% polymer, the graph clear show that sample of 1.18mm recorded the lowest reading of flexural strength even though it is the largest particle which means the result is in good agreement with previous research. . This experiment has prove that wood particle might be having cracks and fructure surface area that increased with increasing particle size increase and that why 1.18mm recorded slowest value because this sample cannot retained max load before 5% of strain (Boufif, Koubaa, Perre, & Cloutier, 2009). One more possible explanation is the matrix which the polymer is not properly bind with the reinforcement which is the sawdust.

From the graph we can clearly see that 60% polymer recorded lowest value of tensile proven. This result shows that sample is not well mix with the polymer because of the small quantity. Even though EVA has higher molecular strength but because of large quantity of sawdust higher strength of EVA molecules being replaced lower interfacial bond of sawdust (S. Ramli, C.T. Ratnam, & S.H. Ahmad, 2013).

4.4 Tensile Test

4.4.1 Result of Tensile Test

Table 26: Tensile Test Ratio: 60 % Polymer and 40 % sawdust

Sample	Particle Size	Elongation break %	Tensile Strength N/mm^2	Elastic Modulus kN/m^2
A	0.063	0.848	2.15	1057330.643
B	0.212	0.558	1.653	-
C	0.425	3.190	2.262	4179189.622
D	1.18	19.663	2.355	4694091.603

Table 27: Tensile Test Ratio: 75 % Polymer and 25 % sawdust

Sample	Particle Size	Elongation break %	Tensile Strength N/mm^2	Elastic Modulus kN/m^2
A	0.063	37.770	2.216	53028.328
B	0.212	17.105	1.901	57780.745
C	0.425	4.103	2.584	400401.110
D	1.18	13.995	2.715	68508.509

Table 28: Tensile Test Ratio: 90 % Polymer and 10 % sawdust

Sample	Particle Size	Elongation break %	Tensile Strength N/mm^2	Elastic Modulus kN/m^2
A	0.063	30.297	2.725	37815.344
B	0.212	28.090	2.76	37987.580
C	0.425	36.316	2.94	36625.303
D	1.18	7.123	3.133	63244.878

4.4.2 Discussion of effect of particle size towards tensile strength

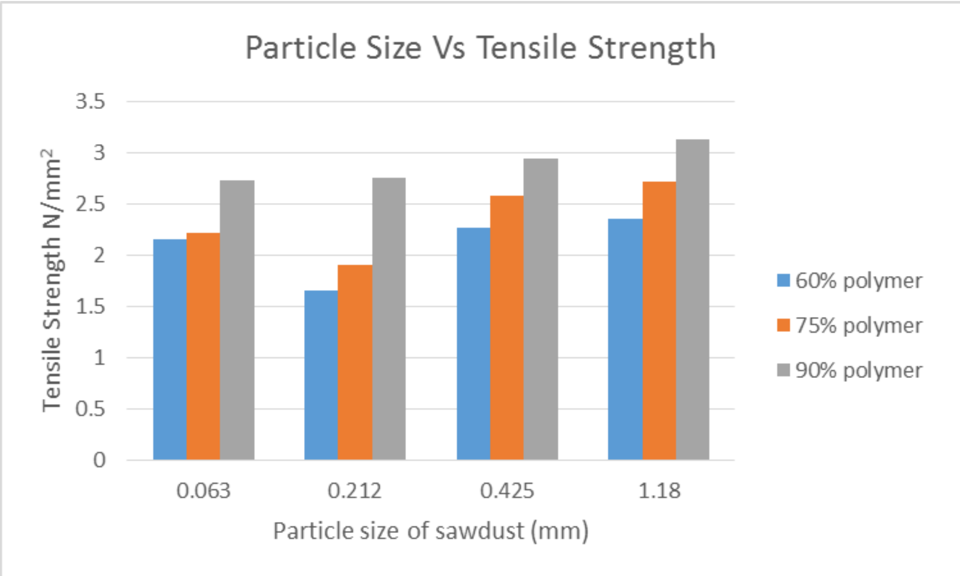


Figure 16: Particle size against tensile strength N/mm^2

Graph above show the result of particle size against tensile strength. There are four particles sizes which are, 0.063mm, 0.212mm, 0.425mm and 1.18mm that have been tested in this experiment. As for this graph, starting from 0.212mm particle size of sawdust, we can clearly see that when the size of particle increase the tensile strength will be increased means this still agree with the previous research (Boufif, Koubaa, Perre, & Cloutier, 2009)

For tensile strengh, particle size 1.18mm manage to record highest tensile strengh compared to the other size particle.The highest reading for tensile strength is 3.133 N/mm^2 , followed by 2.715 N/mm^2 and lastly is 2.355 . Even though this pattern of result is not the same with the flexural test result, but sample with 1.18mm particle size is a course particle which are well bonded together and distributed randomly which can cause increase in the strength of the sample (Charoenwong & Pisuchpen, 2010)

Besides, we can clearly see that particle size 0.212 record lower reading of tensile strengh compared to size partice 0.063 even though the size particle is bigger. Well the most possible explaination for this situaion is the matrix which the polymer is not properly bind with the reinforcement which is the sawdust.

4.4.3 Discussion of effect of polymer composition towards tensile strength (N/mm^2)

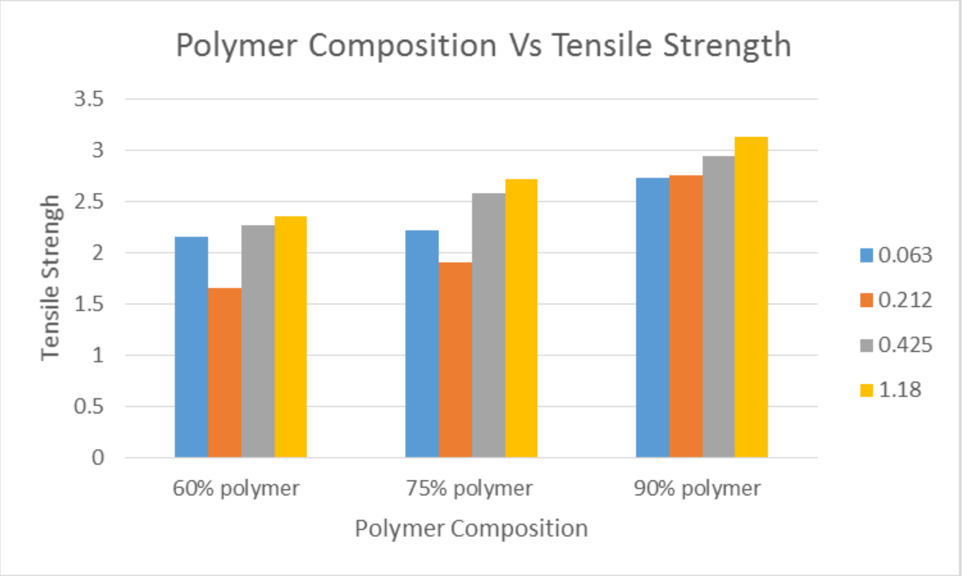


Figure 17 : Polymer Composition against tensile strength N/mm^2

Graph above show the result of polymer composition against tensile strength. There are three different polymer composition which is 60 %, 75% and 90%. From the graph above we can see that the higher composition of polymer recorder the highest value of tensile strength. All samples that contained 90% of polymer managed to record highest value of tensile strength which is 2.725 $N/mm^{2,}$ 2.760 N/mm^2, 2.94 N/mm^2 and 3.113 N/ (S. Ramli, C.T. Ratnam, & S.H. Ahmad, 2013)$mm^{2.}$ So it is proven that chemical treatment towards sawdust has improve the tensile strength of the sawdust (Mohd idrus, Hamdan, Rahman, & Islam, 2011). Clearly, a mixing of raw sawdust with 90% of polymer manage to increase the interfacial interaction between sawdust particle and EVA.

As for the highest tensile strength for the 90% polymer composition, sample with 1.18 mm manage to record the highest value compared to the others. This result has been expected because 1.18 mm sample is made up from course particle size. Course particle size are tightly bonded together and distributed randomly which will increase the strength of the sample (Charoenwong & Pisuchpen, 2010). From the graph we can clearly see that 60% polymer recorded lowest value of tensile proven. This result shows that sample is not well mix with the polymer because of the small quantity. Even though EVA has higher molecular strength but because of large quantity of sawdust higher strength of EVA molecules being replaced lower interfacial bond of 36sawdust (S. Ramli, C.T. Ratnam, & S.H. Ahmad, 2013).

CHAPTER 5

5.1 Conclusion

As a conclusion, this research project has manage to show the mechanical improvement that of raw sawdust after undergone chemical treatment with Ethylene Vinyl Acetate. For this project three parameters has been explore which are water absorption, tensile strength and flexural strength. This result of this project are in good agreement with past research as mentioned above

For this experiment, range of size particle and polymer composition has been the main indicator investigate the mechanical improvement of sawdust. After conducting this experiment, we can arrive to conclusion that sample size of 0.425 mm with 90% polymer composition has managed to show the most improvement in mechanical properties.

This project shows that EVA sawdust polymer composite has a potential to be bring forward to be commercialized to replace uses of raw sawdust in sawdust based material.

5.2 Recommendation

After completing this research there few recommendations that can be done in order for the betterment of research project. Firstly student must pay attention when preparing samples using compression molding machine. Correct melting temperature must be used in order to obtain samples without defects. Secondly, students must repeat their experiment in order to get the best value while doing mechanical testing.

Besides, while doing the tensile and flexural test, student must possess full understanding on those machine in order to get accurate value. Last but not least, student must use different kind of sawdust and different kind of polymer in order to obtain samples with the highest percentages of mechanical improvements.

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APPENDICES

Appendix 1: Sieving Analysis

Figure 10: Sieving machine to sieve the sawdust

Appendix 2: Weighing balance

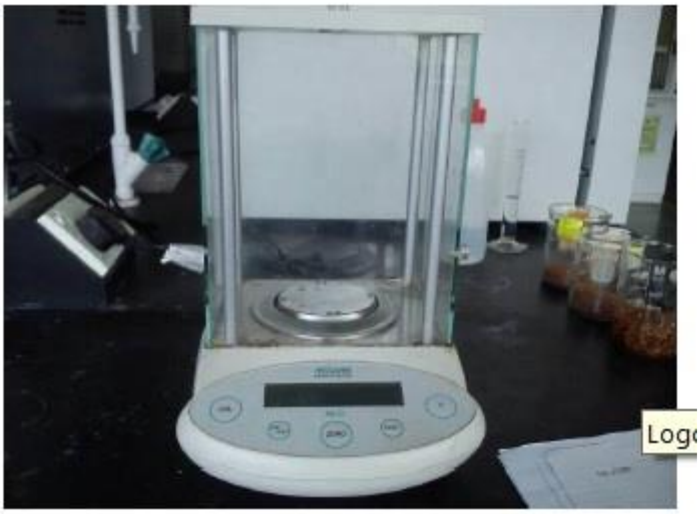


Figure 11: Weighing balance to weight the sawdust particle

Appendix 3: Oven

Figure 12: Oven used to dry sawdust at 100 ^oC

Appendix 4: Dried sawdust

Figure 13: Dried sawdust after being in oven for 24 hours

Appendix 5: Immersed sawdust in the water

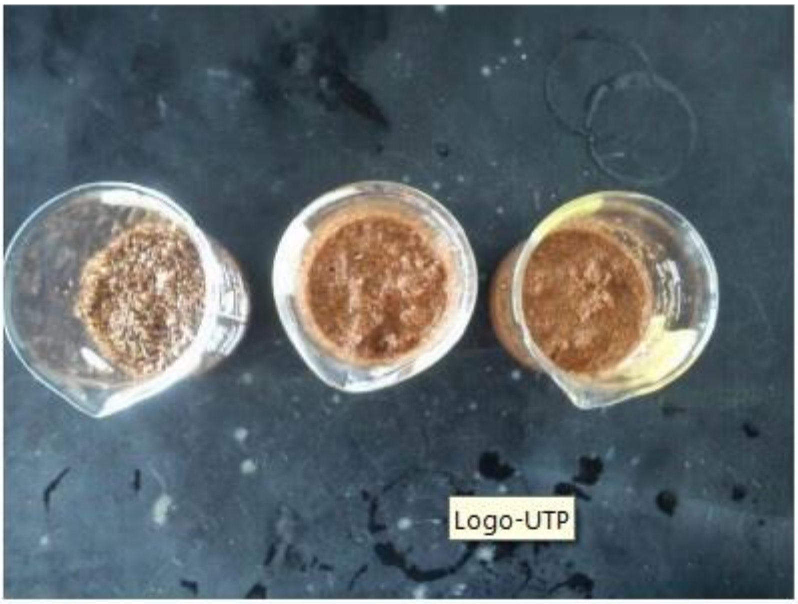
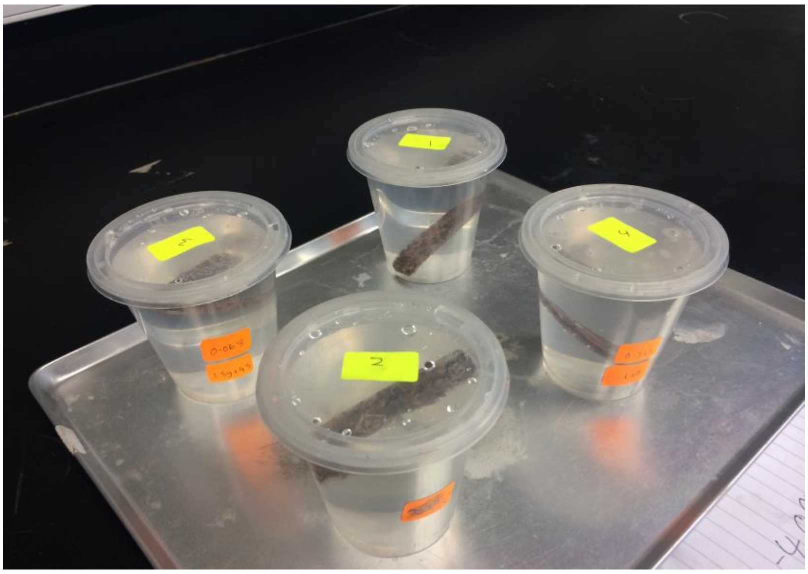


Figure 14: Immersed Sawdust in Water

Appendix six : Immersed sawdust polymer composite in water



Appendix seven : Flexural test on progress

Appendix eight : Tensile test on progress

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