A STUDY ON PALM FIBER REINFORCES AS A FILAMENT IN PORTABLE FDM

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ABSTRACT

The growth of renewable energy has been identified globally to ensure minimal environmental harm. Due to this situation, the development of green technology has enhanced the growth of renewable energy in the country. One of lignocellulosic biomass feedstock, oil palm frond was the raw material for a potential second-generation bioethanol production. Meanwhile, the sample characterizations were conducted by using the melt flow index. In addition, the 10% of oil palm fronds (OPF) was used and mixed with the HDPE which produce the composite grains. The main goals of the present work are the evaluation of the influence of several variables and test parameters on the melt flow index (MFI) of thermoplastics, and the determination of the uncertainty associated with the measurements. Hence, the capillary flow of a high-density polyethylene (HDPE) melts was studied. The shearing flow of polymeric fluids is encountered in a number of polymer processing operations. In other words, viscosity under simple shear is an important material parameter used for determining the pumping efficiency of an extruder, the pressure drop through a die, designing balanced flow runner systems in multiple cavity injection molding, computing the temperature rise due to viscous heat generation during processing. In this works, Thermagravimetric Analysis (TGA) is one of the branches under the thermal analysis, which is to determine the decomposition of the raw material that has been heat in certain temperature according the standard temperature of specific materials. Most of the thermal analysis, testing uses the weight of the sample within milligram or gram. Next, the process in the sample under DTA study is manifested by deviation of temperature difference from its background. This difference ΔT is not directly proportional to the rate of the process $(d\alpha/dt)$ but includes also the effect of heat inertia proportional to the slope $d\Delta T/dt$ as it was derived. The filaments are inferior to the fibers for cement–matrix composites, but are superior to the fibers for polymer–matrix composites.

Keywords: lignocellulosic, thermoplastics, bioethanol.

INTRODUCTION

The oil palm in Malaysia is over a century old. Introduced as an ornamental in 1871, the oil palm was commercially exploited as an oil crop only from 1911 when the first oil palm estate was established. Much has been written about the crop, its products and commercial trade [3].

Malaysia is also known as a major producer of rubber, cocoa and, to some extent, coconuts. Preference for oil palm has led to a rapid expansion of its planted areas at the expense of rubber and other crops over the last four decades. Areas under oil palm increased from 54,000 hectares in 1960 to 4.05 million hectares in 2005, reflecting a compound annual growth of 10.06% [2].

Traditionally the oil palm (Elaeis guineensis) was grown in semi-wild groves in tropical Africa. It was first introduced to Malaysia for planting in the Botanical Gardens in Singapore in 1870 [1].

The oil palm industry had a humble beginning. From a mere four original palms introduced from West Africa to the Bogor Botanical Gardens, Indonesia in 1848, their seeds soon arrived on Malaysian shores in 1871. The rubber companies over the next four decades saw their planters learning how to grow the crop in the country. The R and D undertaken soon showed the potential of the new crop. Following this, the first commercial planting was done in 1911 at Tenammaran Estate, Kuala Selangor. Such was the success of the crop that the area expanded quickly, the most rapid increases occurring during the 1930, 1970 and 1980 [3].

Nowadays, the demanding of vegetable oil has increases that were becoming around the world. In other words, oil palm is now the most important supplier of vegetable oil in the world. There are three oil palm varieties: *Dura*, *Pisifera* and *Tenera*, with the latter being mainly selected for economic production. The oil is concentrated in the fruit bunches, composed of a fresh pulp, and in the fruit kernels. Oil content in the fruit pulp is about 50-60% or 20-22% of bunch weight; oil content in the fruit kernels is 48-52% or 2-3% of bunch weight. Fresh fruit bunches once harvested must be treated in an oil mill within 24 hours to avoid that oil quality decreases [10].

The oil palm tree consists of 20.5% lignin content that in somehow equivalent to that found in hardwood trees. Lignin is the properties that water-resistant, supports cell walls and avoids their break up. This property is important that can makes the fibers to be chemically pulped easily along the process. Oil palm fiber that is consisting of lignin and cellulose is the most abundant polymer in nature. It is present in the cell will provides structural support, impermeability and resistance against microbial attack and oxidative stress [9].

Furthermore, the OPF has the chemical position that was suit for the multipurpose with the current technologies nowadays. In addition, OPF consists primarily of lignocellulosic components, i.e., celluloses, hemicelluloses and lignin. Only a few studies have

focused on utilizing the lignocellulosic components of OPF. One approach is to hydrolyze the lignocellulosic materials into fermentable saccharides, which are then converted to fuels such as bioethanol; this is a promising alternative energy source for the limited crude oil [7]. Table-1 shows the chemical composition of OPF.

Table-1. Chemical properties of OPF [6].

Composition	Content (%)
Cellulose	40-50
Hemicellulose	34-38
Lignin	20-21

By referring the Table-1, the content for each composition in OPF are able to apply as green material for filament.

Since engineering materials are usually classified as metals, ceramics, polymers, and composites, bioengineering materials that can be utilized in RP systems include biometals, bioceramics, biopolymers, and biocomposites. Among these bioengineering materials, biopolymers and biocomposites are the most intensively investigated, especially for tissue engineering and regenerative medicine applications. This is because some of these materials can degrade into metabolic intermediates in the human body, potentially eliminating many problems associated with permanent implants [5]. In shortly, these RP also use in the medical fields.

Nevertheless, these are research towards the fiber where it can be used in RP. By [8], using natural vegetable fibers still has the benefit of being low-cost, having a green image and having low-density fibers which are non-abrasive and do not require strict health regulations for the staff working with them. This is already enough for natural fibers to be adopted into many applications in industry.

METHODOLOGY

There are three methods that were included which is Melt Flow Index (MFI), Thermogravimetric Analysis (TGA) and Differential Thermal Analysis (DTA). The process to produce the filament is called filament winding.

Melt flow index

It is a parameter related to the average molecular weight of the resin chains of polymer extruded through a standard size orifice under specified conditions of pressure and temperature in a ten-minute period of time. The greater the lengths of molecules, the greater the molecular weight and the greater the difficulty in extruding the resin through the standard orifice. The result: resins of greater viscosity as measured by a lower melt flow rate. When the test is conducted with pressure delivered by a standard load caused by a 47.6 lb (21.6 kg) weight at a temperature of 374°F (190°C), the resulting melt flow rate is termed the melt index (MI). The greater the viscosity is the lower

the melt index value. The sample mass of HDPE is in range 5g to 8 g.

From the testing, to obtain the result of the viscosity, the following formula need to be consider as shown below: Figure-1 shows the composite grain of the materials.

$$\text{MFI} = \frac{427 \times L \times d}{t} \tag{1}$$

t = time taken(s)
L= 2.54cm *(given)*
d = density

To find the volume:

$$v = A \times h \tag{2}$$

A = 0.7106 cm²
h = 1.804 cm³ (*area and height already given*)

To get the density:
$$d = \frac{w}{v} \tag{3}$$
w = weight
v = volume

Figure-1. The composite grain.

The composite grain is produce from the mixing of the Oil Palm Frond (10%) and HDPE. Where this grain is use for the all testing. The composite grain was used to be tested for its capability to be used as a filament in portable FDM machine.
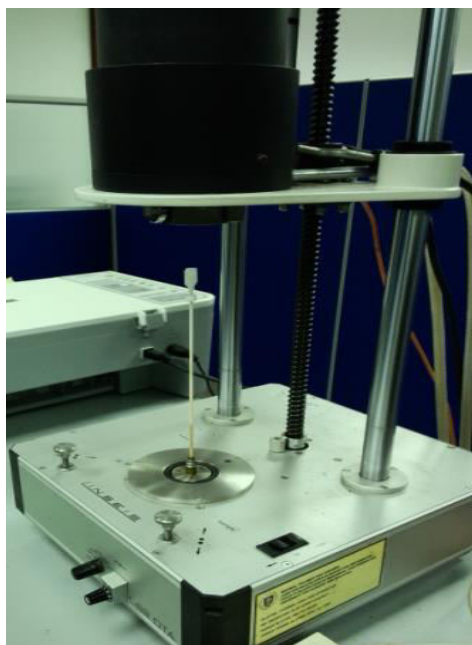
Figure-2. Melt flow index machine.

Preheat the machine Melt Flow Index for 30 minutes with 190°c. Next, the composite grains were taken the mass before going to start the MFI test. Note down the mass that were taken before the test. The processes were started when the grain composite start to melt and when the piston has been the force of the 2160 g of the mass is applied. The Figure-3 shows the result of the product after the MFI process.

Figure-3. The sample from the grains composite that has been extruded.

Thermogravimetric process
Thermogravimetric Analysis (TGA) process is one of the branches under the thermal analysis, which is to determine the decomposition of the raw material that has been heat in certain temperature according the standard temperature of specific materials. Most of the thermal analysis testing uses the weight of the sample within milligram or gram. On the other hands, the weight loss of a polymer as a function of time or temperature is commonly determined by the technique of TGA. Weight loss of a polymer due to thermal degradation is an irreversible process. This thermal degradation is largely related to oxidation whereby the molecular bonds of a polymer are attacked by oxygen molecules [11].

The TGA instrument consists sample holder (metallic/ceramic pans), microbalance, programmable heater (furnace), gas flow control, temperature control (thermostat), temperature sensor (thermocouple) and read-out the analysis through the software.

Method of TGA is when the sample of material placed on the weighing of micro-sensors, which are sensitive to changes in weight and it continuously measures the percentage of the weight and it will be recorded and scrutinized during combustion or cooling control. Figure 4 shows after the preparation of sample had done then set down the furnace. Run the process of TGA about one hour.

Figure-4. The furnace of TGA.

Differential thermal analysis (DTA)
The technique involves measuring the changes of temperature, ΔT between the sample and an inert reference material is measured as a function of temperature. DTA data recorded as ΔT on the y-axis and the x-axis is for the temperature. As usual, the sample will be placed in the crucible about in a little quantity with a milligram and the crucible will attach with another thermocouple which it comes with standard sample. Both of thermocouple is to define the temperature and to measure the different temperature, which occurring in both samples. After that, set the time about 30 minutes to take the data result. Figure 5 shows the DTA machine for filament analysis.

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Figure-5. The DTA machine.

In Figure-5, the similarity of the function of TGA machine is quite same. The technique involves measuring the changes of temperature, ΔT between the sample and an inert reference material is measured as a function of temperature. DTA data recorded as ΔT on the y-axis and x-axis is for the temperature. As usual, the sample will be places in the crucible in a little quantity with a milligram and the crucible will attach with another thermocouple which it come with standard sample. Both of thermocouple is to define the temperature and to measure the different temperature which is occurs for both samples. After that, set the time about 30 minutes to take the data result.

Filament extruder

In general, plastic extrusion is high volume machines that can be used for processing raw plastic material to form a continuous profile. The compression process in which material is forced to flow through a die orifice to provide long continuous product whose cross-

sectional shape is determined by the shape of the orifice. The machine widely used for thermoplastics and elastomers to make mass produce items such as tubing, pipes, hose, structural shapes, sheet and film, continuous filaments, and coated electrical wire. The machine also undergone a continuous process; which then the filament was cut into desired lengths.

Extrusion is a method of forming in which metals or plastics are forced through a die or series of dies, resulting in a specific shape of constant cross section. With the proper tooling, extrusions may be tapered or stepped. Extrusions can be either very thick in cross section or very thin and be either solid or hollow. The extruded stock, which can be 100 feet in length or longer, is then cut to a convenient stock size and used as specific products, assembly components, or as raw stock material for further processing. Extrusion size is expressed as a circle size, which relates to the smallest circle diameter, which can enclose an extrusion's cross.

The process of this extrusion involves a high volume manufacturing process which plastic material is melted and moves towards a screw mechanism, it may be mixed with colorants before the process begins. While melting and "pumping" as much polymer to the die as possible, while mixing material in compounding applications is equally important. Besides that, there are many ways of achieving good mixing such as pins may be placed in strategic placed in the metering section of a screw plus the fluted sections at the end of the screw help to both mix and melt leftover solid polymer. The screw rotates, forcing the plastic material to advance through the extruder cavity and it pushed through the die. After the melt polymer exiting the die then let it cooled, solidifies and cut to pallets.

RESULTS AND DISCUSSIONS

Melt flow index

The data has taken after the testing was done. The nine samples have shown by the different result for the viscosity and the melt index. Table-2 shows the results of melt flow index.

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Table-2. Results of melt flow index.

Sample	Weight (g)	Time taken (s)	Sample Weight (g)	Melt Flow Index (g/10 mins)
Material: OPF (10%) + HDPE				
1	5.643	51	0.956	11.21
2	5.771	57	1.183	12.62
3	5.662	53	0.990	11.34
4	5.613	68	1.538	13.61
5	5.358	63	1.546	14.75
6	5.370	70	1.668	14.33
7	5.513	71	1.366	11.56
8	5.606	80	1.164	8.74
9	5.317	58	1.268	13.15

Based on the data taken, it shows the changes in the MFI results. Melt flow rate is inversely proportionally to the viscosity of the melt at the condition of the materials. Nevertheless, to know the materials are coming with good behavior or not is measured by the viscosity and flow rate. As sample number four (4), the weight taken before going to test is 5.613 g. The time taken for piston going down for a distance 2.54 cm is 68s and the sample of weight after this test done is 13.61 g. It shows the weight will influence the time taken of this test also the weight of the sample after the extrusion process occurs. As the flow rate is high, the material has the low viscosity, while the flow rate is low the viscosity is get high. The Figure-6 shown the graph of time taken vs sample of weight for OPF (10%) + HDPE materials.
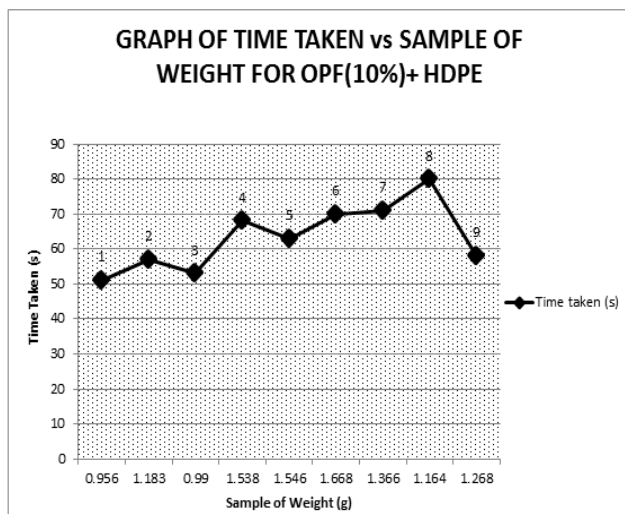
Figure-6. Graph of time taken vs sample of weight for OPF (10%) + HDPE.

From the graph above, it shows the relation of the time taken was influenced by the weight after the test had been done. As can be seen from the results, the sample with the higher weight caused the time taken for materials longer. It indicated that, more weight contains more composition of materials to melt. It can be seen most of the test sample runs on this theory whereas the weight of the materials affected the time taken.

Thermogravimetric analysis (TGA)

TGA analysis was performed on the OPF (10%) and HDPE materials to observe the decomposition of the materials responded within temperature distribution. Basically, the TGA testing is to determine the weight loss as a result of the production of volatile substances. On the other hands, the results corresponded to the mass changes, decomposition temperatures, dehydroxilation, corrosion, oxidation, thermal stability, reduction studies, composition, kinetics reaction and purity determination. Besides that, it also to determine the residual ash content on the materials to ensure the capability of these materials to be used as a filament for portable FDM ABS. TGA is an important criterion in determining the successfulness of the materials decomposition.

Some previous study showed that, the ABS material patterns which undergone burnout process from temperature of 600°C has remaining of 2.4% of the residual ash content. It also has been observed that the totally burnout of the tested ABS FDM material was taken place at 700 °C. In addition, in terms of collapsibility, the lower burnout temperature indicated that it undergone successful stages. Figure-7 shows the raw data material for TGA of OPF (10%) + HDPE.

Displayed in Figure-7 are the TGA results generated on the OPF (10%) and HDPE which applied the heating temperature is 600°C. The plot shows the percent mass as a function of sample temperature of 400.5°C. A single well-defined weight loss even is obtained with an onset temperature of the material were started decompose at 400.5°c and the mass change is about (-18.1%). As the heating rate is increased, the onset of decomposition is pushed to higher temperatures, reflecting the time-temperature dependency of the decomposition reaction. In

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addition, at the end of the plot shows the variable of mass changes at 500.7°c where the percentage is -99.0%. According to [4] a derivative weight loss curve can be used to tell the point at which weight loss is most apparent.
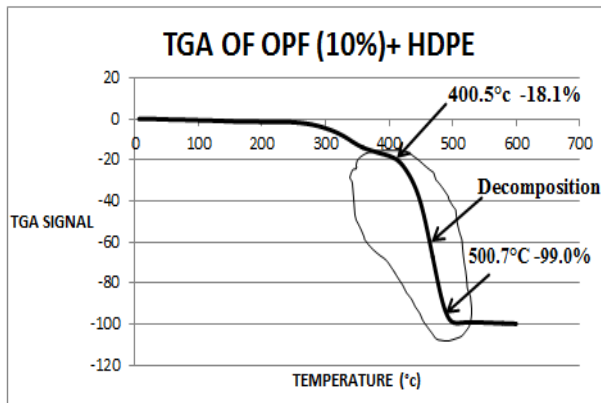

Figure-7. TGA result of OPF (10%) + HDPE.

Differential thermal analysis (DTA)

DTA is a tool that were used to determine the reaction that occurs toward the sample which is by heating the sample at the certain range with continuously to the high temperature. It will able to give the intensity and the general characteristics which occur on the sample. The different of temperature shows the effect of endothermic and exothermic which relate with the temperature and time. Basically, the DTA technique is to define the characteristic of mineral contents and to identify the molecules from the unknown substances that is consists in that sample. Figure-8 shows the melting temperature of OPF (10%) + HDPE composition for DTA process. Figure-8 shows the DTA process.
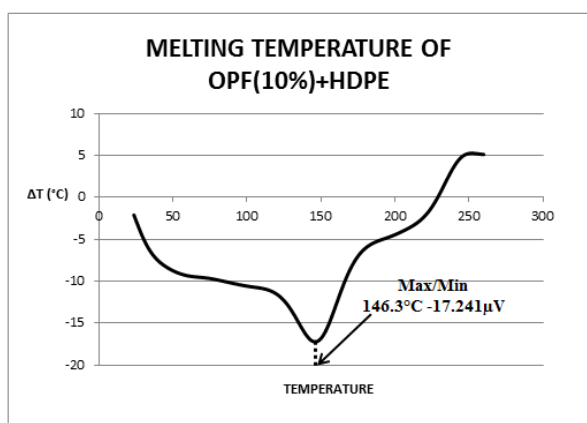

Figure-8. DTA for the temperature.

It can be seen that the maximum point of the time melting at 12.7 minutes. On the other hands, this testing has been run about 30 minutes. Based on the obtained results, at 12 minute the composite material melted. Due to this condition whereby room temperature was 100 °C the phenomenon of the absorption of water which was lost

from the surfaces of the clay particle. The raw data has been taken to observe the composition of composite material. In fact, any temperature difference between sample and reference was recorded. In this technique the heat flow in the sample and reference remain the same rather than the temperature [4].

CONCLUSIONS

Regarding with this research that has been proven there is diversity on the use of fiber palm fronds in developing a product that can be marketed. The MFI process was conducted in OPF (10%) + HDPE materials to investigate the viscosity. Meanwhile, the extrusion period affect the viscosity of the material whereas, the longer the time the higher the viscosity. Based on the observation, the variation weight of the sample implies a role to determine the viscosity of the substances.

The MFI process, this OPF (10%) + HDPE tested for its viscosity. Shortly, while the extrusion period is long the viscosity of the material is high and it's opposite when the extrusion period is taken in a short time. Based on the observation, the weight of the sample will be weighed by the different weight. The weight of the sample is main role to determine the viscosity of the substances. As an example, the fourth sample with the more weight from is takings the longer extrusion period.

Moreover, TGA was performed by the purposes to determine the temperature of the compound material whereby was suitable for the Fused Deposition Modelling (FDM) machine whereas the compound were OPF (10%) + HDPE as the filament. The melting temperature is 46.3°C and the time melting at 12.7 minutes. Through this DTA testing, this compound material that has been used the melting transition will support to determine the viable temperature while processing of FDM is run.

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