FINAL REPORT
RDU17003320

Fatigue Behaviour of Sugar Palm Fibre Reinforced Polylactic Acid Composites for Automotive Application

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JULY 2020

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1 ABSTRACT

The heavy consumption of petroleum-based plastics will give a serious impact to environment. Thus, bio-plastics attain attention of researcher in development and design of environmentally friendly composites materials which are possible to replace the petroleum-based plastics. The disposal of the synthetic fibre composites at the end of their lifetime usually need more energy to discharge and large amount of carbon dioxide will be released and causes global warming. Therefore, researchers try to escalate activities in the development and design of environmental friendly composites materials. As a result, natural fibres was used as reinforcement material which to strengthening in polymer matrices. In the other hand, mechanical properties of the natural fibres reinforced thermoplastics polymer composites are very important in order to identify the application of the composites in real life situation. The purpose of this study is to determine the tensile, flexural and impact properties of untreated sugar palm fibre reinforced polylactic acid composites by using different weight percentage (wt. %) of sugar palm to reinforced polylactic acid was 10%, 20% and 30%. A pure polylactic acid was fabricated to use as a reference to be compared with the others three types of specimen. In this study, a new process was used which is vacuum oven was used to melt the pellet of composites then the composites was take out and press it manually using load of 5KN. The tensile testing would follow the standard of ASTM D-638-02a while the flexural test is test using the standard of ASTM-D790. Besides, the impact test is according to the ASTM standard D256. The mechanical properties of all 100% of polylactic acid is the highest compare to 10%, 20% and 30% of sugar palm fibre reinforced with 90%, 80% and 70% of polylactic acid. In all mechanical test, 100% of PLA has the highest strength for tensile, flexural and impact test. The 30% of sugar palm fibre reinforced with 70% polylactic acid composites have lowest tensile and flexural strength but it has higher impact strength compare to 10% and 20% of sugar palm fibre reinforced with 90% and 80% of polylactic acid composites while the impact result shows that there are no

influence as the fibre content increase. As conclusion, as the fibre content increases the mechanical properties decreases.

2 INTRODUCTION

Fossil resources are widely being used in modern industries especially petroleum and coal. With growing environmental awareness, public and community started to aware the usage of fossil resources and try to minimize the environment impact due to the carbon dioxide (CO_2) emission that cause by the fossil resources. Nowadays, bio-plastics are invented to replace the petroleum-based plastics due to its biodegradability. Polylactic acidcid (PLA) is a type of versatile bio-plastics and biodegradable meanwhile it can be made from corn, potatoes or other natural plant fibre. The productions of PLA are derived from renewable resources and it gained a lot of attention due to it is alternative of conventional synthetic polymers. PLA is made from renewable agricultural raw materials by fermented to lactic acid (Tokoro et al., 2008).

Natural plant fibres are more prefer by public due to its superior mechanical properties. One of the benefits using sugar palm fibre is that the availability of the fibre. The sugar palm fibre can get easily in tropical regions such as Malaysia and Indonesia. The fibre is cover the length of truck of the sugar palm tree. The sugar palm fibre is black in colour namely ijuk fibre and it can be used to manufacturing the brooms, paint brushes and door mats. The glass or carbon fibre can be replaced by the sugar palm fibre due to its economic benefits and mechanical properties. Sugar palm tree is a multipurpose tree because all part of the tree can be used including its fibre. Sugar palm fibre has three main advantages which are its high tensile strength that can make it to have a longer life time, heat and moisture will not affected the performance of the fibre compared coir fibre and it has good resistance and durable to sea water (Ishak, Leman, Sapuan, Rahman, & Anwar, 2011). The sugar palm fibres do not need any secondary process for the preparation of it. The sugar palm fibres are consider as effortless fibre due to the fact that the fibres are originally wrapped around the sugar palm trunk from the bottom to the top part of the tree. The fibres are in the natural woven fibre form (Ishak et al., 2013).

However, the biodegradable polymer are increasing recognize due to its environmental friendly and can degrade on normal environment by microorganism into water or carbon dioxide. Polylactic acid is a type of polyester which made from lactic acid. There are some advantages of polylactic Acid which are recyclability, compostable, high strength and stiffness (Garlotta, 2001). The sugar palm fibres as reinforcement in polylactic acid has not been studied in the past. This research is to determine the mechanical properties of sugar palm fibre reinforced polylactic acid composites. Mechanical properties of the sugar palm fibre reinforced polylactic lactic acid can be determined by the tensile test, impact test and flexural test.

The heavy consumption of petroleum-based plastics will give a serious impact to environment due to the emission of carbon dioxide from the process of disposal. Besides, the fossil resource is non-renewable resources and limited that take millions of years to form. Since the demands increases from years to years hence the global environmental impact become more and more serious. Therefore, researches have try to study about properties of natural fibres as a renewable alternative such as corn-based polymer and starch-based polymer that can provide the similar performance as well.

In this study, a mechanical property of sugar palm fibre reinforced polylactic acid composites is investigated in case in order to know the application of this composite. The sugar palm fibre reinforced polylactic acid composites is biodegradable that it can be dispose without any work is apply to it while the petroleum-based plastics will not dispose by itself ever few millions of year and it need to have disposal process to dispose it. Normally, the disposal process of the petroleum-based plastics is by the burning it and this will causes the emission of carbon dioxide during the process of disposal. Various mechanical testing are done to perform in order to know the mechanical properties of the natural fibre reinforced polymer and their application. The objective of this research is to investigate the mechanical properties of untreated sugar palm fibre reinforced polylactic acid composite.

3 LITERATURE REVIEW

Researcher and engineer shifting interest from classic monolithic materials to fibre-reinforced polymer-based materials since the past few decades. The glass fibre reinforced composites have special properties of high fracture toughness, high strength to weight ratio and non-corrosive property. The composites materials consisted of some characteristics which are the carbon, glass, aramid and low strength polymeric matrix (Cheung, Ho, Lau, Cardona, & Hui, 2009). Most of the glass fibre reinforced polymer based polymer are used in aerospace, leisure, automotive, construction and sporting industries. However, these glass fibre-reinforced have some critical disadvantages such as it is unrenewable and non-recyclable resources and it need high energy consumption in the manufacturing process and the most drawbacks factor is non-degradable properties which may cause the environmental pollution (Wambua, Ivens, & Verpoest, 2003).

Glass fibre composites have been widely used for many year which help to solve the structural problems. While these glass fibre composites will induce critical environmental problem that most concerning by public (Cheung et al., 2009). Nowadays, environmental awareness worldwide have been strongly emphasis and it brought the attention on recyclable and environment friendly composite materials. The legislation of environment and consumer demand in many countries are putting pressure on manufacturers of materials to take in consider of environmental impact of their products at all stages of their life cycle which including recycling and disposal (Wambua et al., 2003). If the interconnection of components is close then the composite is relatively stable thus it difficult to separate and recycle. Due to many serious problem causes by glass fibre reinforced polymer composites, so researcher have study about the material of natural resources from plant which may reduce the harmful effect to environment.

The use of natural fibres is dramatic increase within the past few years due to its non-abrasive properties and freedom from health problems that cause by the skin irritation during manufacture processing. There are many type of natural fibres are used as polymer composites such as flax, oil palm, pineapple, hemp, flax, sisal, jute, henequen, pineapple, pseudo-stem, sugarcane, coir, wood, bamboo, bagasse, kenaf, abaca, rice husk and sugar palm fibres. While, these fibres have some passive characteristics such as the hydrophilic is high and the vary properties due to influence of their growing conditions, fibre processing technique, the fitness of the fibre and the sample test- length which increase the difficulty to have an accurate prediction of respectively composite properties (D Bachtiar, Sapuan, & Hamdan, 2010). Besides, plant fibres are made from cellulose, hemicelluloses, lignin, and others thus they are cannot be consider as same. Recent advances in natural fibre development thus genetic engineering and composites science have offer important chance for improves materials from renewable resources with enhanced support for world sustainability (Cheung et al., 2009).

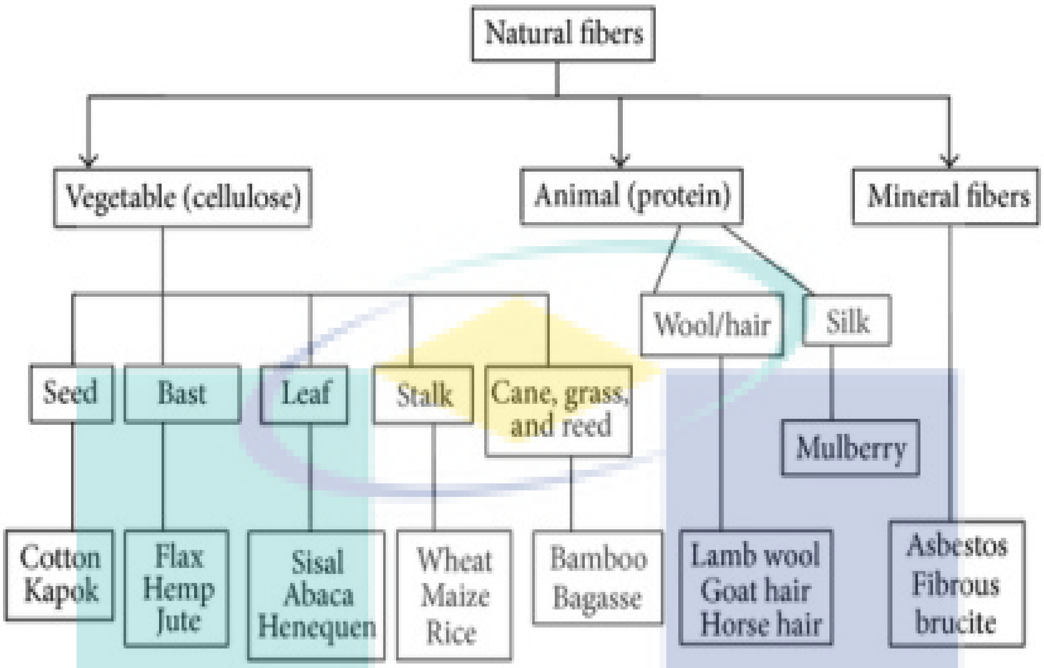

Figure 2.1 Classification of natural fibres (Bavan & Kumar, 2013)

Natural fibres have a special structure which consists a hollow space namely lumen and random nodes which divide the fibre into individual cells. The strength and Young's modulus will be improved as the size of lumen decrease and the thickness of secondary cell wall increase(Fidelis, Pereira, Gomes, de Andrade Silva, & Toledo Filho, 2013). The adhesion to matrix in the structure of composite will be good as the surface of natural fibre are rough (Riedel & Nickel, 2005). The main part of natural fibre gained from plant is the cellulose, hemicellulose and lignin. Mechanical strength of fibre are provided by the cellulose. Hemicellulose will provides a hydrogen bond to the cellulose to cementing matrix between each cellulose micro fibrils that form the cellulose-hemicellulose network which contribute to the main structural component of the cells. The coupling agent, lignin will increase the stiffness of the cellulose-hemicellulose and gives rigidity to the plants.

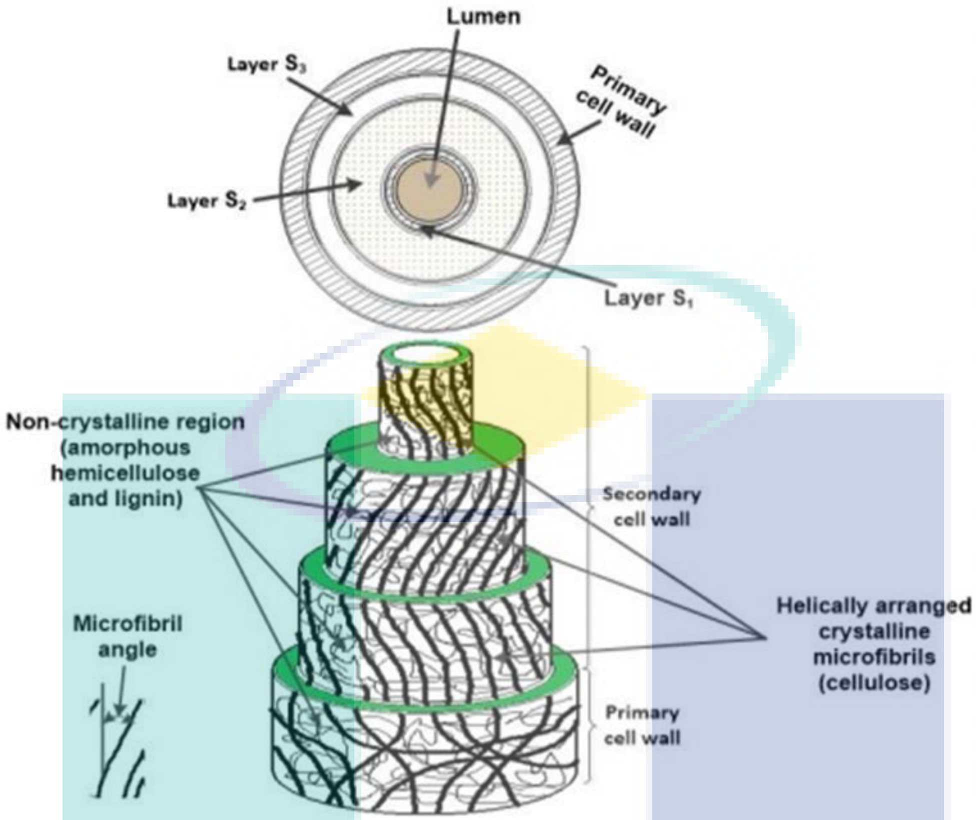

Figure 2.2 Structure of natural fibre (Jacob John, Francis, Varughese, & Thomas, 2008)

The cellulose in plants is organised into micro fibrils which are the main reinforcement for plants. There are composed of two regions in cellulose fibrils which crystalline and amorphous regions. The strong crystalline cellulose blocked any penetration occurred unless the cell wall is swollen. Thus, the disordered of cellulose chain can be built up the amorphous regions which make it to absorb dye and resins more easily. The hydroxyl groups present in plant fibres will contributed to the hydrophilic nature of the cellulose (Aziz, Ansell, Clarke, & Panteny, 2005; Moon, Martini, Nairn, Simonsen, & Youngblood, 2011; Mwaikambo & Ansell, 2002). Acid can hydrolysed the cellulose easily to become water-soluble sugar but it resistant to strong alkali and oxidising agents. Hemicellulose can be soluble in alkali and can be hydrolysed in acids easily and very hydrophilic. Besides, lignin is hydrophobic in nature and can totally soluble in most solvents (Jacob John et al., 2008). Table I shows the chemical content of plant fibres.

Table 2.1 Chemical Composition of Sugar Palm Fibre Obtained from Different Heights of Sugar Palm Tree (Ishak et al., 2013)

Height (m)	1	3	5	7	9	11	13	15
Holocellulose (%)	43.3	56.36	64.28	65.55	64.8	63.75	62.42	57.41
Cellulose (%)	37.3	49.36	55.28	56.55	56.8	55.75	54.42	53.41
Hemicelluloses (%)	4.71	6.11	7.36	7.68	7.93	7.92	7.89	7.45
Lignin (%)	17.93	18.491	20.89	20.45	23.6	22.96	24.27	24.92
Ash (%)	30.92	14.04	5.8	4.23	2.06	4.09	3.98	4.27
Extractive (%)	2.49	2.019	1.71	1.41	1.35	1.48	1.21	0.85
Moisture Content	5.36	8.64	7.92	8.38	8.19	7.72	8.12	8.7

Most of the natural fibres are suitable to reinforce with polymer such as thermosets as well as thermoplastics due to their relative high strength, high stiffness and low density. The flax and soft-wood-kraft-fibres having the characteristics value that close to the value for glass fibre. Glass fibre are types E fibres because of their early use in electronic applications. At present day, the glass fibre typically used to reinforce with polymer in non-aggressive media.

Table 2.2 Range of the characteristic values natural fibres (Bledzki & Gassan, 1999).

Fibre	Density (g/cm^3)	Elongation (%)	Tensile Strength (MPa)	Young Modulus (GPa)
Cotton	1.5 – 1.6	7.0 – 8.0	287 – 597	5.5 – 12.6
Jute	1.3	1.5 – 1.8	393 – 773	26.5
Flax	1.5	2.7 – 3.2	345 – 1035	27.6
Hemp	-	1.6	690	-
Ramie	-	3.6 – 3.8	400 – 938	61.4 - 128
Sisal	1.5	20.0 – 2.5	511 – 635	9.4 – 22.0
Coir	1.2	30.0	175	4.0 – 6.0
Viscose (cord)	-	11.4	593	11.0
Soft wood Kraft	1.5	-	1000	40.0
E-glass	2.5	2.5	2000 – 3500	70.0

S-glass	2.5	2.8	4570	86.0
Aramide (normal)	1.4	3.3 -3.7	3000 – 3150	63.0 – 67.0
Carbon (standard)	1.4	1.4 – 1.8	4000	230.0 – 240.0

The use of natural fibres as reinforcements in composites has grown in importance in recent years. If compared to others fibre such as synthetic fibres, natural fibres got a lot of advantages such as lower cost, massive availability, lower density and biodegradability. Natural fibres are a class of hair-like materials that are continuous filaments or are in discrete elongated pieces, similar to pieces of thread. They can be spun into filaments, thread, or rope. They can be used as a component of composite materials. They can also be matted into sheets to make products such as paper or felt. The causes of this increasing demand of natural fibre is due to natural fibre has a higher specific strength than ordinary fiberglass and the same specific modulus. With those advantages, natural fibre is more preferable compare to others fibres at a lower cost but better good mechanical properties. Most natural fibre was taken from biodegradable waste from agricultural, industrial or taken from some naturally grown plant and can be reuse.

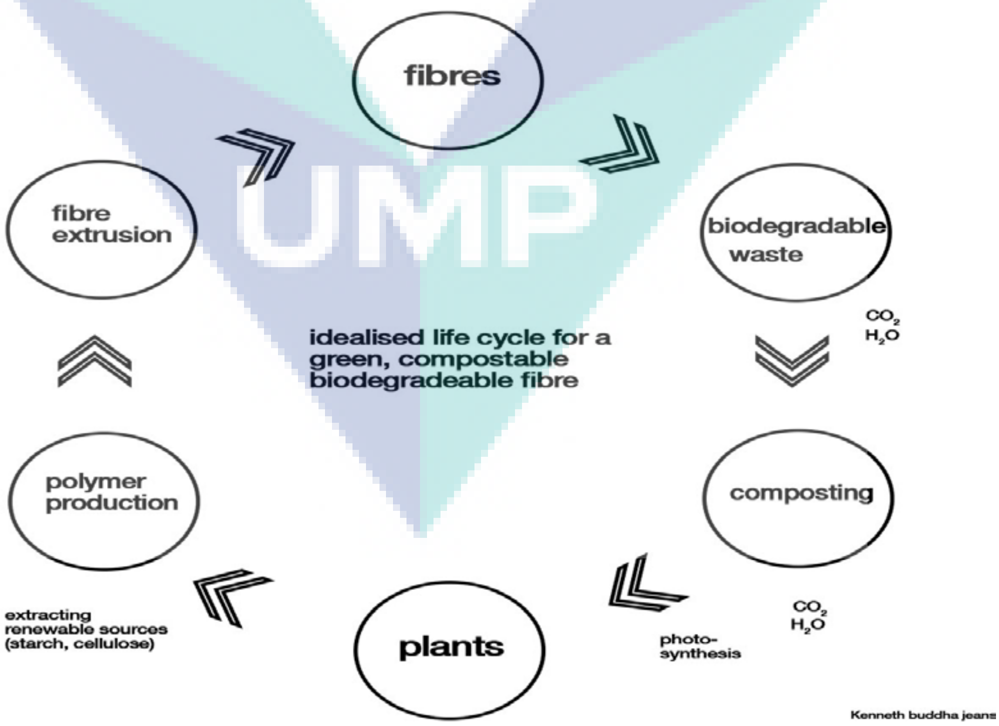

Figure 2.3 The life cycle of bio-composites (Dashtizadeh et al., 2017)

4 METHODOLOGY

FIBRE PREPARATION

First, the sugar palm fibre were washed then dried at 35°C for 14 days (Mohammed, Bachtiar, Siregar, Rejab, & Hasany, 2016). After dried, the sugar palm fibre will then cut mechanically into around 1cm per pieces then it will crushed by a grinder (Retsch Ultra Centrifugal Mill Model ZM200, Haan, Germany). The sugar palm fibre were ground and sieved into 30-50 mesh which in very short sizes.

PREPARATION OF PLA

Polylactic acid however is prepared in form of pellets that will be added at the mixing stage to be produce the composite. The amount is given in such that it is in a form of fully PLA, 10%, 20% and 30% of the sugar palm fibre's weight. A weighing machine will be used in order to precisely ensure that the mixture ratio is accordingly.

MOULD MAKING

Six pieces of square sheet metal was cut by shearing machine with the dimension 200 mm x 200 mm. Besides, CNC machine was used to cut a square shape out at the center of two of the square sheet metal. The size of the center square shape I s150 mm x 150 mm will a small radius of 5 mm at each corner.

PREPARATION OF COMPOSITES

In the preparation of the specimens is to use the square mould with dimension of 150 mm x 150 mm x 3 mm. The sugar palm fibres were compound with polylactic acid by using a ThermoScience Eurolab 16 extruder machine (Karlsruhe, Germany).

The addition of sugar palm fibre in the polylactic acid will cause the viscosity of the mixture increase and this may cause the fibre to degrade due to the increasing in the melting temperature and torque load. While, the temperature range are then set to be 170°C-190°C in order to control the degradation. Meanwhile, a flashing process is needed before start to extrude new composites in order to clean up the remaining material inside the extruder machine and the temperature is set to 250 °c when the flashing process is undergoes.

The range of temperature set is in the transition phase during the temperature studies. The temperature was varied between 160°C- 180°C in different studding (Mohammed et al., 2016). The weight of the sugar palm fibre and polylactic acid had been measure using weighing machine. 10%, 20%, 30% of sugar palm fibre was mix to the 90%, 80%, 70% of polylactic acid respectively to fabricate different weight percentage of composites.

The compound of sugar palm fibres and the polylactic acid were go through a manual hot press process by using vacuum oven to heat it until the composites that in pallet shape melt with the temperatures of 180°c to 190°c. The composites were pouring at the center of mould then the mould was put into the vacuum oven.

After the composites fully melt, the top plate of mould is cover then the heat it for 10 minutes and take out from the vacuum oven to press it using a load of 5kg and let it to press for 10 minutes. Then remove the composites which in 150 mm x 150 mm square shape.

The plate was measure by follow the standard of ASTM for tensile, flexural and impact test using vernier caliper. After mark and measure, the plate was cut using jigsaw and rub it until the surface is smooth. All the specimens are measure again after smoothen in order to record and insert the dimension of specimen during the experiment testing. This step is very important to minimize the error during testing.

Experiment Detail

The purpose of this study is to determine the tensile, flexural and impact properties of untreated sugar palm fibre reinforced polylactic acid composites by using different weight percentage (wt. %) of sugar palm to reinforced polylactic acid was 10%, 20% and 30%. A pure polylactic acid was fabricated to use as a reference to be compared with the others three types of specimen. Various specimen of each parameter was fabricated to get an average tensile, flexural and impact test results. The tensile testing ould follow the standard of ASTM D-638-02a while the flexural test is test using the standard of ASTM-D790. Besides, the impact test is according to the ASTM standard D256.

Mechanical Testing

Mechanical testing were carry out in order to determine the properties of untreated sugar palm fibre reinforced polylactic acid composites. There are three type of mechanical properties are determined in this study which are the tensile properties, flexural properties and impact properties of the composites.

Tensile Test

Instron universal testing machine model 3369 (Norwood, USA) was used in this study to determine the tensile strength of untreated sugar palm fibre reinforced polylactic acid composites. This machine has a crosshead velocity of 5mm/min. A 5 specimen were cut into dumbbell shapes which follow the standard of ASTM D-638-02a for each of the composition of sugar palm fibres. The specimen's size for ASTM D638 is dumbbell-shaped with either a 25 mm or 50 mm gauge length.

The specimens are placed in the grips of the universal tester which at a specified grip separation before the testing started. The specimens are then will be pulled until it failure which is the specimen stretches to that breaking point. The test speed of ASTM D-638-02a is determined by the materials specification. The elongation and tensile modulus of the specimen can be determine by the extensometer. The results were collected and analyzed after the specimen failure.

Flexural Test

The same machine of Instron Universal Testing machine was used for the flexural test too. The span length was set to equal to 16 times of the specimen thickness. The 16 times thickness of specimen also equals to 48mm according to ASTM D790. The dimensions of sample were 130 mm x 13 mm x 3 mm by follow the standard of ASTM D90 which have been set in 1974.

Before the testing start, the machine was calibrated and the test rig was changed to base that suitable for 3-point bending test. The software in the computer that linked to the machine had also been set up properly by inserting the length, width and the thickness of the specimen into the software. The speed of the rig moves toward the specimen had also been set to 2mm/min. A truly prepared and set-up machine was ensured.

When the testing started, the specimen was located on the test rig properly and precisely and start button was pressed to proceed with the testing. When the specimen breaks, stop button was pressed and the results were displayed. The results were collected and will be analysed later.

Impact Test

The samples for the notched impact strength testing were prepared per ASTM standard D256. The specimens of this test is with the dimensions of 63 mm x 13 mm x 3 mm. this test will performed using the machine of Zwick/Roell 5113 pendulum impact machine (Ulm, Germany). The impact strength was evaluated by dividing the impact energy used from the cross-section area in all samples.

The temperature of environmental chamber of this Izod impact test was maintained at range of 0°C to 20°C. The velocity of this impact test will be set to 3.4m/s. Before the testing started, the specimen was located on the proper position and on the machine. The results of impact test is collected and analysed.

The result of all experiment testing was recorded. Furthermore, the result will be analyse and showing out in graph form which to clearly show the result for the experiment testing.

5 RESULT

TENSILE TESTING

Tensile test was carry out for 100% of PLA, 10%, 20% and 30% of sugar palm fibre reinforced with 90%, 80% and 70% PLA respectively. Every specimen will be undergoes the tensile test until the specimen break. Besides, the maximum load that can be withstand by the specimen will be record in table and a graph will be perform to show the tensile properties of all specimen with same composition. The ultimate strength of the composites are the maximum stress that the composites can be withstand while being stretched or pulled before breaking. 5 specimen for each composition of composites are undergoes the tensile test in order to get the extension and force that the specimen can be withstand. Besides, graph will be performing in order to show the result clearly.

The extension and load of 100% PLA is used to calculate the stress and strain of the composites. The tensile stress of the composites can be calculated using the following formula.

$$\sigma = \frac{F}{A}$$

Where

σ = tensile stress measured in Nm^{-2} or pascals (Pa)

F = Force in newtons (N)

A = cross-sectional area in m^2

While the tensile strain of the specimen can be calculated by using the formula below.

$$stain = \frac{\Delta L}{L}$$

strain = tensile strain with no units

ΔL = extension measured in metres

L = original length measured in metres

All the calculated tensile stress and strain was tabulated in the table 4.6 and a graph 4.1 was performed to show the tensile properties of 100% of PLA.

The ultimate strength of each specimen is the maximum load that a specimen can be withstand during stretched. The average of ultimate stress for each composition of composites was tabulated.

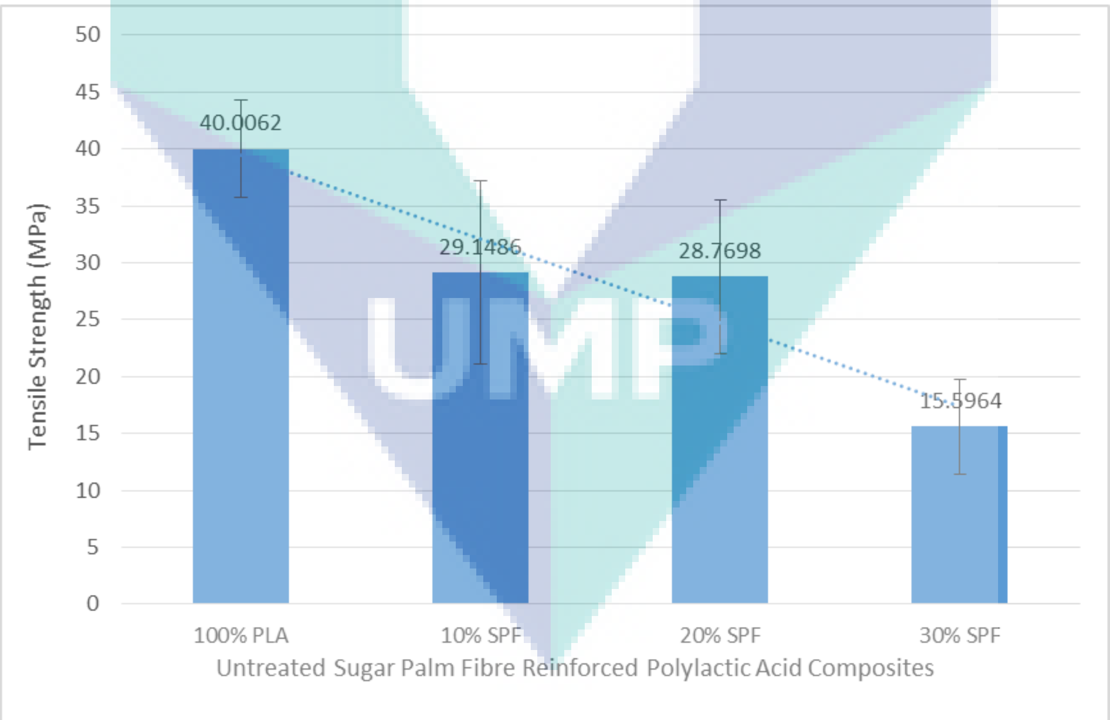

Figure 4.1: Tensile Strength for Untreated Sugar Palm Fibre Reinforced Polylactic Acid Composites

From the figure 4.5, a downward trend was show and this mean that when the fibre content increase the tensile strength decrease. From the mean of ultimate strength for each composition of composites, the 100% of PLA has highest ultimate tensile strength which means the 100% of PLA can withstand highest load compare to 10%, 20% and 30% of sugar palm fibre reinforced with 90%, 80% and 70% of the PLA. While, the 30% of sugar palm fibre reinforced with 30% of PLA has the lowest ultimate strength. The result that was be expected are the 30% of sugar palm fibre reinforced with 70 % of PLA should have the highest ultimate strength follow by 20% and 10% of sugar palm fibre reinforced with 80% and 90% of PLA then lastly is the 100% of PLA but the result shown by the experiment testing was totally different. The highest ultimate stress is 100% of PLA which is 39.522 MPa and follow with 10% sugar palm fibre reinforced with 90% polylactic acid composites of 30.101 MPa then 20% of sugar palm fibre reinforced 80% polylactic acid composites and lastly the 30% of sugar palm fibre reinforced 70% polylactic acid composites which has 14.81 MPa for ultimate tensile stress.

The error bar show the standard deviation of the tensile strength which means the range of the data to be accurate and precise. The 100% of PLA can have range of ± 4.294 from 40.00 MPa, ± 8.047 from 29.14 MPa for 10% of sugar palm fibre reinforced with 90% of polylactic acid composites, ±6.749 from 28.14 MPa for 20% of sugar palm fibre reinforced polylactic acid composites and lastly is ±4.147 from 15.59 MPa for 30% of sugar palm fibre reinforced 70% polylactic acid composites.

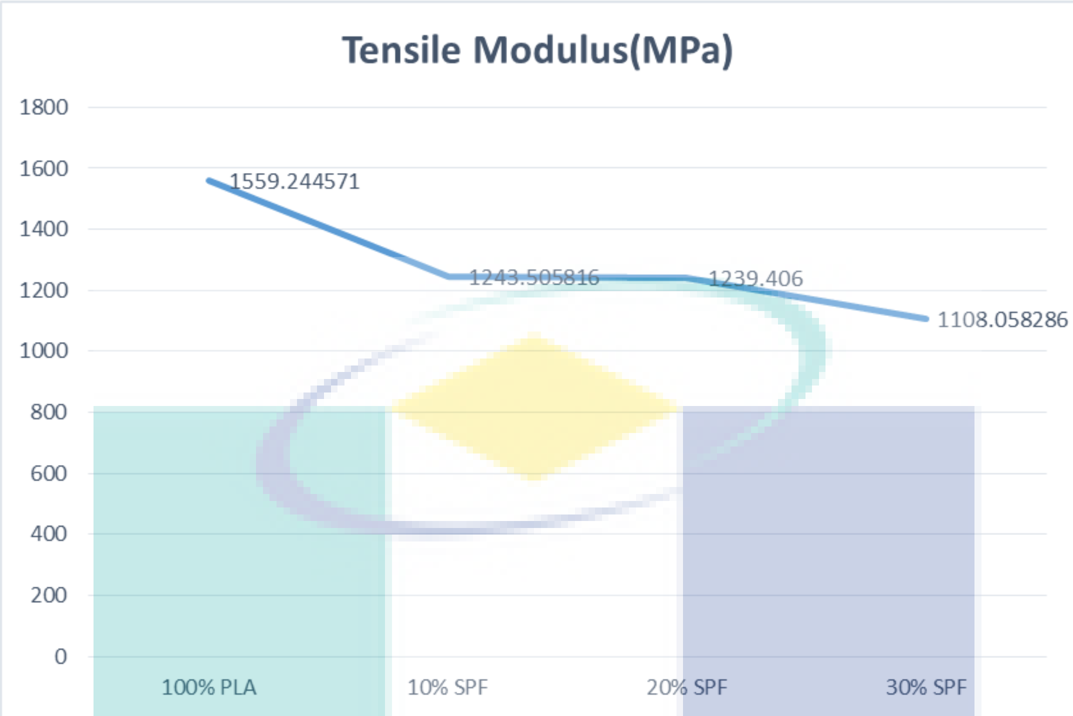

Figure 4.2: Tensile Modulus for Untreated Sugar Palm Fibre Reinforced Polylactic Acid Composites

The tensile modulus graph above shows a declining trend which shows that the tensile modulus decrease as the fibre content is increase. 100% of PLA has the highest tensile modulus which is 1559.25 MPa and the 30% of sugar palm fibre reinforced 70% of polylactic acid composites has the lowest tensile modulus which is 1108.06 MPa.

Some research was done to discuss why the percentage of sugar palm fibre increase then the tensile properties decrease. Some reason causes this to be happen which including the bonding of untreated sugar palm fibre reinforced with polylactic acid composites, the process of mixing for untreated sugar palm fibre reinforced with polylactic acid composites and the degree of compaction of untreated sugar palm fibre reinforced with polylactic acid composites. The bonding of the untreated sugar palm fibre and polylactic acid are weak and the fibre can be pull out easily from matrix locking (Dandi Bachtiar, Sapuan, & Hamdan, 2008). The micro pores on the fibre's which allow the matrix to fill into the holes and forming a good mechanical interlocking and in this study show that the polylactic acid did not fill the pore hole of sugar palm fibre. The tensile strength decrease as the fibre content increase due to the weak interfacial area between the fibre and matrix increased (Haque, 2009). Besides, the untreated sugar palm fibre reinforced polylactic acid composites by extrude using extruder machine which might not mix the untreated sugar palm fibre and polylactic acid evenly. The mechanical properties of untreated sugar palm fibre reinforced with polylactic acid will be frustrate if the degree of compaction is difference.

FLEXURAL TESTING

Flexural test was carry out for 100% of PLA, 10%, 20% and 30% of sugar palm fibre reinforced with 90%, 80% and 70% PLA respectively. Every specimen will be undergoes the tensile test until the specimen break. Besides, the maximum bending that can be withstand by the specimen will be record in table. Flexural test is measuring the force required to bend a specimen under 3-point loading conditions. 5 specimens for each composition of composites are undergoes the flexural test in order to get the extension and force that the specimen can be withstand.

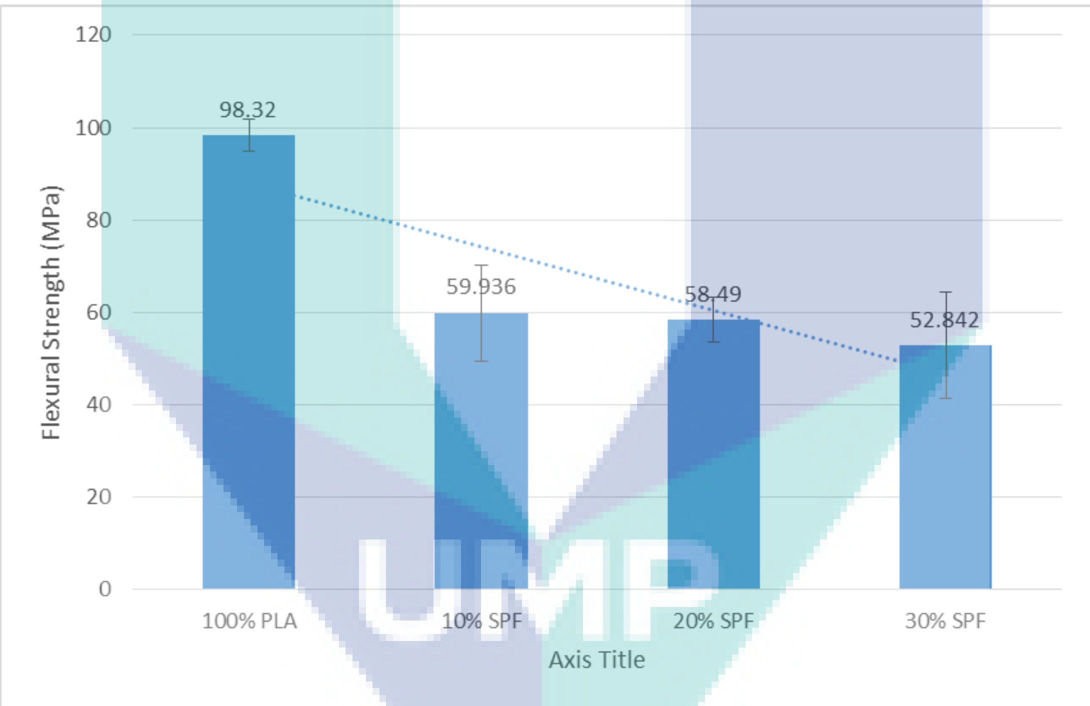

Figure 4.3: Flexural Strength of Untreated Sugar Palm Fibre Reinforced Polylactic Acid Composites

Table 4.30 shows the flexural strength of different composition of sugar palm fibre reinforced with polylactic acid composites. From the table 4.30 shows 100% of PLA have the highest of flexural strength compare to 10%, 20% and 30% of sugar palm fibre reinforced with 90%, 80% and 70% of polylactic acid composites respectively and 30% of sugar palm fibre reinforced with 70% of polylactic acid composites shows the lowest average flexural stress, average flexural strain and average modulus. The difference of the average flexural stress for the highest which is the 100% of PLA and the lowest which is the 30% of sugar palm fibre reinforced 70% of polylactic acid composites is the difference of 98.32 MPa and 52.84 MPa and the differences is 45.48 MPa. The differences between highest and lowest of average of flexural stress are around 46.26%.

Besides, the 100% of PLA has the highest value of average flexural strain of 0.044 and 30% of sugar palm fibre has the lowest value of flexural strain of 0.028 which has a difference of 0.016. The difference between highest and lowest in flexural strain is around 36.36%. The error bar show the standard deviation of the flexural strength which means the range of the data to be accurate and precise. The 100% of PLA can have range of ±3.434 from 98.32 MPa, ±10.383 from 59.936 MPa for 10% of sugar palm fibre reinforced with 90% of polylactic acid composites, ±4.855 from 58.49 MPa for 20% of sugar palm fibre reinforced polylactic acid composites and lastly is ±11.52 from 52.842 MPa for 30% of sugar palm fibre reinforced 70% polylactic acid composites.

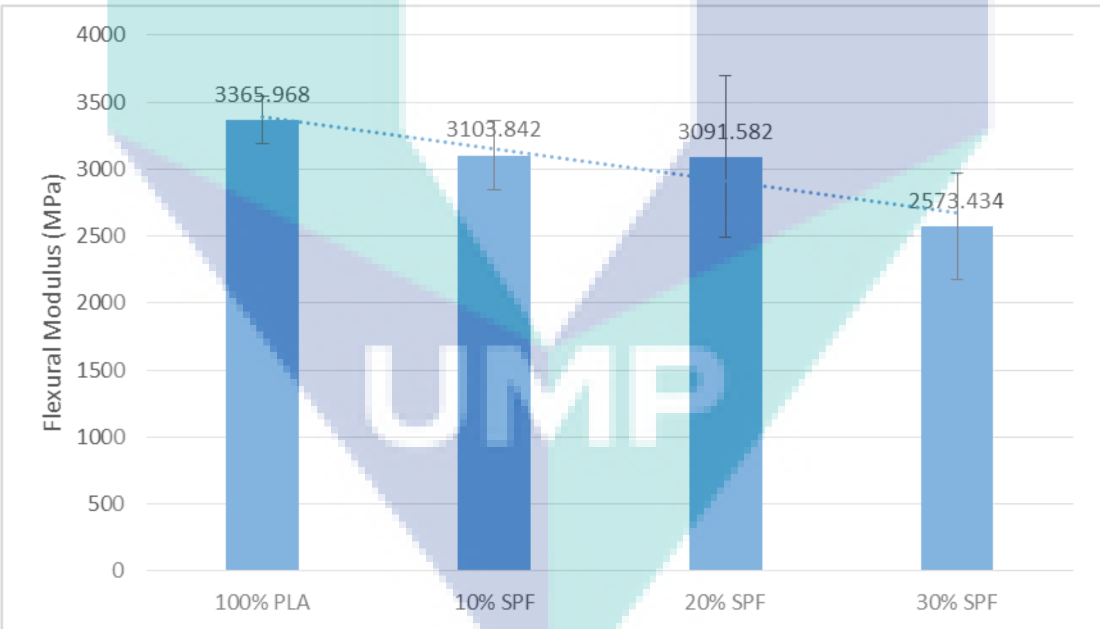

Figure 4.4: Flexural Modulus of Untreated Sugar Palm Fibre Reinforced Polylactic Acid Composites.

The mean of flexural modulus of 100% of PLA is 3365.98 MPa, the 10% of sugar palm fibre reinforced 90% of polylactic acid composites has 3103.84 MPa, the 20% of sugar palm fibre reinforced 80% of polylactic acid composites has 3091.58 MPa and 30% of sugar palm fibre reinforced 90% of polylactic acid composites has 2571.43 MPa. The 100% of PLA has the highest value of mean modulus and the 30% of sugar palm reinforced polylactic acid composites has the lowest value of mean modulus. There are differences of 794.54 MPa for mean modulus and it is around 23.61%.

Some research was done to discuss why the percentages of sugar palm fibre increase then the flexural properties decrease. The flexural strength decrease as the fibre increase which is due to the surface of the untreated sugar palm fibre was covered by the outer layer of hemicelluloses and pectin and the layer is used to protect the fibre from weather and heat degradation but it has weak bonding with the second layer which is the lignin and crystal celluloses (Sapuan& Bachtiar, 2012). The outer layer of hemicelluloses causes the compatibility of fibre and matrix low and the layer should be remove in order to improve the adhesion of fibre and the matrix (Rowell,1998).

IMPACT TEST

Impact test is a test which used to measure the toughness of material. The toughness of a material is the capacity of material to absorb the energy before fracture. Impact test was carry out for 100% of PLA, 10%, 20% and 30% of sugar palm fibre reinforced with 90%, 80% and 70% PLA respectively. Every specimen will be undergoes the impact test until the specimen break. Besides, the load will be release and the load will directly hit the specimen and the specimen will break the impact energy will be record in table. 5 specimens for each composition of composites are undergoes the impact test in order to get the impact energy that the specimen can withstand. After the impact test, impact energy was tabulated in table and the impact strength was calculated. Besides, the mean and the standard deviation are calculate and a graph are plot to show the range of the results.

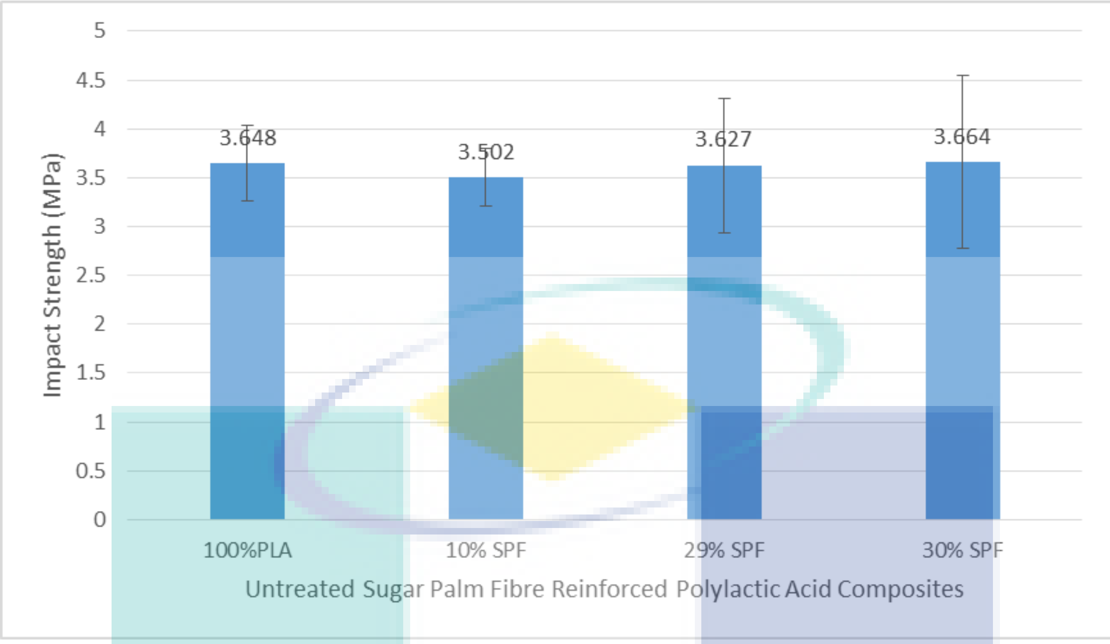

Figure 4.5: Impact Strength of Untreated Sugar Palm Fibre Reinforced Polylactic Acid Composites.

The mean of impact energy of 100% of PLA is the highest which is 3.64 KJ/m^2 and the second high is the 30% of sugar palm fibre reinforced with 70% of sugar palm fibre reinforced with polylactic acid composites with the figure of 3.66 KJ/m^2 then follow by the 20% of sugar palm fibre reinforced 80% of polylactic acid composites is 3.62 KJ/m^2 and then follow with the lowest 10% of sugar palm fibre reinforced 90% of polylactic acid composites of 3.50 KJ/m^2. The differences of the highest and lowest mean of impact energy of the composites are 1.46 KJ/m^2 which shows it is around 4%. The error bar shows the standard deviation of the impact strength which means the range of the data to be accurate and precise. The 100% of PLA can have range of ± 0.388 from 3.648 KJ/m^2, ± 0.294 from 3.502 KJ/m^2 for 10% of sugar palm fibre reinforced with 90% of polylactic acid composites, ±0.689 from 3.627 KJ/m^2 for 20% of sugar palm fibre reinforced polylactic acid composites and lastly is ±0.889 from 3.661 KJ/m^2 for 30% of sugar palm fibre reinforced 70% polylactic acid composites.

A small increase in impact strength is seen between 10% to 30% of sugar palm fibre weight fraction. The impact result show small increase but when the results been round off then the impact strength for all composites are same and this is due to the fibre do not help in absorb the impact energy before the untreated sugar palm fibre reinforced polylactic acid fracture.

6 CONCLUSION

In conclusion, all three objectives have been successfully achieved through different types of testing, experiment and analysis. The mechanical properties of all 100% of polylactic acid is the highest compare to 10%, 20% and 30% of sugar palm fibre reinforced with 90%, 80% and 70% of polylactic acid. In all mechanical test, 100% of PLA has the highest strength for tensile, flexural and impact test. The 30% of sugar palm fibre reinforced with 70% polylactic acid composites have lowest tensile and flexural strength but it has higher impact strength compare to 10% and 20% of sugar palm fibre reinforced with 90% and 80% of polylactic acid composites. For the impact test, the 30% sugar palm fibre reinforced with 70% of polylactic acid composites has second high strength of 3.66 KJ/m^2 while the 20% of sugar palm fibre reinforced 80% of polylactic acid composites is 3.627 KJ/m^2 and then follow with the lowest 10% of sugar palm fibre reinforced 90% of polylactic acid composites of 3.502 KJ/m^2. The mechanical properties decrease as the fibre content of composites increase.

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