UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

A STUDY ON EXTRUSION PROCESS OF FLD-25 3D FILAMENT MACHINE AND OPTIMIZATION OF TEMPERATURE PARAMETER FOR FILAMENT PRODUCTION

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering Technology (Product Design) with Honours.

by

SITI NURMARIAH BINTI SAUPI

B071610489

960829105006

FACULTY OF MECHANICAL AND MANUFACTURING ENGINEERING TECHNOLOGY

2019

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **A Study on Extrusion Process of FLD-25 3D Filament Machine and Optimization of Temperature Parameter for Filament Production**

SESI PENGAJIAN: **2019/2020 Semester 1**

Saya **SITI NURMARIAH BINTI SAUPI**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐	TERHAD	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)
☐	SULIT	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☒	TIDAK TERHAD	

Disahkan oleh:

Alamat Tetap:

P/T 100 KG TEMPOYAK, BEKELAM JELAWAT, 16070 BACHOK, KELANTAN.

Cop Rasmi:

TS. HASSAN BIN ATTAN
Jurutera Pengajar Kanan
Jabatan Teknologi Kejuruteraan Pembuatan
Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan
Universiti Teknikal Malaysia Melaka

Tarikh: 16th JANUARY 2020

Tarikh: 22/1/2020

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declare this report entitled "A Study on Extrusion Process of FLD-25 3D Filament Machine and Optimization of Temperature Parameters for Filament Production" is the results of my own research except as cited in references.

Signature : .....

Author's Name : Siti Nurmariah Binti Saupi

Date : 16th JANUARY 2020

APPROVAL

This report is submitted to the Faculty of Mechanical and Manufacturing 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:

Signature : .....

TS. HASSAN BIN ATTAN
Jurutera Pengajar Kanan
Jabatan Teknologi Kejuruteraan Pembuatan
Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan
Universiti Teknikal Malaysia Melaka

Supervisor's Name : Ts. En. Hassan Bin Attan

Date : 22/1/2020

ABSTRAK

Oleh kerana percetakan 3D berkembang dengan pesat dan meningkatkan penghasilan produk, pengekstrusan filamen telah menjadi sangat popular dan penting kerana pengeluar percetakan 3D perlu terus memenuhi permintaan pencetakan dan mengekalkan kuantiti dan kualiti stok filamen yang sesuai. Filamen yang berkualiti tinggi sangat penting untuk mendapatkan hasil pencetakan model yang terbaik. Tesis ini dilakukan untuk menambahbaik parameter suhu untuk proses pengekstrusan filamen dalam usaha untuk mendapatkan diameter filamen yang konsisten iaitu 1.75mm dengan toleransi ± 0.03mm. Filamen yang tidak mempunyai bentuk bulat yang sempurna tidak akan dianggap sebagai filamen yang bagus kerana menurut penyelidikan kesusasteraan, salah satu ciri penting untuk pencetakan 3D yang baik adalah diameter bulat filamen yang konsisten sepanjang kili. Tanpa bentuk bulat yang sempurna, hanya akan mengakibatkan kerosakan mesin pengekstrusan yang serius. Dalam tesis ini, hasil optimum yang diinginkan berkaitan dengan kualiti filamen dapat diperolehi dengan meningkatkan suhu pengekstrusan kerana peningkatan suhu boleh memberikan permukaan yang lebih licin, menghilangkan kawasan kawasan yang bengkak dan kawasan filamen yang tidak cair sepenuhnya.

ABSTRACT

As 3D printing is increasing rapidly and enhancing product growth, filament extrusion has becoming very popular and important due to the 3D printing manufacturers need to continually satisfy the demands of printing and retain an appropriate quantity and quality of filament stock. A good quality filament is very important to get the best result for printed models. This thesis will be working on the optimization of the temperature parameter for filament extrusion process in an attempt to obtain a consistent filament diameter which is 1.75mm with the tolerances ±0.03mm. A filament that does not have a perfectly round shape will not consider as a good filament because according to the literature research, one of the important features for a good 3D print is constant filament roundness along the spools. Without the perfect round shape, will only resulting in a serious extruder failure. In this thesis, the optimum desired outcome could be obtained with regard to the filament quality by increasing the temperature of the extrusion because increased the temperatures can result in a smoother surface, eliminating the swelled and not completely melted areas throughout the length of the filament.

DEDICATION

I dedicate this thesis to my parents especially my great and beloved mother, Normah Binti Hj Omar 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 supervisor Ts. Encik. Hassan Bin Attan, who are my Guru on providing me so much useful knowledge and provide guidance or supports for me along the way of my Bachelor Degree Project 1. Furthermore, I would like to dedicate this project to the engineer assistants Tc En. Basri Bin Bidin and Tc En. Kamaruddin Bin Abu Bakar who provide me a great assist and guidance during running the machine for my project. I also dedicated this thesis to my supportive friends Anisah Atirah Binti Hamzah, Nur Afiqah Binti Zulkifli, Siti Nadhirah Binti Mohd Shukor and Nur Hidayah Binti Mohd Rozlan who give me great encouragement and lend me a help in completing this project.

ACKNOWLEDGEMENT

Praise to Allah SWT for His help and guidance. I am able to complete the task for this Bachelor Degree Project 1. I would like to express my gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for providing me an opportunity to become a student to gain precious knowledge from both academy and practical in my study life. I would also like to give a great thank to my project supervisor, Ts. Encik. Hassan Bin Attan for his guide, advices, knowledge and encouragement that he give me along the way of the project in order for me to complete this project. On the other hand, not to forget the engineer assistants, Tc En. Basri Bin Bidin and Tc En. Kamaruddin Bin Abu Bakar who give me a lot of guidance and new knowledge during the process to complete this project.

Next, I feel so grateful to my mother and siblings for their love and supports for me when doing this Bachelor Degree Project 1. Their loves and supports really give me the strength to finish this project successfully. I also want to say thank you to all my friends, for sharing some ideas also lending me their ears and hands from obstacles that I had encountered along the way to complete this project report. Last but not least, thank you to other people who are directly or indirectly help me to finish this project. I sincerely appreciated the helps from all of you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

3D	-	3Dimension
ABS	-	Acrylonitrile-Butadiene-Styrene
PLA	-	Polylactic Acid
PVC	-	Polyvinyl Chloride
PC	-	Polycarbonate
PP	-	Polypropylene
PA	-	Polyamide
PS	-	Polystyrene
PE	-	Polyethylene
PVA	-	Polyvinyl Alcohol
HIPS	-	High-Impact Polystyrene
PET	-	Polyethylene Terephthalate
FDM	-	Fused Deposition Modelling
MW	-	Molecular weight
MWD	-	Molecular weight Distribution
Tg	-	Glass Transition
Tm	-	Melting Temperature
SAN	-	Styrene-Acrylonitrile
Mm	-	Millimetre
°C	-	Degree Celcius

CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter is about a brief explanation about the project. Chapter 1 consists of 4 elements such as background of study, problem statement, objectives of study and scope.

1.1 Background of Study

Extrusion is a technique of manufacturing lengthy, consistent cross-section products (rods, plates, tubes, films cable insulation layer) requiring soft material through a die with an entrance. Using a hopper, thermoplastic substance is fed into an extruder in the form of pellets or granules where it is heated up, blended and delivered to the die to mold the extrudate. The substance is then pushed forward through a feeding screw and forced to transform it into a constant polymer product through a die. The product is cooled after leaving the die by blown wind or in a water tank. During the last phase of extrusion, the melted extrudate solidified and then molded into the final shape and at constant speed the molten extrudate pulled away from the extruder to acquire the suitable cross section needed for the next step of the thermoplastic process. Placed above the barrel the heating components dampen and melt the material. Thermocouples control the temperature of the material. Extrusion is used primarily for thermoplastics, but it is also possible to extrude elastomers and thermosets.

In terms of temperature or any setting of parameters, if the temperature profile of th e extruder is incorrectly set, the ingredients of the product are not correctly formulated, the cooling on the extruder feed throat is not working properly, the temperature of the melt at t

he end of the extruder is incorrect, the temperature of the cooling bath is not set correctly, t he puller at the end of the line is running at the wrong speed, or any other incorrect operating condition or combinations of conditions, the product may not meet with the requirements.

There are two broad categories of extruders that are single-screw and twin-screw extruders. The single-screw extruder has been around for many years and is still the main type of extruder today owing to the ease of manufacturing and lower cost of materials, as well as its potential to manage high torques during polymer processing. Twin-screw extruders were mainly used for extrusion and compounding of polymer powder where high-quality dispersive mixing or well-defined residence periods for depolarization, temperature-sensitive materials, and reactive extrusion.

1.2 Problem Statement

The plastic extrusion technique is now an excellently-known method broadly used in the polymerization field in line with the growing demand for 3D printing products. Extrusion is a continuous method of production of the semi-finished component. Extrusion is a method of the main formation. Pumping the polymer into the die and mold the shape. It is possible to produce a profile, plate, cable, film tube or any other type of geometric form. In the industry, a 3D printer filament extruder plant was used to process the plastic material and then generate filament spools. Numerous filaments with varying materials were manufactured with the filament extruder machine.

In UTeM, there is a filament extruder machine which is FLD-25 3D Filament Machine. The machine production line is a single screw extruder and suitable for the extrusion of ABS, PLA. However, problem arise when the diameter of the filament cannot be maintain consistently. The problem occurs when the filament exiting through the die and insert the haul-off machine which is the filament traction. When the filament passes through the traction, it was pressed down by the traction and become flattened. This is due to the filament condition that does not cure enough or in another word it is not fully hardened after exiting the die.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

First, this chapter provides vital hypothesis about the process of extrusion and the most common plastic materials used in the production of 3D printing filament. Secondly, appropriate data about the content concerned with this job, which is PLA and ABS, is also evaluated. In addition, an outline of the manufacturing technique engaged in filament production is provided.

2.1 3D Printer Filament Extruder Machine

(Murugan, 2016) stated that 3d printer filament extruder is a machine that used thermoplastic materials such as PLA and ABS or may consist of plastic waste materials in the form of pellets or granules to produces specified diameter plastic filament by using matching dies.

2.1.1 History and Development of 3D Printer Filament Extruder

(Poudel & Poliakova, 2015) noted that the first screw machine was created in the 1870s and commercially produced in the USA in the 1890s. After that in 1900, Francis Shaw and Paul Troester created the extrusion process commercially in Europe. Then in 1870, Extrusion Technology was launched, which revolutionized the extruder system by setting precise temperatures in extrusion. Because of this technology, plastic deformation has been efficiently decreased. Also, the development of various thermoplastic materials had increased side by side. But, only some particular polymers had been processed by the

extruder machines. This is why it is important to design and produce extrusion machines that the broad variety of polymer kinds are incorporated and processed. However, the continuous developments produced in the manufacture of extruder machines have been effective in this respect since 1960. Afterward, the fundamental structure of the extruder machines did not alter. In fact, during manufacturing, each extruder machine follows certain mechanical procedures also the extruder system has recently been completely automated and the extrusion system has undergone enormous growth.

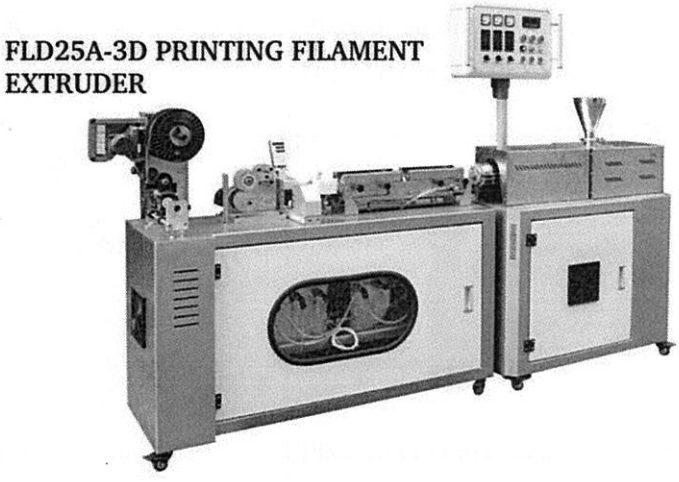
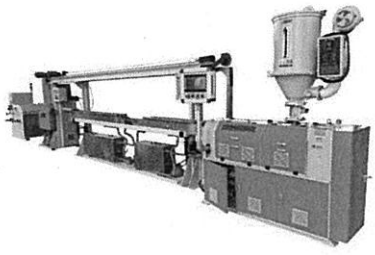
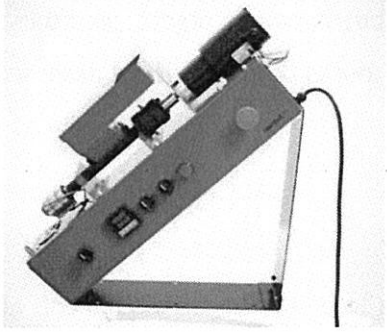
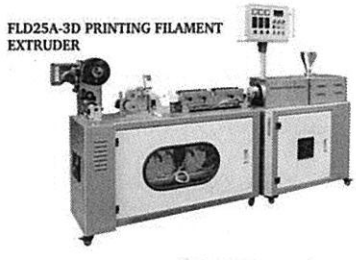
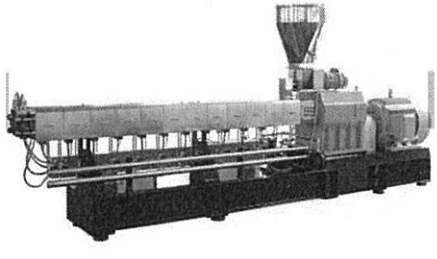


Figure 2.1: 3D Filament Extruder

(Source: https://www.friendplasticmachine.com)

2.1.2 3D Filament Machine in Industry

Table 2.1: Extruder Machine Used In Industry

 Place of Origin: China Brand Name: GS-mach Certification: CE ISO9001 Model Number: GS45	 Place of origin: UK Brand name: Noztek Pro
 Place of Origin: Jiangsu, China Brand Name: Friend Certification: CE,SGS,TUV Model Number: SJ25	 Place of Origin: China Brand Name: Friend Certification: CE,SGS,UV Model Number: FLD25
 Place of Origin: Guangdong, China Brand Name: SANREDIAN Certification: CE ISO Model Number: SESIL-20/28	 Place of Origin: Jiangsu, China Brand Name: Kairong Certification: CE ISO9001 Model Number: TSE-40

2.2 Types of Extruder

There are three types of extruder that been used in industry which is single screw extruder, twin screw extruder and multi screw extruder. Single screw extruder and twin screw extruder are the one that is the most popular used in polymer production.

2.2.1 Single Screw Extruder

(Poudel & Poliakova, 2015) stated that in this couple of years, lots of research has been done in order to find a more consistent and steady extrusion. Single screw extruder is frequently use for the basic and universal materials. It is uses only one screw within the system. Furthermore, (Campbell & Spalding, 2013) stated that over the past several decades, the use of single-screw extruders in production processes has made significant progress. This has resulted in a dramatic increase in the number of single-screw extruders in use, as has the diameter and length of the machine, particularly for melt-fed extruders used in large resin production plants. Resin manufacturers have also developed many new resins for finished products such as extruded sheet, film, pipe, fibers, coatings, and profiles. The extruder is still the process unit of choice in the production of polymer materials for producing pellets.

In addition, single screw extruder also often used in the plastic's industry to produce a molten polymer by melting, mixing and pump it through a die. Plus, (Altinkaynak, Gupta, Spalding, & Crabtree, 2006) stated that for a screw extruder, it will produce a poor quality extrudate because the solid fragments can be release from the extruder if the screw speed is increased over the limit which is why a larger screw length is needed as the screw speed is increased to fully melt the polymer. Due to this, it is very crucial to have an overall understanding of the melting process in order to get a proper design and operation of an extruder.

Besides, single screw extruder is a low-cost operating machines that are designed to be used for simple operations such as dry extrusion and simple formulations. These extruders are simple to operate and have been described by Wilson and Tribelhorn. As stated by (Dynisco, 2018) single screw extruder are reasonably low-priced, undemanding and simply

provide a constant output, which is why single screw extruder is the most favored type of extruder.

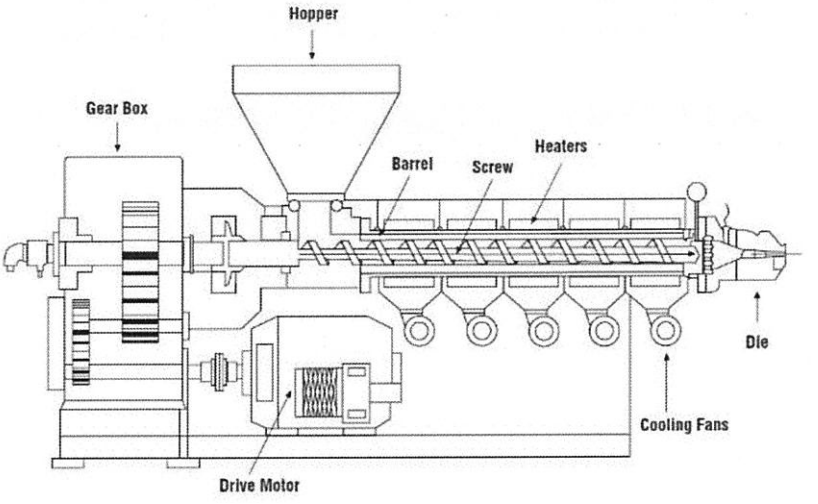


Figure 2.2: Schematic Diagram of Single Screw Filament Extruder (Dynisco, 2018)

2.2.2 Twin Screw Extruder

A two-screw extruder is a twin-screw machine. There is a wide range of twin-screw extruders, with variations in design, working principle, and application field. Twin-screw extrusion is a very adaptable process. The main reason for this flexibility is a modular design of both the screw and the barrel (shown in Figure 2.3). The screw can be configured to control the degree of mixing and conveying in a variety of ways stated by (Pept-flow, Programme, Union, & No, 2006). Besides, twin-screw extrusion equipment's flexibility allows these machines to be specifically designed for the desired task. Twin-screw extruders can be designed conically or in parallel. The two screws may be counter-rotating or co-rotating, intermeshing or non-intermeshing. Thereby, for the processing of PVC products such as pipe, profile, sheet, pellets and film, counter-rotating twin-screw extruders are mainly used.

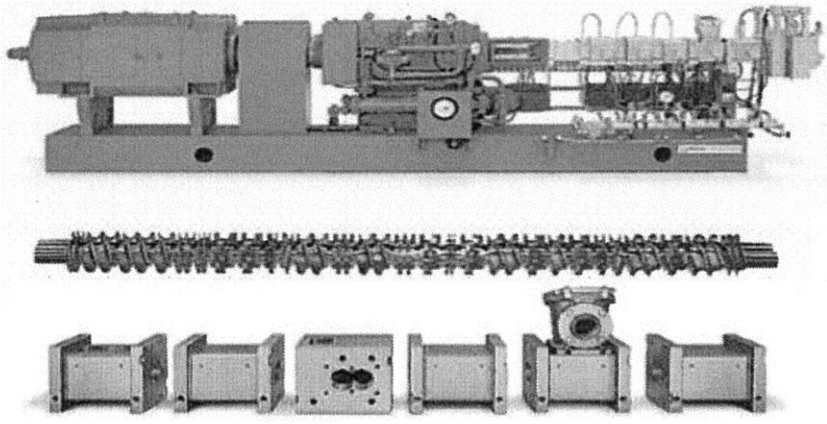


Figure 2.3: Machine concept of twin-screw extruder (Pept-flow et al., 2006)

In addition, (Jinescu & Sporea, 2018) stated that twin screw extruders are only available commercially and are widely used for compounding, blending, reactive processing, etc. in the polymer processing industry. The machine's versatility to some extent originates from the extruder's modular nature as a number of machine manufacturers offer co-rotating twin-screw extruders with replaceable barrel and screw sections. Therefore, the versatile twin-screw extrusion technology plays an important role in the age of flexible manufacturing where manufacturers are encouraged to move from one product line to another using the same capital equipment.

Plus, as stated by (Teixeira, Faria, Covas, & Gaspar-Cunha, 2009) because of interesting constructive and functional features, co-rotating twin-screw extruders are widely used by polymer materials producers and compounders. Besides, modular screw and barrel construction provides excellent flexibility and adaptability to each polymer system's specific requirements. Both are built by elements of different type's available, enabling good control of dispersive and distributive mixing, residence times, sequence of feeding, etc. Thus, the performance of twin screw extruders is dictated in industrial practice by the proper selection of operating conditions such as screw speed and output controlled independently, barrel temperature profile and the configuration of the screw. In fact, by adjusting the operating conditions such as output, screw speed and barrel temperature profile also the geometry or configuration screws, a wide range of polymer systems can be processed.