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JUDUL: DEVELOPMENT OF MINI MICRO INJECTION MOULDING MACHINE

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DEVELOPMENT OF MINI MICRO INJECTION MOULDING MACHINE

DAELAMI BIN AMINUDDIN

A report submitted in partial fulfilment of the requirements

for the award of the degree of

Bachelor of Manufacturing Engineering

Faculty of Manufacturing Engineering

UNIVERSITY MALAYSIA PAHANG

JUNE 2012

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Manufacturing Engineering.

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I hereby declare that the work in this thesis is my own except for quotations and Summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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DEDICATION

To my parents Mr. Aminuddin Bin Hussin and Mrs. Norhani Bt. Abdullah

and those made it possible

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In the name of Allah, the Most Gracious and the Most Merciful Alhamdulillah, all praises to Allah for the strengths and His blessing in completing this thesis First and foremost I offer my sincerest gratitude to my supervisor, En. Ahmad Rosli Bin Abdul Manaf, who has supported me throughout my thesis with his patience and knowledge. I attribute the level of my degree to his encouragement and effort and without him this thesis, too, would not have been completed or written. One simply could not wish for a better or friendlier supervisor.

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ABSTRACT

The project is to develop a mini micro injection moulding machine. This study consists of three stages which are design concept, fabrication process, and assembly process of the mini micro injection molding that will capable to run similarly as the real industries conventional micro injection molding machine. For the design concepts, two to three injection molding mechanism is designed, compared and choose the best design that can match the requirement of the mini micro injection machine. After the design has been decided, fabrication process will take place. In this project, it is important to define and organize the best and fastest method that suitable to fabricate the machine. Assembly processes need to be done to complete the machine. It consist of assemble the two unit of injection machine which are injection unit and clamping unit. For the last stage, in order to test and function the machine, we need to make it capable to melt the resin plastic and the injection plunger can inject the molten plastic in to the mould cavity through the nozzle.

ABSTRAK

Projek ini adalah untuk membangunkan mesin acuan suntikan mikro mini. Kajian ini terdiri daripada tiga peringkat iaitu konsep reka bentuk, proses fabrikasi, dan proses pemasangan acuan suntikan mikro mini yang akan mampu untuk berfungsi seperti mesin pengacuan suntikan konvensional mikro. Bagi konsep reka bentuk, dua hingga tiga acuan suntikan mekanisme direka, dibandingkan dan memilih reka bentuk terbaik yang dapat memenuhi keperluan sebuah mesin suntikan mikro mini. Selepas reka bentuk telah diputuskan, proses fabrikasi akan dijalankan. Dalam projek ini, ia adalah penting untuk menentukan dan mengatur kaedah terbaik dan paling pantas yang sesuai untuk membina mesin. Proses pemasangan perlu dilakukan untuk menyiapkan mesin. Ia terdiri daripada memasang dua unit mesin iaitu unit suntikan dan unit pengapit. Untuk peringkat terakhir, untuk menguji dan mengfungsikan mesin, kita perlu menjadikan ia mampu untuk mencairkan bahan plastik dan pelekap suntikan boleh menyuntik plastik lebur dalam rongga acuan melalui muncung.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

F	Force
P	Density
V	Volume
m	Mass
r	Radius
L	Length of travel expected of plunger
p	Circular pitch distance of gear
Pc	Diameter of pitch circle
Ω	Angular velocity
v	Injection linear velocity
N	Revolution per minute
T	Torque

CHAPTER 1

INTRODUCTION

1.1 Research background

Injection moulding machine is a machine that always been use in the competitive industries such as automotive industry, electrical and electronic industries, medical industry and etc. Injection moulding machine offers many advantages compare to others manufacturing methods such as minimal losses from scrap due to recycled plastic and minimal finishing requirement. Refer figure 1.0.

Conventional injection moulding machine and micro injection moulding machine has the same purpose which is producing product by injecting process. But what make the micro injection moulding machine is differ compare to injection moulding machine are the specification and parameters that need to control in the micro injection moulding machine. Micro injection moulding is a machine that produces a product that has a weight less than 1 gram and a diameter less than 1mm.

Figure 1.0: Example of injection moulding machine

1.2 Problem Statement

Injection moulding machine in the market is in big size and very expensive in price. It is hard for the small-scale industries especially the industries that forming small or micro plastic product to buy the injection moulding machine due to the costs that can't be afford. Even though the small-scale industries manage to buy the injection moulding machine, the machine still doesn't give a good and reasonable returns compared to the price that been invest. So, the idea of design and fabricate the mini micro injection moulding machine has come out in order to help the industries for production of micro parts where the weight of the product is less than one gram.

Besides that, the mini micro injection moulding machine can be used as rapid prototyping, testing, sample and new product design and development in the economical and practical within the quantities required.

1.3 Research Objectives

In order to develop the mini micro injection moulding machine, there are two main objectives have been identified which are:

I. To design the mini micro injection moulding machine
II. To fabricate the mini micro injection moulding machine according to the decided design.

1.4 Scope of the project

The scope of this project is to design and fabricate a mini version of injection moulding machine, cost effective and environmentally friendly mini micro injection moulding machine for the production of small plastic product that is less than one gram of weight

The mini micro injection moulding machine is simply function by using the electrical motor to drive the injection plunger in order to inject the molten plastic in to the mould cavity. Besides that, the machine also consists of barrel, hopper, nozzle, heater band and others that going to function as the production of micro products.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The micro injection moulding is established as one of the most common manufacturing processes for polymeric materials in micro system technology, especially for thermoplastic resins. Injection moulding is often used to produce large numbers of micro components at a high automation level, and thus at low cost. Complexly shaped micro components with high function integrity are state of the art. [1]

The injection moulding machine processes can be describe as where a granule of plastic material is fed into the hopper that commonly at the top of the machine. The materials are feeds into the barrel that contains a reciprocating screw or a ram injector. The barrel is heated and the reciprocating screw crushes the pallet, making it easier for the material to be in liquid form and has a uniform mixture. The reciprocating screw propels the molten plastic forward and injects the molten plastic through a nozzle and fills the mould. [2]

2.2 Fundamentals of Injection Moulding Machine

2.2.1 Injection unit

The injection unit is responsible for both heating and injecting the material into the mould. The first part of this unit is the hopper, a large container into which the raw plastic is poured. It has an open bottom, which allows the material to feed into the barrel. The barrel contains the mechanism for heating and injecting the material into the mould. This mechanism is usually a ram injector or a reciprocating screw. A ram injector forces the material forward through a heated section with a ram or plunger that is usually hydraulically powered. Refer figure 2.0.

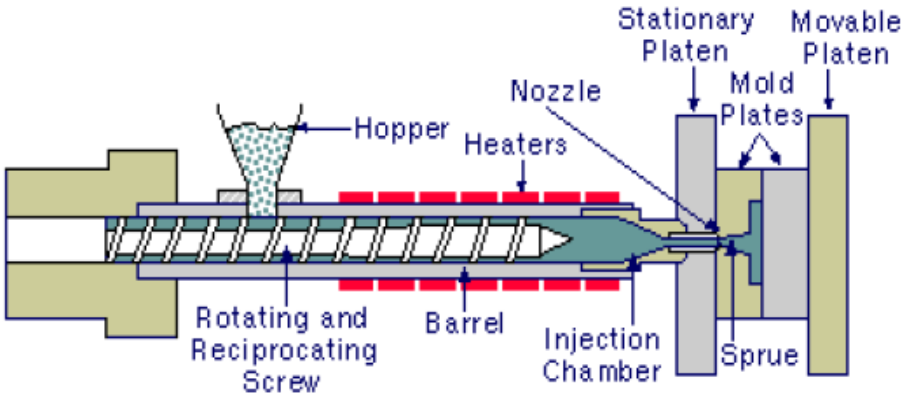


Figure 2.0: Injection unit of Injection Moulding Machine

The injection unit can be divided into several parts which are feed hopper, injection ram, injection screw, injection cylinder and barrel. Below are the description for every parts of the injection unit [3].

I. Feed hopper – the container that commonly in a shape of triangle holding a supply moulding material to be fed to the screw to be heated.

II. Injection plunger/ ram – the molten plastic in the barrel can be fed in to the mould by apply the force or pressure towards the material using this ram or screw.

III. Injection screw – the common screw that use in the machine is reciprocating screw. The function of reciprocating screw is to melt the material and at the same time inject the molten plastic into the mould.

IV. Barrel – the major section that functions to melts the plastic material that transfer from the hopper. Barrel has a control system that can control the suitable and proper temperature to meet the plastic characteristics and get the best uniformity.

V. Injection cylinder – Injection cylinder is composed of cylinder body, piston, and piston load. Hydraulic motor located inside bearing box, which is connected to injection cylinder load, rotates screw, and the melted resins are measures at the nose of screw.

2.2.2 Clamping unit

Prior to the injection of the molten plastic into the mould, the two halves of the mould must first be securely closed by the clamping unit. When the mould is attached to the injection moulding machine, each half is fixed to a large plate, called a platen. The front half of the mould, called the mould cavity, is mounted to a stationary platen and aligns with the nozzle of the injection unit. The rear half of the mould, called the mould core, is mounted to a movable platen, which slides along the tie bars. The hydraulically powered clamping motor actuates clamping bars that push the moveable platen towards the stationary platen and exert sufficient force to keep the mould securely closed while the material is injected and subsequently cools. After the required cooling time, the mould is then opened by the clamping motor. An ejection system, which is attached to the rear half of the mould, is actuated by the ejector bar and pushes the solidified part out of the open cavity. Refer figure

Clamping unit consists of injection mould, injection platens, clamping cylinder and tie bar. Below are the descriptions for each parts of the clamping unit. Refer figure 2.1

I. Injection mould – the mould is the part where the molten plastic is injected to fill the cavity in the mould.

II. Injection platens – the section where the mould is attached. Commonly there are two platens are used which are fix halve and movable halve. The cavity side of the mould is attaching at the fix platens while the core side of the mould is attach at the movable platen. The platens consist of several holes so that the mould can be mounted using clamps.

III. Clamping cylinder - A device that actuates the chuck through the aid of pneumatic or hydraulic energy.

IV. Tie bar – it function to support the force of the clamping. Generally, there are four tie bars located between the fix platen and movable platen.

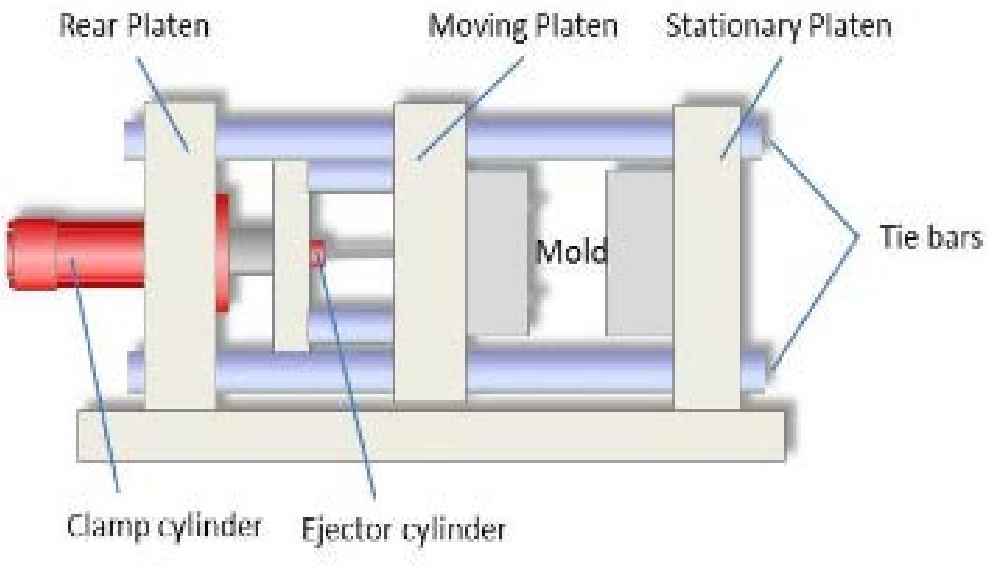


Figure 2.1: Clamping Unit of Injection Moulding Machine

2.2.2.1 Clamping mechanism

The clamping mechanism opens and closes the mould (preferably rapidly) as required during the cycle. It must also supply the necessary clamping force to keep the mould closed during injection, because the injection pressure acting on the internal, or projected, surface of the cavity space tends to open the mould at the parting-plane or parting line. [4]

2.2.2.2 Types of clamping system

The clamping system opens and closes the mould, supports and carries the constituent parts of the mould, and generates sufficient force to prevent the mould from opening. Clamping force can be generated by a mechanical (toggle) lock, hydraulic lock, or a combination of the two basic types. [4]

2.3 Plasticizing unit

Today's plasticizing unit is almost exclusively an extruder that heats the cold plastic material to the required temperature to make it fluid for injection, or melt. The heating is generated mostly by the mechanical energy that created by the screw motor, as the extruder screw rotates in the barrel and works the plastic. This screw action also advances the plastic toward the tip of the screw.

Heaters around the barrel, usually in three or more heating zones, provide additional heating, which is mainly required during start-up of the machine but also where the mechanical working of the screw alone would not plasticize the amount of plastic required for each shot. [4]

2.4 Melt temperature

The melt temperature of the moulding material (stock temperature) is controlled by the barrel temperatures, screw speed, injection speed and back pressure. The water jackets around the barrel regulate the point at which the material will start to plasticize. The screw speed, injection speed and back pressure create frictional heat. To maintain a consistent and workable melt temperature, all of these variables must to be coordinated and adjusted. The stock temperature cannot be so hot that the material cures before it is able to fill the parts, nor so cold that the cycle times have to be extended in order for acceptable parts to be produced from the mould.

2.5 Injection pressure

The pressure on the material is controlled by the primary pressure, which moves the screw forward at a rapid speed to fill the cavities. The secondary pressure (holding pressure) finishes the filling of the cavities and maintains pressure on the material until it is sufficiently cured to allow the screw to return and plasticize the next shot. [4]

Plastic Injection pressure involves two stages. The first stage is, inject the melt plastic material into mould by a high speed, this pressure called first plastic injection pressure. We always called it plastic injection pressure too. Second stage is, the pressure we put after plastic material filled mould, called second plastic injection pressure or packing pressure.

2.6 Suitable materials

There are many types of materials that may be used in the injection moulding process. Most polymers may be used, including all thermoplastics, some thermosets, and some elastomers. When these materials are used in the injection moulding process, their raw form is usually small pellets or a fine powder. Also, colorants may be added in the process to control the colour of the final part. The selection of a material for creating injection moulded parts is not solely based upon the desired characteristics of the final part. While each material has different properties that will affect the strength and function of the final part, these properties also dictate the parameters used in processing these materials. Each material requires a different set of processing parameters in the injection moulding process, including the injection temperature, injection pressure, mould temperature, ejection temperature, and cycle time. A description and applications of some commonly used materials in the industry is shown below. [5]. Refer table 2.0.

Table 2.0: Example of materials used in injection moulding

NO.	Material name	Description	Applications
1.	Acetal (POM)	Strong, rigid, excellent fatigue resistance, chemical resistance, naturally opaque white, low/medium cost.	Bearings, cams, gears, handles, plumbing components and etc.
2.	Acrylic	Rigid, brittle, scratch resistant, transparent, optical clarity, low/medium cost.	Display stands, knobs, lenses, light housings and etc.
3.	Acrylonitrile Butadiene Styrene	Strong, flexible, low mould shrinkage (tight tolerances) and chemical resistance.	Automotive (consoles, panels, trim, vents), boxes and etc.
4.	Polycarbonate	Very tough, temperature resistance, dimensional stability, transparent and high cost.	Automotive (panels, lenses, consoles), bottles and etc.
5.	Polypropylene	Lightweight, heat resistance, high chemical resistance, scratch resistance, and low cost.	Automotive (bumpers, covers, trim) and etc.

2.7 Design Concept

Design concept is the first consideration that needs to define to start design the mini micro injection moulding machine. Design concept compromises the whole parts of an injection machine so that the machine can be run exactly like the micro injection moulding machine. The concept of the mini micro injection moulding machine is same with the micro injection moulding machine, they just differ in size and some of mechanical and electric parts but still not affect the mechanism of plastic injection machine.

The major part in design concept is the maximum volume of the molten plastic needed to fill the mould. This compromise the plunger travel, diameter of the barrel, melts density and melt mass. From the characteristics, the injection plunger needs to be design that functions to inject the molten plastic into the mould cavity. While for the mini injection moulding machine, it must have both injection and clamping unit equipped with the electrical panel that consist of temperature control, contactors, thermocouple, heat resistance wire, and control button. [6]

2.7.1 Machine Design

The design of mini micro injection moulding is based on the design of conventional micro injection moulding machine. However, the design of mini micro injection moulding machine is much smaller compare to the conventional machine. The machine designs for mini micro injection moulding machine consists of injection unit design and clamping unit design. Both two designs are very important in order to specify the machine size. [6]

To determine the machine size, the most important component is the design of the injection unit. The injection unit size depends on injection capacity, which means the volume of melt plastic in the barrel that can be injected. Second is the clamping unit size, it is very important to define the force that needs to lock the mould together. The amount of force that is going to be determined depends on size of the mould.

In designing the mini micro injection moulding machine, it is critical to define the most critical component that will reflect it function as the mini micro injection moulding machine. Some of the components are tie bars, injection screw, injection plunger, nozzle and others.

2.7.2 Design of barrel

To process thermoset materials, the barrel temperature is typically controlled by water jackets that are placed around the barrel. Usually the barrel is set up with two zones of temperature control, but some presses provide the ability to setup as many as five or six zones, which is not recommended. In the two zone arrangement, the front zone, which can include the end cap and nozzle, should be quarter of the effective length of the barrel and the rear zone should be the remaining more than half of the effective length of the barrel. [7]

Barrels experience their greatest wear at a distance approximately equal to three times the diameter of the screw from the nozzle. As a result, it is recommended that the barrel be sleeved for a length equal to 6 diameters of the screw. Refer figure 2.2.

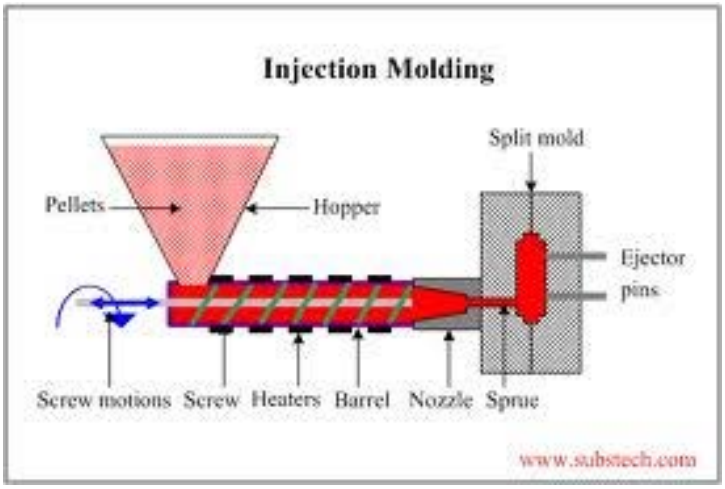


Figure 2.2: Example of barrel design

2.7.3 Design of hopper

Hoppers are used on thermoset injection moulding machines that will be processing phenolic, melamine-phenolic and granular polyester materials. The two basic hopper designs are square and round. A square hopper does not allow the full flow of the material to the screw due to the "dead" zones created by the corners. In addition, these corners can cause segregation of the coarse and fine particles in the material, which may result in erratic material pickup that will produce variations in shot size. A round hopper allows the full flow of the material to the screw and generally will not cause particle size segregation in the material. Refer figure 2.3. [7]

Figure 2.3: Example of barrel design

2.7.4 Design of injection screw

The function of injection screw is to fed the molten plastic in to the mould by apply the force or pressure towards the materials. Besides that, in some machine it also function to melt the material and at the same time inject the molten plastic into the mould, this kind of screw is called reciprocating screw. The reciprocating screw performs the multiple functions of mixing, convening, melting, homogenizing, and injecting the melt into the mould significantly faster. In every type of micro injection moulding machine, there will be a different types and size of injection screw has been used. It depends on the applicable and functions of the machine. [7]

The working process of reciprocating screw can be explained as the screw melts the resin, the screw will moves backward and allowing the melted plastic to accumulate in the end of the barrel. When the screw pushes forward under hydraulic pressure, the plastic is pushed out of the barrel, extruded through a nozzle and filling the mould to form a plastic product. Refer figure 2.4.

Figure 2.4: Example of injection screw design

2.7.5 Design of injection plunger/ ram

The function of injection plunger or ram is not differ compare to the reciprocating screw which is to push the molten plastic in to the mould. The plunger can't apply the multiple functions such as mixing and convening like the reciprocating screw can do. Generally, the injection plunger is common use in small size of injection moulding machine and producing small parts in low production. The design of the plunger machine is ideally suited for moulding thermoset moulding compounds and bulk moulding compounds.

The working process of injection plunger can be explained where the mouldings compound is fed into the heating cylinder (barrel). The plunger or ram forces the compound through the cylinder where it is heated by conduction of heat from the cylinder wall. As the material is forced forward, it passes over a spreader or torpedo within the barrel that causes mixing. The plunger forces the material through the nozzle and into the mould.

The heat from the barrel heaters and the pressure from the ram join in melting the plastic. As the pellets melt, the pressure from the ram squeeze traps the air out and forces the air to flow back and finally out through the hopper. Generally, the melting of the pellet is accomplished by external heating of the barrel. Refer figure 2.5.

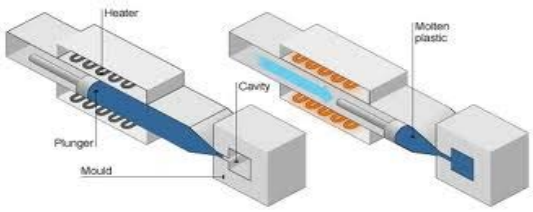


Figure 2.5: Example of plunger design

2.7.6 Design of nozzle

The nozzle and the sprue bushing should have the same radius. Nozzles designed for thermoset materials should allow the screw tip to come forward to a point that is from the end of the nozzle. The smallest diameter of the nozzle orifice should be located at this same point. The nozzle orifice should be tapered so the orifice diameter at the open end is larger than it started. Extended nozzles are not recommended for use with phenolic materials due to an increased probability of nozzle freeze-ups. [7] Refer figure 2.6.

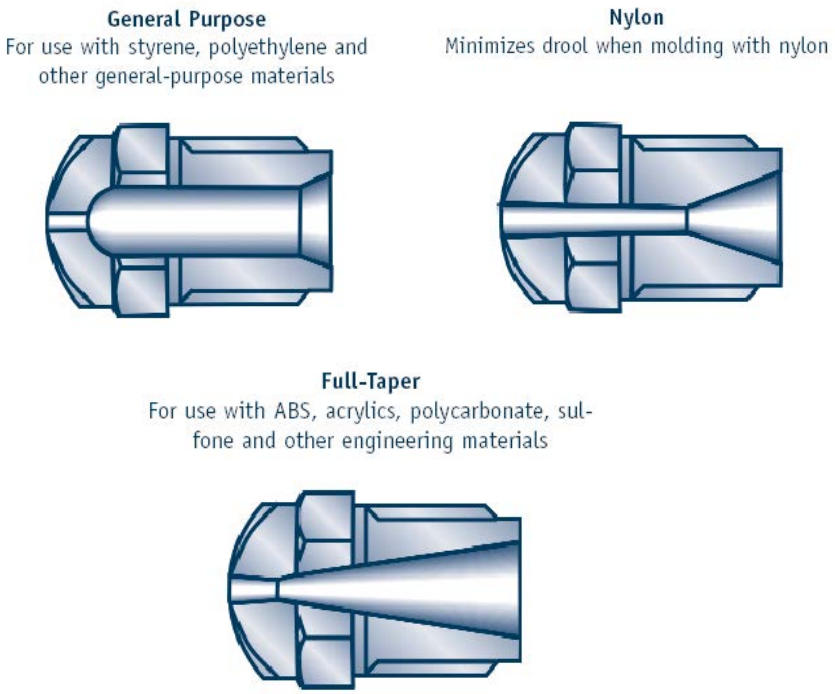


Figure 2.6: Examples of nozzle tip types for different type of materials

2.8 The IKV-micro injection moulding machine prototype

For this micro injection moulding machine, a concept using a two plungers unit was followed. During the plasticising phase, the upper plasticising plunger pushes resin through a die heated at melting temperature as the injection plunger is cored back at the same time. Injection follows when the desired shot volume is reached. A ball check valve between injection plunger and metering plunger prevents the melt from flowing back into the metering cylinder. [1]. Refer figure 2.7.

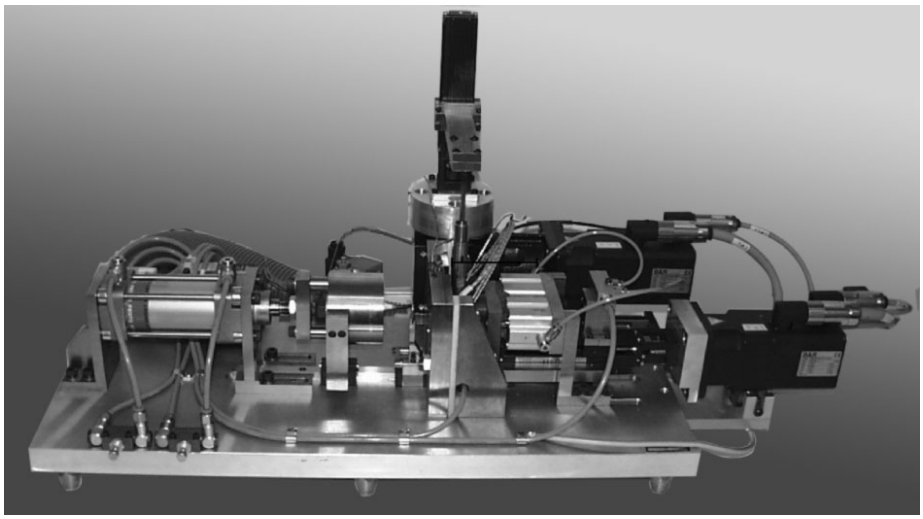


Figure 2.7: The IKV-micro injection moulding machine prototype

2.8.1 Type of plunger

Using a plunger for injection instead of a standard screw is an appropriate method to ensure higher process accuracy, which is needed in micro injection moulding: Since plasticising screws cannot be scaled down to less than 12–14 mm, the melt throughput per unit stroke during injection is much smaller with a plunger of 2–5 mm than with a screw. Thus, inaccuracies caused by the machine control lead nonetheless to a more reproductive process. As a consequence of the smaller volume throughput, machine movement inaccuracies are less critical and oversized compensation sprues can be avoided. The injection plunger diameter can generally be chosen as small as required to assure exact melt dosing; the diameter is 2 mm in the illustrated case. With this configuration the shot volume of the machine reaches 0.1 cm^3. [1]. Refer figure 2.8.

Figure 2.8: Plunger design of IKV machine

2.8.2 Clamping unit

Similar to thermoplastics, only small clamping forces are needed in micro injection moulding with thermosets due to the small dimensions of micro parts. In this case, a pneumatic cylinder runs at a pressure of 12 bars, which is sufficient to hold mould opening forces. For the mould design, other requirements have to be considered, like more precise mating surfaces and higher temperatures than in injection moulding for thermoplastic grades. [1]

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this section, it will comprise all the methods and processes that will use in order to achieve two objectives which are design the mini micro injection moulding machine and fabricate the mini micro injection moulding machine.

The project has been started with finding all the materials that related with the project title for research and study such as journals, articles and books. After the research and study have been made, it followed with project planning. In this process, predictions have been made and determine for the next process that needs to take in order to smooth the project progress. For the methodology, it is important to stress more on how the product or machine is being fabricated, start from the design process until gain the final shape of the machine. Through this chapter also, the full explanation of all processes and tools that involve in fabricate the mini micro injection moulding machine will also include. Figure 4 shows the process flow chart for implement the project and flow chart for the methodology processes which focus on design and fabricate the machine.

3.2 Project Flow Chart

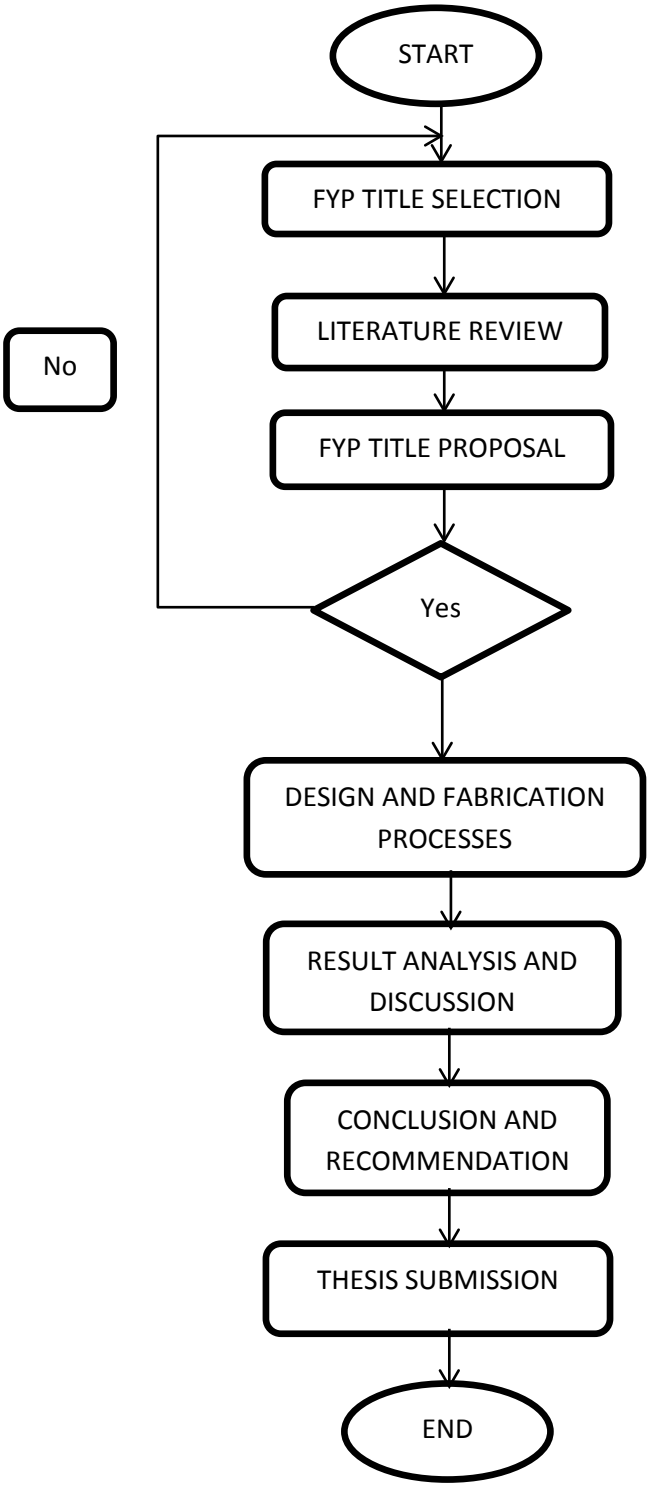


Figure 3.0: Project Flow Chart

3.3 Process Flow Chart for Design and Fabricate the Machine

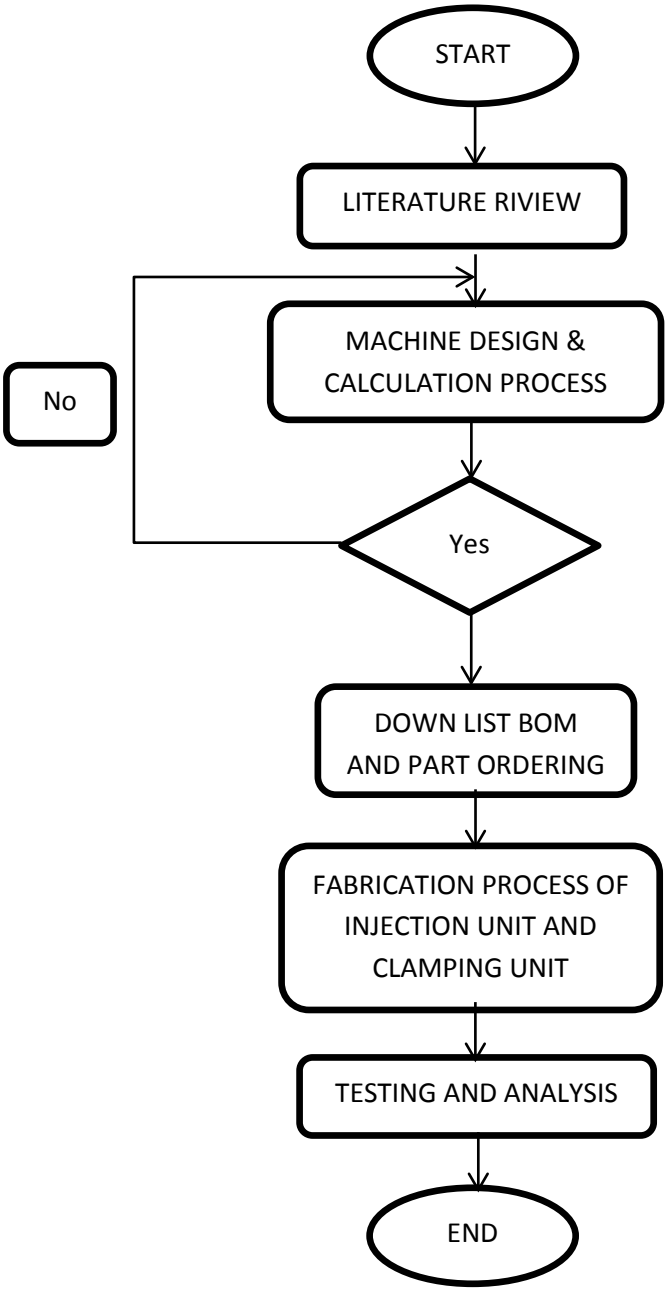


Figure 3.1: Process Flow Chart for Design and Fabricate the Machine

3.4 Literature Review

Regarding to Figure 3.1 which shows the process flow chart for design and fabricate the mini micro injection moulding machine, the project started with the literature review, where the research and study are done by referring to books, journal articles and others references. After all the information needed have been gathered, then it will come out with the related data and findings that can be used in order to design and fabricate the mini micro injection moulding machine.

3.5 Machine Design Process

In this section, all the data and information that related with design of injection moulding machine has been compiled. The first step is to figure the size of the mini micro injection moulding machine. There are two important considerations was define in order to specify the size of the machines which are size of the injection units and the size of clamping unit. Size of the injection unit is depends on injection capacity, which means the volume of melt plastic in the barrel that can be injected. While for the clamping unit size, it will use the suitable size that can meet the specification and needs of mini micro injection moulding machine. It may affect by several factors such as maximum mould size and clamping force.

After that, standard parts for the mini micro injection moulding machine is taking place and defined. In this process, it will consider all parts that required executing the machine. After all the information, data and rough design have been made, design of the machine by using the CAD modelling software can be start. The reason of use this software is the high quality and performance

compared to other software. Industries nowadays prefer the use of CAD modelling in doing designing process.

3.5.1 Design of the machine

In designing the mini micro injection moulding machine, they are two types of design of mini micro injection moulding machine have been made which are differ in major specification and components that being used.

Generally, there are two types of conventional injection moulding machine in the industry which are vertical and horizontal mechanism. The vertical and horizontal are the mechanism where the position of injection unit is placed in the machine. In other word, it shows the movement of the screw or plunger either it moves vertically and horizontally.

Each of design have their own reason why the machines is build, means that the machine have their own ability and specification that will be compare within each other in order to get the best design that is going to fabricate. The design process for the mini micro injection moulding machine applied the skill of designing by using CAD software. In this section, it will compromise all the types of design that been done.

Before designing the machine, some research about the existing micro injection moulding in the market has been done. After that, sketching the design concept and transfer the design into the drawing by CAD software is taking place.

3.5.2 Design 1 of mini micro injection moulding machine

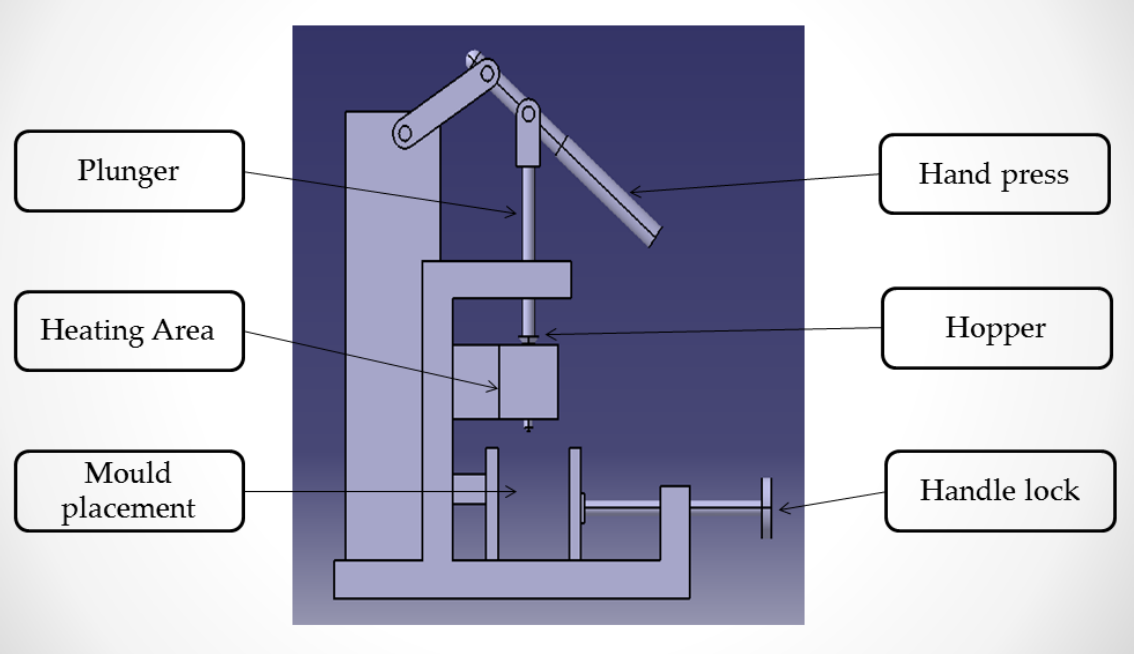
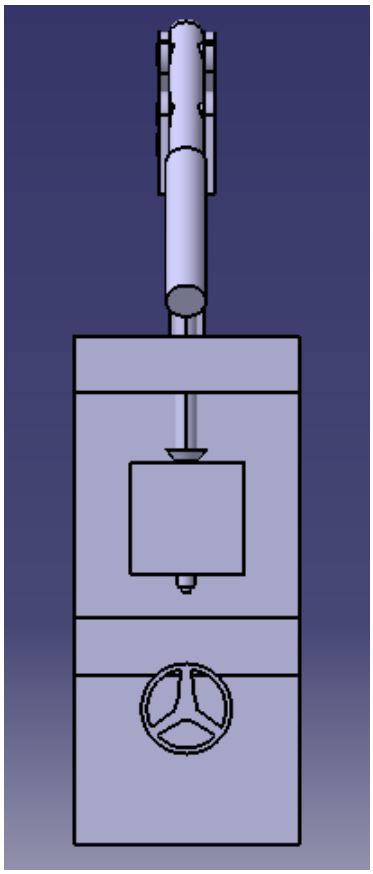


Figure 3.2: Isometric view of design 1

Design 1 is using the vertical type of injection mechanism where the injection plunger is moved vertically or downward in order to inject the molten plastic into the mould. The plunger is manually press in order to move the injection plunger downward. Due to small size of micro injection moulding machine, so the pressure that needed to inject the plastic is sufficient by human force. The injection unit and clamping unit is combined together in one machine. Refer figure 3.2 and figure 3.3.



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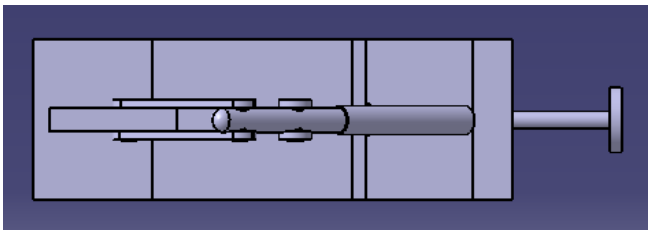

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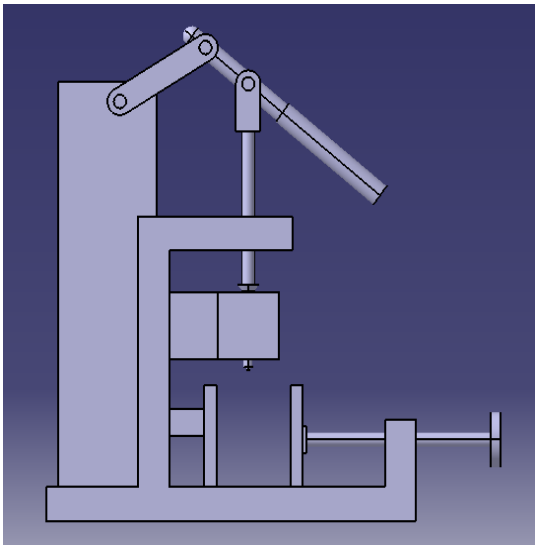

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Figure 3.3: 1) front view, 2) top view and 3) side view of design 1

3.5.3 Design 2 of mini micro injection moulding machine

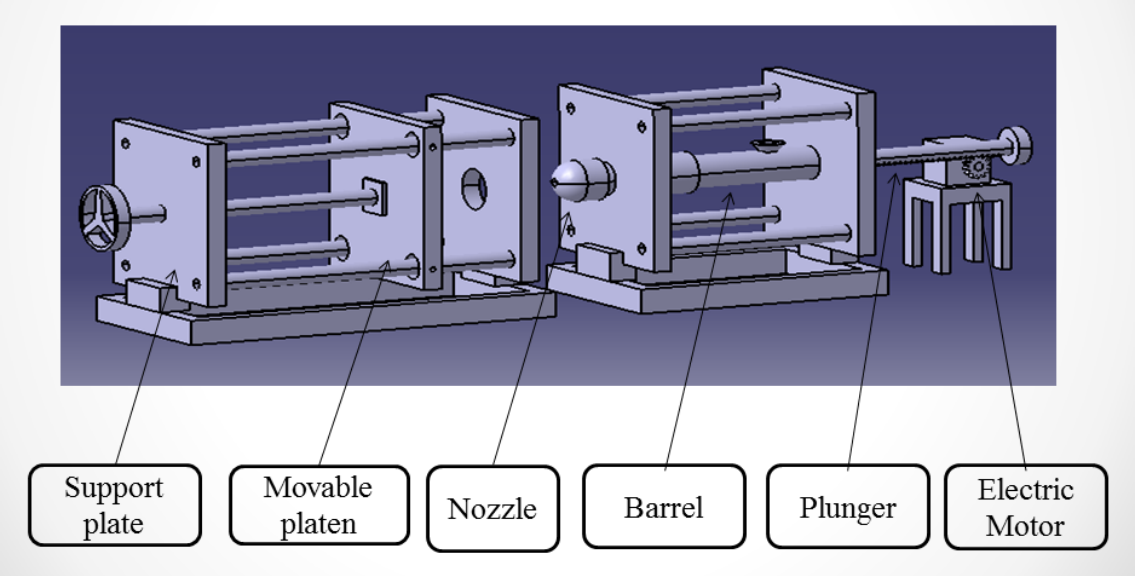
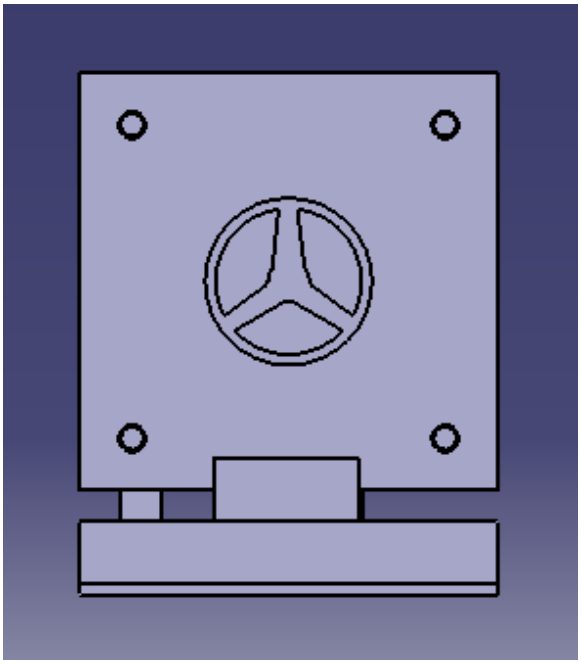


Figure 3.4: Isometric view of Design 2

Design 2 is differ to design 1 where it uses the horizontal type of injection mechanism which the injection plunger is moved horizontally to push the molten plastic. This design entails of two parts which are clamping unit and injection unit. Clamping unit consists of platen and movable platen that function to hold the injection mould while the injection unit consists of barrel and injection plunger that function to inject the molten plastic into the mould cavity.



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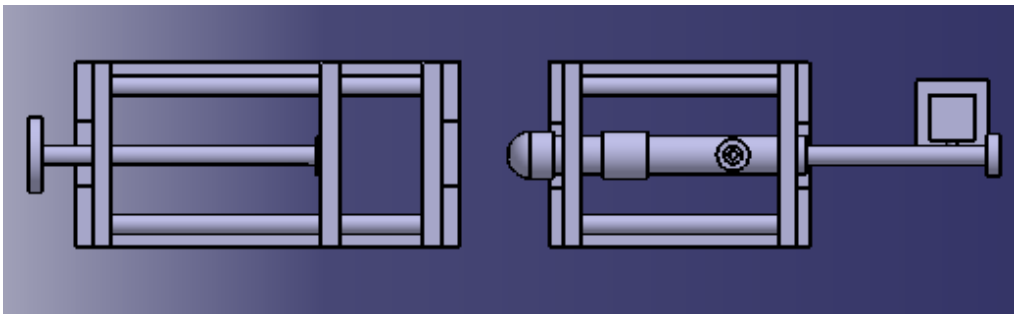

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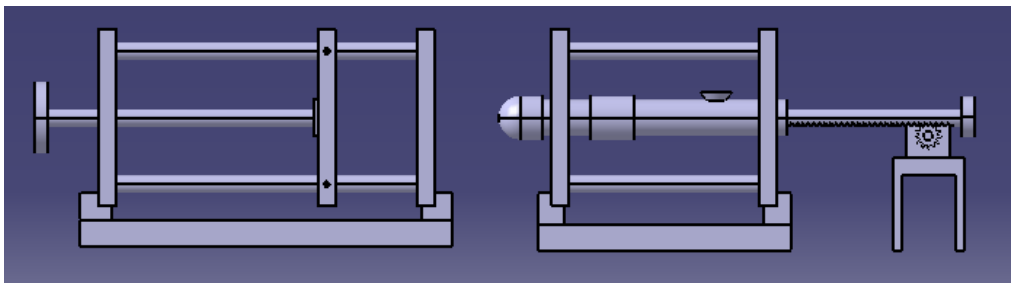


(3)

Figure 3.5: 1) Front view, 2) top view and 3) side view of design 2

3.6 Materials Selection

In this section will discuss about the materials suitable for the making of mini micro injection moulding machine. The material selection process plays an important role before through the fabrication process, this is because, the machine that are going to build must be stable and strong enough to stand the load and can stand the high temperature that been produced by the heater band. Materials are selected based on designed and metallurgical properties of the materials such as machinability, formability, weld ability that greatly influences the construction methods and other joining methods. Other factors considered are cost of the materials and mechanical properties of the materials. Some study has been made and find that the most suitable materials for making the machine are from mild steel. The material type of mild steel has been choosing because of its good characteristic beside of low cost. Most of the machine structures are made from mild steel.

But for the certain components such as barrel and plunger, they are made from hardened steel which has a better strength and can stand a high temperature. Moreover, hardened steel are corrosion and rust resistances that can bring good advantage to the machine because the rust occur inside of the barrel. If the rust occurs inside of the barrel, it will affect the flow of the molten plastic. Furthermore, the movement of the injection plunger also not smooth due to the corrosion area. Table 3.0 shows the bill of materials of the mini micro injection moulding machine.

Table 3.0: Specifications for Materials Utilized

3

NO.	Components	Material	Size (mm)	Quantity	Production
1.	Injection plunger	Hardened steel	Dia.20 x 350	1	Fabrication
2.	Barrel	Hardened steel	Dia. 40 x 300	1	Brought out
3.	Hopper	Mild steel	40 x 40 x 50	1	Fabrication
4.	Spur gear	Mild steel	Dia. 30	1	Fabrication
4.	Supporting plates	Mild steel	200 x 200	4	Fabrication
5.	Platen	Mild steel	200 x 200	1	Fabrication
6.	Tie bars	Mild steel	1. 4 unit Dia. 20 x 370	4	Fabrication
			2. 4 pieces dia. 20 x 125	4	
7.	Machine foundation	Mild steel	200 x 600	1	Fabrication
8.	Nozzle	Aluminium	Dia. 50 x 50	1	Fabrication
9.	Heater band	-	-	1	Brought out
10.	Stepping motor	-	-	1	Brought out

3.7 Fabrication Process

After the design of the machine and the all the materials needed have been finalize, the fabrication process is taking place. In this process, there are some suitable methods and machines have been specified to obtain the best and smooth progress within the time given. Below is the process flow chart for fabrication process. Refer to Figure 3.6.

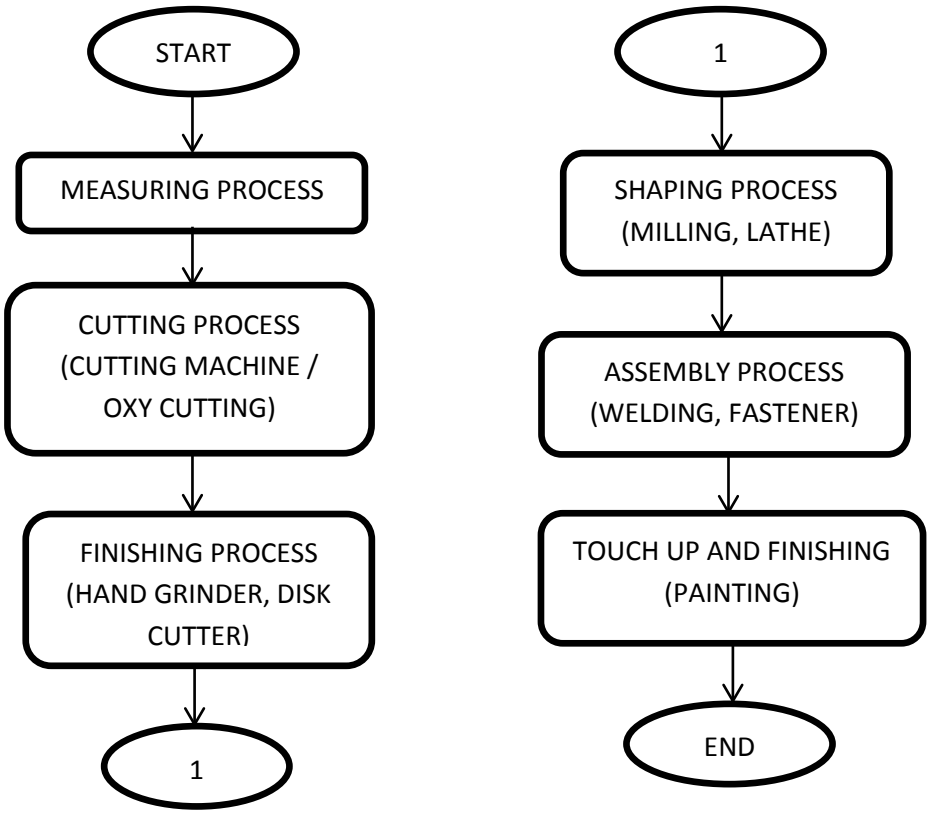


Figure 3.6: Flow of fabrication process

In the fabrication process, the processes have been divided into two sections which are fabrication of clamping unit and fabrication of injection unit. For the fabrication of clamping unit, it will compromise all the components that function to clamp the mould. Some of the components are platen, movable platen, tie bars, bushing, machine foundation, and others. While for the fabrication of injection unit, it consists of barrel, plunger, heater band and stepper motor.

3.7.1 Fabrication of clamping unit

Before through the fabrication of clamping unit, defined and select the suitable materials that can suit in the mini micro injection moulding machine have been done. Most of the materials that selected are mild steel. Even though mild steel doesn’t good in corrosion resistance, but it still have good strength to support the machine. Fabrication process has been started with measuring the material according to the design dimension. The cutting process is take place to gain the exact size. The cutting machine has been used to do all the cutting process and the work piece that been cut need to be touch up to remove all the burrs to avoid any disruption while doing the assembly process.

3.7.1.1 Fabrication of platens

The first work pieces that have been machined are platens. All the platens which are support plate and movable platen have been shaped by using milling machine. The function of milling machine is to do the pocket and holes to allow the screw to be attached on it, this process can be called pocketing process, drilling process and counter bore process. Besides that, milling machine also can be used to remove the thickness of the work piece. Before do the machining, it is important to ensure all the personal protective equipment is complete to avoid any accident happen while machining process. Refer figure 3.7.

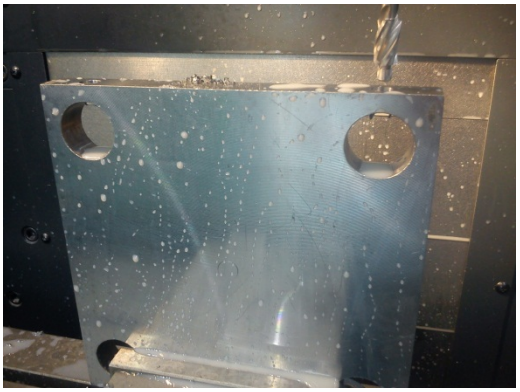


Figure 3.7: Platen under the milling process

3.7.1.2 Fabrication of tie bars

The turning process is take place after the milling process. In the turning process, lathe machine has been used to remove the thickness of cylinder work piece and make the holes to allow the threading process. The cylinder work pieces are function as the tie bar in the mini micro injection moulding machine. After finished the turning processes, proceed with the threading process. The function of threading process is to make thread on the holes. The M10 size of screw that functions as fastener has been used to attach the tie bars to the support plates. Refer figure 3.8 and figure 3.9.

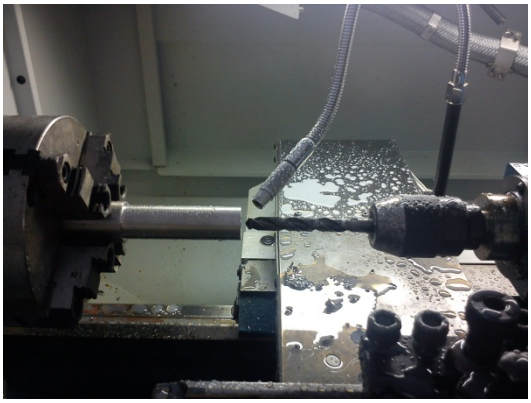


Figure 3.8: Turning process for the cylinder

Figure 3.9: Threading process in the hole

3.7.1.3 Fabrication of foundation of the machine

The final process is welding process which is a sculptural process that joint materials mostly metals and thermoplastic. For the mini micro injection moulding machine, the joint process has been applied to the foundation of the machine. Type of welding machine that been used is metal inert gas welding machine. The foundation is a shape of square where the materials are hollow square mild steel. It is critical to make sure that the joining process is strong and stable enough to support the clamping unit. As the foundation is finished the fabrication process, the clamping unit can be attach on it and ready to use. Refer figure 3.10.

Figure 3.10: Welding process by MIG welding machine

3.7.2 Fabrication of Injection Unit

As the clamping unit has been fabricated, the procedure is same goes to the fabrication of injection unit which are defining and selecting the suitable material in order to get the steady structure of the machine. Injection unit is the critical part where it functions to inject the molten plastic into the mould, so the selection of the material in term of high temperature resistance and strength especially in selecting the materials for barrel and plunger must be consider. The materials for barrel and plunger must be made from hardened steel because those parts need to stand the high temperature that been produced by the heater bands.

3.7.2.1 Fabrication of platens

The injection unit consists of barrel, plunger, hopper, heater band, stepper motor and the foundation of the machine. The fabrication of injection unit is started with the fabrication of platen that supports the barrel. The platen need to be fabricated by using milling machine to make holes to allow the screw to be attach on it while assemble the platen with the bars. Refer figure 3.7.

3.7.2.2 Fabrication of injection plunger

The next process is to make the rack on the plunger. The function of the rack is to allow the gear to make contact with the injection plunger. The gear that attach with the motor will move the plunger when the motor is function. The shape of rack is done by using Electric Discharge Machine (EDM). The EDM has been chosen because of its ability to produce high precision and good finishing product. Refer figure 3.11.

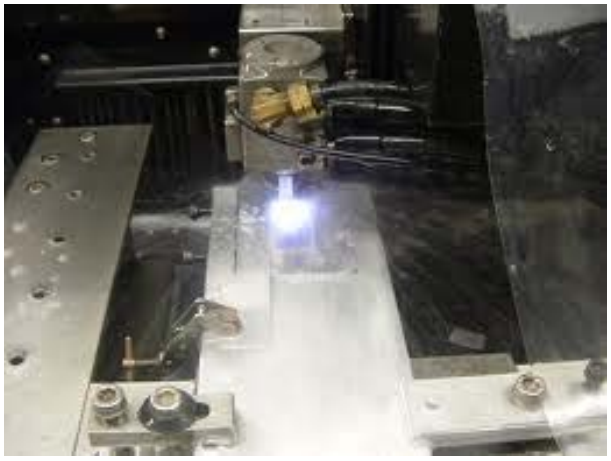


Figure 3.11: Electrical Discharge Machine process

3.7.2.3 Fabrication of gear

It same goes to the fabrication process for gear which is use the EDM machine to get the high accuracy and precision result according to the desired design. The suitable material that been used for the gear is mild steel. Mild steel has the strength required to make contact with the rack of the injection plunger. Refer figure 3.12.

Figure 3.12: Fabrication of gear

3.7.2.4 Fabrication of nozzle

The fabrication of nozzle involves the use of advance machining process which is the use of turn mill machine. The first operation is to make an outer radius of the nozzle that needs us to create the program through the machine computer. After desired shape have been gained, continue the shaping process by using conventional lathe machine to make a hole inside of the nozzle. Because we have decided to use the ABS plastic as the main material, the nozzle tip must be design to be full-taper. The last process to finish the nozzle is to make a hole to allow the screw to be attached on it during fitting the nozzle with the barrel. Refer figure 3.13.

Figure 3.13: The Mazak Nexus 200 turn mill machine

3.7.2.5 Fabrication of hopper

The main machines that been used to fabricate the hopper are vertical bend saw and Metal Inert Gas welding machine (MIG). The suitable material for the hopper has been defined which is mild steel with the thickness of 1 mm. The first step is cut the plate material with the vertical bend saw machine according to the design. After gain the desired shape, the joining process of the hopper is done through the welding process. This process is quite hard to utilize due to the small dimension of the hopper. The welding process must be done smoothly to avoid any mistakes and disablement of the product. Refer figure 3.14.

Figure 3.14: Part of the hopper that through the welding process

3.7.2.6 Fabrication the foundation of the machine

Last but not least is the fabrication of the foundation for the injection unit. The processes involve are cutting process by using cutting machine and joining process by using MIG machine. After the foundation has finished the welding process, it is important to make sure there are no burrs left on the product to avoid any unbalance structure because this structure needs to be stable and solid enough stand and support the injection unit.

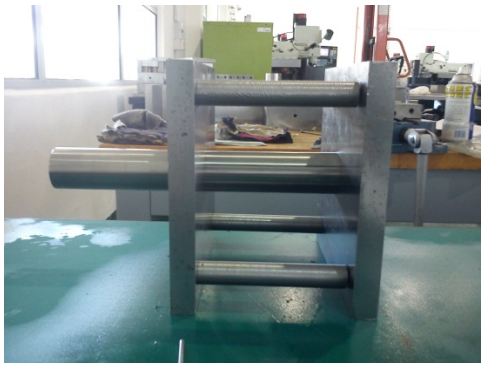
3.8 Assembly Process

The next process that takes place is the assembly process. Assembly process is the process where the assembly of the entire components to be a complete mini micro injection moulding machine. The assembly process is separated into two parts which are assembly of the clamping unit components and the assembly of the injection unit component.

The clamping unit consists of platen, movable platen, tie bars and foundation. Most of the assembly process is using the fastener which is M10 and M6 size of screws. The injection unit consist of barrel, injection plunger, support plate, tie bars, hopper, heater band and motor. The assembly process that required by this unit are using fastener and welding process. The fastener such screw with the size of M10 is use to assemble the support plates and tie bars. Welding process that applied the joining process is use to attach the hopper on top of the barrel.

After both clamping and injection units are finished the assembly process, both components will be place and align at the same position. It is important to ensure that the level or height of clamping and injection units is same in order to fitting the nozzle with the mould. Finally the mini micro injection moulding machine is ready to be tested and analysis. Refer figure 3.15.

(1)



(2)

(3)

Figure 3.15: (1) Assembly of clamping unit, (2) Assembly of injection unit, and (3) Full assembly of machine

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

In this chapter, is discussed the result that gained from the product that been completely finish the fabrication process. The mini micro injection moulding machine has been develop through some processes which started from designing the machine, design comparison, fabrication process and assembly process.

The analysis process plays an important role in order to develop the mini micro injection moulding machine. This analysis has been started in the time of design the machine. In order to follow the specification, design, and mechanism of injection moulding machine, there are some calculation must be done such as the injection plunger size, the suitable electric motor required by the injection moulding machine and others.

For the mini micro injection moulding machine, it is very important to consider those calculations to develop a machine that can meet the needs of micro injection moulding machine. Every injection moulding machine has a difference specification and ability, but all the machines have the same purpose. The machine may differ to others conventional injection moulding machine, but it still follows the same mechanism of injection moulding machine and the main function of the machine is to inject the molten plastic into the mould. Besides of cost effective, the machine that been develop is reasonable and can be function to produce prototyping product.

4.2 Machine Design Comparison

4.2.1 Introduction

Before through the machine design comparison, at least two kind of difference design must be done in order gain the best result from the machine design comparison process. The main components also need to define which plays an important role in the mini micro injection moulding machine.

Each of the machines that have been designed has their own specifications that are totally different with each other in term of type of mini micro injection moulding machine, type of plunger, type of motor which function to move the injection plunger, cost effective which is less money is used to fabricate the machine and number of component that going to use that will affect the assembly process either it is easy or hard to assemble. There are two types of injection moulding machine which are horizontal and vertical position. In other word, it shows the movement of the screw or plunger either it moves vertically and horizontally.

4.2.2 Design 1 of Mini Micro Injection Moulding Machine

In designing the first mini micro injection moulding machine, the injection mechanism is move vertically, which means the plunger will push the molten plastic into the mould vertically. Refer figure 4.0.

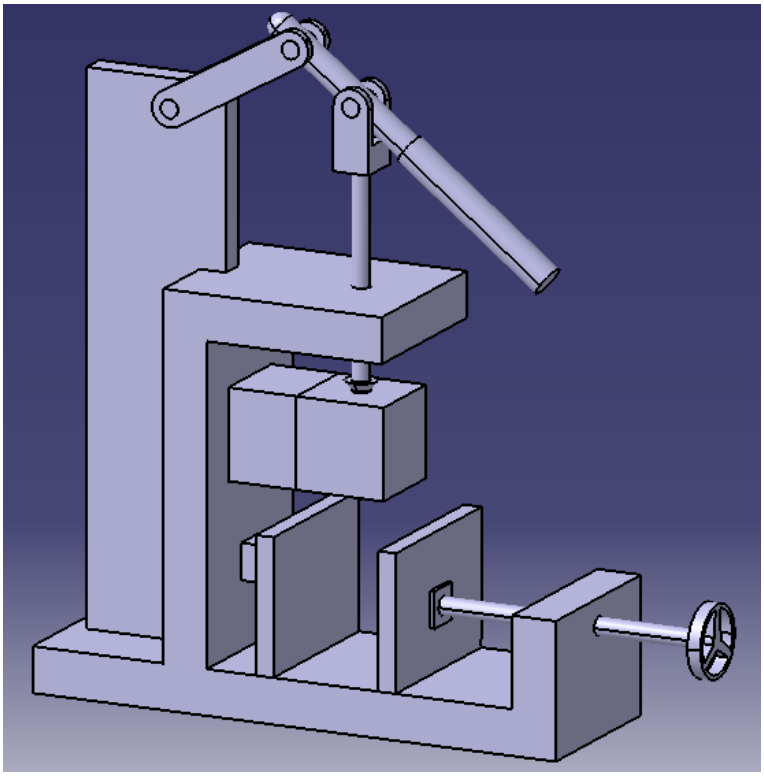


Figure 4.0: Design 1 Mini Micro Injection Moulding Machine

4.2.3 Design 2 of Mini Micro Injection Moulding Machine

While for the second design, the injection mechanism is move horizontally, which means the plunger will push the molten plastic into the mould horizontally. Refer figure 4.1.

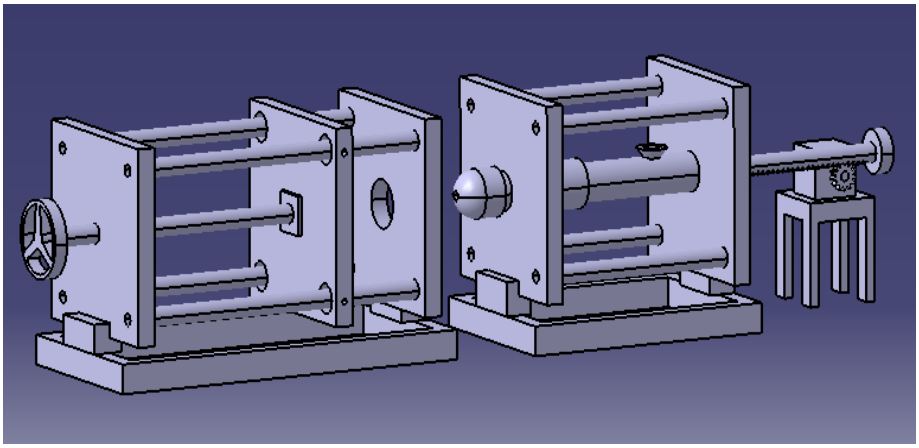


Figure 4.1: Design 2 Mini Micro Injection Moulding Machine

4.2.4 Comparison between design 1 and design 2

There are lot differences between design 1 and design 2 of mini micro injection moulding machine. The first comparison that has been made is type of the machine. Design 1 used the vertical injection mechanism while design 2 used the horizontal injection mechanism. Generally, the common conventional injection moulding machine in the industry is the horizontal type of injection mechanism, this is because, the horizontal type of injection mechanism is easy to handle in term of injection operation, machine handling, maintenance and others. Refer table 4.0.

For the design 1, the injection pressure is applied by the users practically which means the force that going to apply to the molten plastic through injection plunger is use by hand. The reason we use this type of pressure is because it is not suitable for the stepping motor to move the plunger vertically. The force or pressure that produced by the human still can be acceptable and afford to produce the force needed in this mini micro injection moulding machine.

While for the design 2, electric motor has been chosen as the element to move the plunger to inject the molten plastic into the mould. The electric motor such as stepping motor has a good accuracy in movement, which is the good characteristic that can bring good precision to the machine. In the mini micro injection moulding machine, the flow rate on molten plastic that going to be injected into the mould must be consistent in order to get the best result of plastic filling. The pressure that produced by the motor also must be suitable to avoid over pack in the time of filling the mould. Furthermore, by using stepping motor, through the controller, it can decide how much the injection plunger needs to be travel to inject 1 gram of molten plastic.

The dimensions that owned by both designs are not much different because they have been designed to be mini machine that easy to place, easy to carry and effective cost but still can function to inject the molten plastic. The fabrication processes for design 1 are estimate to be harder compare to design 2. This is because, the design 1 has more complex components that hard to fabricate and this will affect the assembly process. Design 2 has more simple design and fewer components due to smooth the assembly process.

As the result, design 2 has been choose as the design for mini micro injection moulding machine. The fabrication processes of the machine have been done accordingly to the dimension and all specifications of design 2.

Table 4.0: Design comparison of mini micro injection moulding machine

NO.	Specification	Design 1	Design 2
1.	Type	Vertical	Horizontal
2.	Injection plunger/ screw	Plunger	Plunger
3.	Movement of plunger	By hand pressure	By electric motor
4..	Accuracy	Low	Medium
5.	Injection flow	Not consistent	Consistent
6.	Cost	Low	Low
7.	Assembly	Medium	Medium

4.3 Product Calculation

The mini micro injection moulding machine is function to produce a product that has a weight less than 1 gram. In this section, it will discuss how much the injection plunger needs to be travel to inject the 1 gram of product including sprue and runner. The machine has used the injection plunger that size of 20 mm diameter. From the size of the injection plunge, the distance of travel that need by the plunger can be determine. But before that we need to define the melt plastic density for Acrylonitrile Butadiene Styrene (ABS) plastic type. For the mini micro injection moulding machine, ABS plastic is the material to be melted in the barrel. The melt plastic density for ABS is 0.97 gr/cm³. By using the formula of density, we can find the value of travel that needed by the plunger to produced 1 gram of product.

$$P = m/ v$$

Where;

Density, P = 0.97 gr/cm³

Mass, m = 1 gram

Volume, V = unknown

Find the value of volume (V). Replace the equation with the given value.

$P = m/ v$

$0.97\ gr/cm^3 = 1gr/ V$

$V = \underline{1.03\ cm^3}$

4.4 Plunger Travel Distance

After the value of volume (V) has been gained, which is 1.03 cm^3, now w the value of distance that need to travel by the plunger can be determine by using the formula of volume

$$V = \pi r^2 t$$

Where;

Volume, V = 1.03 cm^3

Radius of plunger, r = 1 cm

Thickness or length of travel, t = unknown

Find the value of thickness (t). Substitute the equation with the given value.

$V = \pi r^2 t$

$1.03\ cm^3 = \pi (1)^2 t$

$t = \underline{0.327\ cm}$

The value of t, that gain from the calculation is the value that needed by the injection plunger to move in order to inject 1 gram of molten plastic into the mould cavity. As the conclusion, the injection plunger needs to move about 0.327 cm to inject 1 gram of product.

4.5 Plunger rack calculation

In this section, the calculation related in order to find the number of teeth required by the plunger rack will be discuss. The function of rack on the plunger is to allow the gear to make contact on it so that the gear that powered by motor can move the plunger forward or backward. A rack is a rectangular prism with gear teeth machined along one side- it is in effect a gear wheel with an infinite pitch circle diameter. The gear that going to used has 6mm per tooth of circular pitch distance. The formula that have been apply to get the value of number of teeth required is

$$n = L/ p$$

Where;

Number of teeth required by the rack, n = unknown

Length of travel expected of plunger, L = 50mm

Circular pitch distance of gear, p = 6mm/ tooth

Find the value of n by substitute all the value

n = L/ p

n = 50mm/ 6mm per tooth

Number of teeth required by the rack, n = 10 teeth

This mean, the plunger rack needs 10 teeth so that it can travel about 50mm of distance. Refer figure 4.2 and figure 4.3.

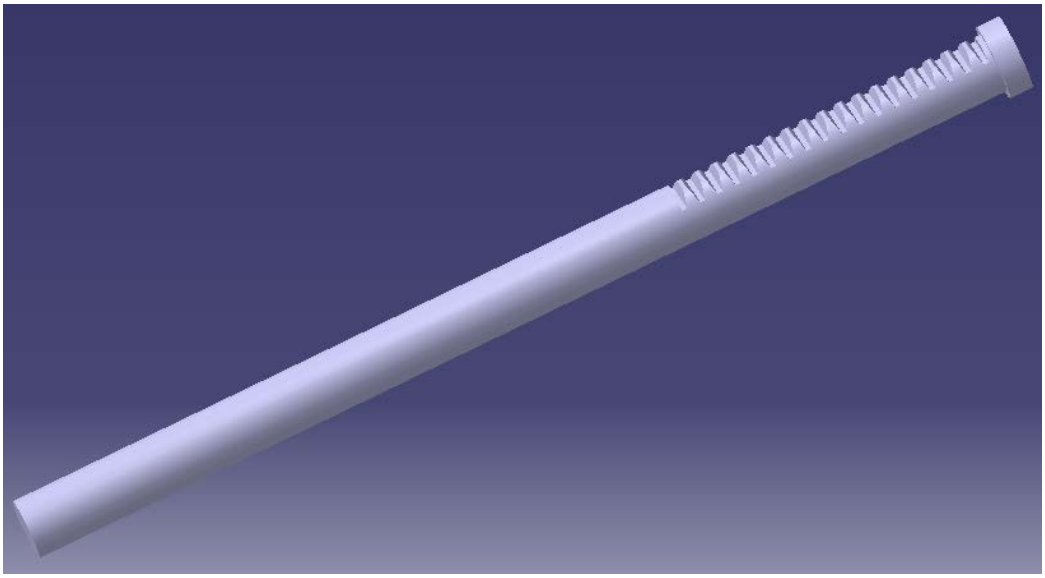


Figure 4.2: Isometric view of injection plunger with rack

Figure 4.3: Side view of injection plunger with rack

4.6 Calculation of spur gear

The gear plays a critical part in the movement of injection plunger. Gears are machine elements used to transmit rotary motion between two shafts, normally with a constant ratio. Design of gear must be suitable with the design of rack on the injection plunger due to the importance of accuracy for both rack and gear in order to get smooth fitting.

To get the number of teeth required on spur gear, some calculation has been done by using related formula which is

$$n = \pi \text{ (Pc diameter)}/ p$$

Where;

Number of teeth required on spur gear, n = unknown

Diameter of pitch circle, Pc = 24mm

Circular pitch distance, p = 6mm per tooth

Find the value of n by substituting all the value we get

$n = \pi$ (Pc diameter)/ p

$n = \pi$ (24mm)/ 6mm per tooth

Number of teeth required on spur gear, n = 14 teeth

This mean, spur gear needs 14 teeth so that it can finish the cycle to move the plunger rack about 50mm of distance. Refer figure 4.4 and figure 4.5.

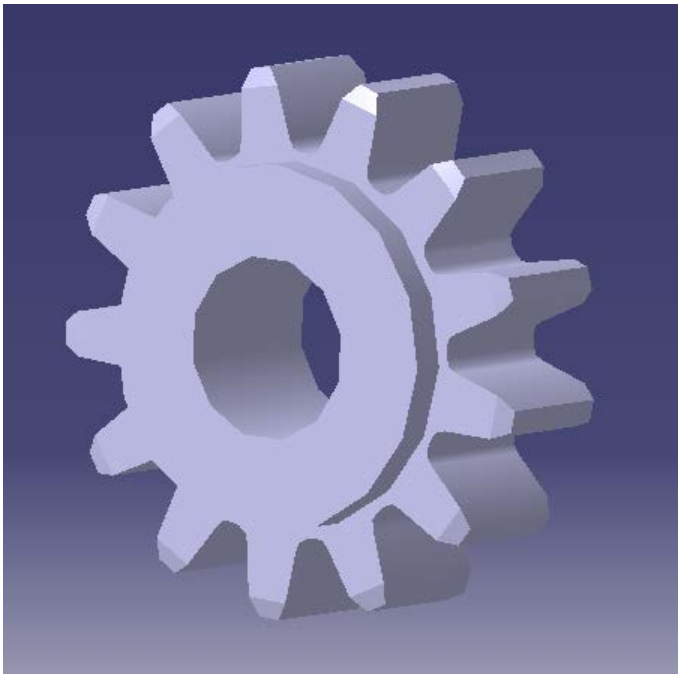


Figure 4.4: Isometric view of spur gear

Figure 4.5: Side view of spur gear

4.7 Selecting the suitable motor calculations

The next calculation is to select the suitable motor to move the injection plunger. There are some parameters that we need to consider in order to find the suitable motor which are the angular velocity, torque of the motor, turning force and power.

First, the angular velocity must be calculate by applying the formula of

$$\omega = v/ r$$

Where,

Angular velocity, ω = unknown

Injection linear velocity, v = 1.6 m/s

Radius of motor shaft, r = 0.005 m

Substitute these values into the equation we get

$\omega = v/ r$

$\omega = \underline{320 \text{ rad/ sec}}$

After the value of angular velocity has been obtain, the next calculation is to find the number of revolution per minute (RPM) by using the formula of

$$N = 60\ \omega/ 2\pi$$

Where,

Revolution per minute, N = unknown

Angular velocity, ω = 320 rad/ sec

By substitute the values into the equation

$N = 60\ \omega / 2\pi$

$N = 60\ (320\ rad/\ sec)\ /2\pi$

N = 3055 rpm

The torque of the motor can be finding by the formula of

$$T = Fr$$

Where,

Torque, T = unknown

Force, F = 19.62 N where the force required by the motor to move the injection plunger

Radius of shaft, r = 0.005 m

By substitute the values into the equation, the value of torque can be find

T = Fr

T = 0.0981 N.m

As the result, the suitable motor required for the mini micro injection moulding machine can be refer to motor specification summary. Refer table 4.1.

Table 4.1: Specification of an electric motor

NO.	Item	Description
1.	RPM	3055
2.	Torque	0.0981 N.m

4.7.1 Comparison of motor type

In order to select the suitable of motor type that going to use in the mini micro injection moulding machine, some comparison of motor types that exist in the market have been made. The most suitable motor for our injection moulding machine is stepper motor due to the precision positioning and high holding torque. The injection plunger needs to be move precisely to inject 1 gram of product including runner and sprue. Refer table 4.2.

Table 4.2: Comparison of motor types

NO.	Type	Advantages	Disadvantages	Application
1.	Universal motor	High starting torque, compact, high speed.	Maintenance (brushes) Shorter lifespan Usually acoustically noisy Only small ratings are economic	Handheld power tools, blenders, vacuum cleaners, insulation blowers
2.	AC Synchronous	Synchronous speed	More costly	Industrial motors Clocks Audio turntables Tape drives
3.	Stepper DC	Precision positioning High holding torque	Some can be costly Require a controller	Positioning in printers and floppy disc drives; industrial machine tools
4.	Brushed DC	Simple speed control	Maintenance (brushes) Medium lifespan Costly commutator and brushes	Automotive accessories

4.8 The Mini Micro Injection Moulding Specification

After all the calculation has been made, the specification for the final product of the mini micro injection moulding machine can be describe from table 4.3.

Table 4.3: Mini micro injection moulding machine specification

NO.	Components	Descriptions	Materials
1.	Injection plunger	17 teeth of rack. Need 10 teeth to move 50mm of distance.	Hardened steel
2.	Barrel	Single heater band	Mild steel
3.	Hopper	Square type	Mild steel
4.	Spur gear	14 teeth on spur gear	Mild steel
5.	Supporting plates	Hold the cavity mould	Mild steel
6.	Platen	Movable platen which hold the core mould	Mild steel
7.	Tie bars	Support the platens	Mild steel
8.	Machine foundation	Support both clamping and injection unit	Mild steel
9.	Nozzle	Full taper tip type	Aluminium
10.	Heater band	Misumi heater band	-
11.	Electric motor	Stepper motor with 3055Rpm and 0.0981N.m of torque	-

4.9 Final Design

The final design of mini micro injection moulding machine has been achieved after going through some analysis processes. The analysis processes have been started with the design comparison that bring to the selection of the best design. The best design that been selected is the design that apply the horizontal of injection mechanism where the injection plunger is move horizontally to inject the melted plastic material.

After the best design has been selected, the next processes is to determine the distance that need to travel by the plunger in order to inject one gram of product, number of rack on the plunger, number of teeth needed by the spur gear and the suitable electric motor require to move the injection plunger. After all the specifications of the mini micro injection moulding machine have been determine, the fabrication process of the machine is taking place.

This machine is separated into two sections which are clamping unit and injection unit. Generally, the clamping unit consist of movable platen and support plate that function to hold the mould. While the injection unit consists of electric motor that function to drive the injection plunger that move horizontally to inject the molten plastic into the mould cavity trough nozzle. Besides that, the machine also uses a full taper tip nozzle that suitable for the materials such as ABS and acrylic. The material will be melted by using the heater band that will supply the heat to the barrel. All the components of the final design of mini micro injection moulding machine can be refer to figure 4.6.

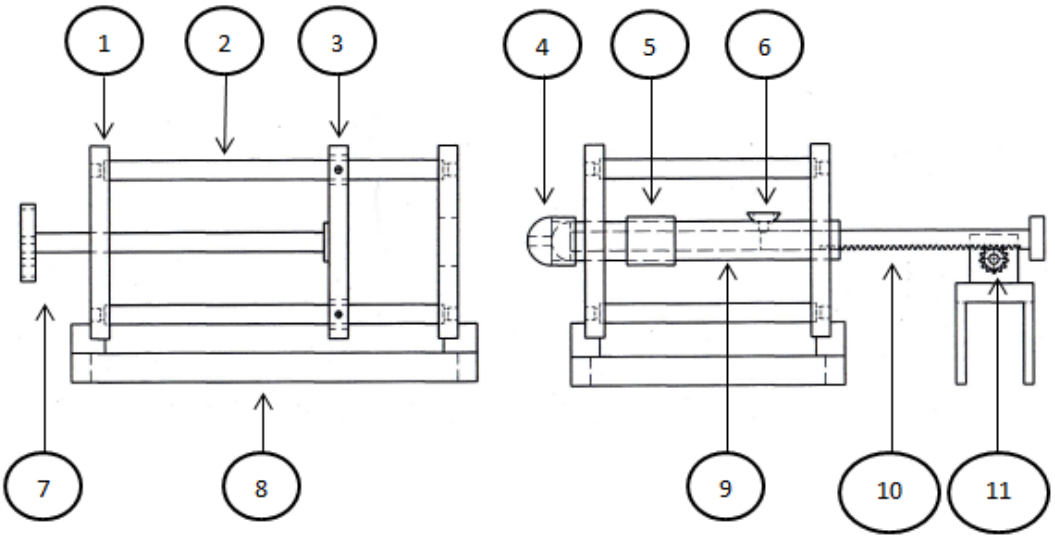


Figure 4.6: Side view of mini micro injection moulding machine

Refer to figure 4.6; the list of component can be described as:

1. Platen
2. Tie bars
3. Movable platen
4. Nozzle (full taper tip)
5. Heater band
6. Hopper
7. Handle lock
8. Machine foundation
9. Barrel
10. Plunger
11. Electric motor with gear

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The objectives of the project which are to design and fabricate the mini micro injection moulding machine have been achieved. During the time of develop the mini micro injection moulding machine, the project has been started by doing some research about the existing mini injection moulding machine in the market. There are lot of sources that can be referring such as journal, books, internet and others. After done with the research study, the process continued with the designing process according to the standard specification that owned by the mini injection moulding machine. There are two designs had been create in order to do the design comparison. From the design comparison, defining the best design that will going through the fabrication process is taking place. At this stage, the objective to design the mini micro injection moulding machine has been achieved. After the machine has finished the fabrication process, the second objective has met the target.

The machine is separated into two sections which are clamping unit and injection unit. The clamping unit consist of movable platen and support plate that function to hold the mould. While the injection unit consists of electric motor that function to drive the injection plunger that move horizontally to inject the molten plastic into the mould cavity trough nozzle. Besides that, the machine also uses a full taper tip nozzle that suitable for the materials such as ABS and acrylic. The material will be melted by using the heater band that will supply the heat to the barrel.

In order to develop the mini micro injection moulding machine, there are lot of skill and knowledge have been applied such as designing the product by using CAD software, fabrication process that need a process flow and define the suitable machine required to fabricate the product and last but not least apply the calculation related with the machine design.

During the development, there are some difficulties have been faces while utilize the fabrication process such as fabrication of the nozzle, hopper and rack on the injection plunger where the patient and focus are comes first.

5.2 RECOMMENDATION

As the recommendation for the future, the mini micro injection moulding machine still require a lot of improvement in term of temperature control, injection speed control and others. In addition to improve the application, here is some recommendation that might be required by the machine.

1. Develop the suitable mini micro moulding to be testing on the machine
2. Study and improve the temperature controller
3. Improve the injection speed control by study the electric motor
4. Study the clamping force require to hold the mini micro moulding
5. Study the suitable pressure needed to inject one gram of product

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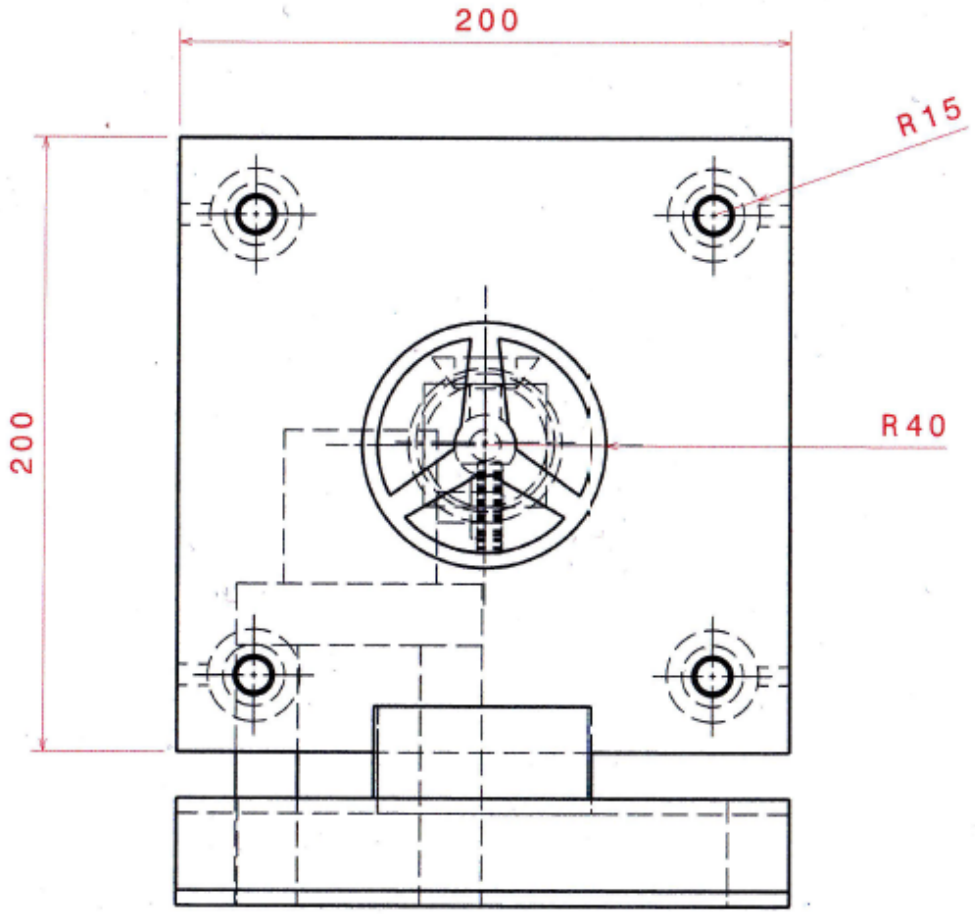
APPENDIX A

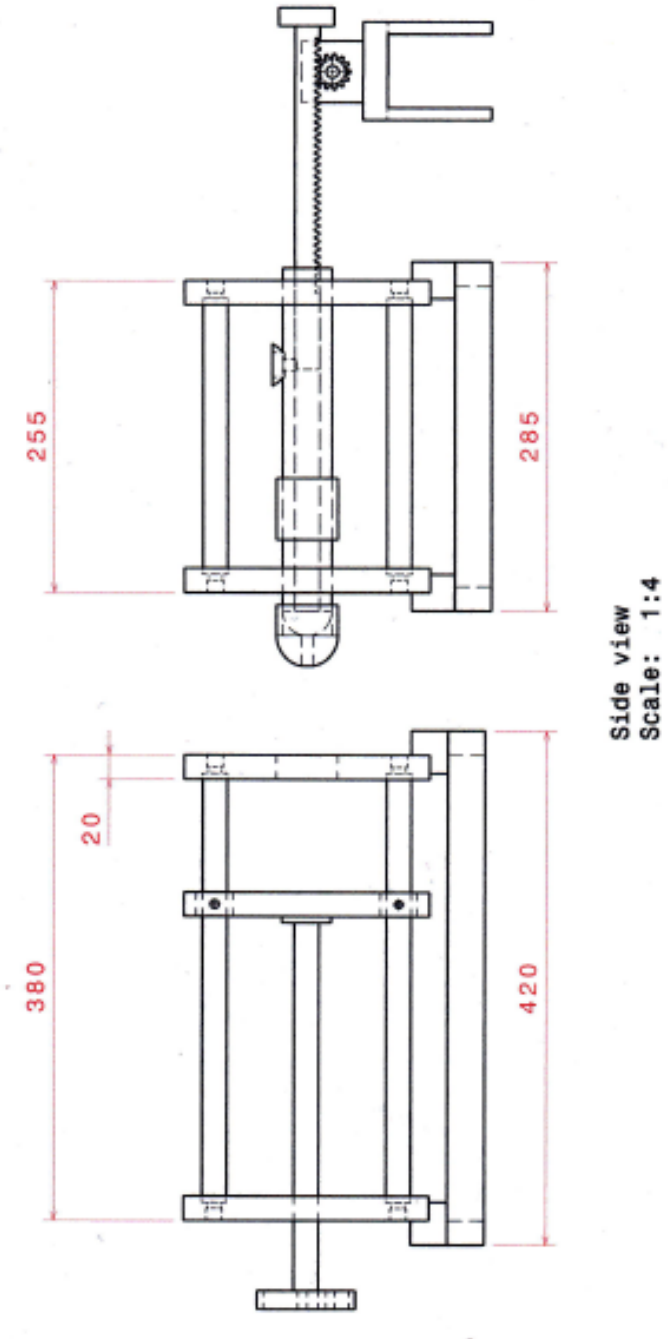
FRONT VIEW OF MINI MICRO INJECTION MOULDING MACHINE



Front view
Scale: 1:2

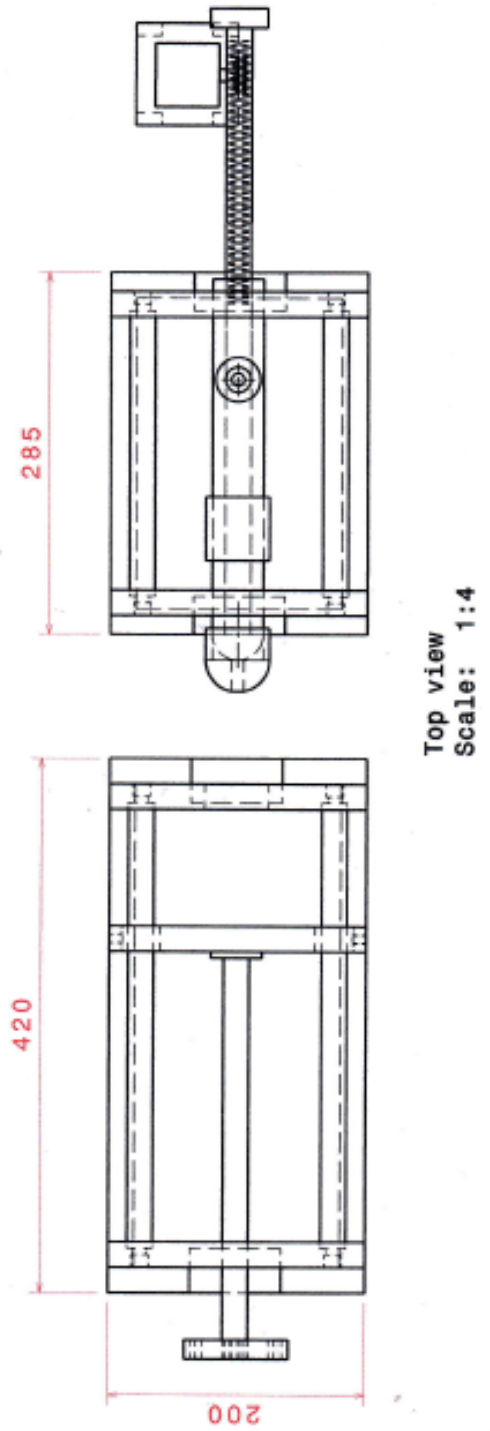
APPENDIX B

SIDE VIEW OF MINI MICRO INJECTION MOULDING MACHINE



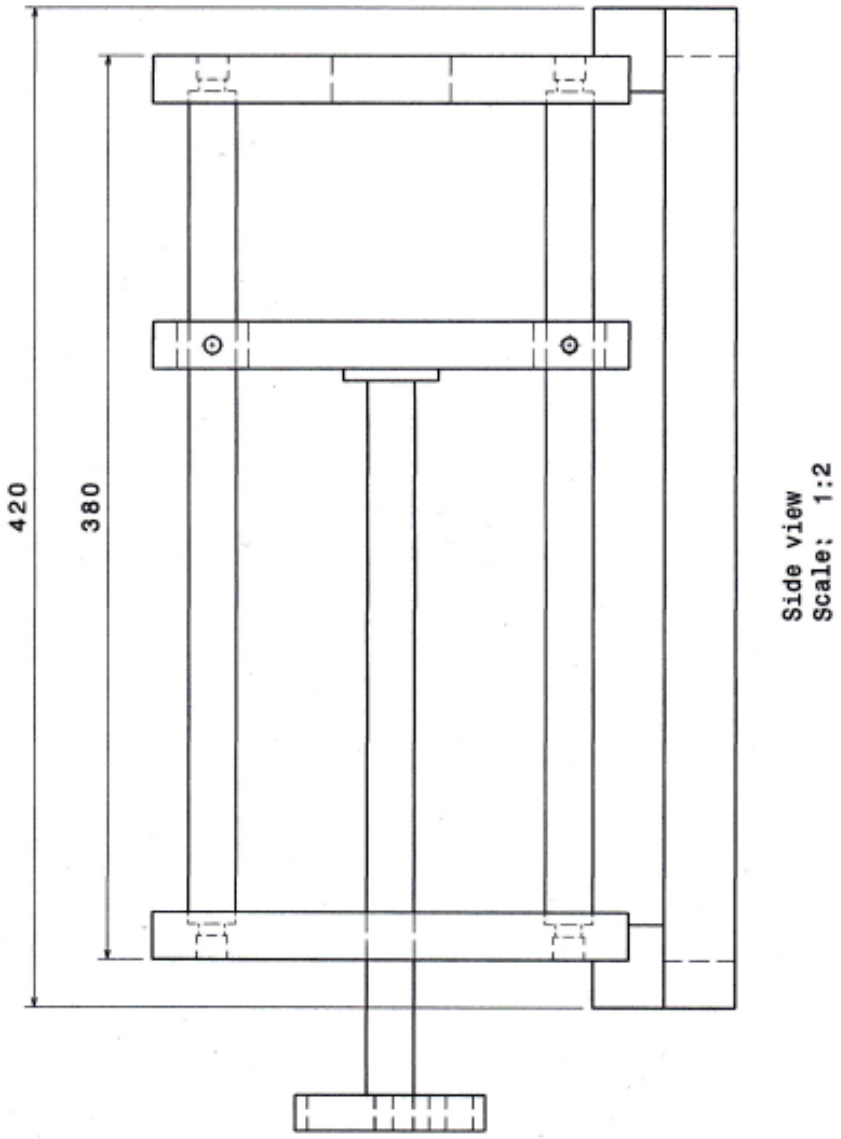
APPENDIX C

TOP VIEW OF MINI MICRO INJECTION MOULDING MACHINE



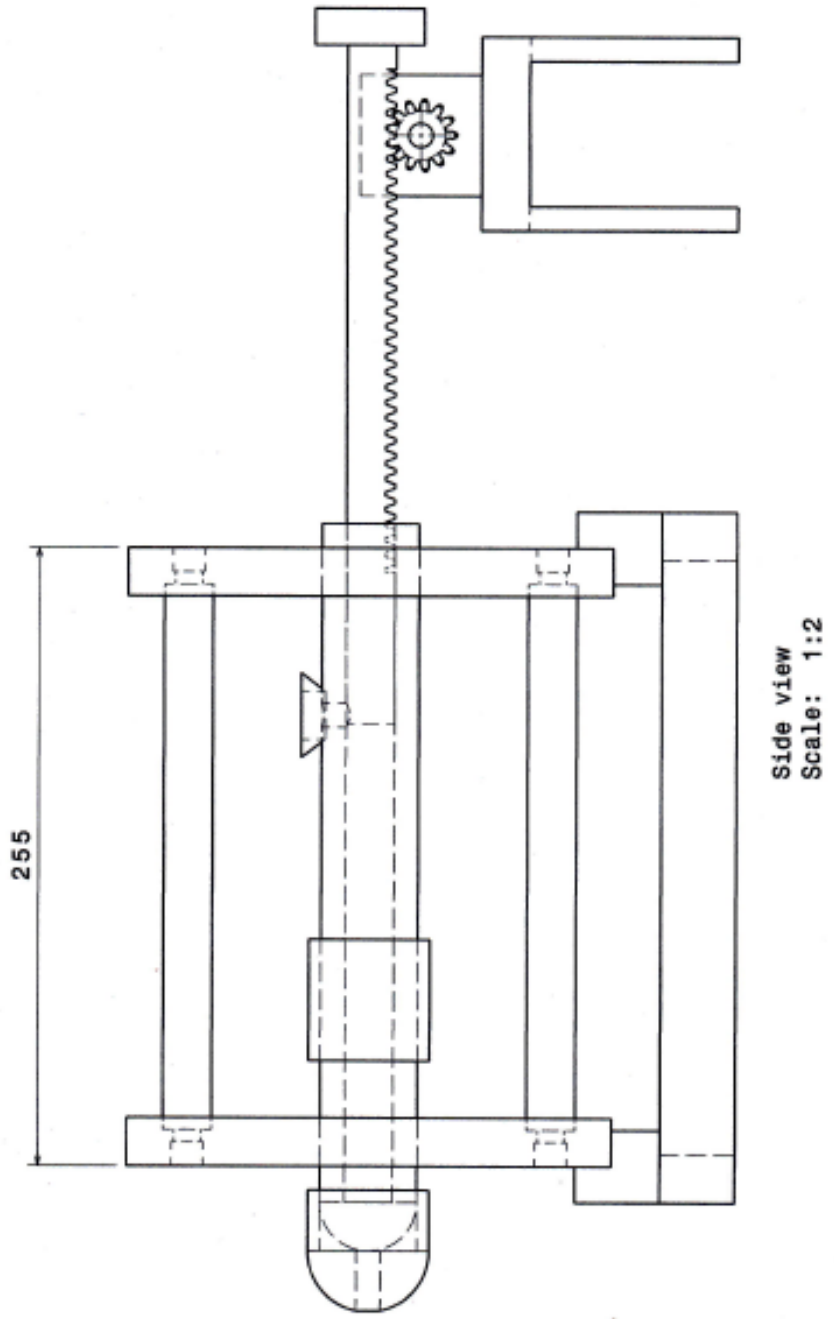
APPENDIX D

SIDE VIEW OF CLAMPING UNIT



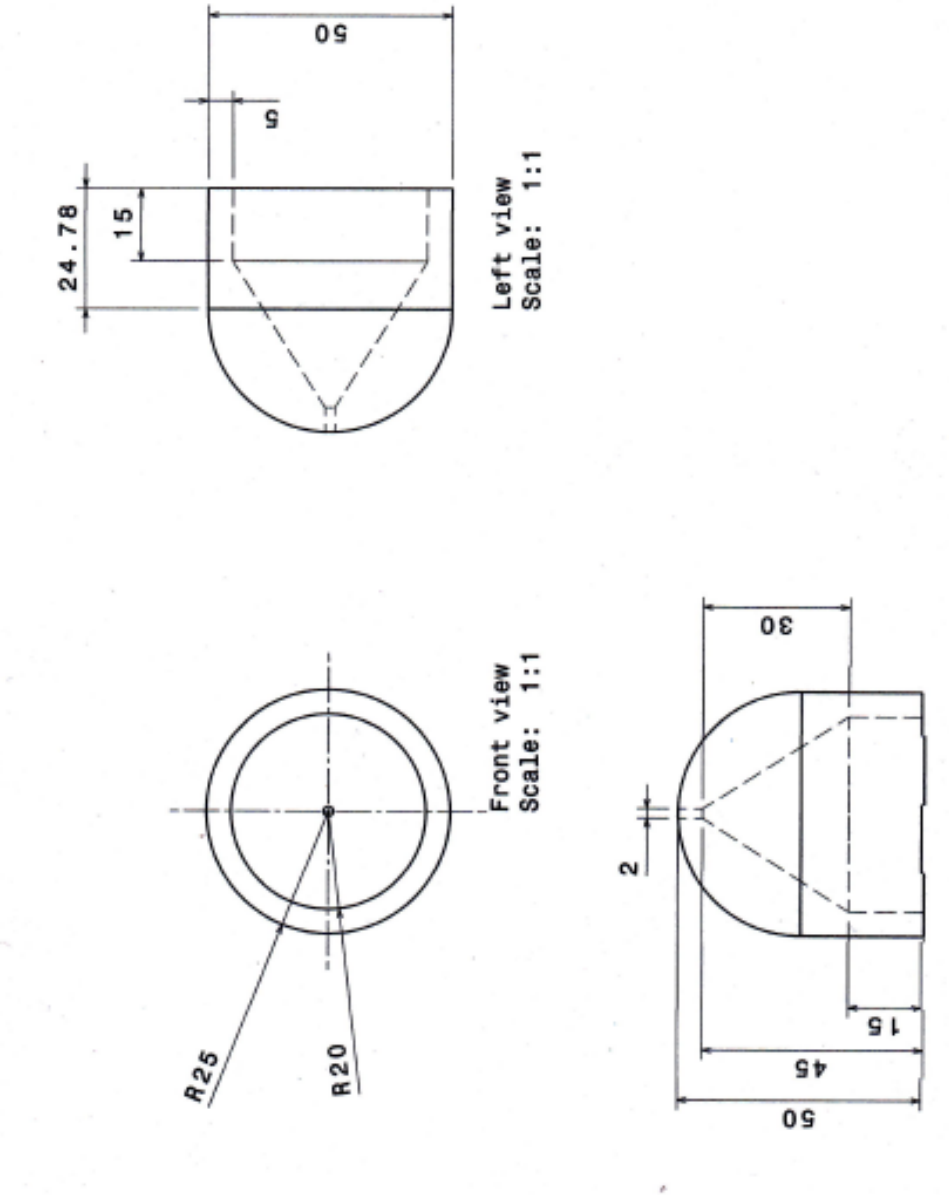
APPENDIX E

SIDE VIEW OF INJECTION UNIT



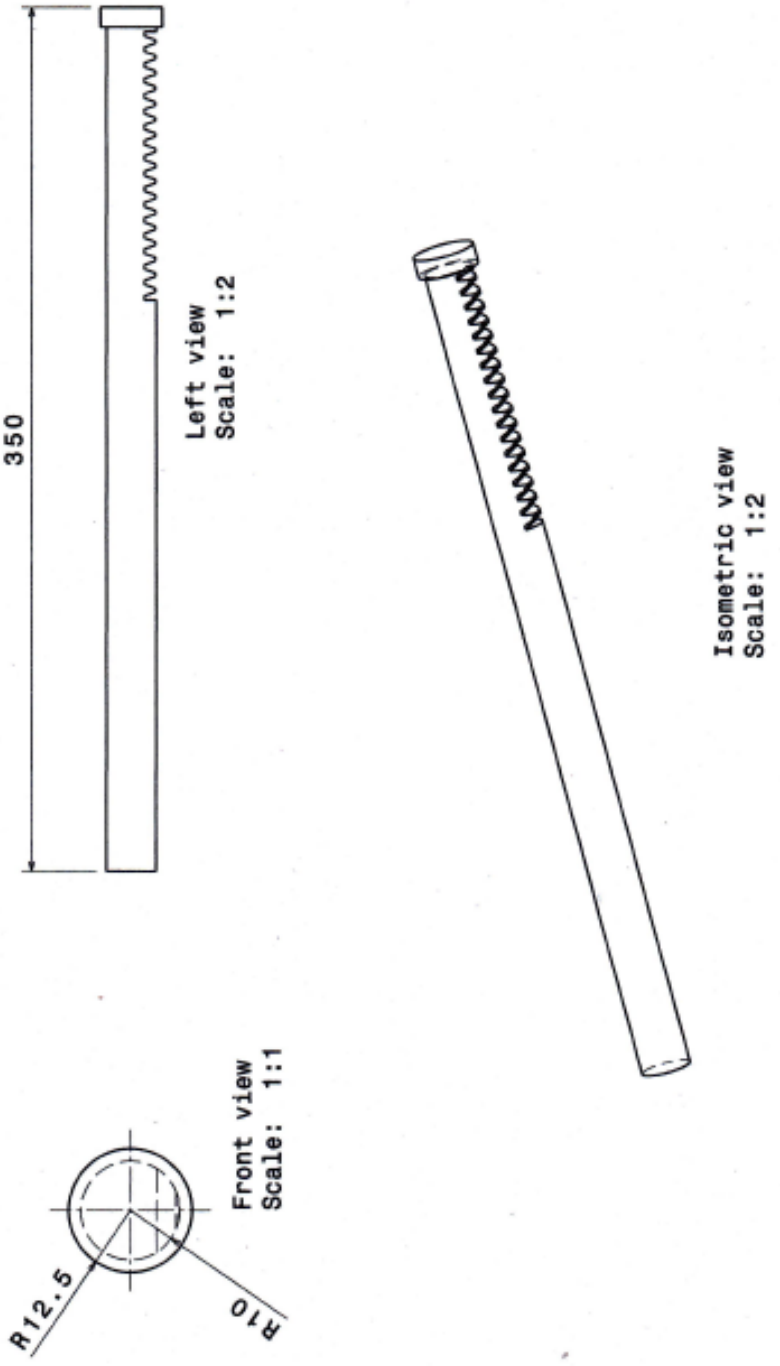
APPENDIX F

ORTHOGRAPHIC VIEW OF NOZZLE



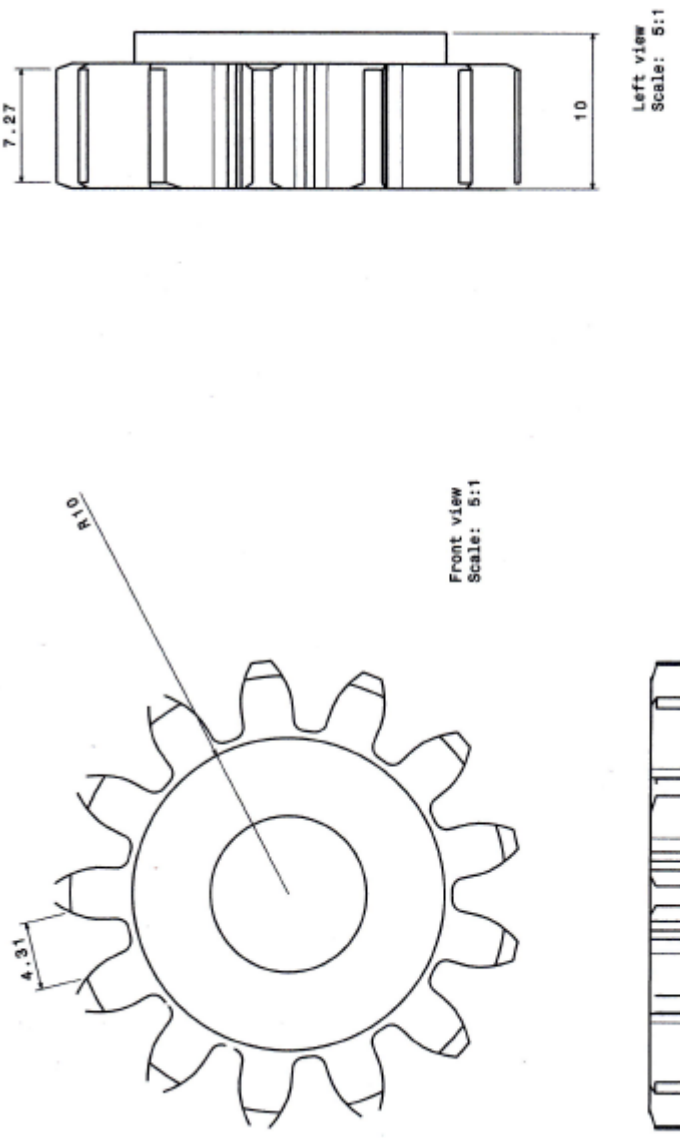
APPENDIX G

ORTHOGRAPHIC VIEW OF INJECTION PLUNGER



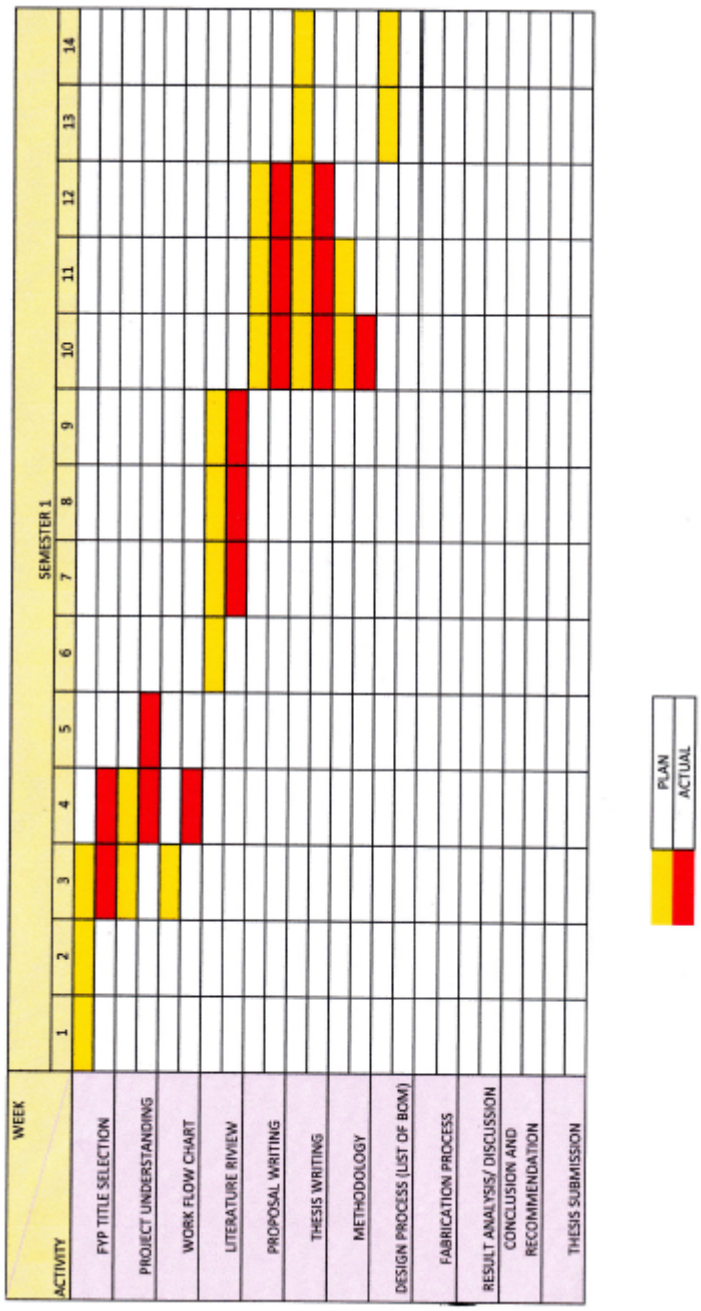
APPENDIX H

ORTHOGRAPHIC VIEW OF SPUR GEAR



APPENDIX I

GANTT CHART FOR SEMESTER 1



APPENDIX J

GANTT CHART FOR SEMESTER 2