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Development of Plastic Extruder for Environmental, Economic and Social Sustainability in Education Perspective

Ahmad Zahin Hassan[1], Wan Ismail, W.O.A.S.[1], Sharizal Ahmad Sobri[2], R. Rohimi[1], Siti Nuratirah Che Mohd Nasir[3]

[1]Faculty of Innovative Design and Technology, Universiti Sultan Zainal Abidin, Malaysia
[2]Advanced Material Research Cluster, Faculty of Bioengineering & Technology, Universiti Malaysia Kelantan, Malaysia
[2]Green Design and Manufacture Research Group, Centre of Excellence Geopolymer and Green Technology (CEGeoTech), Universiti Malaysia Perlis, Malaysia
[2]Global Entrepreneurship Research and Innovation Centre (GERIC), Universiti Malaysia Kelantan, Malaysia
[3]Faculty of Architecture and Ekistics, Universiti Malaysia Kelantan, Malaysia
woasaifuddin@unisza.edu.my

Abstract:

A plastic extruder is one of the machines highly use in the manufacturing industry. This project aims to develop a plastic extruder for sustainability. The plastic extruder is one of the manufacturing topics in highest education. The machine is very costly to use for education. Besides, plastic waste is very critical for the environment. The purpose of creating this machine is to overcome this problem and at the same time to gain sustainability in living. The machine is create started by designing the extruder then fabricate the prototype. After fabrication is complete, test the machine, and the result of the outcome filament will be compared to existing filament such as 3D printer filament. The outcome of this project is following the sustainability pillar, which is an environment, economic and social.

Keywords: *Plastic Extruder, Sustainability, 3D printer filament, Plastic Waste Management, Plastic Recycle*

I. INTRODUCTION

As a demand for high sensitivity of manufactured goods is rapidly increasing, the manufacturing is constantly struggling to increase the quality of components [1]. Plastic extrusion is a manufacturing process which is melted the plastic then convert it into a continuous profile. The main component that needs to be in extrusion machine is hopper, barrel, screw, heaters and nozzle [2]. The machine will start the operation by feeding plastic material (granules, pellets or flakes)

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through the hopper and then flow into the barrel. The rotation of screws will melt the plastic with a combination of heaters along the barrel that make plastic melt quickly. Plastic that already in the molten state will force into a die, which shapes the plastic [3,4]. The screw is the most critical element of an extruder, which is transport, heating and melting the plastic [5]. It generates sufficient pressure to the plastic than force it through the nozzle

Sustainable development definition is meeting the present need without compromising the ability of future generation to meet the demand [6]. Sustainable has three pillars which are social, environmental and economic [7,8].

Fig. 1: Sustainability Three Pillars [6]

Figure 1 shown the sustainability of three pillars which from the environmental, economic, and social. Environmental sustainability is defined as responsible interaction with the environment to avoid depletion or degradation of natural resources and allow for long-term environmental quality [9]. The practice of environmental sustainability helps to ensure that the needs of today's population are met without jeopardizing the ability of future generations to meet their needs. Besides, recycle, reuse and also reduce the other name of sustainability [10]. Environment sustainability is all about nature. How pollution can be prevented from happening to our nature [11]. Nowadays, plastic waste can be introducing as most treated to the environment [12]. Plastic waste created many problems especially to the sea that cause difficulty in the natural ecosystem.

Economic sustainability encompasses financial costs and benefits. The general definition of economic sustainability is the ability of an economy to support a defined level of economic production indefinitely [13]. Economic sustainability refers to practices that support long-term economic growth without negatively impacting the social, environmental, and cultural aspects of the community [14]. Economic and social always related to each other. The economy will determine the social lives of people. According to the Western Australia Council of Social Services (WACOSS): "Social sustainability occurs when the formal and informal processes; systems; structures; and relationships actively support the capacity of current and future generations to create healthy and liveable communities [15]. Socially sustainable communities are

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equitable, diverse, connected and democratic and provide a good quality of life. The component of social sustainability is standard of living, education, community and equal opportunities [16].

This study aims to design a plastic extruder machine that can follow the concept of sustainable development. This machine follows three pillars of sustainable, which is social, environmental and economic — started with creating a design that aims to reduce the cost of manufacturing for the product. The next step is fabricating the prototype and testing the prototype. The outcome of this product will be compared to the existing machine.

II. MATERIALS AND METHODOLOGY

The method required in developing plastic extruder has a various stage which is design development, fabrication of the prototype.

Design Development

Design development is a stage that starts with generating the idea of the product. The research has proposed three concept design for evaluation based on the criteria need. The final concept design as illustrated in Figure 2, and it has been selected based on ranking specification given. The next step is to create a technical drawing of the final concept design. All the dimension and technical specification have been providing before going to the next stage which is the fabrication process.

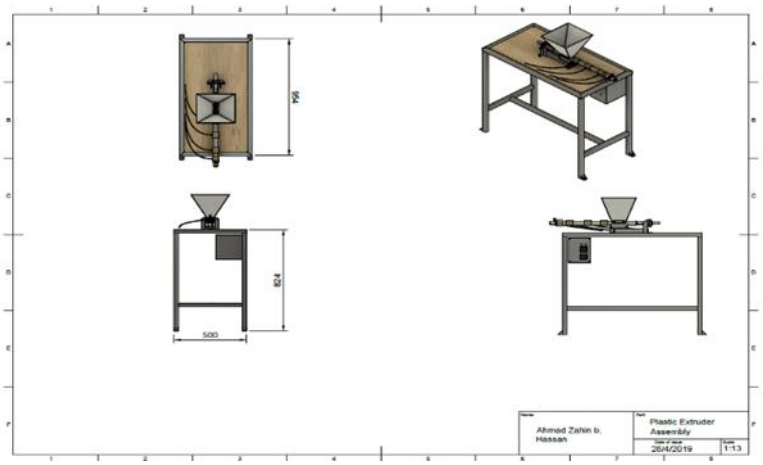

Fig 2. Technical Drawing of Extruder Design

Figure 2 shows the full assembly of extruder design. The design is based on the existing plastic extruder available in the market. The design meets the criteria of the extruder are including such as barrel, hopper and nozzle for making it easy to fabricate and assemble.

Based on Table 1, it has shown the list of material used for fabricating the frame base of the extruder. This material is chosen based on the criteria that target low-cost material without

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neglecting the quality of the product. The estimated cost of the product is based on the local market survey.

Table 1. Material Selection and Estimation Cost

Parts	Materials	Estimation Cost (RM)
Hopper	Sheet Metal	50
Barrel	G.I. Pipe	50
Nozzle	Mild Steel	20
Barrel Holder	Mild Steel Square Hollow	20
Framework	Mild Steel Square Hollow	20

In Table 2, all list of electrical and electronic component for the plastic extruder. The list of material and component are considered based on current research of an existing product in the market. Auger bit is the economical replacement for extrusion screw even do the efficiency of auger bit is not to good compare to extrusion screw but in the aspect of low-cost, it's still accepted [17]. For heating element use the band heater to heat the barrel and PID controller as a temperature controller. DC motor used to rotate the screw. All of this component is used as a replacement to the high-cost component with the same functionality without decreasing its efficiency when operate.

Table 2. Component Selection and Specification

Component	Specification
Auger Bit	25 x 260 mm
PID controller	100 – 240vAC
Band heater	40 x 40 x 35 mm
Solid-state relay	25A 40A
DC motor	12vDC 5A

Plastic Extruder Fabrication

Fabrication is a process where the part will be cutting, joining, assemble to create a final product [18,19]. The process divides into a few parts which is hopper, barrel, nozzle, barrel support, and table frame. The most common process use is cutting, drilling and welding. Most of the process use a MIG welding machine for joining the part by part.

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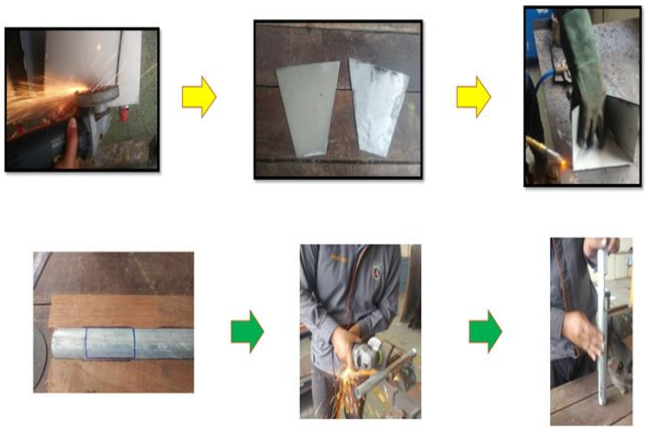

Fig. 3: Hopper and Barrel Fabrication Process

Figure 3 shown the hopper fabrication starting from cutting the sheet metal using the dimension provide during design development. After that, joining the part using the MIG welding process. Grind the excess part for finishing. The fabrication process of the barrel is the same as the hopper. Start with cutting the pipe to grind the excess part for finishing.

Fig. 4: Nozzle Fabrication Process

Nozzle fabrication is different from another part. It uses the turning process to create as shown in Figure 4. Lathe machine has been used for creating the nozzle.

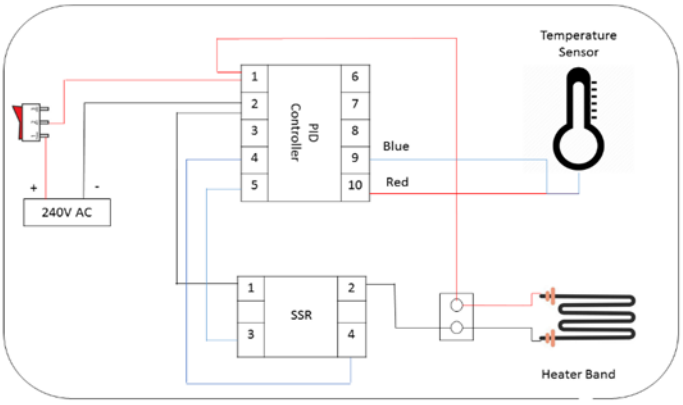

Fig. 5: Schematic Diagram of Heating Element

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After finishing all fabrication, the framework of the extruder, start wiring the electrical and electronic part. For the PID controller and heater, the wiring connection is connected by using the schematic diagram software as shown in Figure 5.

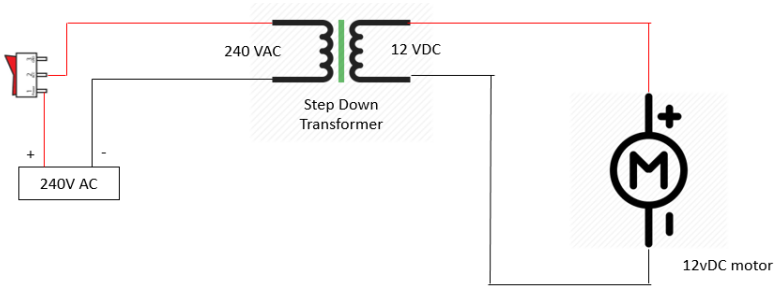

Fig. 6: Schematic Diagram for Motor

Figure 6 above shown the wiring connection for the motor. For this project, the researcher using 12vDC motor. So, step down transformer is used. Finishing of plastic extruder starts with polish the body of extruder using sandpaper and wire brush. The process needs to be done to remove all rusty before start painting the frame. After all, the body is smooth and flat, coating the body using the white colour spray. Then finish using the black flat spray.

III. DATA ANALYSIS AND INTERPRETATION

The fabrication process of the plastic extruder is taken four months to finish with all the process including assembly, finishing and wiring system

Fig. 7: Final Product of Plastic Extruder

Based on Figure 7, showing the final prototype of the plastic extruder. Motor runs very efficient as it rotates the screw effectively to push the raw plastics across the barrel. The heater band is heating the barrel successfully with the combination of PID controller that controls the temperature of the heater band. The figure below shows the outcome of plastic filament from the extrusion.

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Fig. 8: Plastic Extruder Testing Process

In figure 8, showing the outcome of plastic during the testing process. In this testing, the temperature is set around 260°C for heating barrel parts and 300°C for the heating part for the nozzle. At first, the output of plastic is not stable and not smooth because of heating temperature still not stable and plastic is not melting properly. After a few minutes, plastic that comes out from the nozzle start to melt properly and outcome become smoother. At the end of this testing, comparison between output filament from the plastic extruder is compared to the existing plastic filament. The heating temperature of plastic is based on Table 3 below:

Table 3. Melting Point of Polymer

Type of Polymer	Melting Point (°C)
PLA – Polylactic Acid [20]	150 – 160
ABS – acrylonitrile butadiene styrene [21]	200 - 280
PP – polypropylene [21]	168 - 175
PET – polyethylene terephthalate [21]	245 - 270

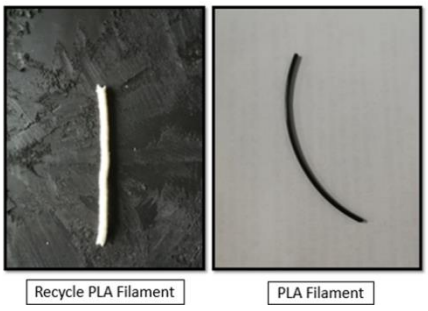

Fig. 9: Comparison Between Recycled PLA Filament and Existing PLA Filament

From figure 9 above, show the comparison between plastic extruder filament and existing filament. From the comparison showing that the existing filament is more smooth than the outcome

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filament from the extruder. The initial heating temperature may affect the output filament of the extruder.

The final cost for this project showing that costs for the development of plastic extruder can be categorized as a low-cost machine compares to the existing plastic extruder. Table 4 below shows the comparison in costing of the plastic extruder.

Table 4. Price Comparison of Plastic Extruder

Type of Machine	Diagram	Price
Plastic extrusion machine pp pipe extruder single screw extruder		50,000 USD
Mini plastic extrusion machine		25,000 USD
Plastic Extruder		300 USD

III. CONCLUSION

The conclusion for this project shows that this machine successfully functions. Start with the design development, fabrication process and finally testing the prototype is fully functional same as the target set by the researcher for this project in term of education perspective. The sustainability concept is also applied for this project. The raw material is taken from plastic waste, besides the cost of this project is much lower than the existing product.

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REFERENCES

[1] A. Mohd, M. H. L. Adnan, N. B. Baba, Z. A. Selamat, A. N. M. Rose, S. B. Mohamed, 'Optimization of surface roughness and tool wear on AISI 4140 using coated Ni-YSZ for CNC turn-ing process', Journal of Physics: Conf Ser. 2020;1532

[2] D. E. Crawford, 'Extrusion–back to the future: Using an established technique to reform automated chemical synthesis', Beilstein journal of organic chemistry, vol. 13, no. 1, pp. 65–75, 2017.

[3] N. Singh, D. Hui, R. Singh, I. Ahuja, L. Feo, and F. Fraternali, 'Recycling of plastic solid waste: A state of art review and future applications', Composites Part B: Engineering, vol. 115, pp. 409–422, 2017.

[4] Jalal Abdullah S, Shaikh Mohammed J. Low-cost low-tech obstacle pushing/gliding wheelchair accessory. Disabil Rehabil Assist Technol [Internet]. 2019;14(8):849–58. Available from: https://doi.org/10.1080/17483107.2018.1539130

[5] S. Ebnesajjad, 'Extrusion', in Fluoroplastics, Elsevier, 2015, pp. 282–347.

[6] R. Emas, 'The concept of sustainable development: definition and defining principles', Brief for GSDR, vol. 2015, 2015.

[7] K. Tomislav, 'The Concept of Sustainable Development: From its Beginning to theContemporary Issues', Zagreb International Review of Economics & Business, vol. 21, no. 1, pp. 67–94, 2018.

[8] Abdullah SHYS, Mohd Azizudin MAA, Endut A. Design and prototype development of portable trash collector boat for small stream application. Int J Innov Technol Explor Eng. 2019;8(10):350–6.

[9] A. Joseph Rajkumar, K. Anes, and C. Mohan, 'Emerging Threats on Environmental Sustainability', 2018.

[10] S. Radhakrishnan, 'Environmental implications of reuse and recycling of packaging', in Environmental Footprints of Packaging, Springer, 2016, pp. 165–192.

[11] S. Barr, Environment and society: Sustainability, policy and the citizen. Routledge, 2016.

[12] M. T. Lasut et al., 'From coral triangle to trash triangle—how the hot spot of global marine biodiversity is threatened by plastic waste', presented at the Proceedings of the International Conference on Microplastic Pollution in the Mediterranean Sea, 2018, pp. 107–113.

[13] M. Geissdoerfer, P. Savaget, N. M. Bocken, and E. J. Hultink, 'The Circular Economy–A new sustainability paradigm?', Journal of cleaner production, vol. 143, pp. 757–768, 2017.

[14] A. Gilchrist and M. Taylor, The Short Guide to Community Development 2e. Policy Press, 2016.

[15] western Australian Council of Social Service, 'collaboration for sustainability'.

[16] E. Eizenberg and Y. Jabareen, 'Social sustainability: A new conceptual framework', Sustainability, vol. 9, no. 1, p. 68, 2017.

ISSN: 0011-9342 | Year 2021
Issue: 6 | Pages: 4269- 4278

[17] D. Drotman, M. Diagne, R. Bitmead, and M. Krstic, 'Control-Oriented Energy-Based Modeling of a Screw Extruder Used for 3D Printing', presented at the ASME 2016 Dynamic Systems and Control Conference, 2016, p. V002T21A002-V002T21A002.

[18] P. S. Bains, S. S. Sidhu, and H. Payal, 'Fabrication and machining of metal matrix composites: a review', Materials and Manufacturing Processes, vol. 31, no. 5, pp. 553–573, 2016.

[19] Wan Ismail, W.O.A.S., Hamzah, Noraini & Tee, M.N.M.R.. (2018). Skills Workers in Mechanical Engineering to Produce Portable Sprocket. International Journal of Engineering and Technology(UAE). 7. 48-52. 10.14419/ijet.v7i2.14.11153.

[20] J. Milde, R. Hrušecký, R. Zaujec, L. Morovič, and A. Görög, 'Research of ABS and PLA materials in the process of fused deposition modeling method', Annals of DAAAM & Proceedings, vol. 28, pp. 812–820, 2017.

[21] H. A. Maddah, 'Polypropylene as a promising plastic: A review', Am. J. Polym. Sci, vol. 6, no. 1, pp. 1–11, 2016.