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Potential Behaviour of Oil Palm Empty Fruit Bunch Fibre Reinforced With Polypropelene For 3D Printing Filament Material

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Abstract — *The biomass of oil palm industry such as empty fruit bunch, fronds and trunks have been identified as a potential source for green material utilised in many applications. There were many researches on natural fibres for 3 Dimensional Printing (3DP) composite material application, but less studies focused on oil palm fibre especially for a part of empty fruit bunch. In some researches, Empty Fruit Bunch (EFB) fibres reinforced with polymer matrix showed the mechanical property improvement in terms of durability, thermal energy and sustainability in manufacturing aerospace and construction parts. Therefore, this research aims to explore the potential of using EFB fibre in additive manufacturing materials as a composite filament. The analysis involved in this research covered one test for thermal properties and two tests for mechanical properties. The tests were Differential Scanning Calorimetry (DSC), tensile strength and shore hardness. The thermal properties result of DSC showed melting temperature (T_m) of (10%EFB fibres + PP) was 162.81°C, while for glass transition, the temperature (T_g) was 147.02°C. In addition, for the evaluation of mechanical properties, tensile strength and shore hardness tests were investigated. The tests showed the results of 33.26MPa and 74.4shore, respectively. Then, the comparison result was done with established filament in 3DP which are polylactide (PLA) and acrylonitrile butadiene styrene (ABS) to investigate the ability. From the comparison result analysis, it showed that (EFB fibres + PP) have the potential as a composite filament because it has the ability equivalent to PLA in terms of thermal and better ability to ABS in terms of shore hardness.*

Keywords — *Oil Palm Fibre, 3D Printer, Composite material*.

I. INTRODUCTION

Today in Malaysia, a millions tons per year of an abundant biomass was generated by oil palm industries [1], whereas the disposal problem can be solved and value-added products can be created when a proper management was applied to the biomass. Moreover, the scenario of agriculture and economy in Malaysia was changed due to oil palm industries which makes them as the most important product from Malaysia. In the oil palm industries,empty fruit bunches (EFB), oil palm trunks (OPT), palm oil mill effluent palm (POME) and oil palm fronds (OPF) are some of the lignocellulosic biomass that produced from this industry where a major disposal problem was created by the presence of this wastes. Therefore, as the fundamental waste management principles are recover the energy, recycle and dispose the waste, then these principals should applied in agro-industrial such as palm oil residues as a proper management of oil palm biomass waste [2].

Rapid prototyping (RP) has become a popular method during the product development cycle for the evaluation of physical prototypes and fabrication [3]. In addition, to simplify and shorten the product development cycle, RP is a technology used in many applications such as aerospace, automobile and others. This is because, to finalize a product design, model making is one of the important steps and by RP technology it can produce tangible objects directly from a 3D CAD model [4] . Fused Deposition Modelling (FDM), Selective Laser Sintering (SLS) and Stereolithography (SLA) are some of the popular methods used in RP area [5].

Lately, in a way to achieve green environment, there are many technologies that combine natural fibres with polymers such as polyethylene (PP), polylactic acid (PLA) and high-density polyethylene (HDPE). Other than that, an application of waste material polymer composite like oil palm empty fruit bunch (EFB) and Polypropylene materials as alternative manufacturing purpose is not fully discovered yet. Additionally, less study related to the combination of EFB and PP materials as the alternative is reported in literature. Therefore, this research aims to investigate comparative microstructure at 10% EFB and PP materials to be formed into solid filament for FDM extrusion machine.

Reinforcement between oil palm empty fruit bunch with Polypropylene will enhance the mechanical properties in terms of toughness, durability, low energy and increase the sustainability in manufacturing a new filament. Therefore, it is indispensable to explore the potential of using renewable resources in new Additive Manufacturing materials as a sustainable filament.

II. METHODOLOGY

A. *Differential Scanning Calorimetry*

In a process to determine the transition temperature of vitrified (polymer) and melting temperature (crystalline polymer), a differential scanning calorimetry (DSC) was used in this investigation. A Mettler Toledo Star instrument, DSC 1 was used to perform analysis of the samples in an aluminium pan with a heating rate of 10 ºC/min. A heat/cool/heat method was applied in a temperature range of 20-220 ºC.

B. *Tensile Test*

The tensile tests were conducted according to ISO 527 - 1: standard test method [6]. All tension testing specimens were cut into dog-bone shape [7], [8]. The specimen size had thickness of 2.0 mm, width of 4.0 mm and gauge length of 20.0 mm. Testing was performed using SHIMADZU (Model AGS-J) Universal Testing Machine until tensile failure occurred with used 1kN of load and 50 mm/min of crosshead speed. Five replication of seven specimens were tested to get an average of tested specimens.

C. *Shore Hardness Test*

This testing was used to measure the hardness of the composite material. Durometer Hardness Type D was used to determine the relative hardness of soft materials, usually plastic or rubber. This experiment referred to the standard ASTM D2240 for shore hardness testing. The test specimens are generally 4.1mm thick, 10.0mm width and 80.0mm long. There were five specimens tested by durometer. Testing was conducted on three points in each specimen to get average reading of hardness test.

III. RESULTS AND DISCUSSION

A. *Differential Scanning Calorimetry*

The DSC testing elaborated the T_m and T_g for the samples of 10% EFB + PP. The DSC result was shown in Fig. 1.

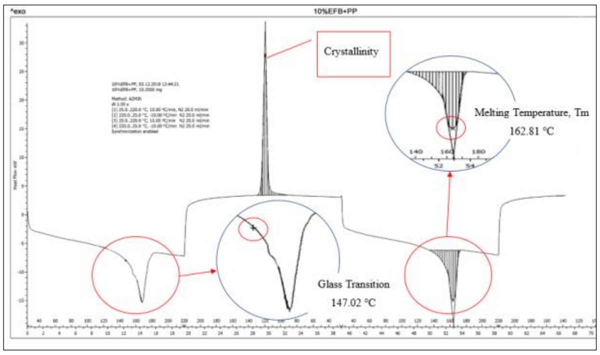

Fig. 1: Transition Temperature Graph of 10% EFB + PP

The endothermal peak took place in the temperature region at 162.81°C as it was correlated to the melting of the material. Then, the exothermal peak also known as crystallization was took place at 120.62°C which during the cooling phase. In addition, for the glass transition, it took place at 147.02°C.

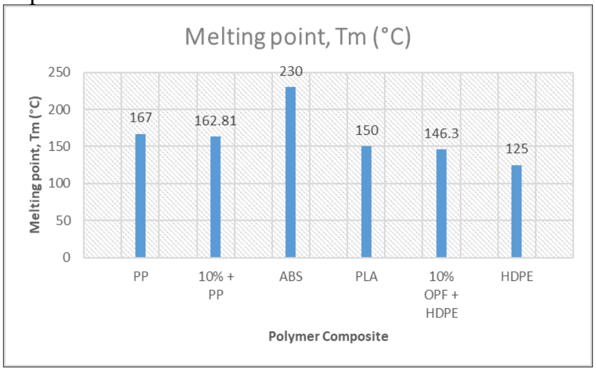

Fig. 2: Comparison of melting point for each polymer composites

From the temperature result, the T_m for (EFB fibres + PP) was compared with established filament material in 3DP such as PLA and ABS. The comparison was also made with composite filament from previous study which is 10% OPF fibre + high density polyethylene (HDPE). Fig. 2 shows the detailed comparison result between them. The Tm of (10% EFB + PP) which is 162.81ºC was only higher 12.81°C than PLA, but showed approximately 68ºC lower Tm than ABS [10]–[12]. Then, compared to previous study on oil palm composite filament, the Tm of (10% EFB + PP) was 25.71°C higher than the (10% OPF + HDPE). Furthermore, the specific temperature of the machine was applied from the initial temperature of 0°C until 250°C, but it usually depends on the type of material used and their melting temperature. PLA is a bio-plastic derived from natural sources like corn and sugarcane, whereas PLA is the most suitable benchmark comparable with (10% EFB + PP). In general, PLA filament settings have an optimal printing of PLA temperature ranging from 185ºC to 205ºC. From the comparing analysis, it can be concluded that the (10% EFB + PP) had the potential that was suitable for use as filament in 3D printing application.

B. *Tensile Test*

This study investigated how the 10% EFB fibre affected the tensile properties of PP composites. The comparison of tensile strength with pure PP, ABS, PLA, (10% OPF + HDPE) and virgin HDPE are shown in Fig. 3 and Fig. 4 respectively.

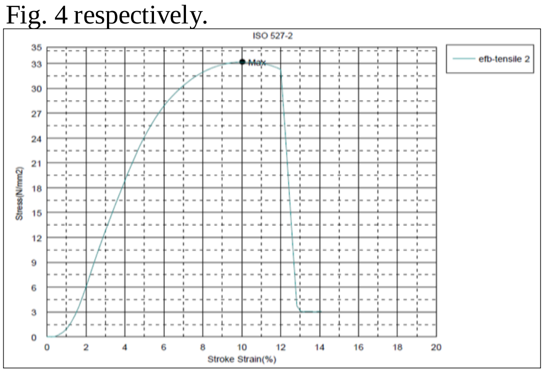

Fig. 3: Graph of stress vs stroke strain in tensile test

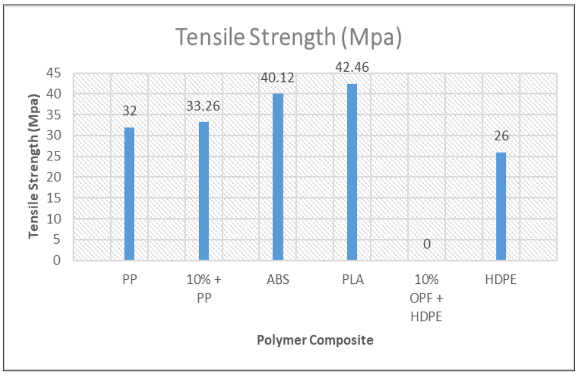

Fig. 4: Comparison of tensile strength with others polymer composite

Fig. 3 shows that (10% EFB + PP) achieved maximum stress about 33N/mm^2 at 10% stroke strain before failure took place. This value of stress was the maximum strength point of (10% EFB + PP) that can handle the maximum load. Then, at 12% of stroke strain, the failure of the material took place with the value of stress of 32.5N/mm^2, whereas the fracture of material happened at this point. In addition, to compare the tensile capability of (10% EFB + PP) with established filament material, Fig. 4 shows the detailed comparison result. According to Fig. 4, PLA showed the highest tensile strength of 42.46 MPa followed by ABS= 40.12 MPa and (10% EFB + PP)= 33.26MPa [10],[12]. The (10% EFB + PP) showed lower tensile strength differed than PLA and ABS, but their difference was not more than 10MPa, where some improvement can be done to increase the tensile strength. This composite material showed tensile improvement compared to pure polymer like PP and HDPE. In 3D printing process, the tensile strength of the material is one of important aspects to make sure either it will give a good product which can withstand a certain force while used in various fields. Based on the results obtained, (10% EFB + PP) can be used in 3D printing process to produce a low stress application product.

C. Shore Hardness

The shore hardness test is one of mechanical tests needed to conduct new polymer composite material. Fig. 5 shows the detailed comparison shore hardness capability of (10% EFB + PP) with other polymers that are commonly used in 3DP.

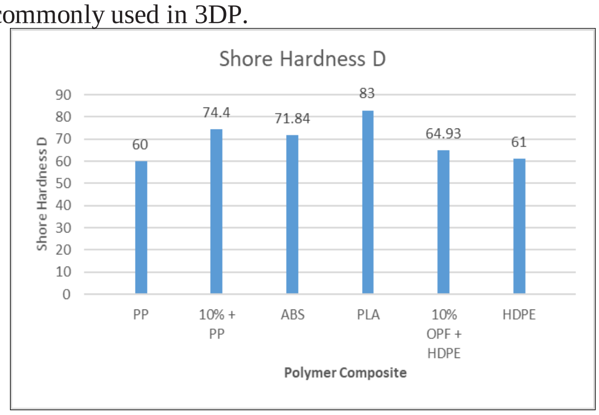

Fig. 5: Comparison of shore hardness with others polymer composite

The result comparison in Fig. 5 shows that (10%EFB + PP) has higher value of shore which is 74.4shore, compared to ABS=71.84shore, but a bit lower than PLA=83shore [11]–[13]. This means that in terms of hardness, the composite materials have better performance and equivalent with established filament material. By comparing with oil palm composite filament from previous study, (10%EFB + PP) still shows the better performance than (10%OPF + HDPE) [5]. Based on previous research by [5], the value shore hardness of (10% OPF + HDPE) is higher that the virgin HDPE. This condition shows fibre reinforcement with polymer matrix will increase the value of shore hardness of the materials. From this result, it can be concluded that (10% EFB + PP) composite polymer was suitable to be applied in 3D printing process because the result shows its properties equivalent to standard filament used in 3D printing which were PLA and ABS.

IV. CONCLUSIONS

In conclusion, this study focuses on proving the potential of oil palm fibre to be applied in rapid prototyping process for 3D printing process as composite material filament. (10% EFB + PP) is mixed as composite polymer, then tested for thermal and mechanical properties. The DSC test for thermal properties show the result of T_m=162.81°C in 14 minutes and T_g= 147.02°C. Then, to compare the result, the Tm of (10% EFB + PP) is only higher 12.81°C than PLA, but shows approximately 68ºC lower T_m than ABS.

Then, for mechanical properties, the tensile result of (10% EFB + PP) is 33.26 MPa which is lower than PLA= 42.46 MPa and ABS= 40.12 MPa. Even though (10% EFB + PP) shows the lower tensile strength different than PLA and ABS, but their differences are not more than 10MPa where some improvement can be done to increase the tensile strength. Meanwhile, for shore hardness result, (10% EFB + PP) has higher value of shore which was 74.4shore than ABS=71.84shore but a bit lower than PLA=83shore. By comparing with pure PP, the results show dramatic increment of hardness of 74.4shore compared to 60shore. It is also the second highest shore hardness value after PLA as shown in Fig. 5.

Overall analysis for the (10% EFB + PP) proves that this composite material is suitable to be applied for 3D printing application, but needs some improvement in terms of coupling agent or binder addition during the mixing process to improve the bonding between fibre and polymer, as it can also improve tensile properties. Other than that, for other properties like melting temperature, glass transition and shore hardness, the composite material shows an achievement equivalent to standard material for 3D printing. This is proven that oil palm EFB fibre has the potential as composite material that can be applied as composite filament in FDM application.

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REFERENCES

[1] H.P.S. Abdul., Oil Palm Biomass Fibres and Recent Advancement in Oil Palm Biomass Fibres Based Hybrid Biocomposites, Compos. Their Appl.,(2012).

[2] N. Abdullah and F. Sulaim., The Oil Palm Wastes in Malaysia, Biomass Now - Sustain. Growth Use,(2013).

[3] J. Stampfl and R. Liska., New Materials For Rapid Prototyping Applications., Macromol. Chem. Phys., 206(13)(2005) 1253–1256.

[4] A. T. Sutton, C. S. Kriewall, M. C. Leu, and J. W. Newkirk., Powders for Additive Manufacturing Processes: Characterization Techniques and Effects on Part Properties, Solid Free. Fabr. Proc., (2016) 1004–1030.

[5] Farhadina., Material Properties Study On Oil Palm Frond Fibers,thesis project., (2016).

[6] Zwick Roell., Testing of Plastics and Rubber Intelligent Testing., (2011).

[7] M. Khalid, C. T. Ratnam, T. G. Chuah, S. Ali and T. S. Y. Choong., Comparative Study Of Polypropylene Composites Reinforced With Oil Palm Empty Fruit Bunch Fiber And Oil Palm Derived Cellulose, Mater. Des.,29(1)(2008) 173–178.

[8] N.G. Tanikella, B. Wittbrodt and J.M. Pearce., Tensile Strength Of Commercial Polymer Materials For Fused Filament Fabrication 3D Printing, Addit. Manuf.,15, (2017) 40–47.

[9] M. Rivai, A. Gupta, M.R. Islam, and M.D.H. Beg., Characterization Of Oil Palm Empty Fruit Bunch And Glass Fibre Reinforced Recycled Polypropylene Hybrid Composites, Fibers Polym., 15(7)(2014) 1523–1530.

[10] C. Ou., The Crystallization Characteristics Of Polypropylene And Low Ethylene Content Polypropylene Copolymer With Copolyesters, 38(2002) 467–473.

[11] J.Vácha and M. Borůvka., Mechanical Properties of Acrylonitrile Butadiene Styrene Thermoplastic Polymer Matrix With Carbon Nanotubes, Nanocon, (2015) 1–6.

[12] H. Özkan Gülsoy and M. Taşdemir., Physical and mechanical properties of polypropylene reinforced with Fe particles., Int. J. Polym. Mater. Polym. Biomater.,55(8) (2006) 619–626.

[13] M. Pollutants., Technical data sheet, (1944) 1–3.