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The Effect of Printing Speed Variations on Dimensional Stability of 3D Printing Results Made from Waste Bottle Filament

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Abstract

3D printers have grown in popularity in recent years because of their ability to print objects quickly and easily. The material used to print objects on a 3d printer is called the filament. Using recycled materials to produce 3D printer filament is gaining popularity in the 3D printing industry. One material that can be recycled to make filament is waste bottles of the Polyethylene Terephthalate (PET) type. This research was conducted to see the effect of printing speed on object dimensional stability. In this study used an experimental method by designing variations in printing speed on a 3D printer and using waste bottle filament as raw material. Each variation of printing speed was repeated five times and the dimensions were measured using a micrometer. The results showed that printing speed affects the dimensional stability of 3D printing results from waste bottle filament.
Keywords: *Filaments, 3D Printing, PET, Dimensions*

Abstrak

Printer 3D adalah teknologi yang semakin populer dalam beberapa tahun terakhir karena kemampuannya untuk mencetak objek dengan cepat dan mudah. Material yang digunakan untuk mencetak objek pada printer 3d disebut dengan filamen. Penggunaan bahan daur ulang untuk memproduksi filamen printer 3D semakin popular dalam industri pencetakan 3D. Salah satu jenis bahan yang dapat didaur ulang untuk memproduksi filamen adalah botol bekas jenis Polyethylene Terephthalate (PET). Penelitian ini dilakukan untuk meliihat pengaruh kecepatan printing terhadap kestabilan dimensi objek. Pada penelitian ini digunakan metode eksperimental dengan mendesain variasi kecepatan printing pada printer 3D dan menggunakan filamen botol bekas sebagai bahan baku. Setiap variasi kecepatan printing diulang sebanyak lima kali dan diukur dimensinya menggunakan mikrometer. Hasil penelitian menunjukkan bahwa kecepatan printing mempengaruhi kestabilan dimensi hasil 3D printing berbahan filamen botol bekas.
***Kata-kata kunci**: Filamen, 3D Printing, PET, Dimensi*

1. Introduction

The use of recycled materials to manufacture 3D printer filaments is gaining popularity in the 3D printing industry **[1] [2]**. Used PET bottles are one type of material that can be recycled to produce 3D printer filaments **[3] [4] [5]**. The use of recycled materials is expected to reduce plastic waste and provide more environmentally friendly solutions in 3D printing **[6] [7]**. However, further research is still needed to determine the effect of variations in printing speed on the dimensional stability of 3D printing results using filaments made from used PET bottles **[8] [9] [10]**.

Dimensional stability is one of the important factors in 3D printing, especially for the production of products that require precise and consistent measurements **[11] [12]**. Variations in printing speed can affect the dimensional stability of 3D printing results **[13] [14] [15]**. Therefore, this study aims to evaluate the effect of variations in printing speed on the dimensional stability of 3D printing results using filaments made from used PET bottles.

In this study variations in printing speed from 40 mm/s, 50 mm/s, to 60 mm/s were used to print cube objects with a size of 20 mm x 20 mm x 20 mm. Then, the dimensions of the object will be measured and analyzed to evaluate the effect of variations in printing speed on the dimensional stability of 3D printing results. The results of making specimens with waste bottle filaments will be compared with specimens using PLA filaments.

The results of this study can provide important information in choosing printing parameters on 3D printers that use filaments made from used bottles. This can help in improving the quality of the products produced by minimizing dimensional variations and ensuring precise and consistent dimensional stability.

2. Method

This research method starts with preparing tools and materials, fabrication of filaments using waste bottles, printing, measuring, and finally, data analysis.

The material used in this study was a used PET-type bottle that had been washed and cleaned thoroughly. The bottle is then cut into small sheets of tape with a width of 5 mm. 3d printing filament making materials presented on **Figure 1**.

Figure 1. 3d Printing Filament Making Materials

The PET plastic tape sheet is fed into the 3D filament extrusion machine. At this stage, the engine will process the PET plastic tape into a 3D filament with a diameter of 1.75 mm and then roll it up. The 3D filament is then stored at room temperature. 3D printing filament manufacturing process can be seen in **Figure 2**.

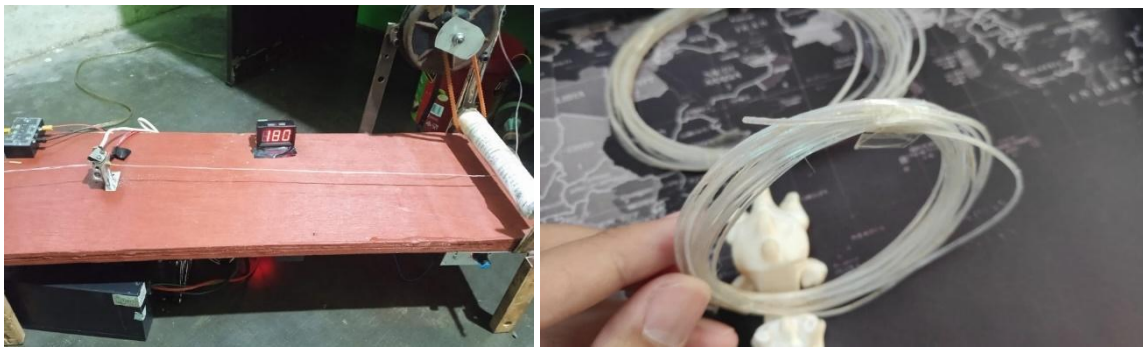

Figure 2. 3D Printing Filament Manufacturing Process

The test specimen is in the shape of a cube of 20 mm x 20 mm x 20 mm and was printed using a 3D printer using PET filaments made in the previous stage. Three variations of printing speed are used, namely 40 mm/s, 50 mm/s, and 60 mm/s, where the standard speed commonly used for printing with PLA material is 50 mm/s. Each speed variation is printed five times to get the average of the dimensions. Specimen shape and size can be seen in **Figure 3**.

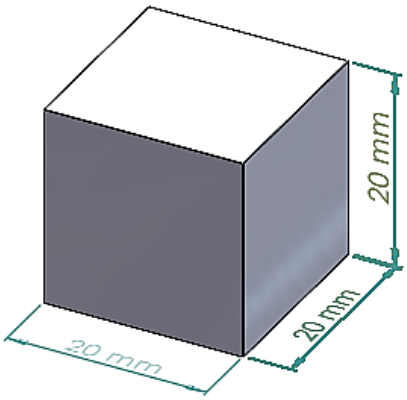

Figure 3. Specimen shape and size

Parameter Printing of Waste Bottle Filament Specimens is presented on **Table 1**.

Table 1. Parameter Printing of Waste Bottle Filament Specimens

Layer Height	Wall Thickness	Infill	Printing Temperature	Build Plate Temperature
0.12 mm	1.2 mm	20 %	260 ^{0}C	50 ^{0}C

The process of making specimens made from waste bottle filaments is presented on **Figure 4**.

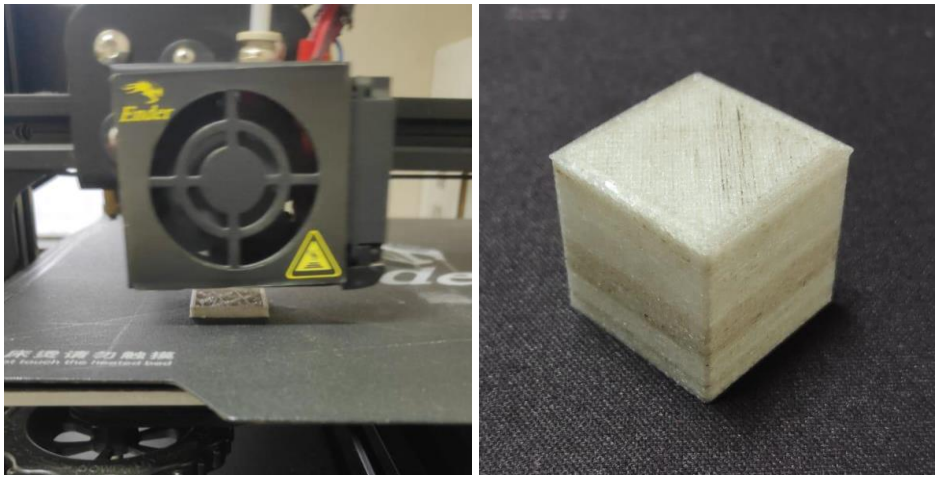

Figure 4. The Process of Making Specimens Made from Waste Bottle Filaments

The temperature of 260 ^{0}C was chosen because the melting point of the PET polymer is 260 ^{0}C. It is higher than the temperature for PLA, which is 200 ^{0}C. The parameters used to manufacture filament specimens made from PLA are shown in **Table 2**.

Table 2. PLA Filament Specimen Printing Parameters

Layer Height	Wall Thickness	Infill	Printing Temperature	Build Plate Temperature
0.12 mm	1.2 mm	20 %	200 ^{0}C	50 ^{0}C

PLA filament specimen manufacturing process can be presented on **Figure 5**.

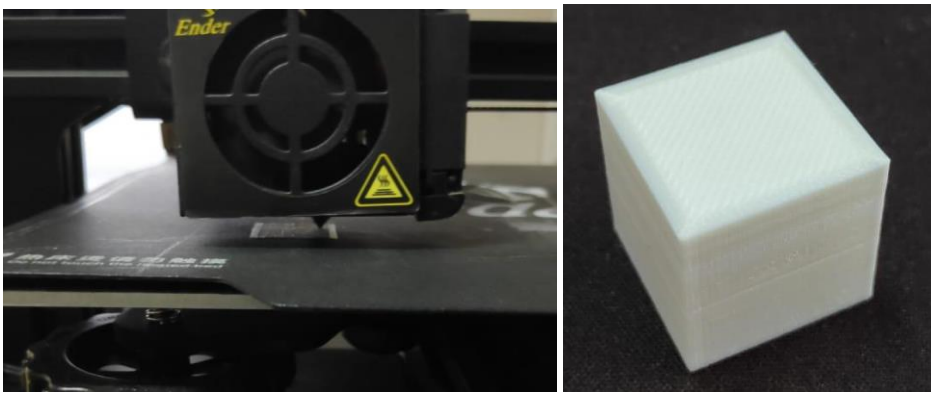

Figure 5. PLA Filament Specimen Manufacturing Process

After the printing process is complete, the dimensions of the resulting cube object are measured using a digital caliper. The object's dimensions are measured on all sides and averaged as the final result. In addition, dimensional variations at each printing speed are calculated to evaluate dimensional stability. Specimen measurement using digital calipers is presented on **Figure 6**.

Figure 6. Specimen Measurement Using Digital Calipers

The data obtained from dimensional measurements are then analyzed using statistics to determine a significant difference between the variation in printing speed and dimensional stability of 3D printing results using filaments from used bottles. Regression analysis is also used to determine whether there is a linear relationship between printing speed and dimensional stability. By using this methodology, it is expected to produce accurate and reliable data to determine the effect of printing speed variations on the dimensional stability of 3D printing results using filaments made from used bottles.

3. Results and Discussion

3.1 Result

The results show that variations in printing speed significantly affect the dimensional stability of 3D *printing* results. The higher the *printing* speed, the greater the dimensional deviation from the size it should be. The measurement results in used bottle filament specimens show that the resulting size is smaller than it should be. The variations in *printing* speed of 40 mm/s produce dimensions closest to the actual size compared to printing speeds of 50 mm/s and 60 mm/s. As for PLA filament specimens, the measurement results show that the resulting size is more significant than it should be. The variation in printing speed of 40 mm/s produces dimensions closest to the actual size compared to the *printing* speed of 50 mm/s and 60 mm/s.

3.2 Discussion

From the results of measurements as in Table 2. It is known that the variation in printing speed of 40 mm/s produces dimensions closest to the size that should be compared to speeds of 50 mm/s and 60 mm/s. The average dimensional variation at 40 mm/s speed is -0.054 mm, while at speeds of 50 mm/s and 60 mm/s, respectively, is -0,12 mm and -0.132 mm. These results show that the higher the printing speed, the more unstable the dimensions of the 3D printing result. Measurement results of used bottle filament specimens presented in **Table 2**.

Table 2. Measurement Results of Used Bottle Filament Specimens

Print Speed	*specimen 1*	*specimen 2*	*specimen 3*	*Specimen 4*	*specimen 5*	*Average*
40 mm/s	-0,1	-0,08	-0,07	-0,08	-0,06	-0,054
50 mm/s	-0,15	-0,1	-0,08	-0,12	-0,15	-0,12
60 mm/s	-0,12	-0,13	-0,13	-0,14	-0,14	-0,132

Comparison diagram of size deviation of waste bottle filament specimens can be seen on **Figure 7**.

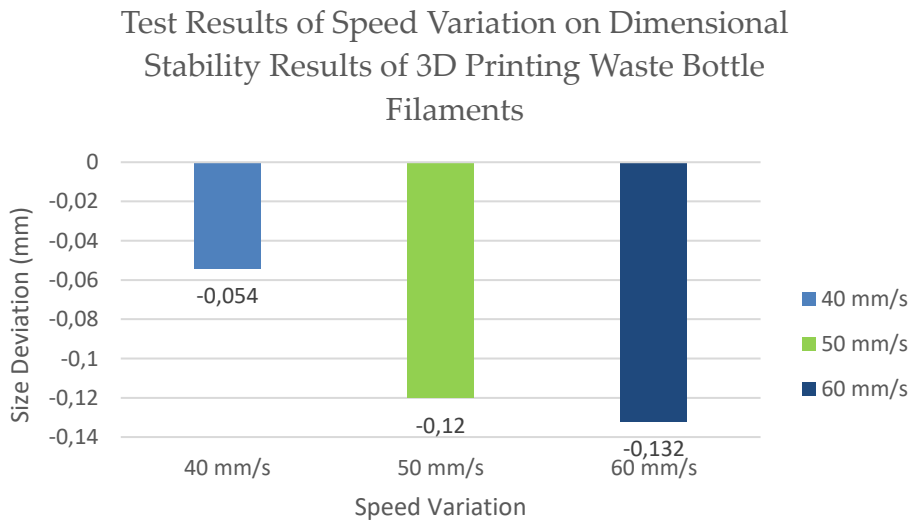

Figure 7. Comparison Diagram of Size Deviation of Waste Bottle Filament Specimens

The same results were also obtained on PLA filament specimen measurements. Judging in Table 3, the variation in printing speed of 40 mm / s produces dimensions that are closest to the size that should be compared to speeds of 50 mm / s and 60 mm / s. The average dimensional variation at a speed of 40 mm/s is 0.022 mm, while at a speed of 5, 0 mm/s is 0.056 mm, and 60 mm/s is 0.152 mm. PLA filament specimen measurement results is presented on **Table 3**.

Table 3. PLA Filament Specimen Measurement Results

Print Speed	specimen 1	specimen 2	specimen 3	Specimen 4	specimen 5	Average
40 mm/s	0,02	0,03	0,01	0,02	0,03	0,022
50 mm/s	0,05	0,06	0,05	0,07	0,05	0,056
60 mm/s	0,15	0,14	0,16	0,15	0,16	0,152

PLA filament specimen size deviation comparison diagram is presented on **Figure 8**.

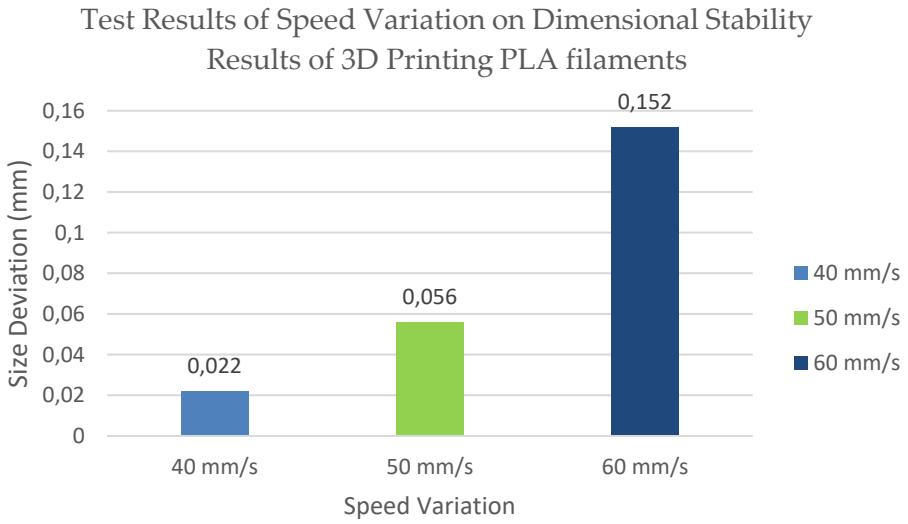

Figure 8. PLA Filament Specimen Size Deviation Comparison Diagram

This can be explained by the fact that the higher the printing speed, the more heat is generated by the 3D printer at the time of printing the object. This condition makes the filament material softer and susceptible to thermal distortion, thus affecting the dimensional stability of 3D printing results. On the other hand, the lower the printing speed, the less heat is generated by the 3D printer, so the filament material becomes more stable and minimizes thermal distortion. Regression analysis results also show a negative linear relationship between printing speed and dimensional stability. The higher the printing speed, the lower the dimensional stability of the 3D printing result.

In used bottle filament specimens, size shrinkage occurs because the filament extrusion process for PET material is still too fast, so the extrusion size that should match the nozzle hole size, which is 0.4 mm, becomes less than that. Data on the weighing results of the used bottle and PLA filament specimens reinforce this. The average weight of used b is 2.06 grams, while for PLA specimens, it is 4.09 grams.

Overall, this study shows that using filaments from waste bottles can produce stable 3D printing results if the printing speed is set correctly. It is hoped that this research can contribute to the development of more effective and sustainable 3D printing technology by utilizing recycled materials

4. Conclusion

Variations in printing speed have a significant effect on the dimensional stability of 3D printing results using filaments made from waste PET bottles. A printing speed of 40 mm/s can produce dimensions closest to the actual size compared to higher printing speeds. It can be a consideration in selecting printing parameters on 3D printers using filaments from waste bottles.

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