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PROCESSING AND MATERIALS EFFICIENCY IN FUSED DEPOSITION MODELING: A COMPARATIVE STUDY ON PARTS MAKING USING ABS AND PLA POLYMERS

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ABSTRACT

There are alot of materials available on market to make a 3D printing part, shuch as ABS, PLA, HIPS, PETG and others. On 3D printing product there are some responses that could be observeb. Some of responses are processing time, mechanical properties dimension accuracy and others. This research is conducted to compare the ABS and PLA efficiency on fused deposition modeling process. Processing time and material consumption are the factor that used in this research to compare the eficiency between ABS and PLA. Processing time, and material consumption were the responses that were measured. The study reports that both of processing time and material consumption using ABS as a printing material was found more efficient compared with using PLA. Printing process using ABS was 2661 seconds, which was faster than using the PLA was 2808 seconds. For the material consumption, show that the average mass of ABS was 7,33 grams compared with using PLA was 8,17 grams. The estimated value of the Axon is always greater than the value of the time recording process and measurement of the mass printing result.

Keywords: fused deposition modelling, ABS, PLA.

INTRODUCTION

Increasing the effectiveness of product development is a requirement in industries. There are three effectiveness criteria for a design process; they are quality, product cost and time to market [1]. Currently there are a lot of technologies and method that are developed to help a designer to make an effective design process. One of them is rapid prototyping (RP). RP is a technique that commonly used to create a data computer aided design (CAD) into 3D form with 3D printing technology additive manufacturing. [2]. At first, RP was used in automotive and aerospace industry, but now it is used in many other industries [3]. Three-D Printing, which is one form of RP that makes the product or design development process becomes faster.

In the product development, there are many types of 3D printing technology, such as fused deposition modeling (FDM), film transfer imaging (FTI), stereolithography, laminated object manufacturing (LOM), selective laser sintering (SLS), etc. [2]. From those various types of technologies, RP is the most commonly used in FDM. Nearly half of RP machines that were introduced to the market are FDM [5]. In FDM, a thermoplastic filament is extruded through of a heated die [3]. Currently, there are a lot of choices of materials available on the market for FDM 3D printing including Nylon, polycarbonate, HIPS (high impact poly styrene), ABS (acrylonitrile butadiene styrene), PLA (poly-lactic acid), and others [6]. Of those many materials, ABS and PLA is the most frequently used. These materials offer properties which make them useful for making a varied object and each of them has been used in the manufacture of additives for some time [4].

Studies on 3D printing process parameters and materials particularly using FDM technology have been investigated by several researchers. Raut *et al.* presented an investigation on the effect of built orientation on mechanical properties and total cost of FDM parts. They calculated the volume of the printed ABS covert to total cost [7].Other research groups like Wittbrodt *et al.* studied the effects of PLA color on material properties of 3D printed components. Results are presented showing a strong relationship between tensile strength and percent crystallinity of a 3-D printed sample and a strong relationship between percent crystallinity and the extruder temperature [8]. Tanoto *et al.*, have studied the effect of printing orientation on the processing time, dimension accuracy, and tensile strength. They were printed using ABS polymer. The study reports that the printing process with third orientation was the fastest printing process [9]. Third orientation is the printing orientation that has the most layers with a minimum raft. This orientation has the processing time 2432 seconds followed by another orientation of 2688 and 2780. However that work has not reported the efficiency of material usage as a result of the printing orientation.

In the industry, the use of materials is also a factor of efficiency calculation. Comparison of PLA and ABS material which is the most commonly used material is needed especially in terms of material usage and time is not there yet. In other to close the gap, comparative study on processing and materials efficiency on parts made of ABS and PLA polymers using FDM was carried out to study in this research.

EXPERIMENTAL METHOD

Materials used in this research were 1 kg BFB (Bits from Bytes) ABS and PLA polymer filaments with 3 mm diameter (Figure-1). The color for ABS was white and for PLA was green. ABS is a popular plastic that widely

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used in households appliances and toys [10]. PLA has also been widely used by operators of 3D printing or model maker. Melting point of PLA is relative low, 150-160^{0}C, thus requiring less energy to print with the material. Compared with ABS, PLA has been shown to be a safer alternative, from toxic potential [8]. There werre five simple steps to make a 3D printing part using FDM, i.e. drawing a 3D CAD model, converting it into STL format, slicing of STL format, builtding part in layer by layer then finally cleaning and finishing [11].

3D CAD software was used to drawing a 3D CAD and converting it in to STL format. For slicing of STL using Axon V2. Specimens were fabricated using the BFB 3D Touch Double machine (Figure-1).The specimens (Figure-2) were produced while FDM printing process.Specimen dimension according toASTM D638-14was used as reference dimension(115 x 19 x 4 mm)[12]. Input parameters for layer thickness used were 0.5 mm with 50% fill density. Infill was built in lattice patterns. Setting of extrusion temperature was used as recommended by the manufacturer, i.e. 180-220^{0}C.

The processing time was observed either using time record by Axon and as well recorded it using a stopwatch. Upon setting the parameters on built setting, Axon was able to show the estimates of the printing process in built progress (Figure-3 and Figure-4). The built progress obtained estimated printing time and material mass extruded. Estimated printing time and mass extruded are the overall time and a mass to make a specimen including the raft and support. When extruder began to extrude the material, the starting time was recorded. The ending was recorded when the extruder finished the printing process. The weight of the material used during FDM process was measured either by mass data recorded by Axon as well as weighed the samples using AND digital scale with capacity 1200 gram x 0.1 gram.

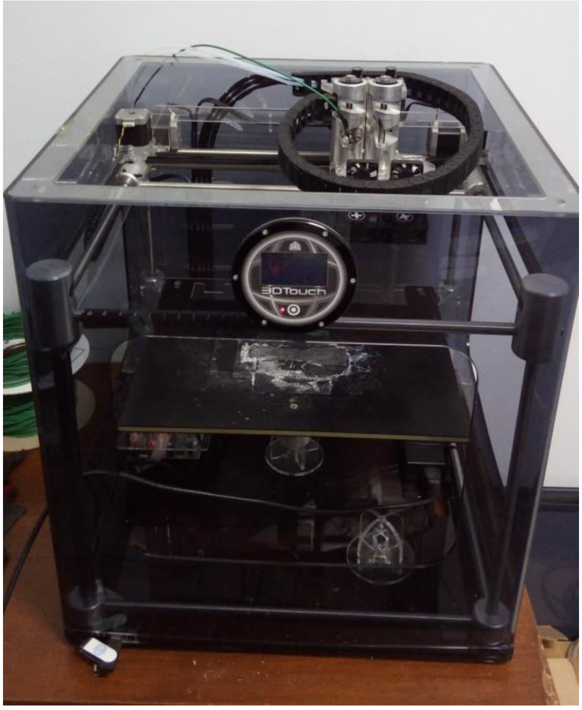

Figure-1. BFB Touch double printer machine.

Figure-2. Specimen printing orientation.

RESULTS AND DISCUSSIONS

Axon estimates

The printing orientation used in this study, there was only one raft, mean while the support was not needed because there are not a hanging segment from the specimen. In this orientation, the specimen was sliced to thickness. Specimen thickness is 4 mm and layer thickness is 0.5 mm so that this specimen has 8 layers. From the built progress, it could be seen that the time used to process ABS was faster (48 minutes or 2880 seconds) compared to the the time needed for PLA (52 minutes or 3120 seconds). In term of mass of ABS used was 9.1 grams and mass of PLA used was less, i.e. 8.7 gram. Those data indicates that processing time of ABS material was more efficient compared with the processing time using PLA material. Interestingly, less processing time with more use of material with ABS compared with the use of PLA material.

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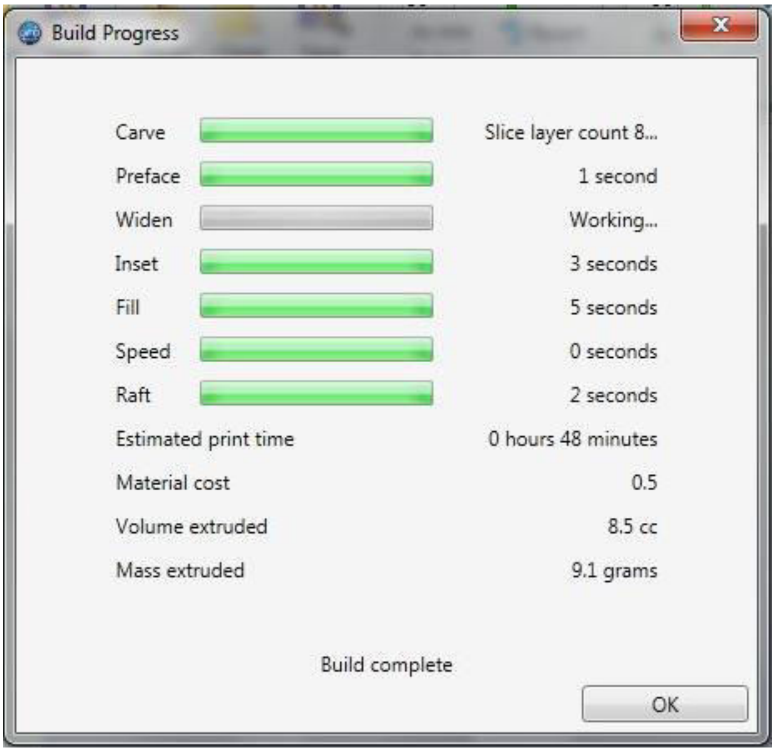

Figure-3. Axon build progress result for ABS.

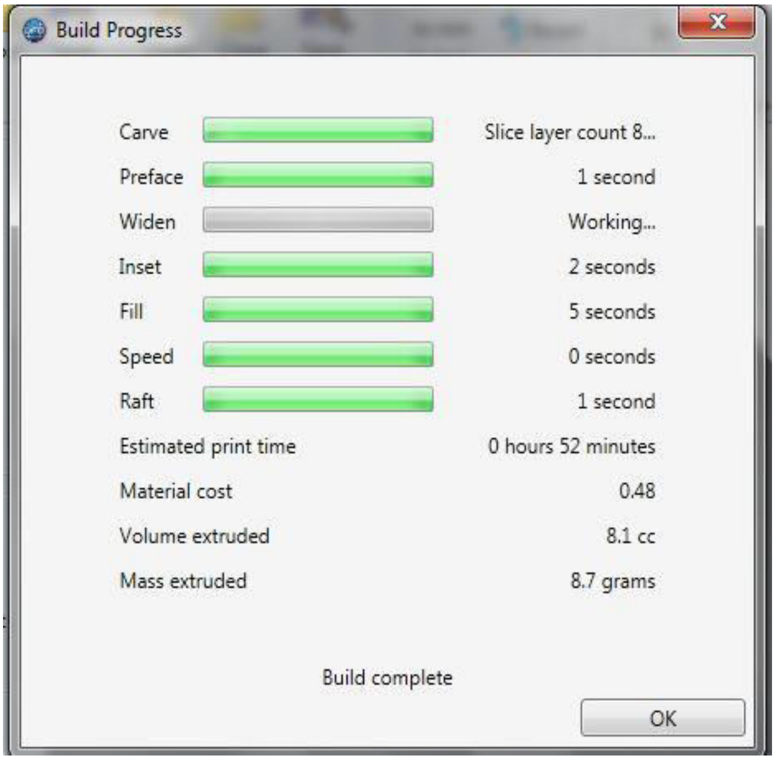

Figure-4. Axon build progress result for PLA.

Comparison in processing time

The processing time recorded during the printing process of 3 specimens using a stopwatch can be seen in Table-1. From those data, they show that the average processing time from the printing process using ABS (2661 seconds), which was faster than using the PLA (2808 seconds). It can be seen in Figure-4 that the time recorded using stopwatch was in line with the time estimation by axon.Those data also shows that the time estimation from axon was always longer than the printing process itself. Printing using ABS resuls in processing time 1.08 times longer than recorded using stopwatch

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result. In the case of PLA, the time estimation from Axon was 1.11 times longer from stopwatch. The longer time obtained from Axon was due to the time estimation include the time of the heating process of the materials in the extruder. From these data we can see that for time aspect, making a 3D print products using ABS material more efficient. Axon accuracy rate in predicting time to process ABS is 92.4% and 90% for PLA.

Table-1. ABS and PLA processing time in seconds.

Specimen	ABS	PLA
1	2672	2805
2	2657	2814
3	2654	2806
Average	2661	2808

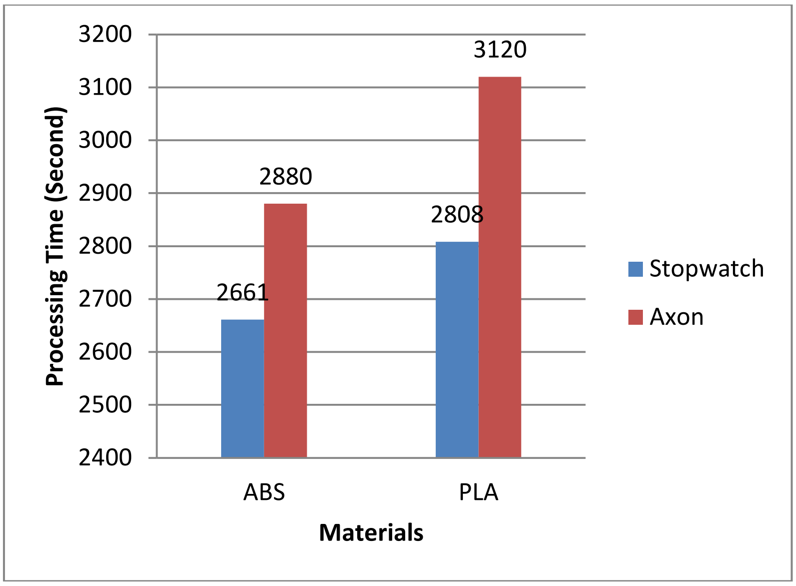

Figure-5. Comparative of processing time of ABS and PLA.

Comparison in mass extruded

The mass of three specimens printed was measured using digital scales and their data can be seen in Table-2. The mass data show that the average mass of ABS was less (7,33 grams) compared with using PLA (8,17 grams). Figure-4shows that the measurement of mass using digital scales contradicts from the mass estimation from Axon. The use of ABS was less than the usage of PLA from mass data measured using digital scales. TheAxon estimates the mass of ABS use was more compared to PLA. Mass measurement done using the digital scales in line with the physical properties of ABS and PLA. ABS has smaller density, i.e. 1.05 g/cm^3 compared to PLA, i.e. 1.2 g/cm^3 [13,14].Both of the processing time and the printing mass obtained from estimation by Axon were found higher than the same results recorde using stopwatch and mass measurement using digital scale. In the case of ABS, estimation of Axon was obtained 1.24 times heavier than the measurement using digital scales. On PLA, the estimation of Axon 1.06 times heavier than the measurement with digital scales. From that data, it can be seen that in term of material consumption, using ABS material was more efficient. On PLA, the difference of the real value compared with the estimated value was 0.53 gram;therefore the axon accuracy rate was 93.3%. i. On ABS, the difference from the real value compared with the estimated value was 1.77 grams. Thereforethe axon accuracy rate of 80.5%.

Table-2. Mass of ABS and PLA time in gram.

Specimen	ABS	PLA
1	7.3	8.1
2	7.4	8.2
3	7.3	8.2
Average	7.33	8.17

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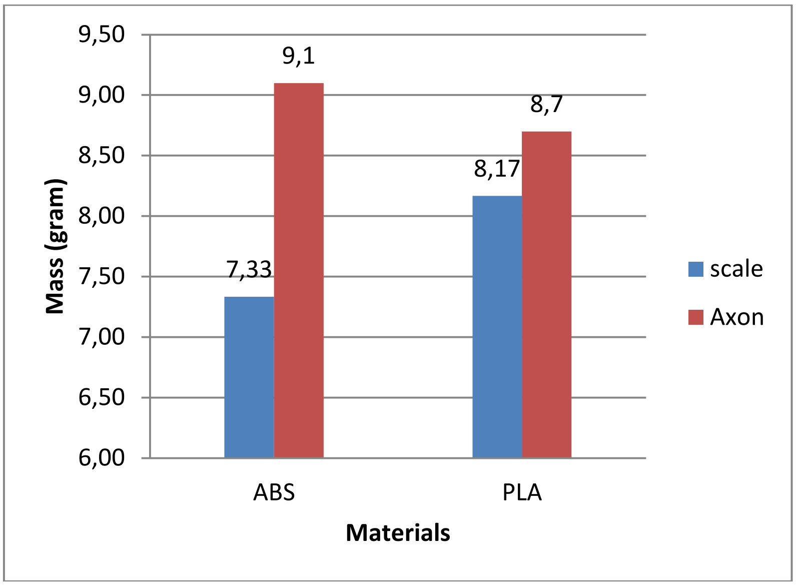

Figure-6. Mass comparative of ABS and PLA.

CONCLUSIONS

Both of processing time and material consumption using ABS as a printing material was found more efficient compared with using PLA. The estimated value of the Axons that have the highest accuracy is to estimate the mass of PLA (93.3%), estimating the processing time material ABS (92.4%), estimating PLA processing time (90%) and estimating the mass ABS (80.5%) respectively. The estimated value of the Axons is always greater than the value of the time recording process and measurement of the mass printing results. For the next research, need to be examined also from other aspects, whether ABS better than PLA. Another aspect is that include the dimensional accuracy and strength of the product.

ACKNOWLEDGEMENTS

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