UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND DEVELOPMENT OF SUSTAINABLE FILAMENT EXTRUDER FOR 3D PRINTER

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering Technology (Product Design) With Honors

by

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TAJUK: **Design and Development of Sustainable Filament Extruder for 3D Printer**

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Product Design) With Honors. The member of the supervisory is as follow:

…………………………………

(Project Supervisor)

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ABSTRACT

The purpose of this study is to design and develop a sustainable filament extruder for 3D printer. A filament extruder is a device that used to create spools of plastic filament for the usage of 3D printer material supply. It also can recycle the expensive plastic waste created from the 3D printing process and transform it to useful thermoplastic 3D printer filaments again and again, which lead to cost reduction for 3D printing process. During the process of this project, several literature reviews are taken out as to study the design of the existing filament extruders and apply the knowledge gained from the researches on developing the methodology of the design. By referring the design of the existing filament extruder, several design concepts and approaches are being developed before going to prototyping process. A filament extruder prototype was fabricated at the end of the project.

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ABSTRAK

Tujuan kajian ini adalah untuk merekacipta dan membangunkan extruder filamen mampan untuk pencetak 3D. Extruder filamen adalah alat yang digunakan untuk membuat gulungan filamen plastik untuk kegunaan dalam bekalan bahan pencetak 3D. Ia juga boleh mengitar semula sisa plastik yang mahal dicipta daripada proses percetakan 3D dan mengubahnya ke filamen termoplastik pencetak 3D yang berguna selagi-lagi, ini membawa ke pengurangan kos untuk proses percetakan 3D. Semasa proses projek ini, beberapa kajian kesusasteraan dijalankan untuk belajar reka bentuk extruder filamen yang sedia ada dan menggunakan pengetahuan yang diperolehi dari penyelidikan itu dalam pembangunan metodologi reka bentuk di mana paten dan standard diambil kira. Dengan merujuk reka bentuk extruder filamen yang sedia ada, beberapa konsep reka bentuk dan prosedur akan dibangunkan sebelum sampai ke proses prototaip. Prototaip extruder filamen telah difabrikasi pada akhir projek.

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DEDICATIONS

I dedicate this thesis to my parents and relatives who have always giving me a great support and love that motivates me on achieving my goals along the way of my study life. In doing so, I would like to dedicate this project to my lecturers Engr. Hassan bin Attan, En. Aminurrashid Bin Noordin, En Khairum Hamzah, En. Mohd Faiz, En. Abd Khahar Bin Nordin, and En. Mohamad Ridzuan Bin Mohamad Kamal who are my Guru on providing me so much useful knowledge and provide guidance or supports for me along the way of my final year project. Furthermore, I would like to dedicate this project to technicians En. Mohd Syafiq Bin Ismail, En. Norhisham Bin Abdul Malik, En. Mohd Azimin Bin Ibrahim, En. Muhammad Zuhri Bin Shari who provide me a great assist and guidance on fabricating my project's prototype. I also dedicated this thesis to my friends Chong Jia Ying, Anddy Chia, Tan Ong Leng, Yoon Boon Hong, and Chan Wei Nick who lend me a help on my project's prototype.

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LIST OF SYMBOLS AND ABBREVIATIONS

ABS	=	Acrylonitrile Butadiene Styrene
PLA	=	Poly-Lactic Acid
HDPE	=	High Density Polyethylene
PPSU	=	Poly-Phenyl-Sulfone
HIPS	=	High Impact Polystyrene
PC	=	Polycarbonate
˚C	=	Degree Celsius
3D	=	Three Dimensions
2D	=	Two Dimensions
RP	=	Rapid Prototyping
FDM	=	Fused Deposition Modelling
STL	=	Standard Triangulation Language
CAD	=	Computer-Aided Design
CAM	=	Computer-Aided Manufacturing
CNC	=	Computer Numerical Control
SLS	=	Selective Laser Sintering
SUV	=	Sustainable Use Value
DLP	=	Digital Light Processing
LOM	=	Laminated Object Manufacturing
LS	=	Laser Sintering
SLA	=	Stereo Lithography

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AC	=	Alternating Current
DC	=	Direct Current
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UTeM	=	Universiti Teknikal Malaysia Melaka
BOM	=	Bill of Material
US$	=	United State Dollar
RM	=	Ringgit Malaysia
kg	=	Kilogram
rpm	=	Rate per Minutes
mm	=	Millimeter
V	=	Volt
W	=	Watt
Hz	=	Hertz
A	=	Ampere

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CHAPTER 1
INTRODUCTION

1.1 Background

3D printing technology has becoming a new fashion way to create and fabricate almost anything in various kind of fields including industry, engineering, biomedical, food tech, buildings, archaeology and many more. The flexibility of this technology has lent their arm to regular people by providing a great and powerful tool on design and production in short period of time with convenient way.

3D printing is also known as additive manufacturing which is a process of fabricating 3D objects from digital file that are created from CAD software. In industry field, the additive process is operated by laying down successive layers of thermoplastic materials until the whole object is formed and it results the thin sliced horizontal layers on the surfaces of the object. Moreover, the material used for the 3D printer appears to be in the filament form that coiled by a spool and the making of the plastic filament is done by a sustainable filament extruder.

A sustainable filament extruder is a device that used to produce a spool of filament from raw thermoplastic materials such as acrylonitrile butadiene styrene (ABS) pellets as to offer material supplement for 3D printer with efficient way. Furthermore, when it comes to the issue of sustainability, the purpose of the sustainable filament extruder is to produce a recyclable 3D printer filament from thermoplastic waste as to enhance the continuity usage of the plastic materials which reduces the cost of 3D printing process.

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1.2 Problem Statement

The 3D printing technology of today's world is so advanced that almost anything can be easily made by printing process compared to the pass. However, when it comes to environment friendly and the issue of production cost, there still a gap is waiting to be improved.

A digital file of 3D modelling is created at the early stage by a designer. By regarding the fancy design of the object, several supporting parts that are going to be removed at the last stage will be generated according to their shapes and geometries, therefore, some portion of the thermoplastic filament will be wasted when the printed object contains large amount of supporting structures. Moreover, some designers may make mistake during the early stage and the fault object is being printed out which causing a great waste of the costly thermoplastic materials.

According to Amazon.com, 1kg spool of ABS plastic material costing a range between US$20 to US$50 which is so expensive to use. Furthermore, 1kg of spool can print out 1kg of objects, which means that it is easy to be rapidly consumed if designer tend to print out a bunch of solid objects instead of just leaving the prototypes with hollow features and bringing the result of increasing of the production cost due to replace and refill the new spools of ABS filament.

1.3 Objective

In this project, several objectives will be implemented such as:

1) To understand the process in developing a sustainable filament extruder.
2) To study the mechanisms of the filament extruder.
3) To design and fabricate a sustainable filament extruder prototype.
4) To develop a recyclable and re-useable filament for 3D printer.

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1.4 Scope of Work

The aim of this project is to understand the process in developing a sustainable filament extruder for 3D printer. At the beginning of this project, several case studies and researches will be carried on as to study and investigate the mechanisms of the existing filament extruder. Parts design will be proceed by using CAD software and reverse engineering also will be conducted upon the existing parts that are chosen to be the part of the filament extruder prototype. Several redesign stages and structure analysis processes will be carried out until the result is satisfied for the outcome of this project. At the next stage, the prototype of the designed filament extruder will be fabricated and several testing and troubleshooting will be carried upon the prototype at which the result will be recorded in the progress report of the project.

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CHAPTER 2

LITERATURE REVIEW

2.1 Sustainability

Sustainability is defined as a process development or system that managed to solve the issues of serious deterioration of the environment and the natural resources that peoples are used to relied on. According to the definition from Brundtland Commission, sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Anthony Johnson, Andy Gibson, 2014). This shows that a high quality of life and a vibrant economy will be created which results from a commitment to "triple bottom line" which is environment, social and health of economy as shown in Figure 2.1 below.

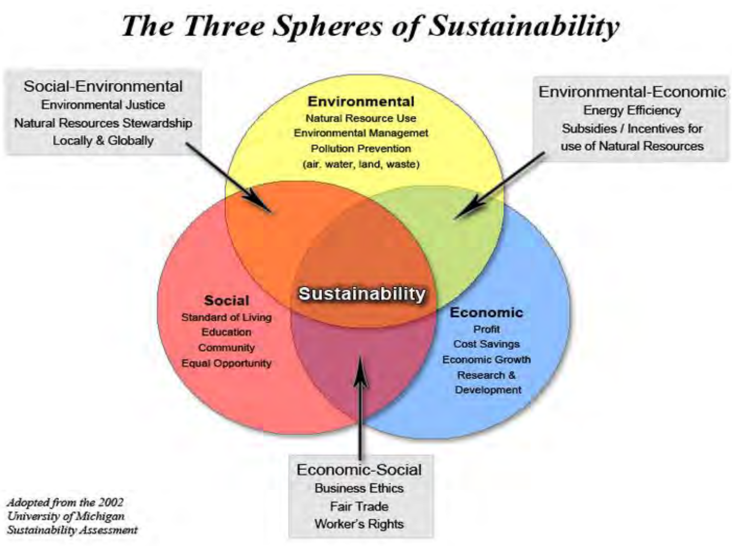

Figure 2.1: The triple bottom line of sustainability

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2.1.1 **Achievement of Sustainability**

According to the words from an unknown industrialist, "Everything costs money; everything has an environmental impact." (Anthony Johnson, Andy Gibson, 2014). This shows that the resources in terms of materials and the manipulating energy are needed for every product development. Hence, the sustainability can be enhanced by 4Rs which are recycles, reuse, refurbish and reduce. By applying the 4Rs approach, the life cycle of a component or product can be hugely addressed and enabling the reuse of the materials.

2.1.2 **Open-loop Material Cycle**

When taking the perspective from the open-loop material cycle shown in Figure 2.2, energy is always being consumed from raw materials extraction to the process of manufacturing production, and then comes to the usage in the form of a product by the users and finally will be disposed when the product have reached their life cycle limit. This clearly shows that it is not sustainable over long-term and fail to consider the issues that are associated with the resources of material or the energy consume to transport those materials.

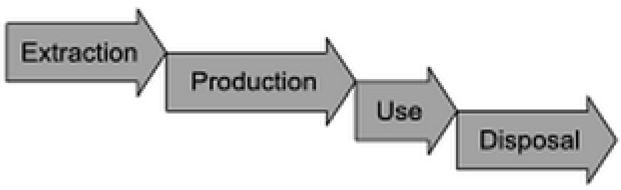

Figure 2.2: Open-Loop Material Cycle

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2.1.3 **Closed-loop Material Cycle**

When comes to the closed-loop material cycle shown in Figure 2.3, raw materials can be used for the next generation of product from the previous form of a product which means that the material and energy of a product can be reproduced, reused, and recovered before comes to disposal at the end of their life cycle limit. Hence, leading a great reduction in materials disposal, extending the reserve life of key materials, lowering required energy to remanufacture a product, and reduce the usage of energy in transport that served as restoration and reparation upon local activities.

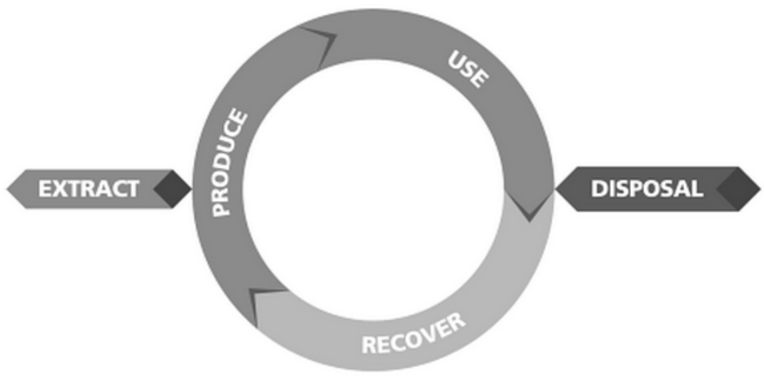

Figure 2.3: Closed-loop material cycle

2.1.4 **Design for Sustainable Use**

Design for sustainable use is an important step to achieve sustainability upon the life cycles of a product where environmental impact is being considered. During the sustainable design process, designers have a responsibility to lower the environmental impact during and after the product are created or massively manufactured. For example, during the past period of time, a machine would be designed in huge size and complexity which consume a lot of energy during their lifetime than its production and causing bad impact to environment, therefore, designers and manufacturers are playing the role to reduce the energy consumptions

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by applying the design for sustainable use, optimizing the design of the machine over years to minimize the size of the machine and improve their life cycles that pose the key challenge to the industry field.

2.1.4.1 Design Optimization

Design optimization is a technical approach that used to improve the methods to solve the problems of design that are integrating with several disciplines. For example, in the aspect of filament extruder design, simplicity is the key of the improvement to reduce the energy consumption by optimize the motor and heaters to smaller size, reduce the size of machine, and remove the unwanted features that cause complexity upon the machine. Besides that, design optimization can be applied in several modes for specific functions and conditions of design, for example, the mechanisms of FDM printer is used to print a 3D object layer-by-layer from plastic filament that is being melted by heater compare to Selective Laser Sintering (SLS) printer where their mechanisms are using laser as power source and uses powder material although both are posing similar function as to printing a 3D object. Furthermore, the sustainable use value (SUV) can be improved by applying this approach by selecting suitable power system and their way of use in order to reduce energy emissions to the environment.

2.1.5 **Design for Sustainable Disposal**

When considering the whole life cycles of a product, the route to disposal should be taken into account and plan correctly by designers. By taking the model for end-of-life decision action shown in Figure 2.4, the design progress would contains several levels of hierarchy that would be included into the design for disposal.

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