MECHANICAL PROPERTIES OF RECYCLED ACRYLONITRILE BUTADIENE STYRENE WASTE FOR ADDITIVE MANUFACTURING

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ABSTRACT: This paper investigates the recycling of 100% ABS and compare the mechanical properties with the standard ABS specimen in X, Y and Z orientation. In addition, investigation on the tensile properties and the surface quality was also done. The recycling process begins with re-granule the waste ABS material and produces it into a new filament. The new recycled filament was used to print the test specimen. The optimum parameters related to the production of the FDM filament was investigated which include the size of recycled ABS pellet, filament diameter and extrusion temperature. The result shows that the recycled ABS can be produced into filament with 335℃ of extrusion temperature and 1.5cm/s travel speed of the extruder conveyor. For the surface quality, the value of surface roughness of recycled filament is 0.453µm which is 6.94% higher than the standard ABS specimen. For ultimate tensile strength, there is only a small difference in X and Y orientation between the standard ABS and the recycled ABS samples which are 22.93% and 19.98% respectively. On the other hand, in Z orientation there is large difference that the UTS of recycled ABS is 52.33% lower than the standard ABS.

Keywords: *Fused Deposition Modeling, Mechanical properties, Build Orientation, Recycling, ABS*

1.0 INTRODUCTION

As plastic have highly beneficial material properties such as lightweight, high strength-to-weight ratio, low cost and easy to manufacture, it has caused growth in global production. The accelerated production and adoption of plastic has caused various extraordinary issue of disposal and recycling of huge amount of plastic. AM aims to reduce material waste. However, the amount of waste produced is about 2.22 times from the predicted amount (Song & Telenko, 2016). This paper investigates the use of 100% recycled ABS for FDM 3D printing process. The investigation compares the quality and the mechanical properties of 3D object created by standard ABS filament with the recycled ABS filament. The analysis includes tensile test and the surface roughness. Besides, the optimum parameter related to the printing process was investigated which include the size of recycled ABS pellet, filament diameter and extrusion temperature. Furthermore, this paper focuses the study of the mechanical properties of specimen printed in X, Y and Z orientation.

2.0 METHODOLOGY

For the granulation process, the waste ABS was crushed by using the polymer crusher TW-SC 400F to produce the ABS granules. This process was repeated 5 times to get the uniform pellet size. Next, 100% recycled ABS granules were used as input material to produce the 100% recycled ABS filament by using the filament extruder Haake Rheomex OS with various extrusion temperature. Then the filament will be laid on a conveyor belt that will pull the filament to the desired diameter. The extrusion speed was fixed at 17.5 rpm and the extrusion temperature and the travel speed of conveyor is adjusted to obtain approximately 1.75mm diameter of the filament. The Odyssey X2 FDM 3D printer was used to print the test specimen. To optimize the 3D printed specimen, printing parameters of the 3D printer need to be controlled such as the extrusion temperature, feed rate and bed temperature. The specimen will be printed in three orientation (X, Y and Z). ASTM 638-02a type I standards is used for the tensile test for rigid and semi rigid polymer. Tensile test was performed using

SHIMADZU AGS-X 20kN +500 tensile test system, where three repeat measurements were conducted. Thus, a total of 18 specimens were printed using the FDM 3D printing machine. The surface roughness was measured by using the Mitutoyo SJ-301.

3.0 RESULTS AND DISCUSSION

3.1 Pellet Size

The result of average size of pellet was taken and measured by randomly picking 20 samples from the pellets that produced by using the mechanical recycling method. Besides, the pellets went through a sieve to filter some large pellet to increase the uniformity. The average size of recycle pellet is 3.18X3.07X2.25mm which is similar with standard ABS pellet.

3.2 Quality and Diameter of Filament

With suitable extrusion temperature, a filament with round shape from cross-sectional area can be produced. If extrusion temperature is too low, defect like melt fracture and containing sign of coarse material will occur. According to Othman et al., (2015), melt fracture can be avoided when the heating temperature of extrusion is more than the melting temperature of ABS. It was noticed that the 235°C is the most suitable to produces filament in good quality which has round shape in cross-sectional area, smooth surface and stiff. During the material extruded from the die and laid on the conveyor, the diameter is controlled with certain travel speed. The speed of conveyor at 1.5cm/s is most suitable for producing the filament with 1.75mm (±1.0).

3.3 Surface Roughness Testing

The average surface roughness along the length of the standard and recycled ABS printed specimen is about 6.526μm and 6.979μm respectively which is shown in Figure 1. The value of surface roughness of recycled filament is higher than the standard filament in 0.453μm which is 6.94% higher than the standard ABS printed object.

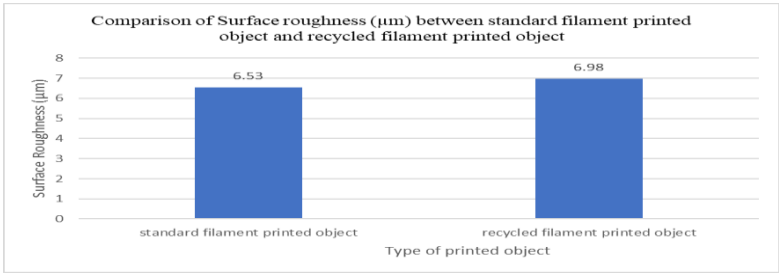

Figure 1: Histogram of comparison of Surface roughness (µm) between standard filament printed object and recycled filament printed object

3.4 Tensile Test

The ultimate tensile strength (UTS) of recycled ABS is 52.33% lower than the standard ABS in Z orientation. It has highest difference in tensile test between the standard printed specimen which shown in Figure 2. The 100% recycled ABS printed specimen in Y and X orientation is 19.98% and 22.93% lower than the standard ABS specimen. Specimen printed in Y orientation has the highest UTS, followed by the specimen printed in X orientation and Z orientation specimen has the lowest UTS.

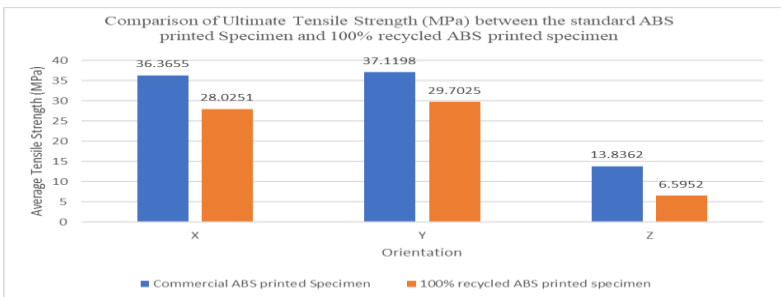

Figure 2: Histogram of Comparison of UTS (MPa) between the standard ABS and 100% recycled ABS printed specimen

The pulling force of the tensile test machine effects on the fibre instead of the bonding between the layers when the specimen built in X and Y orientation (Carneiro et al., 2015). Thus, specimen

in X and Y orientation needs more load to pull to specimen until fracture. Due to the weak inter-layer bonding, the Z orientation specimen has lower UTS. The maximum strength of the inter-layer bonding is lower than the maximum strength of the material itself (Górski et al., 2015).

4.0 CONCLUSION

Mechanical recycling method can produce ABS waste pellet that is similar with standard ABS pellet and has a good uniformity. The best extrusion temperature is 235°C, which can produce filament with smooth surface round cross-sectional shape. The most suitable travel speed of conveyor is 1.5cm/s which can produce the filament in the range of 1.62-1.79mm. For the surface roughness testing, the value of surface roughness of recycled object is 6.94% higher than the standard ABS object. The 100% recycled ABS specimen printed in X, Y and Z orientation decrease in 22.93%, 19.98% and 52.33% respectively compared to standard ABS specimen in term of UTS. There has large different in Z orientation due to the recycling weaken the inter-layer bonding strength.

5.0 REFERENCES

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