The Effect Of Extrusion Machine Against Consistency Filaments Products 3D Printing

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Abstract. The need for filaments is currently increasing but the prices offered in the market are very expensive. This research develops a new extruder machine with HDPE material. The high quality filaments are characterized by high durability and constant diameter. The variables used in this research are temperature, screw speed, towing speed and blower. Based on ANOVA processing using Minitab it is known that all variables have no effect on the uniformity of diameter and ovality response. Based on the results of this research that the bottle cap tensile strength (HDPE) has a value of 15.7 so that it is still far below the PLA tensile strength.

Keywords — HDPE, Design of Experiment, Extrusion, ANOVA, Tukey;

1. Introduction

Technological developments in the field of design experienced a large increase with the discovery of 3D Printers. In 2016, 3D printer sales amounted to 450,000 and is expected to increase to 6 million units by 2020[2]. The management of plastic waste into new products has promising commercial value. The principle of managing plastic waste that is used is reuse, reduce, and recycle [10].

The extrusion process is continuous processing through mixing, kneading, shearing, cooling, and shaping by pushing the raw material to be processed out through the mold hole [11]. More than 66% of plastic is processed through injection and extrusion printing. The advantage of the extruder process is the filling of material in the hopper which can be carried out continuously so as to compensate for material shrinkage [6]. Most extrusions use plastics with much lower melting temperatures such as ABS and PLA, below 250°C [10]. HDPE has the advantage of polyethylene because it has good mechanical properties such as high tensile strength, high rigidity and melting point, and crystallinity[12].

The use of 3D Printer has a big effect on the use of filament as a material, but prices will affect the purchasing power of consumers of 3D printing[1]. Quality filaments are characterized by high durability and constant diameter. The non-constant filament diameter affects the function of the extrusion nozzle mechanism [3,5].

This research [13] applying waste management with the extrusion process using HDPE material (bottle caps). This research uses 3 levels on each variable, including heating temperature and speed that is less than optimal so that it affects the dimensions and ovality of the filament. In general, the work systems of the two devices did not experience a significant difference, but the heater used was only one heater. Different levels, variables, and programs for Arduino there are additional programs because in this research there are two motors. The development that was carried out was designing a portable extruder machine, easy to carry and use anywhere by combining a rolling machine. The factors used are heat temperature, screw speed, rest temperature. While the response is the uniformity of extrusion extrusion.
dan ovality and diameter diameter. Factorial used is $3^2$ and nothing repetitions. The data obtained is then processed with ANOVA.

2. Equipment, material, dan Formula
In this research heating temperature (A) with a level of 190 °C and 200°C with a susceptible heating error of 6%. Screw speed (B) with levels of 11 °C, 13 rpm, and 15 rpm with a vulnerable speed error of 9%. Resting temperature (C) of 5°C, 10°C and 15°C with a vulnerable speed error of 10%. The basic model of research can be seen in Figure 1.

![Fig 1 Research model](image)

Extruder machine is a simple tool that has the working principle of inserting raw material which is processed and then pushed out by the die hole. Extruder machine can be seen in Figure 2.

![Fig 2 Extruder machine](image)

The material used as a filament in this study is a former HDPE bottle cap. The image of the material used can be seen in Figure 3.
For the method of completion in this research using a completely randomized factorial pattern $3^{mn}=2*3*3$. The mathematical models used are:

$$Y_{ijk}=\mu+\alpha_i+\beta_j+\gamma_k+(\alpha\beta)_{ij}+(\alpha\gamma)_{ik}+(\alpha\delta)_{il}$$  \hfill (1)

Information:
- $Y_{ijk}$ = observation on the 1st experimental unit that obtained a combination on the treatment of level 1 level I from factor A, level to j from factor B, level to I from factor C.
- $I, j, k = 1, 2, ..., A, B, C$
- $\mu$ = population mean
- $\alpha_i$ = the effect of the level of the factor A
- $\beta_j$ = the effect of the level of i from factor B
- $\gamma_k$ = the effect of the level of the factor C
- $(\alpha\beta)_{ij}$ = the effect of the level of the factor A and the level of the factor B
- $(\alpha\gamma)_{ik}$ = the effect of the level of the factor A and the level of the factor C
- $(\alpha\delta)_{il}$ = the effect of the level of the factor B and the k-level of factor C

3. Result
3.1 Diameter Uniformity

| Source         | DF | Adj SS  | Adj MS  | F-Value | P-Value |
|----------------|----|---------|---------|---------|---------|
| Model          | 17 | 0.005338| 0.000314| 2.4     | 0.253   |
| Linear         | 5  | 0.001201| 0.00024 | 2.2     | 0.433   |
| a              | 1  | 0.000563| 0.000563| 3.4     | 0.256   |
| b              | 2  | 0.000057| 0.000029| 1.56    | 0.327   |
| c              | 2  | 0.000581| 0.000291| 0.45    | 0.275   |
| 2-Way Interact | 8  | 0.003013| 0.000377| 1.32    | 0.128   |
| a*b            | 2  | 0.002014| 0.001007| 0.32    | 0.699   |
| a*c            | 2  | 0.000338| 0.000169| 1.7     | 0.123   |
| b*c            | 4  | 0.00066 | 0.000165| 1.67    | 0.34    |
| Error          | 4  | 0.002797| 0.000699|         |         |
| Lack-of-Fit    | 3  | 0.002415| 0.000805| 1.8     | 0.36    |
| Pure Error     | 1  | 0.000383| 0.000383|         |         |
| Total          | 17 | 0.016442|         |         |         |
Based on the results of the experiment shows that the factors A, B, C, A*B, A*C, B*c do not have a significant effect on the response to the uniform diameter of the extruded filament. The results of this experiment can be seen in table 1.

3.2 Ovality

| Source          | DF | Adj SS  | Adj MS  | F-Value | P-Value |
|-----------------|----|---------|---------|---------|---------|
| Model           | 13 | 0.013644| 0.00105 | 1.5     | 0.373   |
| Linear          | 5  | 0.004185| 0.000837| 1.2     | 0.443   |
| a               | 1  | 0.002119| 0.002119| 3.03    | 0.157   |
| b               | 2  | 0.00149 | 0.000745| 1.06    | 0.426   |
| c               | 2  | 0.000144| 0.000072| 0.1     | 0.905   |
| 2-Way Interactions | 8  | 0.009051| 0.001131| 1.62    | 0.338   |
| a*b             | 2  | 0.00059 | 0.000295| 0.42    | 0.682   |
| a*c             | 2  | 0.002513| 0.001256| 1.8     | 0.277   |
| b*c             | 4  | 0.004341| 0.001085| 1.55    | 0.34    |
| Error           | 4  | 0.002797| 0.000699|         |         |
| Lack-of-Fit     | 3  | 0.002415| 0.000805| 2.1     | 0.46    |
| Pure Error      | 1  | 0.000383| 0.000383|         |         |
| Total           | 17 | 0.016442|         |         |         |

Based on the results of the experiment shows that the factors A, B, C, A*B, A*C, B*c do not have a significant effect on the response to the uniform diameter of the extruded filament. The results of this experiment can be seen in table 2.

4. Conclusion

Based on the experimental results using Anova, the uniformity of diameter and ovality filament responses are not influenced by A (Heating temperature), B (screw speed), C (resting temperature), A*B (Heating temperature and screw speed), A*C (Heating temperature and resting temperature), and B*C (screw speed), C (resting temperature).

References

[1] Albi, E., Kozel, K., Ventoza, D., & Wilmoth, R., AKABOT: 3D PRINTING FILAMENT EXTRUDER, 2014.
[2] Alec.: Twice as many 3D printers shipped over 2016, Gartner predicts, 2016.
[3] Angatkina, K.: Recycling of HDPE from MSW waste to 3D printing filaments, 2018.
[4] Evendi, Muklis Nur.: OPTIMIZATION OF HOT PRESS PNEUMATIC MACHINE PARAMETERS ON THE STRENGTH OF ATTRACTION USING THE RESPONSE SURFACE METHODOLOGY (RSM), Universitas Trunojoyo Madura, 2019.
[5] Grujovic, N., Zivic, F., & Zivkovic, M.: Custom design of furniture elements by fused filament fabrication, 0(0), 1–8, Analysis of Plastic PET Bottles.” Journal of Chemical Education 83.3 (2006): 439-42, 2016.
[6] Iler, H. Darrell, Eric Ruff, and Seth Althoff.: An Introduction to Polymer Processing, Morphology, and Property Relationships through Thermal, 2006.
[7] Jung, J., Kim, J., Uhyn, Y., R., Jeon, J., K., & Lee, S., Preparations and thermal properties of micro- and nano-BN dispersed HDPE composites, 2010.
[8] Kim, B., J., Byun, J., H., & Park S., J.: Effects of Graphenes/CNTs Co-reinforcement on Electrical and Mechanical Properties of HDPE Matrix Nanocomposites, 2010.
[9] Lubis, S., Djamil, S., & Yolanda.: Effect of Object Orientation on the 3D Printing Process of PLA and ABS Polymer Materials on Tensile Strength and Dimension Accuracy of Products, 2016.

[10] Putra, Kumara, Sadana, S. M.: Utilization of 3D Printing Technology in the Lifestyle Product Design Process. Product Management Design, UBAYA, 2018.

[11] Rosato, D. V.: Injection molding in the 21st century, SPE-IMD Newsletter, 2000.

[12] Vasile, C & Pascu, M.: Practical Guide to Polyethylene. Shawbury: Rapra Technology Limited. pp 16-19, 2005.

[13] Wahyudi, Tri.: Effect of Temperature and Screw Speed on Ovality and Uniformity of HDPE Filament Diameter in Plastic Extruder Designs, Universitas Trunojoyo Madura, 2015.