# CONCEPT DESIGN AND ANALYSIS OF FILAMENTS EXTRUDER FOR 3D PRINTING

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# CONCEPT DESIGN AND ANALYSIS OF FILAMENTS EXTRUDER FOR 3D PRINTING

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**This report is submitted**
**in fulfillment of the requirement for the degree of**
**Bachelor of Mechanical Engineering (Hons.)**



**Faculty of Mechanical Engineering**

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# REKA BENTUK KONSEP DAN ANALISIS EXTRUDER FILAMEN UNTUK PENCETAKAN 3D

**AHMAD FAISAL BIN AZAM**

**Laporan ini dikemukakan sebagai**
**memenuhi sebahagian daripada syarat penganugerahan**
**Ijazah Sarjana Muda Kejuruteraan Mekanikal (Kepujian)**



**Fakulti Kejuruteraan Mekanikal**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2021**

**DECLARATION**

I declare that this project report entitled "Concept Design and Analysis of Filaments Extruder for 3D Printing" is the result of my own work except as cited in the references.

Signature : ......................................

Name : AHMAD FAISAL BIN ADAM.

Date : 17/8/2021

## APPROVAL

I hereby declare that I have read this project report and in my opinion that it is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Hons.).

Signature : ……………………………..

Supervisor's Name : ……………………………..

Date : ……………………………..

## DEDICATION

To my beloved mother and father

# ABSTRACT

The primary aim of this project is to build a DIY filament extruder. The filament needs to be compatible with FDM 3D printers. The filament required has a diameter of 1.75mm. The expected quality is standard filament, which should be capable of feeding into 3D printers. This extruder was designed specifically for 3D printers. Extrusion systems designed specifically for filament are expensive, and only a few manufacturers and engineers throughout the globe produce them. Even the cheapest filament extruder on the market is still costly when compared to the cost of the 3D printer. The cost of an extruder is typically two times that of a 3D printer. This research project allows users to construct a filament extruder for less than 500 Malaysian Ringgit. For people who simply require filament for any reason, the new DIY filament extruder might save a lot of money. Instead of purchasing filament, learners, researchers, and anybody else who wants to create their own filament can use this DIY extruder. This DIY extruder will be a portable equipment, making it simple to use at the office, home as well as while travelling.

# ABSTRAK

Matlamat utama projek ini adalah untuk membina extruder filamen buatan sendiri ataupun DIY. Filamen perlu serasi dengan pencetak 3D FDM. Filamen yang diperlukan mempunyai diameter 1.75mm. Kualiti yang dijangka adalah filamen yang mengikuti piawai, dan seharusnya mampu digunakan oleh pencetak 3D. Extruder ini direka khas untuk pencetak 3D. Sistem penyemperitan yang direka khas untuk filamen adalah mahal, dan hanya beberapa pengeluar dan jurutera di seluruh dunia yang menghasilkannya. Malah extruder filamen termurah di pasaran masih mahal jika dibandingkan dengan kos pencetak 3D. Kos extruder biasanya dua kali ganda daripada pencetak 3D. Projek penyelidikan ini membolehkan pengguna membina filamen extruder dengan harga kurang dari 500 Ringgit Malaysia. Bagi orang yang hanya memerlukan filamen dengan alasan tersendiri, extruder filamen DIY ini mungkin menjimatkan banyak duit. Daripada membeli filamen, pelajar, penyelidik, dan sesiapa yang ingin membuat filamen mereka sendiri boleh menggunakan extruder DIY ini. Extruder DIY ini akan menjadi peralatan mudah alih, menjadikannya mudah digunakan di pejabat, rumah dan juga di mana-mana sahaja.

## ACKNOWLEDGEMENT

I would like to give my supervisor, Dr. Shafizal, a tremendous gratitude for guiding my final year project from start to finish, as he never hesitates to give advice and inspiration to complete the project, I am honoured to do a project under his guidance. In this mission, I am very much in debt to his patience and acceptance while guiding me.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| ABS | Acrylonitrile Butadiene Styrene |
| AM | Additive Manufacturing |
| CAD | Computer-Aided Drawing |
| DIY | Do it yourself |
| FDM | Fused Deposition Modelling |
| FFF | Fused Filament Fabrication |
| PLA | Poly Lactic Acid |
| PDS | Product Design Specification |

# CHAPTER 1

# INTRODUCTION

## 1.1 Project Background

Additive manufacturing also referred as digital fabrication technology or 3D printing by adding material repeatedly to create object. In this day, 3D printing is widely used globally and increasingly used for fabrication of prototypes and custom parts in automotive industry, locomotive industry, agriculture, healthcare and even aviation industry. 3D printing works by printing object layer by layer of material form a computer aided design (CAD) drawing. In addition, researcher has frequently stressed the important role of computer-aided design (CAD) (Maietta et al., 2018), reverse engineering and theoretical/experimental research, since the use of such modi operandi has led to the outline of modern gadgets for various applications (Lanzotti et al., 2015).

The field of 3D printing has increase aggressively in the recent years. This technology that prints object layer by layer of material allows designer to produce prototypes quickly and in a cheaper way (Lanzotti et al., 2019). However, the cheapest filament extruder on the marketplace is still costly as compared to the cost of the 3D printer. The cost of an extruder is usually two times that of a 3D printer (Bijaya Paudel, 2015). For those that just need filament for some reason, this new custom Do It Yourself (DIY) filament extruder would save a lot of money for students, researchers or even industry. Instead of buying filament, they can make their own filament using the DIY filament extruder. Thus, to make the filament extruder feasible, the working principles of the real machine should be investigated to optimize it uses for the end users.

The filament extruder functions when placing the scrap of resin filaments pieces into a tunnel which is then pushed through by a spiraled auger operated by a small stepping motor. The substance will flow through the duct to the "hot end", which will host a heated die. This is a very narrow tunnel with a diameter of just under two millimeters. When the substance approaches the end of the tube with the die, the heaters mounted to the tip will have a hot area, melting the scrap filament fragments before forcing them through the die and extruding them onto a fresh strip of recycled filament, ready for potential use for 3D printing (M. Rensberger et. Al, 2016).

Printing materials such as polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS) are commonly use as FDM product. PLA is biodegradable as it comes from organic medium and can be controlled using different techniques such as reprocessing, combustion, dressing and discarding in landfills causing. Compared to petroleum-based plastics, PLA has less ecological implications. Thus, to save the environment, the filament and product of PLA and ABS plastics are recycled back to become the filament itself (Gaikwad et al., 2018).

## 1.2 Problem Statement

A new study from the United Nation estimates the volume of e-waste in 2021 will hit ~52.2 million tonnes, with a growth rate of 3-4% per annum of 1. On the global scale, the rate of e-waste recycling is poor at 15 percent, and this is because of its diverse existence as it consists of numerous and varied elements including metals, glass, and plastics (Gaikwad et al., 2018).

The PLA and ABS plastic filament is currently in use to construct a prototype or product in additive manufacturing or 3D printing. Since the amount of waste from the product is increasing, they need to be recycled back to become a new filament from the product.

Recycling PLA for 3D-printing applications may minimize harmfulness to the environment, but the depletion of mechanical properties has become a concern (Zhao X.G. et. al, 2018). In terms of thermal properties, the melting point of the first recycled PLA reduces significantly, which can be explained by the presence of shorter PLA chains due to chain breaking (Fonseca Valero et. al, 2014).



Bijaya Poudel (2015) stated that the filament extruder is usually two times of a 3D printer. For example, the price of a filament extruder that available on market is about RM800 to RM5000 that are a little bit expensive for students or even researchers for their uses.

In this research, a few concepts design and DIY filament extruder will be present that are cheaper than the one that are available in the market.

## 1.3 Objective

1. To investigate and study the mechanism and concept of filament extruder.
2. To design an own DIY filament extruder
3. To provide an analysis on the filament extruder part.

## 1.4 Scope of Project

1. The filament extruder is specially designed for PLA and ABS filament materials.
2. The filament extruder will only be design using Solidworks software.
3. Analysis of CFD on die of the filament extruder, stress and shear analysis, and simulation will be carried out using ANSYS and Solidwork software.

## 1.5 General Methodology

The action that needs to be carried out to achieve the objectives in this project are listed below.

1. Literature review
The review will be covered in journals, articles, patents or any relevant materials regarding the project.

2. Study on requirements of operation standard in the industry
A study on the requirements of safety and operation standards will be done to make sure the design follows the standard and can be used in industrial.



3. Design development

Design and development of the filament extruder will be done based on the study and requirements.

4. Analysis and simulation
Analysis of the design will be done to achieve optimal design optimization.

5. Report writing
A report on this study will be produced at the end of the project.

The general methodology is summarized in the Figure 1.1. The literature review is done to obtain the equipment and parts needed, design and development and to know the experience of other researchers about the filament extruder.

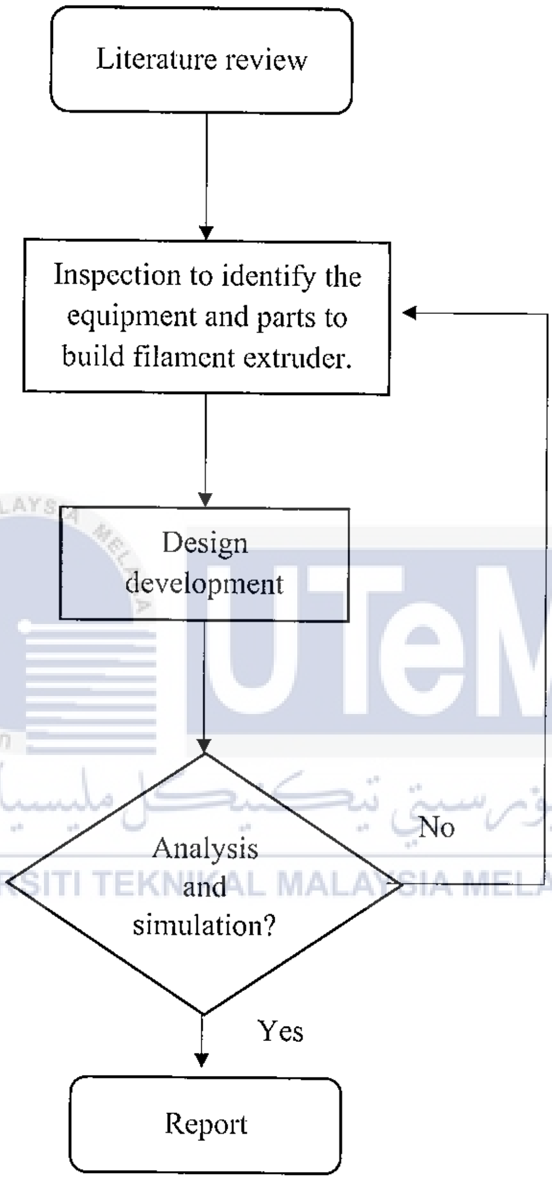


Figure 1.1: Flow Chart of Methodology.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Background of PLA and ABS Plastic

### 2.1.1 Polylactic Acid (PLA) and Its Recyclability

The use of Polylactic Acid (PLA) polymers has been widely spread for a long period. PLA materials is upgrading in different modification by researchers to make it more products friendly. The properties of PLA that exist now may affect the suitability for different products and applications. Proper analysis and classification of PLA and PLA precursors at various stages of development are important for regulating the features and reliability of the resulting product (Saara et. al, 2011).

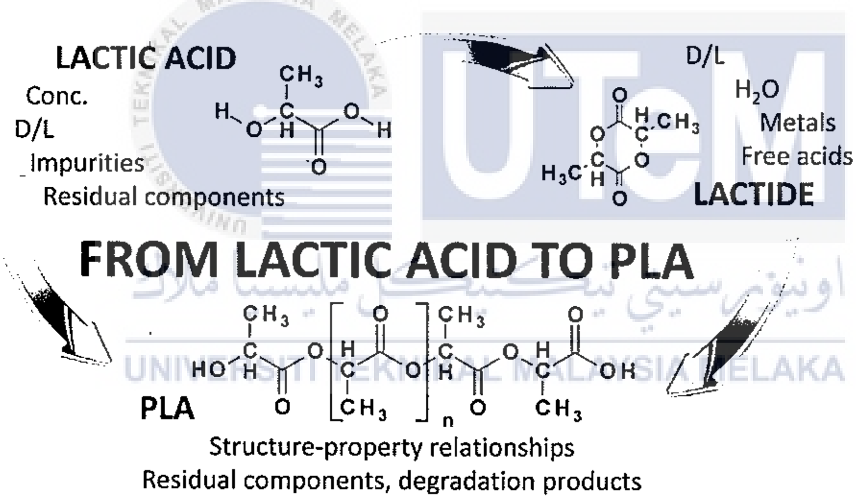


Figure 2.1:Chemical Structure of PLA (Source: Saara et.al, 2011).

According to Figure 2.1 and Figure 2.2, PLA are thermoplastics that made from renewable resources and petroleum based. Corn starch, tapioca roots or sugarcane are some the raw materials that form PLA under fermentation process and controlled conditions of carbohydrates. Then, from the process, it forms either lactic acid or lactide monomers and later being polymerized. Besides, PLA is also biodegradable that are environmentally friendly and can turn into composite. Other plastics in the industry have a different characteristic to the PLA due to users' preference to use unharmed materials to the environment makes PLA is one of the competitive materials in the market. Without degrading its mechanical properties, PLA can be recycled through any process (Rocio Jaimes, 2020).

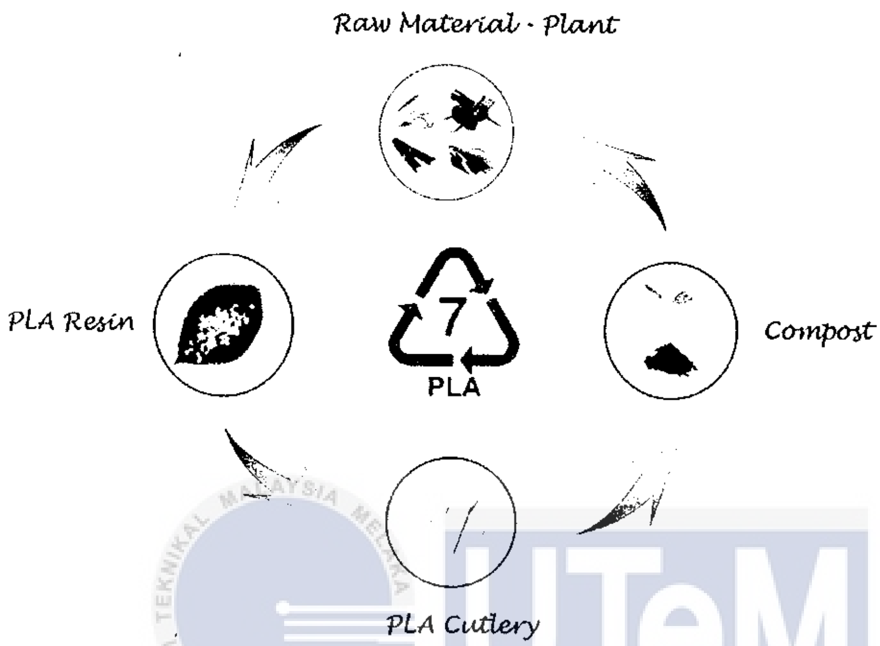


Figure 2.2: Recyclable of PLA (Source: Rocio Jaimes, 2020).



Other than that, PLA can be a competition to Polystyrene due to its large availability and economical value in the market. It also has a lower environmental effect than the Polystyrene but have the same mechanical properties and suitable for medical and food packaging (Auras et. al, 2010). The mechanical properties of PLA is shown in Table 2.1.

Table 2.1: Mechanical Properties of PLA (Source: K. Velde and P. Kiekens, 2002).

| Properties[a] | Type of biopolymer | |
|---|---|---|
| | Unit | PLA |
| $\rho$ | g/cm$^3$ | 1.21–1.25 |
| $\sigma$ | MPa | 21–60 |
| $E$ | GPa | 0.35–3.5 |
| $\varepsilon$ | % | 2.5–6 |
| $\sigma^*$ | Nm/g | 16.8–48.0 |
| $E^*$ | kNm/g | 0.28–2.80 |
| $T_g$ | °C | 45–60 |
| $T_m$ | °C | 150–162 |

[a] $\rho$ – Polymer density, $\sigma$ – tensile strength, $E$ – tensile modulus, $\varepsilon$ – ultimate strain, $\sigma^*$ – specific tensile strength, $E^*$ – specific tensile modulus, $T_g$ – glass transition temperature and $T_m$ – melting temperature.
[b] am – amorphous and thus no melt point.

However, due to degradation, the recycled PLA has decreased in its tensile strength by 10.9%, decreased in hardness by 2.4% but increased in shear strength by 6.8% (Anderson, 2017). The formation PLA is from Lactic acid solutions that than undergoes addition of polymer as shown in Figure 2.3.

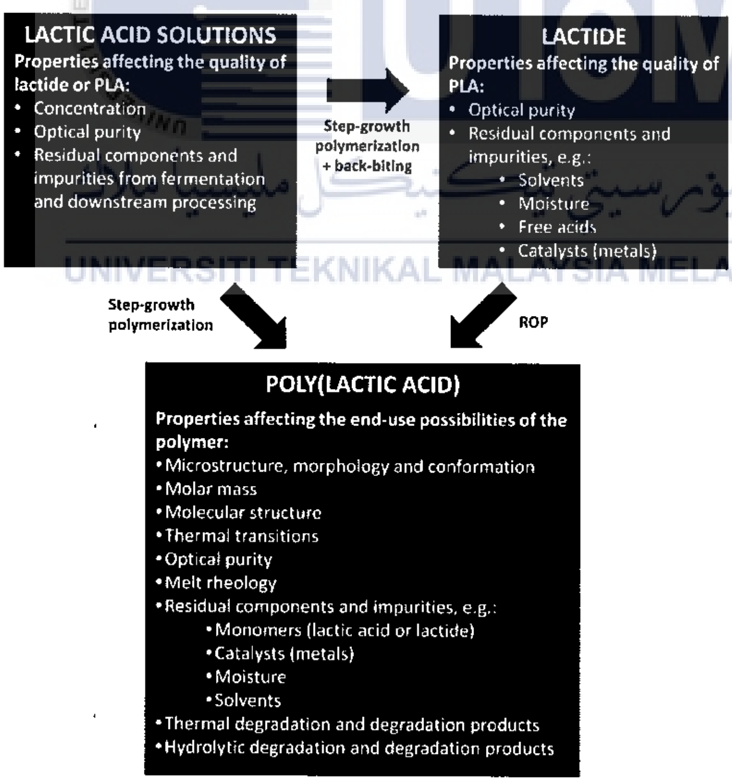


Figure 2.3: Formation of Polylactic Acid (PLA) (Source: Saara et. al, 2011).

### 2.1.2 Acrylonitrile Butadiene Styrene (ABS) and Its Recyclability

Acrylonitrile Butadiene Styrene (ABS) form from polymerization of monomers named acrylonitrile, butadiene, and styrene. ABS is an engineering thermoplastic polymer which consists of an amorphous-continuous condition and a rubbery-dispersed condition. The continuous condition forms from the Poly(styrene-coacrylonitrile) (SAN) and the second condition contains the dispersed butadiene or butadiene polymer. The two conditions are compatible since these fragments have a layer of SAN implant onto their exterior (Mark HF, 1985). The first ABS plastic was use in 1940s that led to a higher strength and impact resistance properties to plastic. During World War II, a bulletproof polymer sheets were manufacture optimizing from a high molecular mass of butadiene-acrylonitrile copolymers and styrene-acrylonitrile copolymers (Olivera et. al, 2016). Figure 2.4 below shows the monomer units of ABS that consist of Acrylonitrile, Butadiene and Styrene.

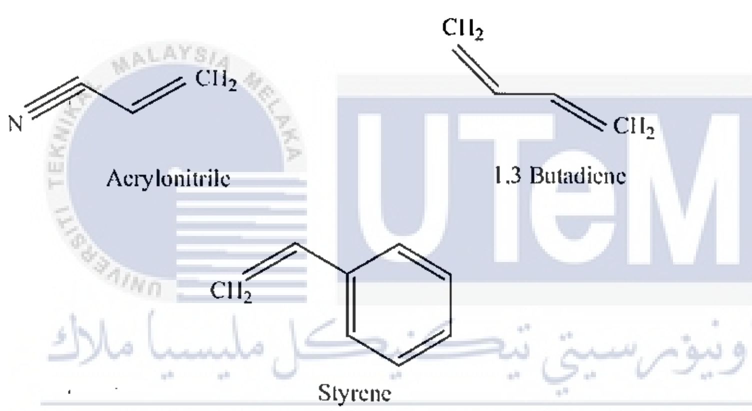



Figure 2.4: Monomer units of ABS (Source: Olivera et. al, 2016).