The Efficiency of Manufacturing 3D Printed Part by Using Resin Polymer

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Abstract. The strength of 3D printed part is an important factor that must be considered before carrying out a product design. Moreover, manufacturing speed was also as key of successfully product design. The main focus of this study was to analyze the strength of 3D printed part and reduce the time manufacturing processing for getting the optimal design. The specimen models were designed according to ASTM D368-IV standards and printed using a 3D printer device. During the printing process, the infill density was varied into two different types, 0% and 100%. Meanwhile the main material used as a base material was Polylactic Acid or PLA which has an initial diameter of 1.75 mm. Furthermore, time consumption of manufacturing process was recorded, whereas the strength of specimens was observed using universal tensile test machine. The specimen model, especially for infill density 0% were added the resin polymer before carry out the tensile test. The results showed that the highest [1]tensile strength was occurred on the specimen that had the infill density of 100% without any addition of resin polymer. Besides that, the time consumption (infill density 0%) was showed significantly reduce than specimen that had infill density of 100%

1 Introduction

Polylactic acid (PLA) is a polymer that has biodegradable properties. This material is generally used as the main material for printing objects using Fused Deposition modeling (FDM) technology. As a part of being biodegradable material, PLA material also has a relatively cheap price when compared to other materials such as ABS [1][2][3]. Furthermore, several printing parameters could influence printing quality, including layer height, infill density, support, and printing orientation [4][5][6]. Based on previous research, the surface roughness of 3D printing technology prints showed a decrease as the layer height becomes lower [7]. In addition, surface roughness was also influenced by printing orientation. Apart from surface quality, several parameters could also influence print speed, including infill density and print orientation [8]. Infill density of 100% could make printing time longer compared to infill density of 10% or 50%, but had higher mechanical properties [9]. Print speed is also influenced by printing orientation [10]. The horizontal print position could

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reduce print time due to the retraction process. Retraction was the delay time during the process of changing layers, this can lengthen printing time if the number of layers used is greater [11]. The horizontal printing position results in a lower number of layers if the vertical position. Based on the previous explanation, this research aims to analyze the effect of adding resin polymer as a filler for 3D printed products on printing speed and material weight. The fillers are used to strengthen the cavity of 3D printed part. Apart from being a reinforcement, filling with other substances can speed up the process of mass manufacturing of objects.

2 Method

2.1 Material Of Experiment

There were two types of materials used in this study, namely PLA and polymer resin. The PLA material used is a filament which has an initial diameter of 1.75mm. This material had a melting point of 98 to 200 degrees C. In addition to PLA materials, resin polymer was used as fillers. The resin material was mixed with other materials, namely the catalyst. The catalyst serves to harden the resin material so that the specimen will be more rigid.

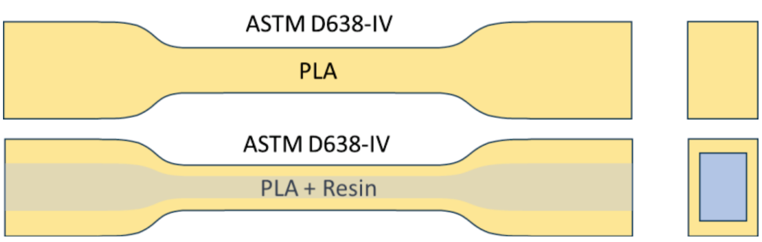


Fig. 1. Dimension and orientation layer of specimen test.

The specimens were designed according to ASTM D638-IV according to Figure 1. The specimens were made with two different types of models, namely solid models and cavity models. Hollow models are molded with a wall thickness of 0.4 mm, while the rest model was made without any cavities.

2.2 Specimen Preparation

ASTM D638-IV was the tensile test material standard used in this research. The two types of specimens described previously were designed using CAD software with output in the form of a stereolithography file (.stl). Then this file is used as a reference for manufacturing process information in the CURA software. This software is used to set printing parameters [12] such as layer height, print orientation, nozzle temperature, bed temperature and print speed (Table 1). Furthermore, the results of this setting were a G-code file which was read by the machine as a reference for printing information.

Table 1. Parameters set on the 3D printing software.

Parameter	Value
Layer height variation (*mm*)	0.15
Layer orientation variation (°)	90
Nozzle set temperature (^0C)	200
Bed temperature (^0C)	60
Printing speed ($mm\ s^{-1}$)	60

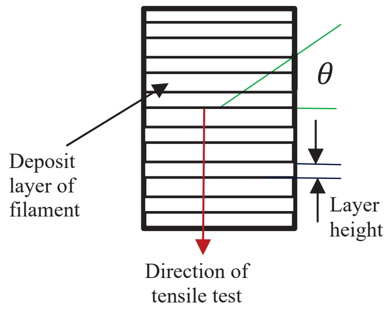


Fig. 2. Deposit layer orientation. a) layer height and slope of layer, b) direction of tensile testing.

The specimens were printed using a Creality Ender 3 which was an accuracy of + 0.1 mm. Furthermore, the specimen was printed with a density of 100%, then both of printing time and weight material was measured and recorded. Meanwhile the cavity specimen was filled with resin polymer material first with a composition ratio of 100:1, for resin and catalyst respectively. The process of filling the cavity specimen was carried out using the infusion method. This method was conducted by a vacuum machine with a suction pressure pump of -10 cmHg to -15 cmHg. To obtain the maximum hardness, the polymer resin was dried process for 2 hours to 4 hours. After the filler material was dried, a tensile test process was carried out. Figure 2 was a schematic of the tensile test carried out on both types of test specimens. Furthermore, the test results for weight, printing time and tensile strength were analyzed to determine the level of effectiveness of this method.

3 Result And Discussion

3.1 Characteristic of PLA Versus Resin Polymer Reinforced PLA

There are three main parameters evaluated in this research, tensile test strength, printing time and material weight. Figure 3 is depicted several data that has been obtained for three test parameters on two different types of specimens, PLA and PLA with addition of resin polymer.

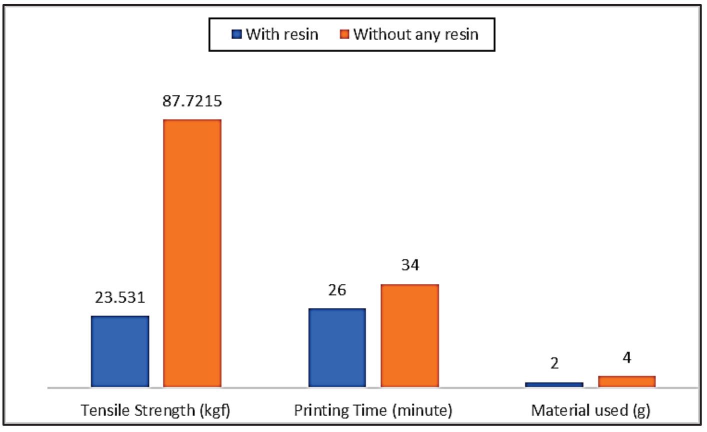


Fig. 3. Experiment result for both specimen type.

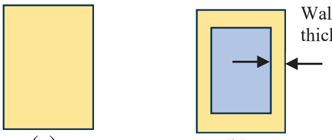
Figure 3 shows that the characteristics of PLA with addition resin polymer tend to decrease when compared to specimens without fillers. If it observes on the figure, the tensile strength of the specimen without any addition of filler is still greater when compared to other types of specimens. The tensile strength of this material reaches 87.72 kgf, while the PLA material with addition filler is only 23.53 kgf. The tensile strength indicates different material properties that occur in the two types of specimens. Figure 4a shows that the nature of the PLA material tends to be brittle, so that the fracture shape of the material tends to be perpendicular to the direction of the deposit material [13][14]. However, PLA material with the addition of polymer resin has a different form of fracture, namely ductile fracture. This is indicated by the appearance of stretch in the tensile test fracture results, so that the tensile strength is lower than PLA material. This condition is important to know if the specimen want use to different application, such as developing a join [15].

PLA
(a)

PLA + resin polymer
(b)

Fig. 4. Fracture characteristic a) brittle fracture and b) ductile fracture.

Besides tensile strength, printing speed is an important parameter that needs to be analysed in this study. Based on Fig. 2, the length of time to print specimens with the addition of polymer resin material is lower than the material without any fillers [16][17]. The specimen with the addition of filler only prints the outer wall of the specimen profile with a wall thickness of 0.4 mm (Fig. 4b), while the other specimens must print the entire specimen profile (Fig. 4a). In addition, printing with a cavity profile can reduce the usage of the raw printing material (PLA). Based on Figure 2, the usage of PLA material in the specimen without a filler is 4 g while the material with a filler is only of 2 g.



(a) (b)

Fig. 5. The difference profile of both specimen test a) PLA and b) PLA + resin polymer

3.2 The efficiency of manufacturing process

Figure 5 is an indicator of the printing process on two different specimens, the specimen without any filler and the specimen with added filler. There is a decrease in the tensile strength of the specimen with the addition of fillers of 73.18%. However, there is an improvement in the manufacturing process for two other parameters, printing time and material used [12]. The length of time the specimen has decreased to 23.53%. In addition, there was also a decrease in the use of PLA material by 50% in specimens with the addition of fillers. This shows an increase in the manufacturing process, especially the length of time to print and the use of materials.

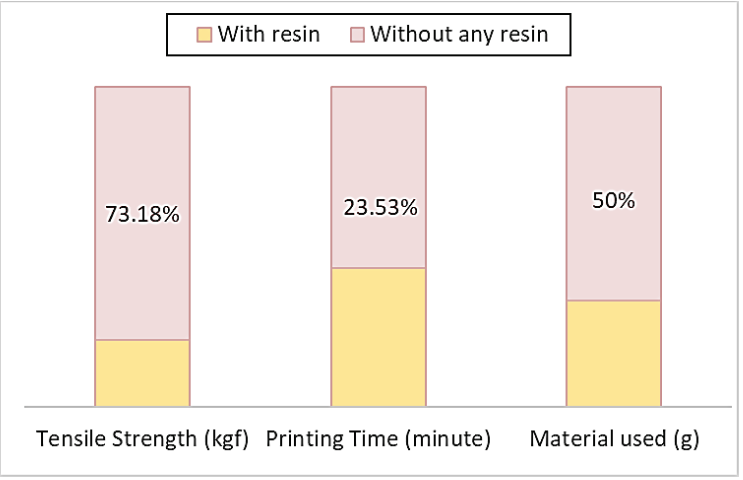


Fig. 6. Manufacturing improvement of both specimen a) PLA and b) PLA + resin polymer.

4 Conclusions

Based on the results obtained, there was a decrease in the tensile strength of the specimens with the addition of filler reaching 73.18%. This is because the characteristics of the specimen tend to be ductile when compared to specimens without filler. Apart from that, there was a decrease in two other parameters, printing time and material usage, namely 23.53% and 50% respectively. This decrease was caused by specimens with additional fillers only printing on the outer walls of the specimen profile, thereby reducing printing time and material weight.

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