# B.Sc. Thesis Writing

# Department of Mechanical Engineering

# University of Central Punjab

# Design and Fabrication of Injection Molding Machine with Efficient Screw Design

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Thesis submitted for the undergraduate degree in Mechanical Engineering
at the University of Central Punjab


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**Session 2019-2023**
**Department of Mechanical Engineering,**
**University of Central Punjab, Lahore Pakistan**

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# ABSTRACT

The rate of demand and supply is increasing day by day due to which the rate of production is affecting. So, it is important to find cost and time saving methods to increase the rate of production.

Injection molding machine is used for mass production, so it is important to notice the quality of product being produced by it. This will help to achieve better result. The injection molding machine is an expensive machine, so it is important to maintain it timely to avoid failures.

Some materials such as Acrylonitrile Butadiene Styrene (ABS) deposit inside the screw of the machine as the machine cools down and difficult to remove or melt them because they stuck inside the sharp edges of screw. So, the  purpose of this project is to design and fabricate an injection molding machine which is easy to maintain.

The overall dimension of machine is design according to the size of the screw of machine. Screw is designed in round shape to avoid the deposition of material inside it. The flow rate is calculated according to the length of screw and opening of the nozzle.

This project will help to learn about the maintenance of injection molding machine and to learn different operation performed for maintaining this machine. The following report contains the detail information about the project. History, costing, components, and fabrication. Every chapter contains the detail of the project.

# ACKNOWLEDGEMENTS

We would like to reveal our gratitude and appreciation to all those who gave us the possibility to complete this report. Special thanks to our supervisor. Prof Sadaf Zeeshan whose help, stimulating suggestions and encouragement helped us in all time of process and in writing this report.

Her expertise and professional experience in Mechanical Engineering has enabled us to complete this research and project successfully. Without her support this project would not have been possible We are also grateful to the University Faculty for their consistent support and encouragement.

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# LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| **ABS** | Acrylonitrile Butadiene styrene |
| **HDPE** | High density polyethylene |
| **LDPE** | Low density Polyethylene |
| **PC** | Polycarbonate |
| **PP** | Polypropylene |
| **TPU** | Thermoplastic polyurethane |

## MAPPING WITH COMPLEX ENGINERRING ATTRIBUTES

| Attribute | Description | Mapping |
|---|---|---|
| WP1 | Depth of Knowledge Required | ✓ |
| WP2 | Range of conflicting Requirements | |
| WP3 | Depth of analysis required | ✓ |
| WP4 | Familiarity of issues | |
| WP5 | Extent of applicable codes | |
| WP6 | Extent of stakeholder involvement and Conflicting requirements | |
| WP7 | Interdependence | |
| EP1 | Consequences (Professional Competency) | |
| EP2 | Judgement (Professional Competency) | |

## MAPPING WITH UN SDGs


# CHAPTER ONE: INTRODUCTION

## Overview

This chapter describes with some basic history of injection molding machine and about manufacturing it also express the type of manufacturing and the products that can be produce using injection molding. This section also explains about the description of machine and the types of injection molding machine. Some manufactured products and type of material that can be used in injection molding are also discussed in this chapter.

## 1.1 History of Injection Molding

Inventing things has been an essential activity of human since before recorded history. American inventor John Wesley Hyatt, together with his brother Isaiah, evident the first injection molding machine. This machine was invented in 1872.it was a simple machine as compared to today’s machine. it worked like a large hypodermic needle, using a plunger to inject plastic through a heated cylinder into a mold. The industry progressed slowly over the years, producing products such as collar stays, buttons, and hair combs. The German chemists Arthur Eichengrun and Theodore Becker invented the first soluble forms of cellulose acetate in 1903, which was much less flammable than cellulose nitrate It was eventually made available in a powder form from which it was readily injection molded. Arthur Eichengrün developed the first injection molding press in 1919. In 1939, Arthur Eichengrün patented the injection molding of plasticized cellulose acetate.

## 1.2 What is Manufacturing?

Technology is the application of science the helps the society and its members to provide with those things that are desired. The technology fascination would not be possible if they cannot be manufactured.

The word manufacturing is derived from two Latin word *manus* (hand) and *factus* (make) which means made by hand. Manufacturing has important role in economy of the country. It is also called as back bone of economy. It is a mean by which nation creates material wealth.

Manufacturing is a process that changes the shape, properties, geometry, and appearance of the given raw material to make different parts or in other words it is a combination of machinery, tools, power, and labor. It’s adding value to the material.

The process contains the three main steps which are follows:

***1.2.1 Starting Material***

The starting material is the raw material that achieve some desired shape.

***1.2.2 Manufacturing Process***

- Machinery
- Tooling
- Power
- Labor

***1.2.3 Processed Part***

This is the final product that is generated by processing the raw material.

## 1.3 Manufacturing Products

These are the final products that are produced by the manufacturing. It can be any of the product that is produced by the method of manufacturing like casting, forging, blow molding or injection molding. The manufactured product can be of any desired material and shape it can be of metal, ceramics, polymers, and composites.

This project is of injection molding machine so the products that are produced by injection molding are made of plastics although this machine can produce large products, but this project is for small products. So the products that are produced by it are plastic cup and spoon.

*Figure 1.1* Plastic Glass (Manufactured Product) [3]

*Figure 1.2* Plastic Spoon (Manufactured product) [3]

## 1.4 Introduction to the Project

Plastic molding is done by placing a polymer in a molten state in a mold cavity so that the molten polymer can achieve the desired shape. This process is achieved by changing temperature and pressure. Plastic can be mold by the processes like blow molding, injection molding and rotational molding.

The process of injection molding has vast applications it can be used in manufacturing of children toys, plastic cups, bottle cap.

The advantage of injection molding machine is good surface finish of the product produced by it, produces less scrap and flashes, and this process has a significant advantage of low labor cost. In large scale industries it is hard to maintain the cleaning of injection molding machine because the material stuck inside the machine as it cools down and is difficult to remove or melt that causes loss in production time.

So, this research work intends to find the solution of these challenges. It involves the simple design which can be produce locally. This work is aimed at design and fabrication of easy maintenance injection Molding machine that can melt the plastic material and the material that melts would not be struck inside the screw of the machine to avoid production loss. This machinery is affordable to those who are working in informal sector which are less complex and cheap to maintain.

## 1.5 Principles of Operations

The injection molding machine has a very simple principle. The injection molding process is initiated with a feeding of polymer which is the form of beads or powder. By the help of hopper. The function of hopper is that it is an inlet point and holder for the raw material. The beads of plastics are passed from hopper to the barrel through gravity. The barrel is an assembly that holds screw and heater inside it. The heater inside the barrel act as a heating source for the plastic to completely transform to liquid state. The screw inside the barrel is used for compressing and melting the material.

There are three zones in the screw:

***1.5.1. Feeding Zone***

This is the first zone in which the material is added to the screw by hopper and there is no change in the orientation of the plastic material which are in the form of beads, and they are transferred to the next zone.

***1.5.2 Transition Zone***

This is the second zone. In this zone the melting of the plastic beads occurs, they are converted into the liquid state and transferred to the next zone.

***1.5.3 Metering Zone***

This is the final zone. In this zone the molten material is ready for the injection.

There is a nozzle connected to screw for injecting the molten material to the die and die forms the required shape.
Finally, the product is removed from the mold marking the end of the process.
The diagram of the machine which are used by large scale industries is shown below:

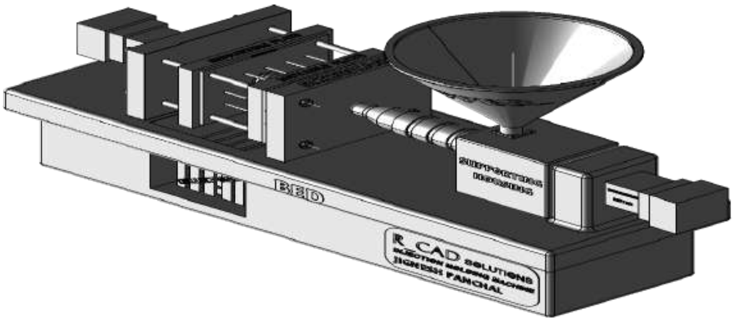



*Figure 1.3* Large Scale Injection Molding Machine [3

## 1.6 Types of Injection Molding Machine

The modern types of injection molding machines are explained in following [1]:

***1.6.1 Hydraulic Injection Molding Machine***

This machine was firstly introduced in Japan in early 1980s. The benefits of hydraulic injection molding machine are:

- Lower price
- Cheaper parts
- Durable parts
- Economical
- Consumes less power.

*Figure 1.4* Hydraulic Injection Molding [3]

### *1.6.2 Electric Injection Molding Machine*

This machine was also introduced in early 1980s and become popular the benefits of this machine are:

- Energy efficient
- No use of oil
- Faster process
- Clean operations

*Figure 1.5* Electric Injection Molding Machine [3]

### *1.6.3 Hybrid Injection Molding Machine*

This machine performs dual operations it can be used on electric motor or hydraulics.

Its benefits are:

- Affordable specially for medical devices manufacturing
- Diversity
- Less maintenance
- Less experienced

*Figure 1.6* Hybrid Injection Molding Machine [3]

## 1.7 Types of Material Used in Injection Molding and Its Applications

There are many types of material used in injection molding process. The type of material depends upon shape and type of geometry to produce. The famous type of material that are used in injection molding are [2].

***1.7.1 Acrylonitrile Butadiene Styrene (ABS)***

ABS is most used material in injection molding. It has a temperature range of 60 – 93℃ and impact strength of 3.0-7.5ft-lb/in. it is used in manufacturing of pipes, automotive body parts and keyboards. It has good properties it has high impact resistance which means it is hard to break.

*Figure 1.7* ABS Pipes [3]

***1.7.2 Nylon***

Nylon is the second most famous type of material used in injection molding. It has a temperature range of 93-177℃ and an impact strength of 2-8ft-lb/in. They are for designing of electrical insulators. It absorbs water from the moisture in the air.

***1.7.3 High Density Polyethylene (HDPE)***

This material has a maximum temperature range of 120C.It has good chemical resistance and tensile strength of 3200Psi. It is affordable and stiff material. The HDPE has a disadvantage of flammable. They are used for making toys, shampoo bottles.


*Figure 1.8* HDPE Bottles [3]

***1.7.4 Low Density Polyethylene (LDPE)***

LDPE is a softer material as compared to the HDPE because of its lower density. It is used for making plastic bags and playground slides. This material has excellent chemical resistance, and it can withstand up to 90°C.

*Figure 1.9* DPE Bottles [3]

***1.7.5 Polycarbonate (PC)***

It is a hard material used in engineering. It is used for making safety helmets, bulletproof glass, and some electrical hardware's. It can be sensitive to scratching. It has poor chemical resistance, and it can withstand up to 316°C.

*Figure 1.10* PC Helmet [3]

***1.7.6 Thermoplastic polyurethane (TPU)***

TPU has many different properties such as elasticity, transparency, and resistances. Its traits are its soft and hard segments. The main use for this type of plastic is cases for mobile phones as well as keyboard protectors and footwear. Its temperature range is 71-121°C. and impact strength of 0.8-10.1ft-lb/in.

*Figure 1.11* TPU Straws [3]

### *1.7.7 Polypropylene (PP)*

PP is basically a thermoplastic polymer it is most common in food and packing industry. It is high impact strength and good moisture resistant material. Polypropylene (PP) is propylene copolymer with a melting point of around 165℃. Polypropylene has the lowest specific density, 0.91 g/$cm^3$, compared to other general-purpose thermoplastics. The main properties of this material are good heat resistance, hardness, and chemical resistance.

*Figure 1.12* PP Bottles [3]

# CHAPTER TWO: LITERATURE REVIEW

## Overview

In this chapter describes about the research work that has been done so far it includes some research work about automation of injection molding machine, types of material that can be used in this machine. Some work about energy consumption of and force measurement.

## 2.1 Literature Review

In past, much research had been done in injection molding machine. Some are regarding the maintaining, mold cooling and venting of the molding machine. Few of them are discussed in the following:

In 2006 a research paper was published in a conference at USA which was the environmental analysis of injection molding machine. It this project a hydraulic type of injection molding machine was used. It noted that when a polymer production stage is considered in the analysis the energy consumption values increased up to 100MJ/kg [4].

In 2007 a research paper was published in Lahore, Pakistan which was about the embedded system design for injection molding machine. It was electrohydraulic controller system which is more reliable and efficient micro controller system. The software program was written in simple language for the closed-loop control of the injection speed process [5].

A research paper was published in Nigeria 2019 which was about the design and fabrication of mini-injection molding machine for small scale plastic products. This machine was fabricated using a locally sourced material and the machine was tested by using different materials like PP and ABS. temperature of 300 °C was used to melt the material. The performance noted by machine was 261 kg/hr. which is 92% efficiency. Therefore, this innovation is recommended for plastic injection molding machine [6].

Another research paper was published in January 2019, it was about the measurement of force for injection molding machine using ultrasonic technology. A series of experiments are then performed to validate the proposed method. Findings show this method corresponds well with the magnetic enclosed type clamping force tester method, with difference squares less than 0.65 $(MPa)^2$, and standard deviations less than 0.11 MPa. Ultrasonic parameters influence measurement results, with larger ultrasonic probe wafer diameter and higher ultrasonic probe frequency producing better measurement accuracy. Additionally, measurement accuracy is insensitive to the sampling frequency of ultrasonic signals. The proposed method has the advantages of high accuracy and high stability, being non-interfering, non-destructive, low-cost, on-line and with good adherence to health and safety, and it has significant application prospects in injection molding production.

A research paper was published in USA 2017, regarding the energy consumption. Energy monitoring of plastic injection molding process running with hydraulic injection molding machines. In this research it was proved that each hydraulic injection molding machine has a unique profile of energy consumption depending on the design of the machine and process, and then according to these profiles, three types of process designs were identified [7].

# CHAPTER THREE: RESEARCH DESIGN

## Overview

This chapter is related to the research design. This section describes the research design methods to achieve it, types of material for designing screw and shape design of screw are also discuss in this chapter.

## 3.1 Description of the Machine

This machine is designed for small scale industries. It is an inexpensive small size and capable of producing small products.

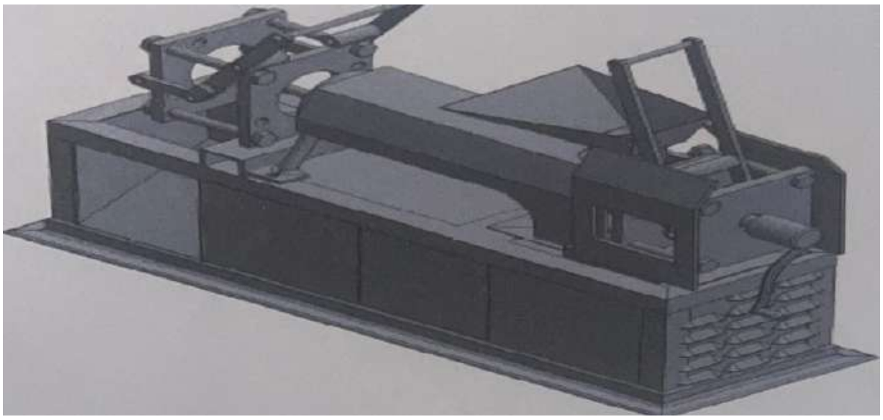


*Figure 3.13* Small-Scale Injection Molding Machine [3]

Table 3.1 *Detail of Required Part and their Quantity*

| Sr | Parts | Quantity |
|---|---|---|
| 1 | Injection fixed plating | 1 |
| 2 | Barrel | 1 |
| 3 | Injection moveable plating | 1 |
| 4 | Plating dwell pine | 8 |
| 5 | Plating dwell pine nut | 8 |
| 6 | Moveable mold plating | 1 |
| 7 | Motor | 1 |
| 8 | Hopper | 1 |
| 9 | Table | 1 |
| 10 | Barrel guard | 1 |
| 11 | Housing | 1 |
| 12 | Injection handle | 1 |

| | | |
|---|---|---|
| 13 | Plating handle | 1 |
| 14 | Nozzle | 1 |
| 15 | Heater | 1 |
| 16 | Injection push bar | 2 |
| 17 | Screw | 1 |
| 18 | Topedo | 1 |

## 3.2 Type of material for Designing Machine Components

Types of material that are used for deigning machine components are mentioned in the following table:

Table 3.2 *Type of Material of Components*

| **Description** | **Material** |
|---|---|
| Barrel | Mild steel |
| Screw | Mild steel shaft |
| Nozzle | Mild steel |
| Topedo | Mild steel |
| Plating hinges | Steel |
| Table | Angle Iron |
| Plating Pin | Steel |

## 3.3 Design of the Component

As this project is related to the maintenance so this project is only focused to the design of screw. For designing an injection molding machine, it is important to keep in view the design of the screw, topedo and nozzle all these three components are the major components of the machine.

### *3.3.1 Screw Designing.*

Screw is the most important part of the machine. It can be also called as heart of machine.it must have higher melting temperature to avoid failures in machine and the edges that are produced over it are very sharp due to which the material stuck in it and create disturbance when machine cools down which ultimately ends in production loss.so to avoid this issue this project is about the maintenance in which the screw will design in round shape. Screw directly affects the machine performance.

The types of screw are following: [8]

*Figure 3.14* Three Section Screw [8]

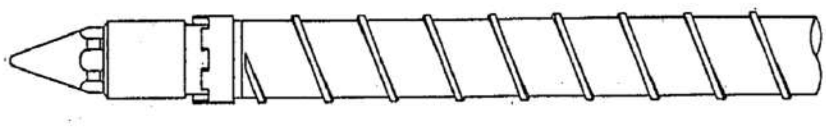


*Figure 3.15* Mixing Ring Screw [8]

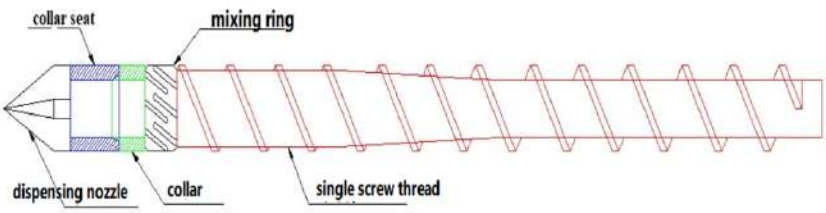



*Figure 3.16* Double Screw Thread [8]

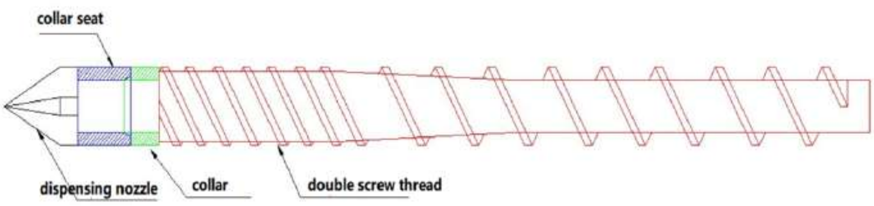



*Figure 3.17* Double Mixing Screw [8]

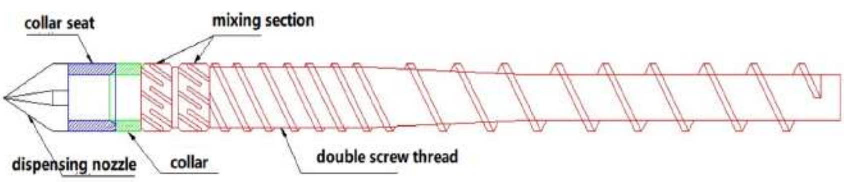
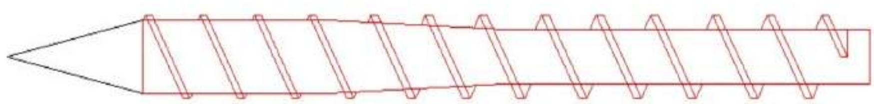



*Figure 3.18* Rocket Screw [8]



## 3.4 Material used for Screw Designing.

Table 3.3 *Type of Material and its Features* [9]

| Types | Features |
|---|---|
| Nickel Alloy | • Excellent wear and acid resistant<br>• Rockwell hardness 58-65 HRc |
| Nickel Boron Silicon | • Hardness 50-55 HRc<br>• Abrasion resistant, acid resistant |
| Full hard screw | • Tool steel<br>• Powered metallurgical steel |
| Ferric alloy | • Good heat resistance<br>• Rockwell Hardness 58-65 HRc<br>• Apply for general plastic |

## 3.5 CREO Model of Screw

For this project the situatable design of screw is three sections screw it is simple design and this is used for small scale products. Moreover, its edges would be of round shape to avoid the deposition of plastic material as it cools down. Its design is follows:

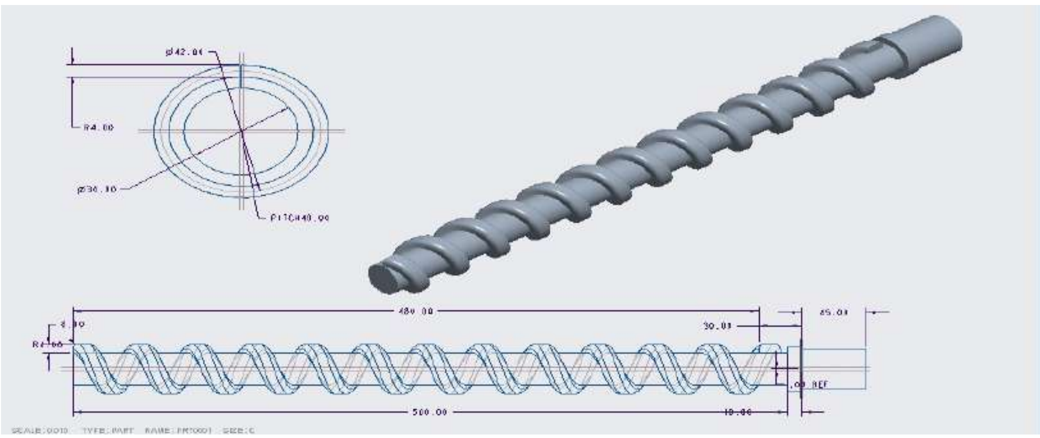


*Figure 3.19* Screw Design

## 3.6 CREO Model of Nozzle, Barrel & Hopper

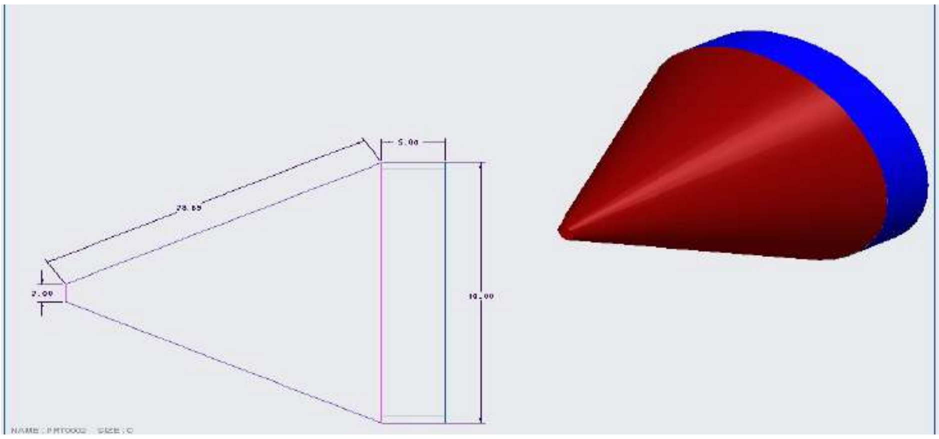


*Figure 3.20* Nozzle Design

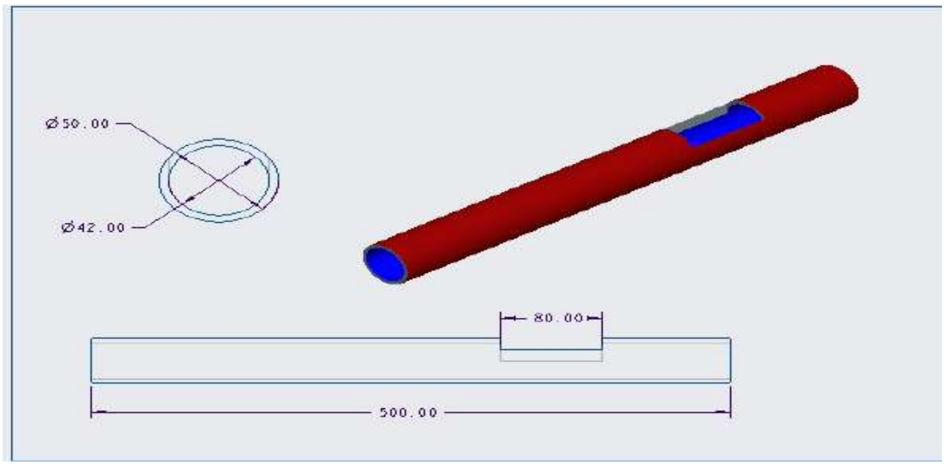



*Figure 3.21* Barrel Design

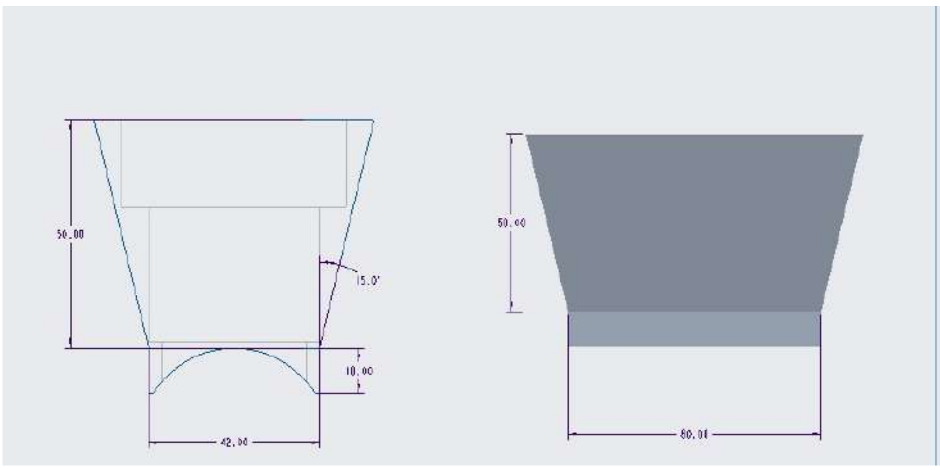


*Figure 3.22* Hopper Design

## 3.7 Assembly of Screw

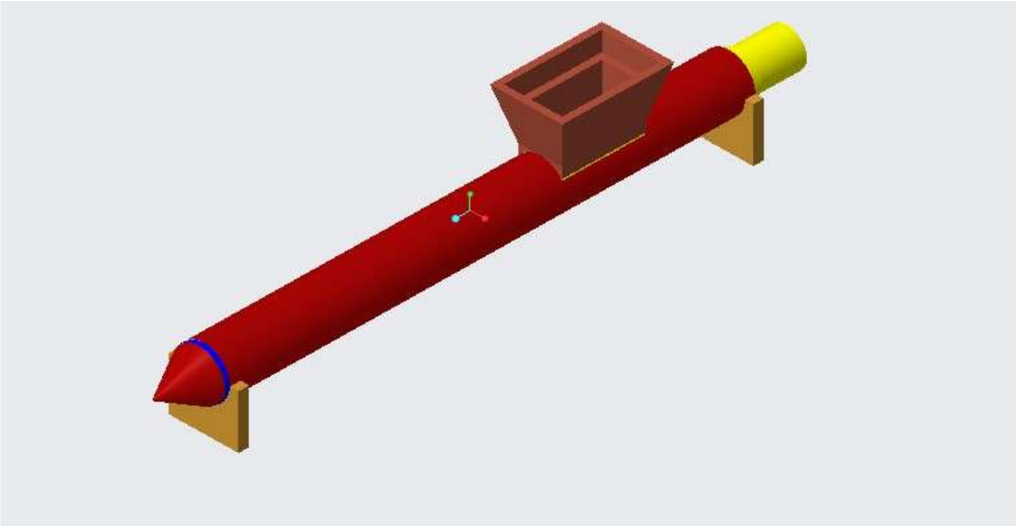


*Figure 3.23* Screw Assembly

# CHAPTER FOUR: FINDINGS

## Overview

It can be clearly seen by the name of the chapter "FINDINGS". which means that this section describes the dimensions and calculation of the project. All the dimensions that are required and calculations such as volume of hopper, barrel dimension heat transfer of the through the barrel is calculated.

## 4.1 Dimensions of Individual Components of Machine

Table 4.1 Dimension of machine

| Description | Size |
|---|---|
| Barrel | Ø50mm x 3000 |
| Screw | Ø60mm x 300mm |
| Nozzle | Ø40mm x 80mm |
| Topedo | Ø50mm x 350mm |
| Plating hinges | 5mm x 100mm |
| Table | 200mm |
| Motor | 400mm |
| M5 Bolt | 20mm |
| M12 Nut | Ø60mm |
| Power breaker | 55mm |
| Plating block | 150mm x150mm x 10mm |
| Plating Pin | 10mm x 150mm |

## 4.2 Required Quantity of Each Component.

*Table 4.2* Quantity of the components

| Description | Quantity |
|---|---|
| Barrel | 1 |
| Screw | 1 |
| Nozzle | 1 |
| Topedo | 1 |
| Plating hinges | 1 |
| Table | 1 |
| Motor | 1 |
| M5 Bolt | 10 |
| M12 Nut | 16 |
| Power breaker | 1 |
| Plating block | 4 |
| Plating Pin | 8 |

## 4.3 Calculations Of Injection Screw

Total length of the screw (L) = 10D. here D is the diameter.
Length of feeding zone (Lf) = 2D
Length of transition zone (Lt) = 3D
Length of melting zone (Lm) = L – (Lf + Lt)
Helix angle Ø = 32°
Flight Pitch = D/2
Flight width = 0.1D
D = 60mm
The result obtained from above data
L = 600mm
Lf = 120mm
Lt = 180mm
Lm = 300mm
Flight pitch = 30mm
Flight width = 6mm

## 4.4 Dimension of Barrel

Barrel is the assembly which contains screw and heater.
Total length of barrel (Lb) = 700mm
Barrel internal diameter = D + Rc = 60 + 0.1 = 60.1mm
Here D is screw diameter which is 60mm and Rc is Radial clearance = 0.1mm
Thickness of barrel = 8mm
External diameter of barrel = internal dia + (2 x thickness)
External dia = 60 + (2 x 8) = 76mm

## 4.5 Volume of Barrel

For volume of the barrel
$V = \pi R^2 L$
R= D/2 = 60/2 = 30mm
Length of barrel L = 700mm
V= 1979 $m^3$

## 4.6 Design of Hopper

Upper end
$h_1$ = horizontal length 80mm.
a = vertical length = 80mm
Lower end
$h_2$= horizontal length = 40mm
b= vertical length = 40mm
Edge = 25mm

Volume of hopper = $(\frac{1}{2}(a+b)h_1)h_2$

Volume of hopper = $(\frac{1}{2}(8+4)(8))4$

Volume of hopper = 192cm$^3$

## 4.7 Heat Transfer Through the Barrel

Heating is important to consider because without achieving.
desired melting temperature of plastic it cannot completely melt.
To calculate the heat

$$Q = \frac{2\pi K(T_1 - T_2)}{\ln(\frac{R_2}{R_1})}$$

Here $T_1$ = temperature achieved by heater = 300°C

$T_2$ = melting temperature of the material =160°C

K = 0.11W/m K thermal conductivity of polypropylene

$R_1$ = inner cylinder radius = 30 mm

$R_2$ = outer cylinder radius = 38mm

The value of Q will be 130 W/m

## 4.8 Screw Design

Pitch = P = 200 mm
D = Diameter of blades = 300 mm
d = diameter of shaft = 100 mm

### *4.8.1 For l*

l = length

l = $\sqrt{(d \times \pi)^2 + P^2}$

l = $\sqrt{(100 \times \pi)^2 + 200^2}$

l = $\sqrt{(314.15)^2 + 200^2}$

l = 372.41 mm

### *4.8.2 For L*

L = length

L = $\sqrt{(D \times \pi)^2 + P^2}$

L = $\sqrt{(300 \times \pi)^2 + 200^2}$

L = 963.47 mm

### *4.8.3 For d*

d = $\frac{D-d}{\left(\frac{L}{l}\right)-1}$

d = $\frac{300-100}{\left(\frac{963.47}{372.42}\right)-1}$

d = 125.8 mm

### *4.8.4 For D*

D = (D – d) + d
D = (300 -100) + 125.8
D = 325.8 mm

### *4.8.5 For Angle θ*

D = $\frac{L}{\left(\frac{D\pi}{360}\right)}$

D = 963.47/2.84
D = 339
D = 360 -339
D = 21°

d = $\frac{l}{\left(\frac{d\pi}{360}\right)}$

d = 372.41/ 1.1
d = 339
d = 360 -339
d = 21°

***4.8.6 For Flow rate***

Q = $0.25 \times \pi \times (2 \times Ro)^2$

Q = $0.25 \times \pi \times (2 \times 163)^2$

Q = 83468.97 mm/s

Q = 8.34 $\frac{m^3}{s}$

# CHAPTER FIVE: DISCUSSION

## Overview

This chapter describes the analysis of the project such the effect of varying different parameters of the injection molding machine on the efficiency of the system.

## 5.1 Comparison of Area of 32 & 16 threads screw

A= area
L = Length
P = Pitch

*Table 5.1* Comparison between 32 & 16 threads screw

| 32 threads screw | 16 threads screw |
|---|---|
| A=3.14*L*P*1.625<br>A=3.14*372.41*200*1.625<br>A=380 mm | A=3.14*L*P*1.625<br>A= 3.14*372.41*400*1.625<br>A= 760mm |

## 5.2 Number of blades VS Pitch ratio

*Table 5.2* Number of blades VS pitch ratio

| Number of blades | Pitch ratio |
|---|---|
| 1 | 0.12 |
| 2 | 0.18 |
| 3 | 0.22 |
| 4 | 0.24 |
| 5 | 0.26 |
| 6 | 0.27 |
| 7 | 0.28 |
| 8 | 0.29 |
| 9 | 0.30 |
| 10 | 0.30 |

*Table5.3* Performance Test Response For 32 Threads Screw

| No of runs | Input mass (g) | Time taken (s) | Output mass (g) | Throughput (g/s) | Machine efficiency% |
|---|---|---|---|---|---|
| 1 | 300 | 120 | 265 | 0.125 | 88 |
| 2 | 300 | 110 | 253 | 1.11 | 84 |
| 3 | 300 | 98 | 250 | 1.25 | 83 |

*Table 5.4* Performance Test Response For 16 Threads Screw

| No of runs | Input mass (g) | Time taken (s) | Output mass (g) | Throughput (g/s) | Machine injection efficiency% |
|---|---|---|---|---|---|
| 1 | 300 | 90 | 290 | 3.2 | 96 |
| 2 | 300 | 82 | 283 | 3.4 | 94 |
| 3 | 300 | 72 | 280 | 3.8 | 93 |

# CHAPTER SIX: CONCLUSION

This project is a difference between two types of threads The one screw has 32 threads per inch and the second one has half threads which is 16 threads per inch. This machine is inexpensive and can be as a learning equipment in school and labs.  The components of the machine are completely designed and fabricated according to the dimensions this machine was tested by using two different screws, but the material used for melting is same. The material which was used to calculate the efficiency of the machine was polypropylene and ABS. The melting range of this material is 200-250°C. From the discussion it can be clearly seen that the efficiency of the 16 threads screw is more as compared to the efficiency of the 32 threads. The 16 threads screw is generating more output such that 290g of output with input of 300g and gives an efficiency of 94% which is better than the 32-thread screw.

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