DESIGN OF INTEGRATED 3D PRINTER RECYCLE MACHINE

MOHD FIRDAUS BIN AHMAD NORDIN

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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MOHD FIRDAUS BIN AHMAD NORDIN

A report submitted in fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering (Design & Innovation)

Faculty of Mechanical Engineering

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DECLARATION

I declare that this project report entitled " Design of Integrated 3D Printer Recycle Machine" is the result of my own work except as cited in the references

Signature	:	....
Name	:	....
Date	:	....

APPROVAL

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

Signature : ....
Supervisor's Name : ....
Date : ....

DEDICATION

To my beloved mom and dad, and those who always support me.

ABSTRACT

As the technology in this world has evolves rapidly, the 3D printing is not excluded from the growth as well as becoming one of the most postulate method in manufacturing process. Opposite to the standard manufacturing process which commonly is subtractive that produces a lot of waste, 3D printing is way friendly to the environment. Application of additive manufacturing method in 3D printing leads to less or no wasted materials. For this promising technology, it still developing especially when there are lot of open source medium for people to access and discover the 3D printing technology. There is always a problem in every human-made creation. As for 3D printing, consumption of plastic materials has significantly increase due to high demand in market. In order to minimize the negative impact of plastic waste to the environment, a study on designing an integrated 3D printer recycle machine is done. Engineering design method is used to formulate and develop new concept design. Identification of current problems on the existing recycle machine is done to make design improvement on the new recycle machine. For the guideline of developing the recycle machine's design, preliminary result from three conceptual designs are used. There are three main components of the recycle machine which are shredder, hopper and extruder. For this study, its focus is on the hopper and extruder due to the objective on having success extrusion of filament. By using CATIA software, analysis has been made on the components and the assembled product. A prototype is built from 3D printed parts and reuse materials. Analysis of extruded filament was done for every 10 cm with minimum of 10 repetitions. Percentage of error for diameter of filament indicates 1.84mm diameter with 5.14% as the lowest error while diameter of 1.90mm with 8.57% as the highest error. So the objective to get below than 9% of percentage error is achieved and it gives hope for future improvement in this project of recycling waste of ABS polymer.

ABSTRAK

Seiring dengan perkembangan teknologi yang pesat, percetakan 3D tidak terkecuali dan turut menjadi salah satu kaedah yang mempunyai banyak permintaan dalam proses pembuatan. Bertentangan dengan proses pembuatan yang biasa seperti kaedah perluakan yang menghasilkan banyak sisa, percetakan 3D adalah jauh lebih mesra terhadap alam sekitar. Aplikasi kaedah pembuatan secara penambahan di dalam percetakan 3D telah menjurus kepada kurangnya atau tiada pembaziran bahan. Untuk teknologi berprospek cerah ini, pembangunan masih berlangsung terutamanya apabila terdapat banyak sumber terbuka untuk manusia mendapat akses dan meneroka teknologi pecetakan 3D. setiap ciptaan manusia, mesti terdapat masalah yang timbul.bagi percetakan 3D, penggunaan bahan plastik telah meningkat secara jelas oleh kerana permintaan yang tinggi di pasaran. Dalam mengurangkan kesan negatif plastik terbuang kepada alam sekitar, satu kajian keatas reka bentuk bersepadu mesin kitar semula untuk percetakan 3D telah dijalankan. Kaedah reka bentuk kejuruteraan telah digunakan untuk merumus dan membangunkan konsep reka bentuk yang baru. Pengenalpastian terhadap masalah semasa mesin kitar semula yang sedia ada telah dilaksanakan demi membuat penambahbaikan ke atas reka bentuk mesin kitar semula yang baru. Sebagai garis panduan untuk membangunkan mesin kitar semula tersebut, keputusan daripada tiga konsep reka bentuk awal telah digunakan. Terdapat tiga komponen utama mesin kitar semula tersebut iaitu pencincang, corong dan penyemperit. Kajian ini menjurus kepada corong dan penyemperit kerana matlamat kajian ialah memperoleh penyemperitan filamen yang berjaya. Analisis terhadap komponen yang siap dipasang telah dilakukan menggunakan perisian CATIA. Sebuah prototaip telah dibina daripada bahan guna semula dan mesin pencetak 3D. Analisis ke atas filamen yang terhasil dilakukan dengan mengambil bacaan setiap 10 cm untuk 10 ulangan. Ralat peratusan diameter filamen menunjukkan diameter 1.84mm bersamaan 5.14% sebagai ralat terendah manakala 1.90m diameter bersamaan 8.57% sebagai ralat tertinggi. Jadi, objektif untuk mendapatkan ralat peratusan di bawah 9% tercapai dan ini memberi harapan untuk penambahbaikan di masa hadapan untuk projek kitar semula sisa polimer ABS ini.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

PID	Proportional Integral Derivative
PLA	Polylactic Acid
ABS	Acrylonitrile Butadiene Styrene
CAD	Computer Aided Engineering
SSR	Solid State Relay
SIP	Society of Plastic Industry
DC	Direct Current
PIC	Plastic Identification Code

LIST OF SYMBOLS

ω	=	Angular velocity
α	=	Angular acceleration
π	=	Pi
N	=	Rotation per minute

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

These modern days, the technology of manufacturing has increase significantly. Rapid prototyping (RP) or mostly known as 3D printing is a good example of manufacturing technology which just not increase production rate but also saves time consumption and overall cost including cutting down labor cost. Before we can successfully manufacture a batch of zero defect product, there is always some reject of final products due to human error or technical error. Due to this, there will be a bunch of 3D printed material waste. Not all materials used for certain product are biodegradable and renewable. In addition, the new materials of filament is quite costly. That is why it is necessary to recycle the rejected products to prevent waste and to achieve cost effective production in 3D printing technology. Thus, in order to overcome this problem, development of integrated recycle machine gives a new hope to the waste material to be used again.

In the market, currently there are two types of materials commonly used as filament for 3D printing which are known as Polylactic Acid (PLA) and Acrylonitrile-Butadiene-Styrene (ABS). Both of the materials are plastic based and easy to melt once it is exposed to heat. The aim for this project is mainly to design a low cost integrated 3D printer recycle machine which could significantly reduce the usage of raw materials in making new filament and also decreasing the negative impact of plastic waste to the environment. Those can be achieved by recycling failed prints of 3D project by shredding and extruding process into new filament.

1.2 PROBLEM STATEMENT

Existing low cost 3D printing machine which is called Mendel 3D printer is used as reference model. It use polyethylene materials known as thermoplastic filament to print and build an object. The filament material are mixture of petroleum-based and plant-based source. To be clear, these materials are costing and not biodegradable. That is why technology on recycle device for filament is elevating. So there goes production of several 3D printer recycle machines by different companies. But, none of them are integrated recycle machine which can be attached to the 3D printer.

Due to that, a project for integrated 3D printer recycle machine had been developed. However, the current machine was too small and the size of filament been extruded does not achieve the standard and consistent filament size. The other limitation are the machine is too heavy to be attached to the 3D printer, there is no temperature control and nothing to insulate the heat produced by the heating element from reaching the hopper and other crucial parts. Therefore, this latest project is about to design a new and improved 3D printer recycle machine to overcome those problems.

1.3 OBJECTIVE

The objectives of this project are as listed below:

1. To design a new and improved integrated 3D printer recycle machine by using CATIA software.
2. To fabricate a prototype for the new integrated 3D printer recycle machine.
3. To extrude filament with percentage of error for diameter below 9%.

1.4 SCOPE OF PROJECT

The scopes of this project are as follow:

1. CATIA software will be used in the designing and development stages of the recycle machine.
2. The new recycle machine will implement the similar working principle of the previous one.
3. Fabrication of the 3D printer recycle machine will use metal on most of the body parts.

CHAPTER 2

LITERATURE REVIEW

2.1 3D PRINTING

3D printing is a common method being used in rapid prototyping technology. It is basically used to manufacture plastic parts used for concept visualization or even final parts. Wohlers *et al.* (2014) stated that in future, 3D printing is going to grow rapidly. In addition, manufacturers in various industries already implement the use of 3D printing due to its efficiency and faster rate of production. This mean that 3D printing is on rising demand for production line.

To ensure faster progress on the improvement of 3D printing technology, open source platform such as RepRap is the one with low cost of investment needed compared to others. There are various model of open source for low cost 3D printer. One of it is Prusa. 3D printing is a technology with high potential to be cost effective with the production while keeping the waste material at low volume compared to conventional method (Lindemann and Reiher, 2015).

As the benefits of 3D printing has lure many developers and manufacturers to use it, this situation results the high volume of filament usage for printing. That is why this state has leads inventor to develop waste recycle system for low cost 3D printing so that the waste can be put into used without having to spend so much money to buy new set of filaments.

2.2 RECYCLE SYSTEM INTEGRATION

As the demand on the low cost 3D printing seems to reach the extravagant level due to its ability to just not only work efficiently but also cheap and reliable, has cause the high request on the building materials. That is why a recycle system for plastic waste is required. In addition to the system, extrusion principal is needed to extrude the filament produced by the recycle system. As for two developers related to 3D printing which are called as RecycleBot and Filamaker, they already made the early projects on the problem (Baechler *et al.*, 2013). They made use of the similar principle to injection moulding that used screw, which in their cases was to force the material into the barrel with heating element and then plastic was melted before being compressed and driven through a die (Chase, 2004).

To be clear, those initial projects are not integrated with low cost 3D printing. They made the recycle machine that extrude new filament separately. Besides, the plastic shredder and filament extruder are disassociated from one another for the recycle system. This will cause more time being consumed due to the need to handle separate machines one after another. Thus, this method does not comply with the requirement for integrated recycle machine with low cost 3D printing.

To meet the objective of having an integrated recycle machine on a low cost 3D printing, Ramli *et al.* (2015) came out with a concept system. The concept was about a low cost 3D printer that are integrated with a plastic waste recycle machine which can produce filament with only one cycle of process. In addition, the cost of feedstock for 3D printing were reduced along with the energy used because of the proposed system did not use filament, but fed directly from the shredded plastic waste as the source of the recycle machine.

2.3 INJECTION MOULDING

Injection moulding can be referred as a process to solidify molten material inside a mould. This process is basically using screw mechanism that pushes the material through the cylinder with heating element into the mould. Various materials can be used with injection moulding depending on the required product to produce. For thermoplastic and thermosetting polymers production, this manufacturing method is suitable and reliable. Olmsted and Davis (2001) stated that all electric and hybrid injection moulding machine are the latest technology for injection moulding.

2.3.1 Process Elements

The fundamental process for injection moulding is part formation in the mould cavity from injected molten polymer that is compressed and forced into a die after being compressed inside the heated barrel (Rauwendaal, 2001).

There are four significant units involve in the injection moulding process which are hopper, injection unit, control unit and the clamp unit. Hopper is mainly to shred material into little pieces or bits before being melted in the injection unit. In the injection unit, there are heating and melting elements followed by pumping and material injection into the mould cavity. Then the control unit has the task to monitor and control the injection unit. Finally the clamp unit that has ejecting plate is used for clamping the mould and ejecting solidify material inside it. Figure 2.1 illustrates the units involved including the important units for single stage screw machine in injection moulding process.

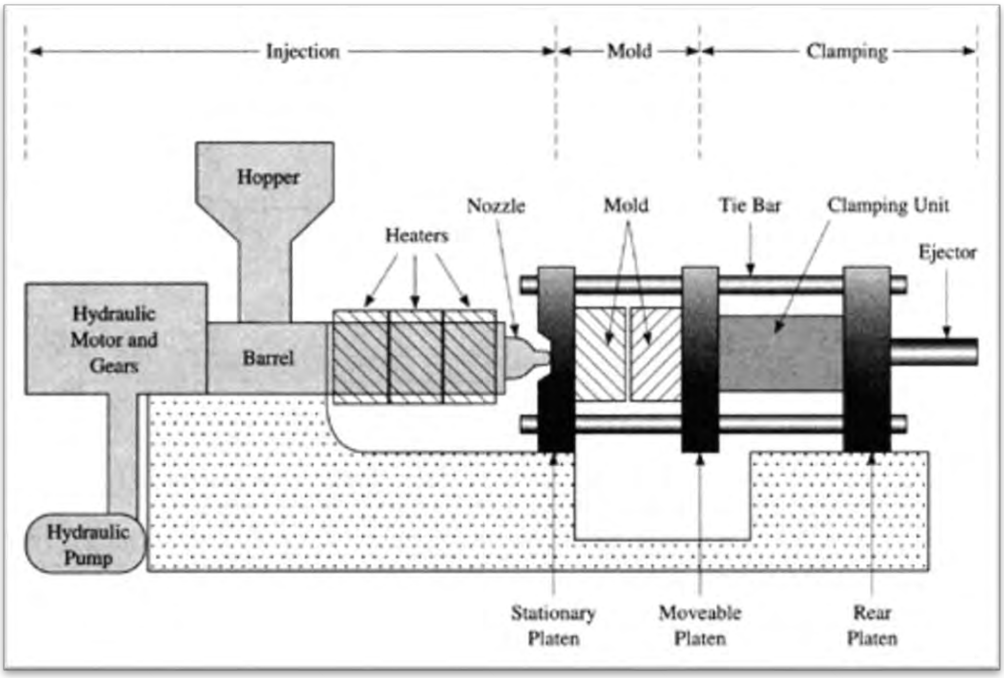

Figure 2.1: Single Stage Screw Machine (*deseng.ryerson.ca*)

2.4 FILAMENT

There are two types of filament that are commonly being used in 3D printing which are Polylatic Acid (PLA) and Acrylonitrile butadiene styrene (ABS). Although there are lots of materials that had been explored for 3D printing because of its characteristic which is thermoplastic, but not all can pass the three distinct tests for qualification (Luke, 2013). The tests are beginning extrusion into plastic filament, next extrusion and trace-bind ability during the process of 3D printing. After the materials has pass all the three tests, then only it can be qualified to be used as filament for 3D printing.

2.4.1 Characteristic of PLA and ABS

Both PLA and ABS do have similarity especially in the way they are used in 3D printing. But there are also differences between them, advantage and disadvantages also the fields of application for those two materials. Table 2.1 summarize the characteristics of PLA and ABS.

Table 2.1: Characteristics of PLA and ABS

CHARACTERISTICS	**PLA**	**ABS**
Melting temperature (°C)	160-190	210-240
Printing temperature (°C)	190-220	230-250
Printbed temperature (°C)	50-70	80-120
Printbed	Not necessary	Compulsory
Cooling system	better in printing	Not required
Material base	Plant	Petroleum
Biodegradable	Yes	No
Warping tendency	Near warp-free	Large part tends to warp
Mechanical properties (Durability, malleability, flexibility)	Good	Excellent
Fumes / smells	Sweet like candy	Bad burnt plastic
Post-processing	good	Excellent
Surface treatment with acetone	Not possible	Possible
Field of application	Household items, toys, gadgets	Interlocking parts, pin-joints

Figure 2.2 shows the physical comparison on the surface of finish parts that were printed with the identical original 3D CAD dimension of 0.10 resolution. On the left side was printed using black PLA while on the right side was printed with black ABS.

Figure 2.2: Surface finish comparison of printed parts using PLA (left) and ABS (right) *(cubex3dprinting.blogspot.my)*

2.5 POLYMER

Affordable, durable and lightweight are the highlighted characteristics mentioned by Thompson et al. (2009a) for this plastics that are chemically made with numerous repeating units. Polymer has a large amount of contribution because it is always been chosen as the material used in manufacturing industries. That is why production of polymers have increase significantly to meet the demands of other manufacturers. Regarding to the finding from Hopewell et al. (2009), the amount of oil and gas being used for feedstock production of plastic and the amount of oil and gas to produce energy for manufacturing are almost at the same rate with 4% and 3-4% usage respectively.