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Advancements in PET bottle plastic slitting devices for raw material 3D printing filament production

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ABSTRACT

The world is facing a significant environmental challenge due to the accumulation of plastic waste, especially PET (Polyethylene Terephthalate) bottles. Indonesia is no exception to this problem. Every year, millions of tons of PET bottles are produced, and most of them end up as waste that takes a long time to decompose. This study aims to investigate the technical and engineering aspects involved in creating a slitting device for PET bottle plastic, which will be used as raw material for Fused Deposition 3D printer filament. The research will focus on overcoming the challenges associated with producing consistent and high-quality raw materials filament and exploring innovative solutions and advancements in filament material design. The slitting device is designed to produce plastic strips with a consistent width of 10 mm and a tolerance of ±1 mm, using easily accessible cutting blades. Ensuring a consistent strip width is crucial for producing 3D printing raw material filament with a diameter of 1.75 mm and a tolerance of ±0.05 mm. Two versions of the slitting design, version 1 and version 2, were tested, and improvements were made to reduce friction and optimize cutting efficiency, resulting in consistent strip width. The second version performed better, producing longer, more uniform strips with lower pulling force. These strips are then proposed to be processed for 3D printing filament, demonstrating the potential of this tool to transform PET bottle waste into valuable raw materials.

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1. INTRODUCTION

Plastic waste is the most prevalent form and has become a significant issue in numerous countries, including Indonesia. According to data from the National Waste Management Information System (SIPSN), in 2023, the total waste generated in 341 districts/cities in Indonesia reached 37.8 million tons annually. Of this amount, approximately 18.95 percent, or around 7 million tons, consists of plastic waste. (Novrizal, 2025)

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Plastic bottle waste can be processed in various ways, such as turning plastic bottles into decorations or handicrafts. This study processes plastic bottle waste into 3D printer filament, creating a high-value product (Nisticò, 2020).

Plastic waste can be identified through the codes found on plastic products, usually represented by a triangular symbol with arrows at the bottom of the packaging. These codes consist of numbers 1 to 7, representing different types of plastics, such as PET (Polyethylene Terephthalate), HDPE (High-Density Polyethylene), PVC (Polyvinyl Chloride), LDPE (Low-Density Polyethylene), PP (Polypropylene), PS (Polystyrene), and other, (Maurilla, 2025), (Smith & Lee, 2020). Among these codes, PET (Polyethylene Terephthalate) is one of the most commonly used plastic materials for food and beverage packaging. Millions of tons of PET bottles are produced and used globally each year. However, a significant portion of these PET bottles becomes waste that pollutes the environment due to the very long time it takes to decompose naturally. Therefore, effective solutions are needed, such as recycling PET bottles into valuable products like filaments for 3D printers. Recycling PET bottles helps reduce plastic waste and provides significant economic and environmental benefits (Oussai, Bártfai, & Kátai, 2021).

Polyethylene terephthalate (PET) is the third most widely used polymer in the packaging industry. It dominates the beverage bottle market and accounts for nearly 16% of European plastic consumption in the packaging sector. Although PET traditionally comes from fossil sources and is not biodegradable in the environment, given its high recycling rate and potential for limitless reuse, its future remains bright (Nisticò, 2020), (Schneevogt et al., 2021).

The production of 3D printer filament using waste PET plastic bottles requires consistent slice width to produce good filament conditions (Schneevogt et al., 2021). The slice width produced from the designed tool must be 10 mm consistent (Jones, 2022), with a tolerance of ± 1 mm. The consistency of slice width affects the resulting 3D printer filament after the slicing heating process to achieve a consistent filament diameter of 1.75 mm with a tolerance of ± 0.5 mm.

2. RESEARCH METHODS

This study uses an experimental method to design and test the performances of PET plastic bottle slicers as the primary material for making filaments for 3D printers (Pratama & Husman, 2021)

2.1. Research method

The research methodology begins with collecting data and specifications for plastic bottle cutting tools through literature studies and field research. Used PET plastic bottles are gathered from various sources, then cleaned, and their surfaces are smoothed to facilitate the next processes. The collected data is utilized to select appropriate materials, components, and assembly processes. Subsequently, the plastic bottle cutting tool is modeled using Fusion 360 software to achieve an optimal design.

Once the design is completed, the cutting tool is fabricated according to the planned design. The tool is then tested for its ability to cut plastic bottles, and the results are evaluated through incision quality testing. Data obtained from the testing is analyzed to assess the tool's performance. The final outcomes of this process are thoroughly documented, complemented with technical drawings, to be used as a basis for conclusions and further development.

The process begins by collecting used PET plastic bottles from various sources, such as households or recycling centers. These collected materials are sorted and cleaned to remove contaminants like labels and bottle caps. The plastic bottle surface is smoothed by applying pressure and heating it with a heat gun. Additionally, a slitting device is designed to cut PET plastic bottles into tape-shaped slitting with a width of 10 mm and a tolerance of ± 1 mm. This tape can then be further processed into 3D printer filaments. The tool design considers efficiency, tape size, and pulling force during cutting.

To validate the design, the experimental method involves testing the plastic bottle slitting to ensure its ability to cut PET bottles into consistent tape and readiness for further processing. The parameters measured in this trial include the pulling force required during the cutting process, the level of consistency, and the tool's efficiency in the cutting results. The resulting tape is tested for quality using several parameters that are tested including:

- Consistency of the tape width using the digital caliper for precision measurements.
- The pulling force required in the cutting process.
- Feasibility of the tape results from the cutting tool.

2.2. Design of the Slitting Device

The plastic bottle cutter was first designed using Fusion 360, a CAD (Computer-Aided Design) software developed by Autodesk (Ji et al., 2018), (Pahl, Beitz, Feldhusen, & Grote, 2021). The Fusion 360 feature

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supports the export of STL files, the most commonly used format for 3D printing, ensuring compatibility with various types of 3D printers. These files are then exported into Creality Print.

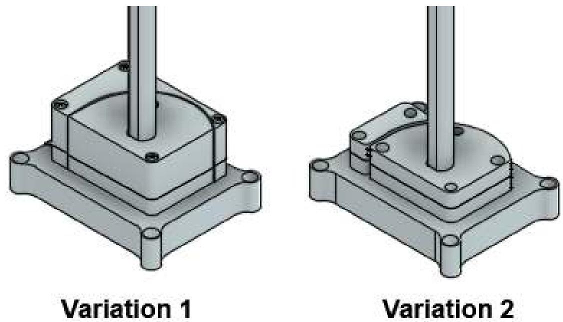

Figure 1. Variation 1(left side) and variation 2 (right side)

In figure 2 above, variation 2 in this study is an improvisation of variation 1 to provide reasonable efficiency values and obtain consistent tape results. Plastic bottle slicers and the differences from variations 1 and 2 are as follows:

1. Top Part of slitting tool

The cross-section functions as a support for the shearer, which is 20 mm thick. This slitting cross-section is 111 mm long and 86 mm wide, and the tape results have the same height as the heater that will be used to form 3D printer filaments.

2. Shaft design

The shaft in variations one and two is the main component for centering and holding plastic bottles during slitting. This shaft ensures the bottle remains stable so the slitting blade can cut it precisely. In addition, the shaft allows the bottle to rotate consistently, ensuring that each section of the bottle is cut consistently.

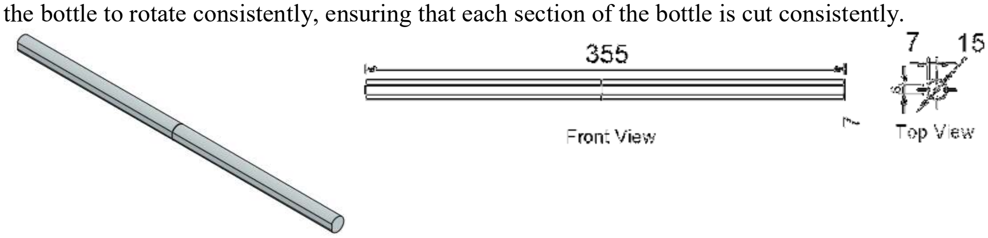

Figure 2. Shaft variation 2 for bottle holder

The shaft's dimensions are 15 mm in diameter and 355 mm in length. As shown in figure 3 above, the shaft is designed to have a slightly flat surface at the cylindrical shape; this consideration is taken due to the ease of manufacture using the 3D printing process.

3. Cutter tool design

The design of the plastic bottle cutter has an essential role in the slitting result. Variations 1 and 2 on the cutter have three different designs: (1) the dimensions of the bottom part block, (2) the holder on the cutting blade, and (3) the design of the bottle groove when the cutting process is carried out. The design differences between the two variations can be seen as follows:

- Variation 1

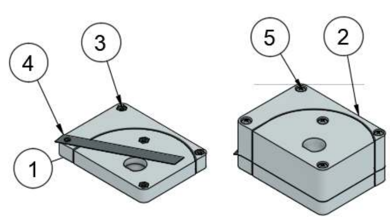

Figure 3. Variation 1 components. 1. Bottom part, 2. top part, 3. hexnut, 4. cutterblade, 5. screw.

Figure 3 above explains the component list. The bottom part of item 1 of variation 1 is larger than that of variation 2. The difference in dimensions affects the length of the tape produced; the longer the slitting result is, the longer the printer 3D filament from the plastic bottle will be. The bottom and top parts have dimensions of 90

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mm length and 80 mm width. However, it has a different height where the bottom part has a thickness of 10 mm, producing a tape width of 10 mm. Meanwhile, the top part has a thickness of 25 mm, which functions as a knife cover.

Figure 4. Cutter blade with 85mm length

The cutter blade used in this tool, as shown in figure 4, is a commonly used cutting blade that is easy to find. In variation 1, the cutter blade is easy to use because it can be used immediately without modification. However, there are drawbacks to its use, such as the blade being only used on certain parts, while the blade should be able to be used on the entire surface of the sharp blade.

- Variation 2

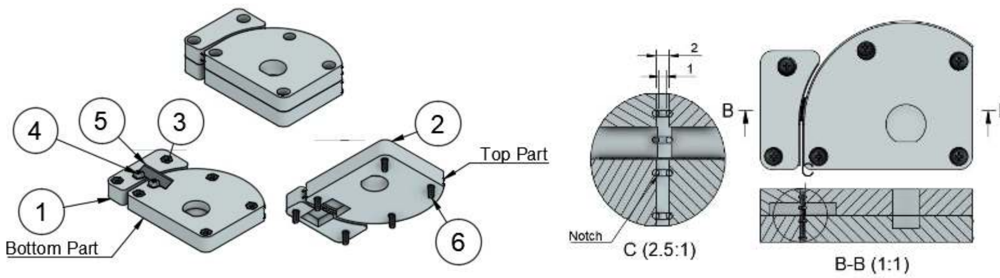

Figure 5. Variation 2 components. 1. Bottom part, 2. top part, 3. hexnut, 4. screw, 5. cutting blade, 6. screw.

Variation 2 has a smaller design compared to variation 1, which aims to make the slitting result longer and reduce the friction surface area that occurs during the cutting process. Variation 2 has dimensions of 80 mm in length, 56 mm in width, and 10 mm in thickness in the top part. In variation 2, components and designs have been developed from variation 1.

The construction designed and made on this plastic bottle cutter is a modified product, namely an existing product that has changed, both changes in shape and size, aiming to increase efficiency, effectiveness, quality, appearance, and safety in the tool so that it is easy to use.

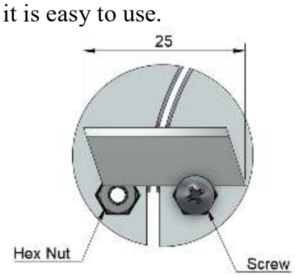

Figure 6. Variation 2 blade design

Figure 6 shows the design of the variation 2 there are two holes for the placement of 3 mm M5 screws that serve as a 25 mm length blade support. The advantage of this design concept is that the 85 mm blade can be divided into three parts, where each part of the blade can be used more than once. When worn out, the blade is easily replaced, so it is more efficient than variation 1, which can only be used once.

On the top part, a small gap slot holds the plastic bottle in place while the slitting process is performed. This small gap in the top part of variation 2 has a design difference in variation 1. The design in variation 2 aims to reduce friction when the bottle comes into contact with the top part's gap wall. A design comparison of the two variations can be seen in the figure 7 below:

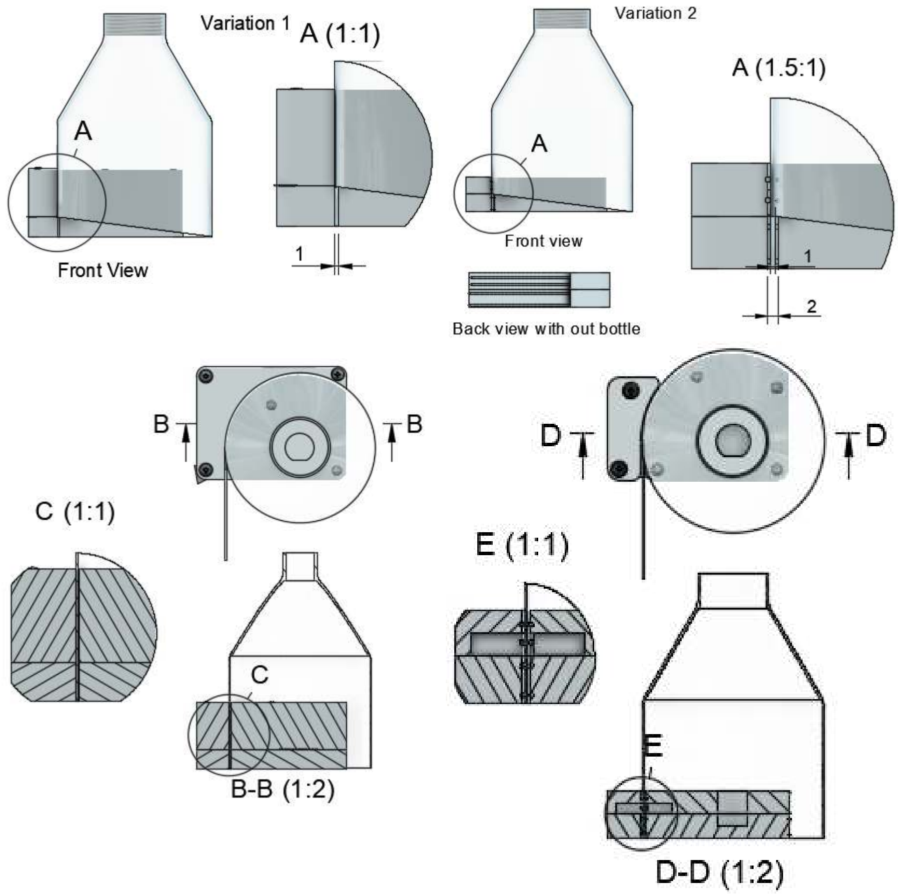

Figure 7. Comparison of variation 1 and variation 2 cutting grooves

In the provided figure 7, variation one demonstrates that the entire surface area of the plastic bottle on the cutter is in contact with the top part of the wall gap, resulting in a larger surface area of contact. Conversely, in variation 2, two pairs of notches were added to the top part, reducing the contact between the bottle and the top part wall gap. Additionally, the width of the top part was reduced as a design improvement to decrease the required pulling force.

2.3. Design Manufacturing Process

The main part's manufacturing process uses the fused deposition method through a 3D printer, Creality Ender 3. The slicer software used in this process is Creality Print v5.1. This 3D printer was chosen as a solution in this research to print digital designs into physical products with a volume. Figure 8 shows the Creality Ender 3 3D printer, which will also be used as the primary method of manufacturing processes. The respective capacity and specifications are shown in table 1.

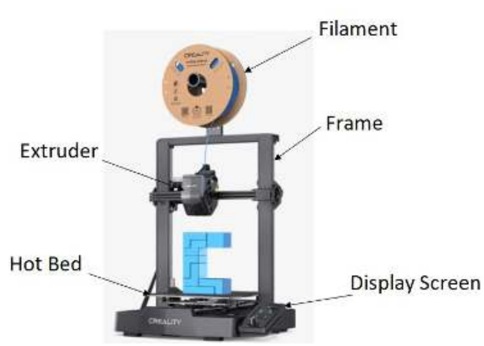

Figure 8. 3D printer Creality Ender 3

In this study, the components of the plastic bottle slitter parts are made using PLA (Polylactic Acid) material because it is low-cost and suitable for prototyping. This filament is also environmentally friendly, made from natural materials such as corn starch or sugarcane.

Parameters play an essential role in the 3D printing process using PLA (polylactic acid) filament, and they include several technical factors that can affect the quality of the print. The following are the parameters of the 3d print in Creality print 5.1 that are used for the manufacture of slitting tools:

Table 1. Creality Print v5.1 capacity and specification

Name	Parameters
Nozzle temperature	220°C
Heated bed	60°C
First layer speed	30 mm/s
First layer infill speed	80 mm/s
Inner wall speed	90 mm/s
Outer wall speed	60 mm/s
Sparse infill speed	180 mm/s
Internal solid infill speed	180 mm/s
Top surface speed	50 mm/s
Gap infill speed	50 mm/s
Layer height	0,2 mm
First layer height	0,2 mm
Skirt speed	50 mm/s
Brim type	No-brim
Sparse infill density	20%
Sparse infill pattern	grid
Infill/wall overlap	15%

The nozzle temperature in this study is 220°C. The right nozzle temperature setting will determine the extrusion quality and adhesion between layers. If it is too low, the filament may not melt well; if it is too high, it can cause stringing or oozing. PLA filaments usually do not require very high bed temperatures, but the appropriate settings help increase the adhesion of the first layer to prevent warping. The bed temperature setting is 60°C. Lower speeds result in better detail but extend print times. Table 1 shows that the initial layer has a speed of 30 mm/s, which aims for the filament to stick well to the bed. In the first layer, the infill has a speed of 80 mm/s. From the above parameters, the manufacture of the overall shredder components in variation 1 is about 6 hours and 23 minutes, while for variation 2, the time required is about 5 hours and 6 minutes.

The height of PLA filament is usually around 0.1 mm—0.3 mm. This study uses a layer height of 0.2 mm and a first layer height of 0.2 mm, as shown in Table 1, to create detailed results. Using glue sticks or blue painter's tape on the heated bed is unnecessary when using PLA filament because PLA can stick quite well to bed ender 3, which has the correct bed temperature. In table 1, the skirt speed used is 50 mm/s without using the brim method due to the large contact area. However, the brim method can be used in printing shafts to ensure that the first layer adheres perfectly because it has a small contact area.

The infill setting is used to give the appropriate force to the print. In Table 1 above, this design using 20% sparse infill density is enough to provide strength to the print and for the pattern on the infill utilizing a grid pattern, as shown in Figure 9.

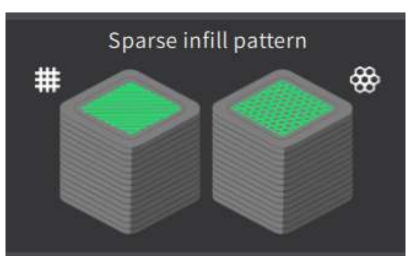

Figure 9. Infill grid pattern

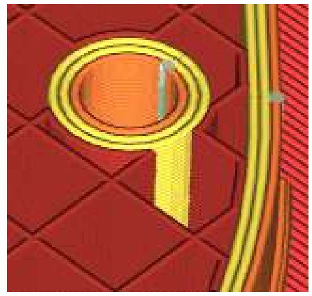

Figure 10. Inner layer wall

Increasing the two inner layer walls, as shown in figure 10, creates a strong structure while maintaining lightweight and material savings. This addition also reduces the need for infill because increasing the number of walls can reduce the infill percentage while still achieving enough strength on the model.

2.4. Experimental setups

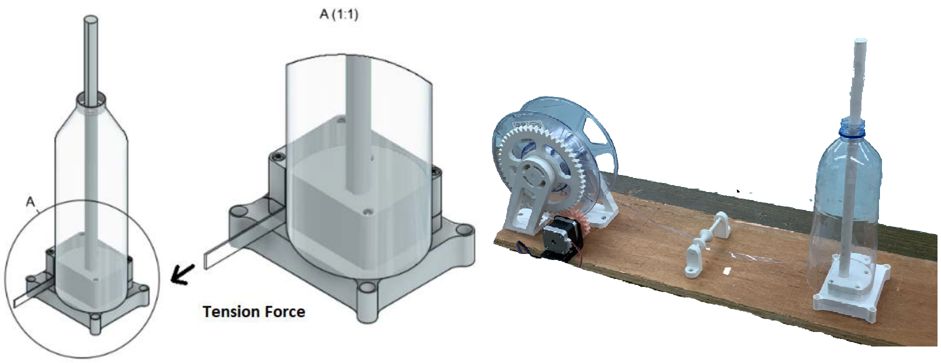

Figure 11. Plastic bottle slitting process, tension force applied on the plastic tape(left), and experimental setup of the process (right)

Slitting plastic bottles has several stages that are carried out to produce tape, which will later be used to produce 3D printing filaments. Variation 1 and variation 2 have similarities in the slitting process. The stages of cutting are as follows:

1. Pre-processing bottle

The collected bottles are washed to remove dirt, labels, and the remnants of the liquid contents inside. This process can involve washing with hot water to ensure the bottle is clean of contamination. The smoothing process is conducted by smoothing the surface of plastic bottle shapes by applying pressure to the bottle's surface and heating it using a heat gun. This process eliminates plastic bottle ornament shapes to facilitate cutting and provide consistent tape results in width and thickness.

2. Slitting process

After smoothing the surface and cleaning the plastic bottle, it is inserted into the slitting gap. This tool uses a sharp cutting blade, and the plastic bottle is then pulled to produce a tape with a width of 10 mm and a tolerance of ± 1 mm.

While the slitting process is in progress, a force sensor is placed on the tape to measure the tension force produced during the process. This measurement is conducted several times on both variations 1 and 2. The tape result then measures the length of each bottle produced, and the consistency width of the tape is also measured using a digital caliper on each fraction of the length produced. Figure 11 shows that the slitting process is progressing, and the tension force is measured.

3. RESULTS AND DISCUSSION

The outcomes of the slitting process, which was conducted using various tested parameters on PET plastic bottle waste for slitting variations 1 and 2, were analyzed to determine their suitability as raw material for manufacturing 3D printer filaments. The result of length and quality of the resulting PET tape from each experimental trial are presented in Table 2 below:

Table 2. Tape length result

No. of experiment	variation 1	variation 2
Experiment 1	4689 mm	6260 mm
Experiment 2	5120 mm	5850 mm
Experiment 3	4773 mm	5540 mm
Experiment 4	4555 mm	5945 mm
Experiment 5	4762 mm	5994 mm

Table 2 above illustrates a comparison between the tape length obtained in variation 2 and that in variation 1. Both tape length measurements are depicted in figure 12 below to provide a more explicit representation of the results. Although both variation 1 and variation 2 utilized identical PET bottles as raw materials, the process of heating the bottle surface with a heat gun was conducted manually. Consequently, the air distribution within the bottle was inconsistent, leading to variations in the bottle's shape and dimensions, with an estimated deviation of approximately 12%. This agrees with the result of variation 2, having longer plastic strips due to the design optimization explained in figure 7 to variation 2.

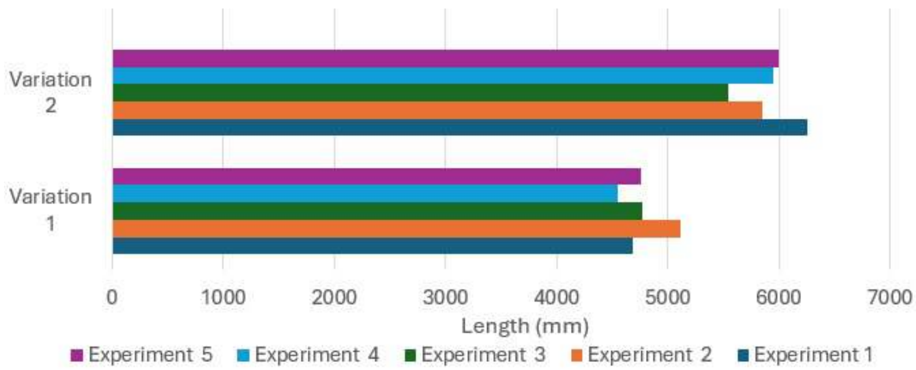

Figure 12. Tape length measurement results

The force required to pull the plastic strip during the slitting process plays a crucial role in determining the operation's success and serves as an indicator of cutting tool wear (Mochtar, Soeparno, & Eko, 2018). A lower pulling force is preferable, as it contributes to better-quality plastic strips. Conversely, a higher pulling force during slitting often results in inconsistencies along the strip's edges, sometimes leading to the formation of chatter marks. Therefore, tensile force measurements were conducted to evaluate the force required for the slitting process. The results of the pulling force test are presented below. The total tensile force required to pull the tape from the plastic bottle differs for slitting variations 1 and 2. It can be seen in the graph figure 13 below:

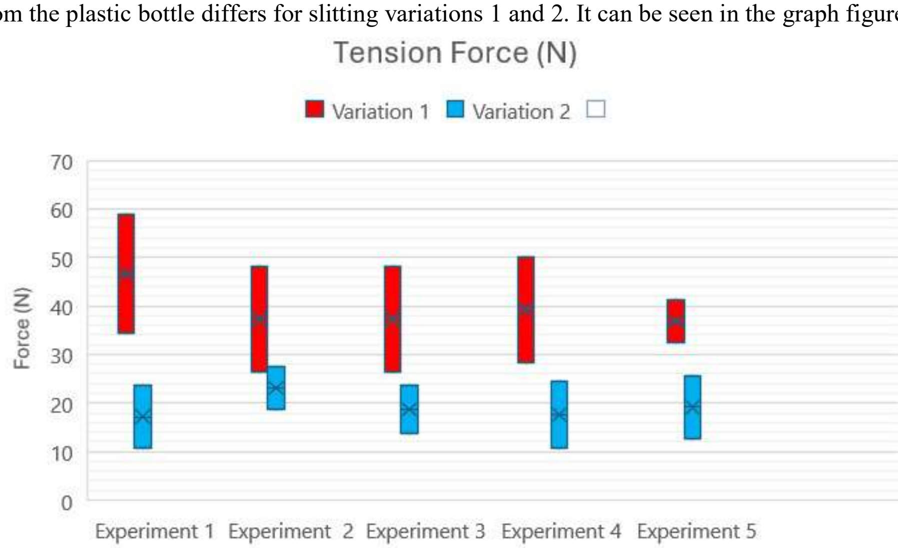

Figure 13. Tension force measurement results

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Figure 13 illustrates the highest and lowest tensile force values for each variation, with the red bars representing variation 1 and the blue bars representing variation 2. The results indicate that the tensile force required for the slitting process in variation 1 was significantly higher than in variation 2. In variation 1, the maximum recorded force was 58.86 N, while the minimum was 24.544 N. Conversely, variation 2 exhibited a lower force range, with a maximum of 27.468 N and a minimum of 10.781 N. These findings suggest that variation 2 enables a more efficient slitting process with reduced tensile force requirements (Doe et al., 2021).

Furthermore, after obtaining the plastic tape results, measurements of tape width were conducted at intervals of 10% along its total length to assess the consistency of the tape width. Figure 14 shows the graph of the average tape width of 5 experiments of variation 1 and 2 per fraction of the length.

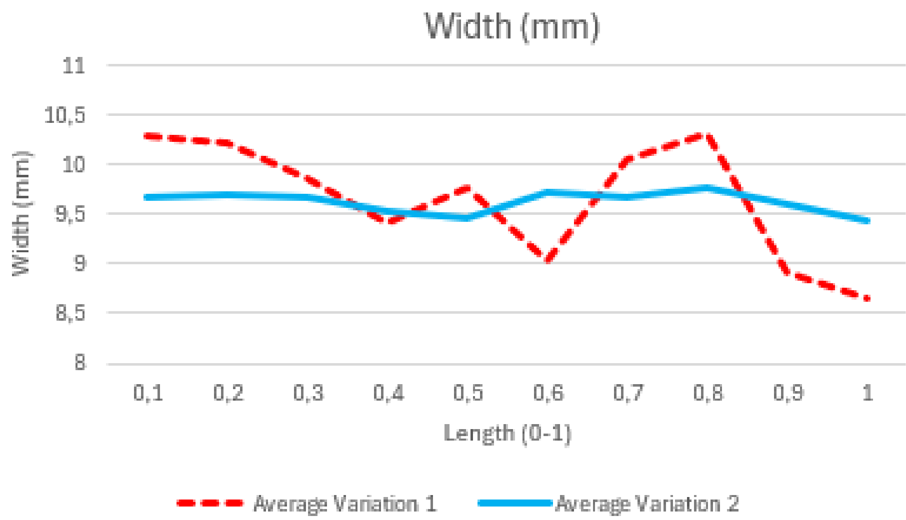

Figure 14. Experimental measurement of the width of the tape

In figure 14, the dashed line represents the width measurements for variation 1, while the continuous line corresponds to variation 2. The results indicate that variation 2 demonstrates significantly greater tape width consistency than variation 1. The standard deviation for variation 1 was recorded at 0.607 mm, whereas variation 2 exhibited a much lower standard deviation of 0.109 mm. This suggests that variation 2 produces a more uniform tape width, essential for ensuring the high quality of 3D printer filament (Rahman, Zalilah, Katiman, 2024). The higher consistency in tape width observed in variation 2 can be attributed to the presence of two pairs of notches discussed in figure 7, which effectively reduce friction between the plastic bottle and the cutting tool during the slitting process. Reducing friction leads to a lower pulling force requirement, thereby enhancing the uniformity of the plastic strip width.

4. CONCLUSION

The slitting devices were designed, and various design improvements were made. Variation 1 is the original design and was compared to design variation 2 through design optimizations. The experimental results show that the design variation 2 is better than variation 1. Some of the key improvements are:

1. Variation 2 uses a cutting blade that is three times more efficient than variation 1. This is because variation 2 has only a 25mm blade length, which is 1/3 of the overall cutting blade length.
2. Variation 2 has a longer slitting tape result compared to variation 1. The average length of variation 1 is 7449.8 mm and 5917.8 mm on the average length of variation 2, and this gives variation 2 additional 19.23% longer results
3. In variation 2, the tension force is lower than in variation 1. Since variation 1 has an average tension force of 39.436N, and variation 2 has 19.13N, variation 2 requires 51.5% less power to pull the tape.
4. The consistency of tape width is the main factor objective of this research; the required width tolerance is 10%, and both variations can achieve that needed tolerance. However, variation 2 has more consistent results in the width tolerance. Since the standard deviation of variation 2 is 0.109, it can be concluded that variation 2 has more consistent results compared to variation 1.
5.

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REFERENCES

Asroni, M., Djiwo, S., Setyawan, E.Y., Pengaruh model pisau pada mesin sampah botol plastik, Jurnal Aplikasi dan Inovasi Ipteks "Soliditas" (J-Solid), 1(1), 2018.

Bintara, R.D., Lubis, D.Z., Pradana, Y.R.A., The effect of layer height on the surface roughness in 3d printed polylactic acid (pla) using fdm 3d printing, IOP Conference Series: Materials Science and Engineering, 1034(1), 012-096, 2021.

Doe, J., Smith, A., Brown, B., Advanced pet recycling for additive manufacturing, Journal of Polymer Engineering, 45(3), 210-225, 2021.

Ji, S., P.P., Qi, Y.M., Cai, D.C., Research and application of autodesk fusion360 in industrial design, Iop conference series: Materials Science and Engineering, 359, 012-037, 2018.

Maurillia, I., 7 simbol dan jenis plastik yang perlu kamu ketahui, from https://zerowaste.id/zero-waste-for-beginners/simbol-dan-jenis-plastik/, 2025.

Nisticò, R., Polyethylene terephthalate (pet) in the packaging industry, Polymer Testing, 90, 106-707, 2020.

Novrizal, T., Sistem informasi pengelolaan sampah nasional, from https://sipsn.menlhk.go.id/sipsn/, 2025.

Pahl, G., Beitz, W., Feldhusen, J., Grote, K. H., Engineering design: a systematic approach, Springer, 1996.

Pratama, W.H., H., H., Optimasi parameter proses 3d printing terhadap kuat tarik material filament pla menggunakan metode taguchi, Sprocket Journal of Mechanical Engineering, 3(1), 39–45, 2021.

Rahman, P. I. A., Zalilah, M.N.A.T, Katiman, A.S., Design of an extrudate filament machine for recycling waste polyethylene terephthalate plastic into 3d printing filament, Journal J Innovation, 13(1), 25-32, 2024.

Smith, R., Lee, C., Thermal treatment effects on recycled pet properties, Sustainable Manufacturing Review, 12(1), 98-112, 2020.