Palestine Polytechnic University

College of Engineering

Design and Implementation of an Extruder Machine to Recycle Waste Plastics

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Submitted to the College of Engineering
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الإهداء

السلام عليكم ورحمه الله وبركاته

أيام مضت من عمرنا بدأناها بخطوة وها نحن

اليوم نقطف ثمار مسيرة أعوام كان هدفنا فيها واضحا وكنا نسعى في كل يوم لتحقيقه والوصول له مهما كان صعبا

وها نحن اليوم نقف أمامكم وها نحن وصلنا وبيدينا شعلة علم وسنحرص كل الحرص عليها حتى لا تنطفئ

ونشكر الله أولا وأخير على أن وفقنا وساعدنا على ذلك

نهدي هذا المشروع إلى القلب الحنون من كانت بجانبنا بكل المراحل التي مضت من تلذذت بالمعاناة وكانت شمعه تحترق لتنير دربنا

إلى أمهاتنا الحبيبات

وإلى من علمنا أن نقف وكيف نبدأ الألف ميل بخطوة إلى يدنا اليمنى إلى من علمنا الصعود وعيناه تراقبنا .... والدنا

لمن أمسك بيدينا وعلمنا حرفاً. حرفاً. سنهدي له نجاحنا اليوم إلى من كانوا سندا لنا

إلى من لهم الفضل بإرشادنا إلى طريق العلم والمعرفة إلى أساتذتنا الأفاضل كم نحن فخورون بكم

أصدقائنا وأحبتنا ومن سهروا معنا في مسيرتنا العلمية إلى من مدوا أياديهم البيضاء في ظلام الليل

وكانوا عونا لنا

أيام جميله قضيناها نعيشها الآن لحظة... بلحظة ونشعر وكأنها شريط يمر بمخيلتنا من جديد عام. وعام يوما.... ويوم

لن ننساكم ما حيينا

... ولن ننسى هذا المكان الذي جمعنا بمقاعده وأبوابه حتى فنائه إلى كل جزء به

ولن ننسى وطننا المعبق بأريج الحب لن ننساه وسنقدم كل ما بوسعنا له وسنجعل كل ركن به يشهد بما سنقدم وسنكون كالمطر ولن نبخل بما تعلمنا

وسنكون كالماء أينما وقعنا نفعنا بأذن الله.

شكر وتقدير

بعد شكر الله سبحانه وتعالى وبتوفيق منه وصلنا الى ختام حلقة من حلقات مسيرتنا التعليمية مرحلة البكالوريوس هذه المرحلة التي استمر على مدار خمس سنوات من الدراسة والسهر والعناء تخللت أخيرا بهذا المشروع الجميل الذي لولا توفيق الله لما تمكن من انجازه وانه لمن دواعي سرورنا ان نتوجه بالشكر الجزيل لكوكبة رائعة من الاناس الاوفياء الذين وقفوا معنا في مسيرة هذا المشروع. هؤلاء المخلصون الذين لم يتوانوا للحظة في تقديم يد العون والمساعدة حين الطلب

وفي البداية نتوجه بالشكر والعرفان لمشرف المشروع الدكتور زهدي سلهب المحترم الذي استمر بتوجيهنا وارشادنا وتقويم مسارنا طوال فترة المشروع ولم يتوان في تقديم المساعدة.

كما نشكر عصبة طيبة من أصدقائنا الذين لولا مساعدتهم ومشاركتهم معنا لما وصلنا لهذه النتيجة وهم الأصدقاء: عبد الرحمن الشرباتي، محمد رأفت نوفل.

نشكركم بكل ما تحمله كلمة شكر من معنى ونهدي لكم كل عمرنا يا أجمل ما مضى به نشكركم تنطقها قلوبنا على ألسنتنا نشكركم كلمة تعني لنا الكثير وتحمل من الشعور الكثير تخوننا كل عبارات الشكر في تقديم ما يليق بكم لن ننسى الفضل ولن ننساكم أبدا.

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symbols	Meaning
NWRA	The National Waste and Recycling Association.
SPI	the Society of the Plastics Industry
MSW	Municipal Solid Waste
PVDC	Polyvinylidene chloride
Tm	Crystalline melting temperature.
Tg	Glass transition temperature.
Td	Heat distortion temperature under a 66-psi load.
Cte	coefficient of linear thermal expansion
VFD	Variable Frequency Drive.
SSR	Solid-state relay.
L/D	Length per Diameter
PID	Proportional Integral Derivative
A	Ampere
V	Volte
AC	Alternating Current
HP	Horsepower
Rpm	revolutions per minute
HZ	Hertz

ABSTRACT

With increasing in global consumption and retreating of natural resistance, concern is growing over widespread plastic waste.

Plastic waste threatens the environment when buried in landfills. Further, when such plastics are burned, quantities of harmful gases are emitted and this can increase chronic diseases.

As a result, the project works on the design and manufacture of an extrusion device by CATIA, in addition to all the components that it chooses, it has a transition system (screw), the storage System (Hopper), (PID temperature control) to control the temperature of the system as required, and the variable frequency driver, in order to control the speed of the motor that rotates the screw.

The selection of plastic materials was (high-density) was to do experiments on it and on the results, and that by put these thermoplastic in the hopper of machine after this machine reaches to proper working temperature, then these materials enter the machine and its temperature will increase by heaters and by friction with the boundaries of chamber until it reaches to 200 degrees Celsius , this will transform it into a plastic paste , then it will go to nozzle by the rotation motion of screw and it will output as a continuous lines of raw plastics in various diameter as want , these can be exploited in various areas such as 3d printing filament

الملخص

في القرون الاخيرة، بدأ استهلاك البلاستيك بشكل كبير جدا على مستوى العالم وأدى عدم وجود حل للتخلص من مخلفاته الى تدهور المقاومة الطبيعية، أصبحت المواد البلاستيكية وتراكمها في البيئة يشكل مصدر قلق متزايد بالنسبة الى مؤسسات حماية البيئة والتي تهدف الى وجود حلول من امكانها حل هذه المشكلة.

النفايات البلاستيكية هي واحدة من الملوثات الضارة بالبيئة وعناصرها وذلك لأن طمر نفايات المواد البلاستيكية لا تتحلل في النظام البيئي. علاوةً على ذلك حرقها يؤدي الى اصدار انبعاثات سامه، والتي تؤدي الى مشاكل كبيره مثل الامراض المزمنة.

ونتيجةً لذلك تم العمل في هذا المشروع على تصميم وتصنيع آلة البثق لقد تم تصميم واختيار هيكل الالة باستخدام برنامج (Catia) بحيث تم تصميم نظام النقل (اللولب الحلزوني) ونظام التخزين (القادوس)، وتم استخدام ساعات الحرارة (PID temperature controller)للتحكم في درجة حرارة اللازمة لإذابة البلاستيك، اضافةً الى ذلك تم استخدام (variable frequency driver) للتحكم في سرعة دوران المحرك الخاص في اللولب الحلزوني .

تم اختيار البلاستك (high-density polyethylene) من اجل عمل التجارب عليها في المشروع، بحيث تم وضعها في القادوس الذي من خلاله يتم تحضير المواد البلاستيكية من اجل دخولها الى اللولب، بعد ذلك يتم رفع درجة حرارة هذه المواد من خلال المقاومات الحرارية ومن خلال احتكاكها مع جدران الانبوب مما يؤدي الى رفع درجة حرارتها الى ٢٠٠ درجة مئوية، مما يؤدي الى ذوبان البلاستيك الحراري وتحوله على شكل عجينة، ثم يتم نقلها وصهرها الى ان تصل الى المخرج الذي يأخذ شكل أسطواني ومن ثَمَّ يتم بثقها حسب القطر المطلوب. من اجل الحصول على بلاسيك خام على شكل خط متواصل يتم استغلاله في مجالات عديدة من اهمها استخدمها في الطابعات ثلاثية الابعاد.

CHAPTER ONE

Introduction

1.1 Overview

Waste is now a global problem, and one that must be addressed in order to solve the world's resource and energy challenges. Plastic is a material of a wide range of synthetic or semi synthetic that are moldable. These are made from limited sources of a petroleum. Huge advances are being made in the development of technologies to recycle Plastic waste among other resources. Plastic pollution involves the accumulation of plastic Products in the environment that adversely affects wildlife, wildlife habitats, or humans. Many types and forms of plastic pollution exist [1].

Plastic pollution can adversely affect lands, waterways and oceans. Plastic reduction efforts have occurred in some areas in attempts to reduce Plastic consumption and promote Plastic recycling. The prominence of Plastic pollution is correlated with Plastic being inexpensive and durable, which lends to high levels of Plastic used by humans, as shown in **figure 1.1**, it describes the effect of Plastic materials at the environment [2].

Figure1.1: Effects of plastic waste materials on the environment [2].

1.2 Project Motivations

The project aims to design and build an Extruder machine to recycle waste Plastics and produce a continuous line of raw plastic, which can reduce of Plastic pollutions and helps to make a good beneficial management of Plastic waste. This solution is starting by design and build an Extruder Machine by using mechatronics approach, by using CATIA software in order to design the components of machine and making a simulation, and using controllers, that will able to control the speed of a motors and the temperature of heaters through the feedback of the thermocouples, To get an integration system that can give a specific production.

❖ Economic issues relating to recycling:

Critics dispute the net economic and environmental benefits of recycling over its costs, and suggest that proponents of recycling often make matters worse and suffer from confirmation bias. Specifically, critics argue that the costs and energy used in collection and transportation detract from (and outweigh) the costs and energy saved in the production process; also that the jobs produced by the recycling industry can be a poor trade for the jobs lost in logging, mining, and other industries associated with production; and that materials such as paper pulp can only be recycled a few times before material degradation prevents further recycling.

The National Waste and Recycling Association (NWRA) reported in May 2015, that recycling and waste made a $6.7 billion economic impact in Ohio, U.S., and employed 14,000 people [4].

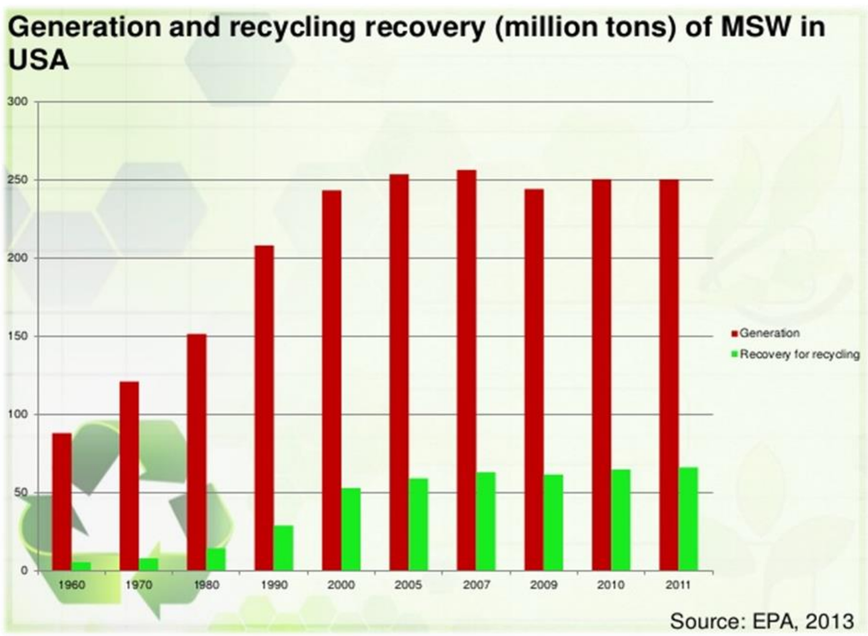

Figure1.2: Generation and recycling recovery (million tons) of MSW in USA [4].

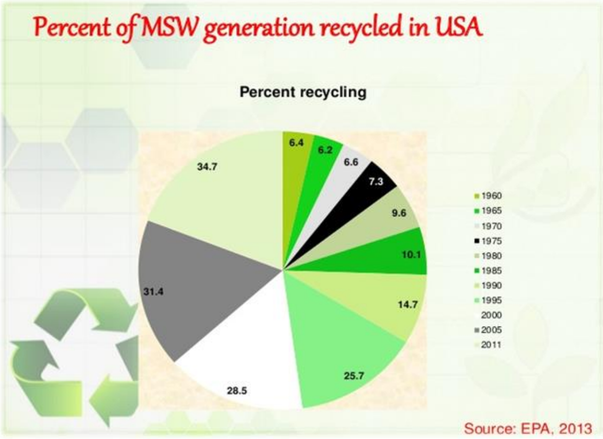

Figure1.3: Percent of waste generation recycled in USA [4].

1.3 Methodology

This project is using the methodology analysis through its process. At first, researchers studied and analysed the recycling steps, process that consists of [4]:

a) Selection: The recyclers have to select the suitable waste for recycling.
b) Segregation: The plastic waste must be separated according to its nature, corresponding to BIS guidelines.
c) Processing: After segregation pre consumer waste can be directly recycled whereas post consume waste has to be washed, shredded, agglomerated and granulated.

Figure1.4: Steps during recycling process [4].

This project will process Plastics by using extrusion, Plastic Extrusion is the process of applying heat and pressure to melt Plastic polymers such as polyethylene, PVC and ABS to name a few. Once heated to a homogenous melt, the polymer is forced through a die to produce continuous shapes of the profile or pipe that is required. There are many shapes that can be produced by extrusion and the dimensions of these shapes are dictated by the size of the die, which is the shaping tool that is bolted onto the front of the extruder machine [5].

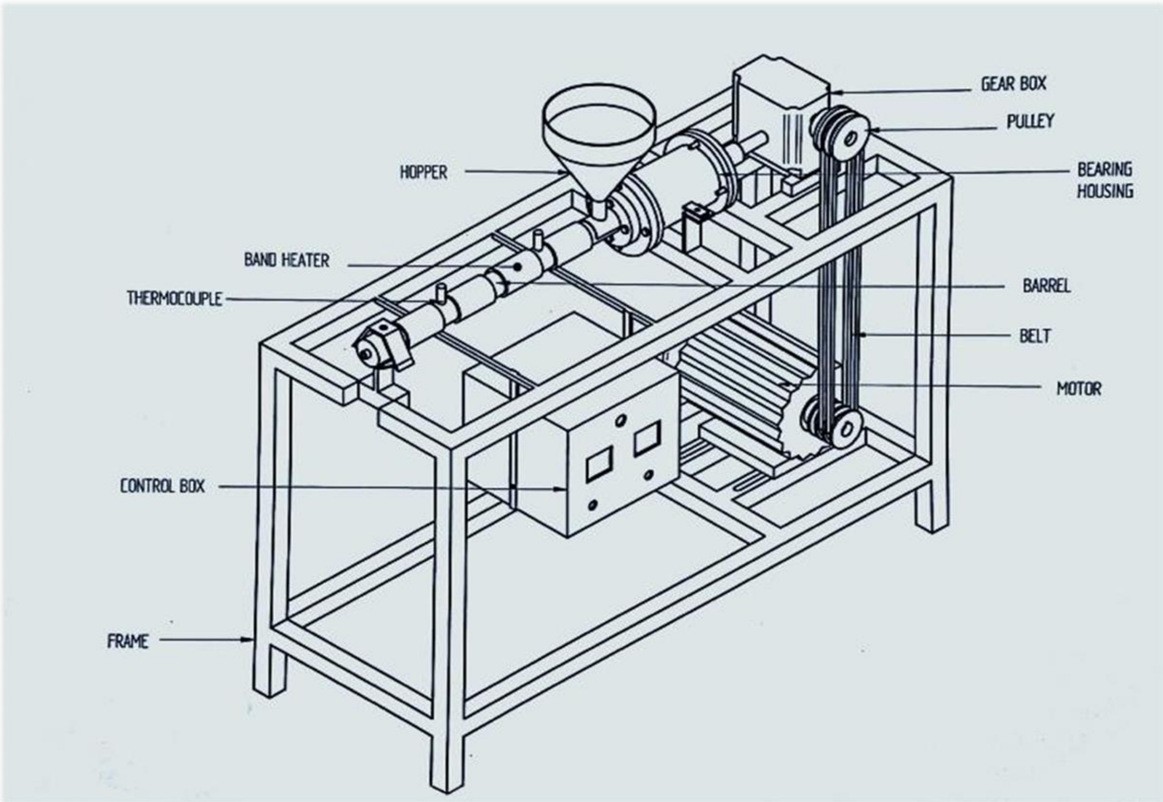

Figure1.5: Extrusion machine Construction [5].

1.4 Design Aspects of extruder machine

The design concept consists of the following:

a) Maximum volume of the melt needed to fill the mold. This entails length of the screw conveyor (l), diameter of the barrel (d), melt density (ρ_m) and melt mass (m).

b) Design of barrel, which entails diameter of the barrel.

c) Design for screw conveyor.

While the design analysis entails the following units:

a) The Extruder unit consists of the hopper, barrel, band heater, nozzle, screw conveyor, bearing housing and gearbox.

b) The clamping unit consists of the mold and clamping for locking device.

c) The electrical panel including temperature control box, and thermocouple.

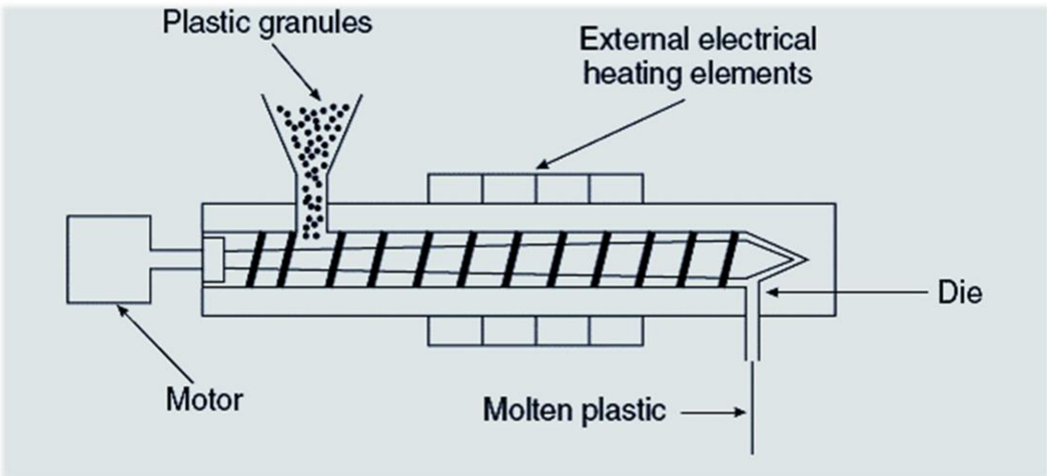

Figure1.6: Extrusion machine structure [5].

1.5 Block diagram of Extrusion process

This **figure 1.7** shows the relationship between the components to each other.

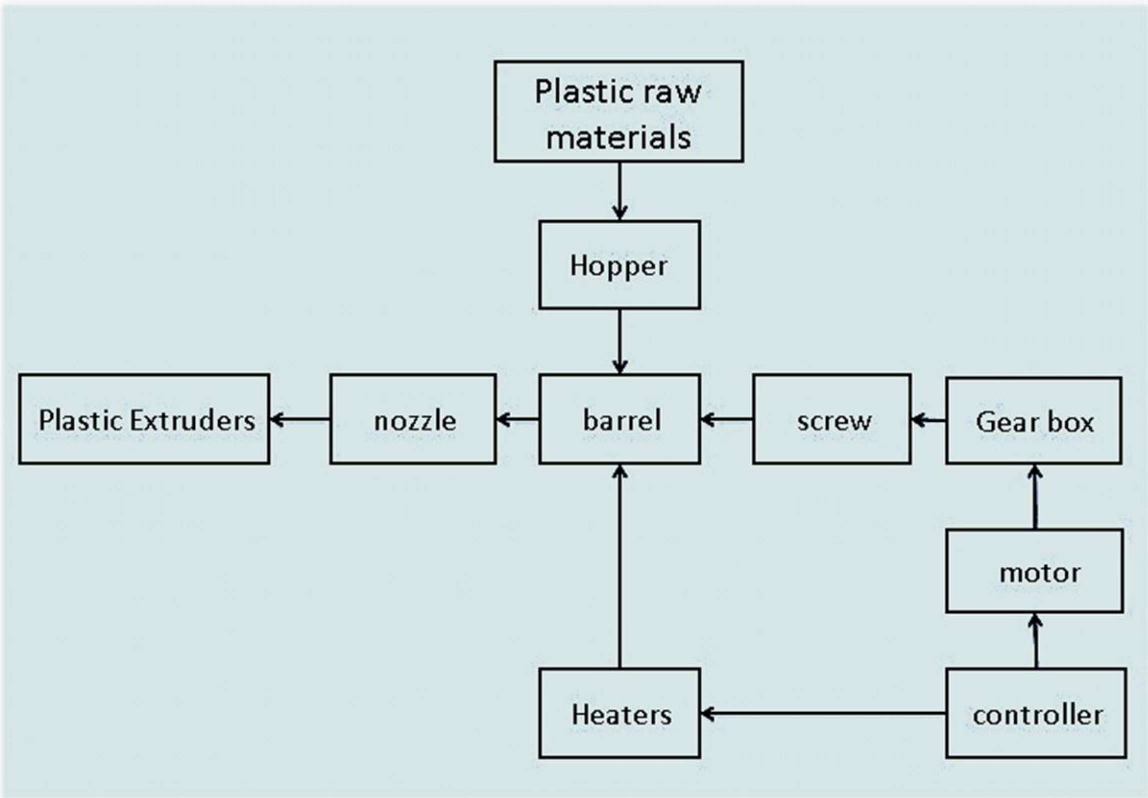

Figure1.7: Block Diagram of Extrusion process.

1.7 Literature Review

1.7.1. History of Polymer Extrusion

The first machine for extrusion of thermoplastic material was built around 1935 by Paul Troester in Germany [6]. Before this time, extruders where primarily used for extrusion of rubber. These earlier rubber extruders were steam heated ram extruders and screw extruders, with the later having very short length to diameter (L/D) ratios, about 3 to 5. After 1935, extruders evolved to electrically heated screw extruders with increase length. Around this time, the basic principle of twin-screw extruders was conceived in Italy by Roberto Colombo. He was working with Carlo Pasquetti on mixing cellulose acetate. Colombo developed an intermeshing co-rotating twin-screw extruder. He obtained patent in many different countries and several companies acquired the right to use these patents. Pasquetti followed a different concept, developed, and patented the intermeshing counter rotating twin-screw extruder [7].

1.8 Project Schedule, Time Plan and cost table

Tables 1.1 and 1.2 show the process through the first and second semester and their times.

Table 1.1: the first semester time -table

Objective	Week #															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Project Selection																
Collect information																
Writing Introduction																
Analysis of system components																
Design machine (catia)																
Presentation																

Table 1.2: The second semester time -table

Objective	Week #															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Review of design and calculation																
Summing of component and machine																
Building the machine																
Testing																
Documentations and analysis the results																
Prepare presentation																

1.8.1 Total Cost for the Project

Table 1.2. Total cost of the project.

Components	Quantity	Price(NIS)	Total (NIS)
Machine parts	**x**	**1500**	**1500**
Inverter	**x**	**X**	**x**
Motor and gear box	**x**	**800**	**800**
PID Controller	**2**	**250**	**500**
SSR	**2**	**50**	**100**
Thermocouple	**2**	**40**	**80**
Band heaters	**5**	**70**	**350**
Power switch	**3**	**30**	**90**
Circuit Breakers	**3**	**20**	**60**
Σ			**3480**

CHAPTER TWO

Plastic material

2.1 Plastic material definition

Plastic is the general common term for a wide range of synthetic or semi-synthetic materials used in a huge, and growing, range of application from packaging to building; from cars to medical devise, toys, clothes etc. [8].

The term "plastic" is derived from the Greek word "plastikos" meaning fit for moulding, and "plastors" meaning moulded. It refers to the material's malleability or Plastic during manufacture that allows it to be cast, pressed, or extruded into a variety of shapes – such as films, fibres, plates, tubes, bottles, boxes, and much more [9].

There are two broad categories of plastic materials: thermoplastics and thermosetting plastic. Thermoplastics can be heated up to form products and then if these products are reheated, the plastic will soften and melt again. In contrast, thermoset plastics can be melted and formed, but once they take shape after they have solidified, they stay solid and, unlike thermoplastics cannot be remelted [8].

2.2 Type of plastic material

Everywhere you look, you will find plastics. We use plastics products to help make our lives cleaner, easier, safer and more enjoyable. You will plastics in the clothes we wear, the houses we live in, and the cares we travel in. The toys we play with, the television we watch, the computers we use and the CDs we listen to contain plastics. Even the toothbrush you use every day contains plastics!

Plastics are organic, the same as wood, paper or wool. The raw materials for plastics production are natural products such as cellulose, coal, natural gas, salt and, of course, crude oil. Plastics are today's and tomorrow's materials of choice because they make it possible to balance modern day need with environmental concerns.

The family is quite diverse, and includes ABS/SAN, Epoxy resins, Expandable Polystyrene, Fluoropolymers, PET, Polystyrene, PVC, PVDC, Styrenic polymers, and Unsaturated Polyester Resins (UPR) [10].

All these types of plastics can be grouped into two main polymer families: Thermoplastics, which soften on heating and then harden again on cooling, and Thermosets, which never soften when they have been moulded [11].

Examples of Thermoplastics:

1) Acrylonitrile butadiene styrene – ABS
2) Polycarbonate – PC
3) Polyethylene - PE
4) Polyethylene terephthalate – PET
5) Poly(vinyl chloride) – PVC
6) Poly(methyl methacrylate) – PMMA
7) Polypropylene – PP
8) Polystyrene – PS
9) Expanded Polystyrene – EPS

Examples of Thermosets:

1) Epoxide (EP)
2) Phenol-formaldehyde (PF)
3) Polyurethane (PUR)
4) Polytetrafluoroethylene (PTFE)
5) Unsaturated polyester resins (UP)

A range of additives are used to enhance the natural properties of the different types of plastics to soften them, colour them, make them more process able or longer lasting, today not only are there many different types of plastic, but products can be made rigid or flexible, opaque, transparent, or coloured; insulating and conducting, fire-resistant etc., through the use of additives [13].

2.3 Properties of plastic materials

Plastics have numerous properties that make them superior to other materials in many applications. Plastics generally have [12, 13]:

1) Strength:

The plastics are sufficiently strong and can be used for load bearing structural members. The strength of plastics can further be increased by reinforcing them with various fibrous materials.

2) Weather resistant:

The plastics, prepared from phenolic resins, are only good in resisting weather effects. Certain plastics are seriously affected by ultraviolet light.

3) Fire resistance:

Plastics, being organic in nature, are combustible. However, the resistance to fire temperature depends upon the plastic structure.

4) Durability:

Plastics generally possess sufficient durability, provided they offer sufficient surface hardness. Thermoplastic varieties are found to be attacked by termites and rodents.

5) Chemical resistance:

Plastics offer great resistance to moisture, chemicals and solvents. Many plastics are found to possess excellent corrosion resistance. Plastics are used to convey chemicals.

6) Thermal resistance:

The plastics have low thermal conductivity and therefore foamed or expanded varieties of plastics are used as thermal insulators.

7) Ductility:

Plastics, generally, have low ductility and hence plastic structural members may fail without prior warning.

- **Effect of molecular weight**:

Increasing the molecular weight of the material increases many of the properties of the material by increasing the entanglement of the molecules [14].

- Increases the chemical resistance.
- Increases how far the material can stretch before rupturing.
- Increases the impact resistance of the material.
- Increases the viscosity of the material – makes it harder to process the material using conventional methods.

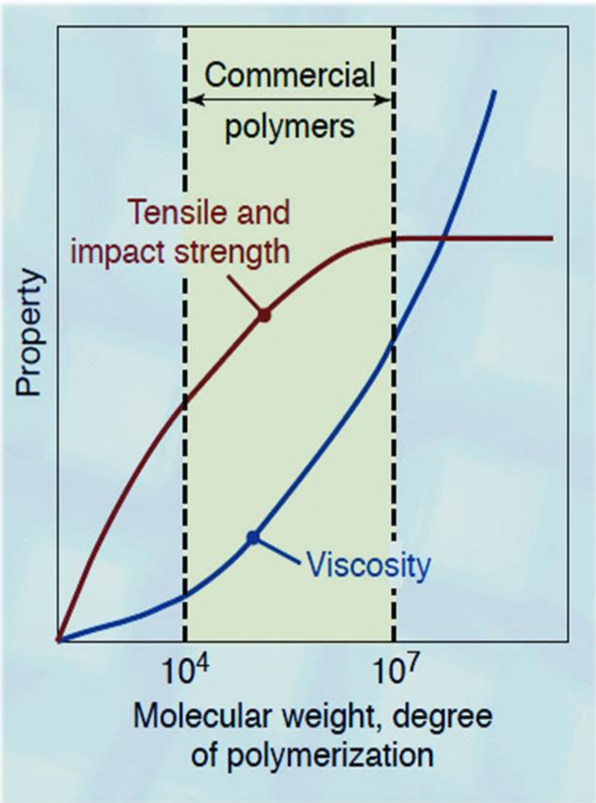

Figure 2.1: Effect of molecular weight and degree of polymerization on the strength, and Viscosity of polymers [14].

- **Effect of Temperature:**

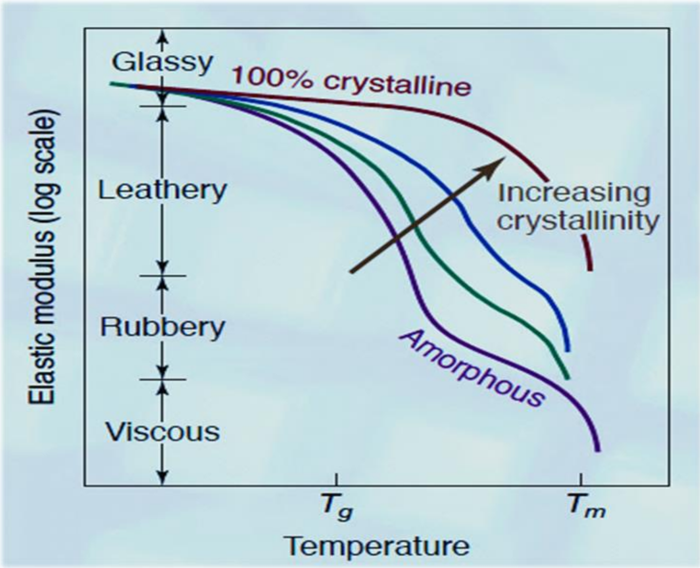

Figure 2.2: Behaviour of polymers as a function of temperature and degree of Crystallinity [14].

- **Deformation of Polymers:**

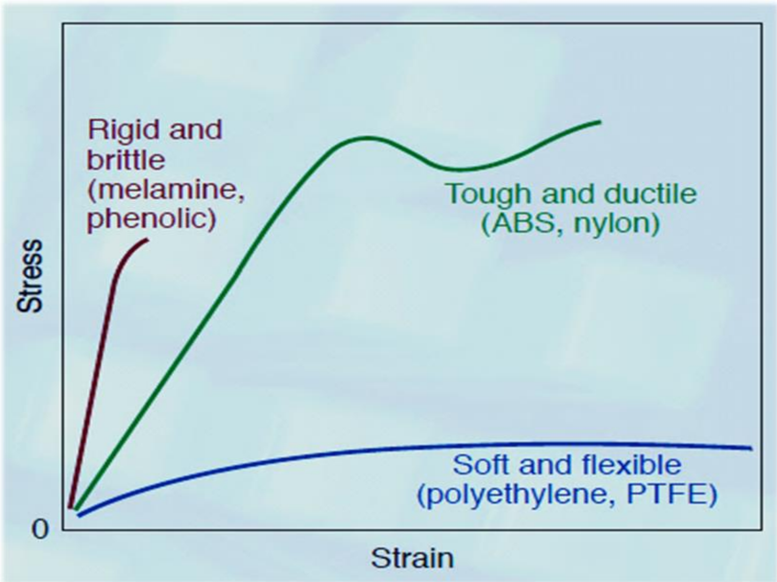

Figure 2.3: Stress Strain analysis of General terminology that describe the behaviour of three types of plastics [14].

- **Viscosity of Melted Polymers:**

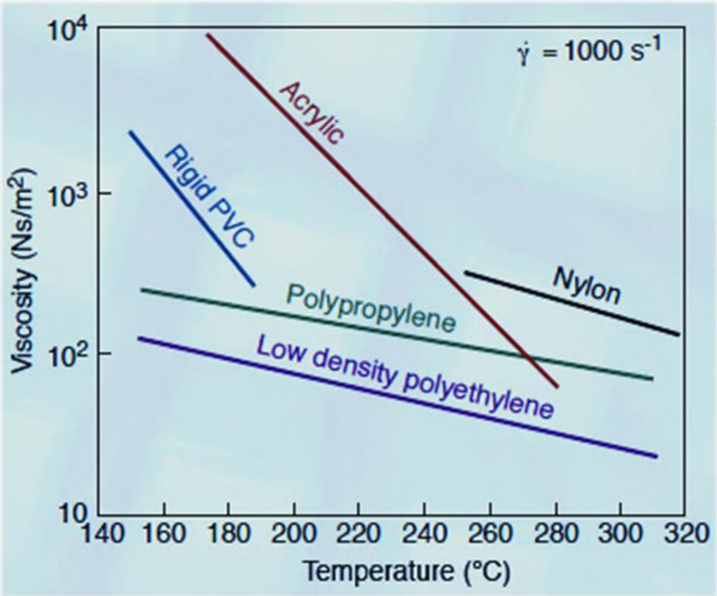

Figure 2.4: Viscosity of some thermoplastics as a function of temperature [14].

- **Polymer Behaviour in Tension:**

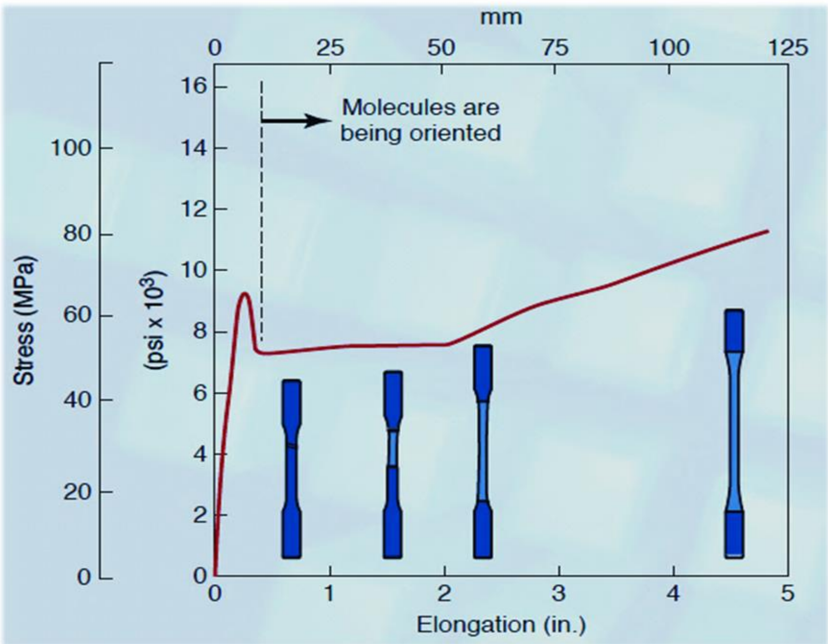

Figure 2.5: Load-elongation curve for polycarbonate, a thermoplastic [14].

- ## Physical properties:

Table 2.1: Physical properties of plastic [14].

Plastic	Thermal Properties				Strength		Density
Abbreviation - Brand name	Tm	Tg	Td	Cte	Tensile	Compressive	
	ºC	ºC	ºC	ppm/ºC	psi	psi	g/cc
PET - Polyethyleneterephthalate	245 265	73 80	21 38	65	7000 10500	11000 15000	1.29 1.40
LDPE - Low density polyethylene	98 115	-25	40 44	100 220	1200 4550		0.917 0.932
HDPE - High density polyethylene	130 137		79 91	59 110	3200 4500	2700 3600	0.952 0.965
PP - polypropylene	168 175	-20	107 121	81 100	4500 6000	5500 8000	0.900 0.910
PVC - polyvinylchloride		75 105	57 82	50 100	5900 7500	8000 13000	1.30 1.58
PS - polystyrene		74 105	68 96	50 83	5200 7500	12000 13000	1.04 1.05

Where:

Tm: Crystalline melting temperature.

Tg: Glass transition temperature.

Td: Heat distortion temperature under a 66-psi load.

Cte: coefficient of linear thermal expansion.

2.4 Classification of different types of plastic.

Plastic is an essential component of numerous consumer products, including water bottles and product containers. However, not every kind of plastic is the same. In 1988, the Society of the Plastics Industry (SPI) established a classification system to help consumers and recyclers properly recycle and dispose of each different type based on its chemical makeup [15].

Today, manufacturers follow a coding system and place a number, or SPI code, on each plastic product, usually molded into the bottom. Although you should always verify the plastic classification number of each product you use, especially if you plan to recycle it, this guide provides a basic outline of the different plastic types associated with each code number.

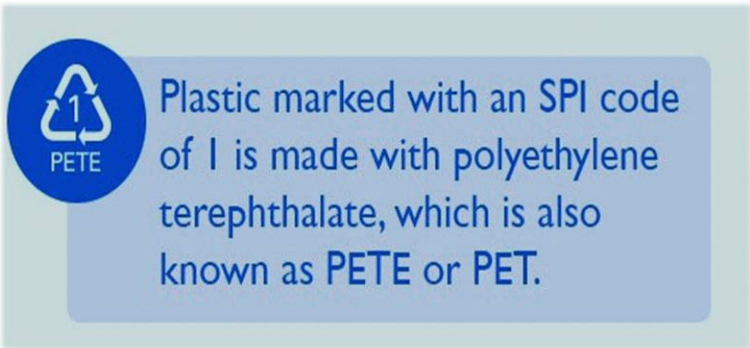

Figure 1: As one of the most recycled plastic materials. Used to make many common household items like beverage bottles, medicine jars, peanut butter jars, combs, bean bags, and rope, softens at 80°.

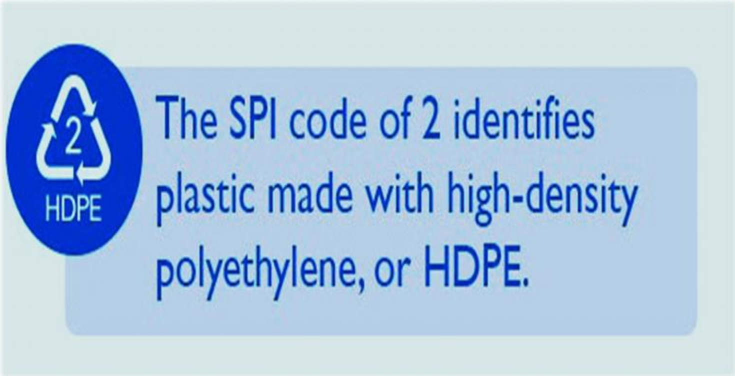

Figure 2: As one of the most recycled plastic materials, used to make containers for milk, motor oil, shampoos and conditioners, soap bottles, detergents, and bleaches, softens at 75°.

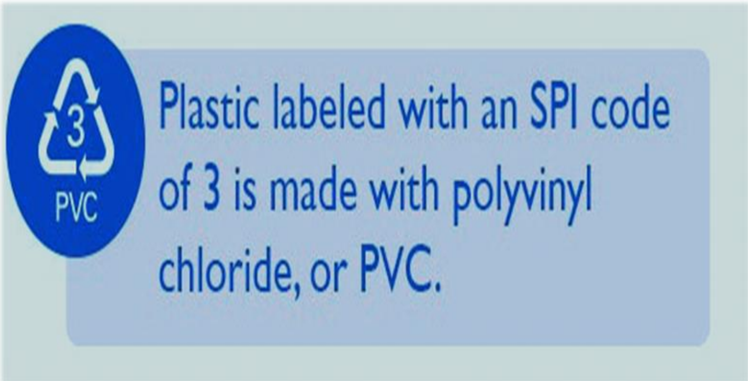

Figure 3: The most dangerous types of plastic, is not often recycled and can be harmful if ingested. Used for all kinds of pipes and tiles, but it's most commonly found in plumbing pipes. This kind of plastic should not come in contact with food items, softens at 60°.

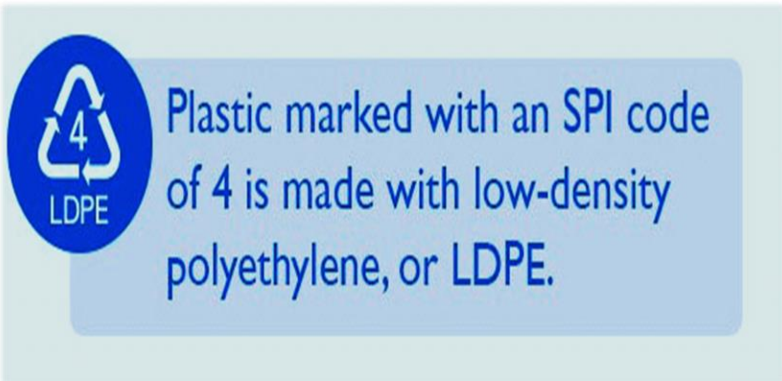

Figure 4: a relatively safe and recyclable, making it a safe choice for food storage. Plastic cling wrap, sandwich bags, squeezable bottles, softens at 70°.

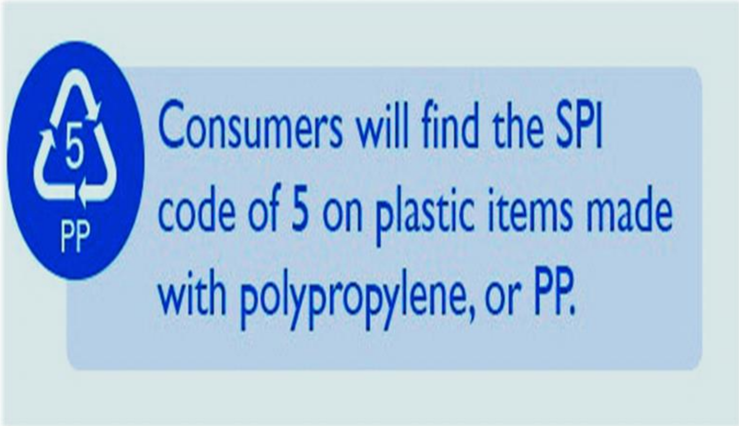

Figure 5: one of the best kinds of plastic and most safe, it is used to make plastic diapers, margarine containers, yogurt boxes, syrup bottles, prescription bottles, and some stadium cups, softens at 140°.

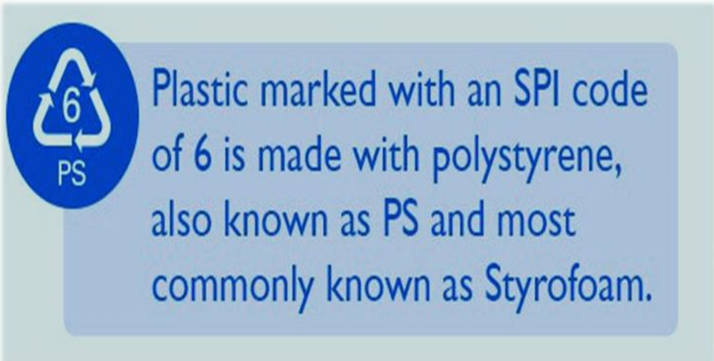

Figure 6: danger and unsafe, used in coffee cups, plastic food boxes, plastic cutlery, packing foam, softens at 95°.

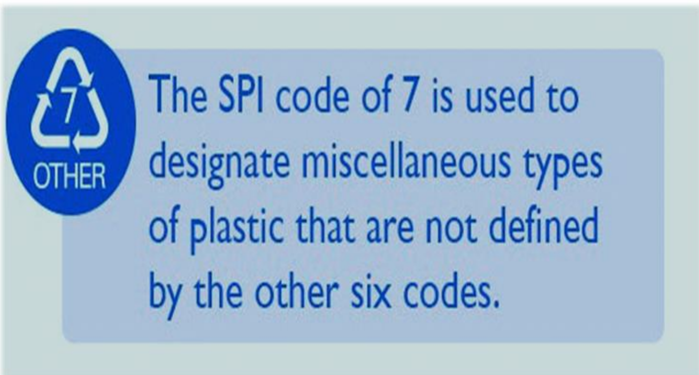

Figure7: These types of plastics are difficult to recycle. Polycarbonate is used in baby bottles, large water bottles (multiple-gallon capacity), compact discs, and medical storage containers.

2.5. Plastics Processing

Because of the properties of polymers, it is possible to mould them and change their shape using a number of different repetitious manufacturing processes. The most important of these are extrusion, injection moulding, blow moulding, vacuum forming, extrusion blow moulding, rotational moulding, calendaring, foaming and compression moulding.

About Extruders machine:

A machine or device that forces ductile or semisoft solids through die openings of appropriate shape to produce a continuous film, strip, or tubing. Most of them takes in electrical energy and convert it to heat during the process.

Types of extruders:

There exist different types of extruders in the polymer industries. Extruders may be distinguished by their mode of function; continuous or discontinuous. Continuous extruders are equipped with rotating parts whereas discontinuous extruders extruded plastics in a recurrent manner and this type is suited for batch type processes such as injection molding. Extruders may be used in different type of industries such as food processing industries, plastics industries, metals and aluminium industries as well as different secondary manufacturing industries. The mode of operation of this machine is very simple; material enters the hopper of the extruder usually by gravity and is push down along the barrel by the rotation of the screw, this pushing generate friction between the barrel wall and the screw hence generating the heat energy required to melt the material. There is different types of extruders as Single Screw Extruder, Double Screw Extrude, and Vented Extruder.

This project is using Single Screw Extruder, this type is the most common of extruders used, because of it straight forward design, relatively low costing, and it reliability,. Their screw has only one compression section, even though the screw has three distinct geometrical sections; the first section (closest to the fed opening) generally has deep flights. The material in this section will be mostly in the solid state. This section is referred to as the feed section of the screw. The last section usually has shallow flights; the material in this section will be mostly in the molten state. This screw section is referred to as the metering section. This section is called the transition section or compression section. In most cases, the depth of the screw channel reduces in a linear fashion, going from the feed section towards the metering section, thus causing a compression of the material in the screw channel.

Chapter Three

Mechanical Design of Extruder Machine

3.1 Introduction

This chapter will explain the three dimensional drawings and design of the Recycling machine by extruder. There are five main components of an extruder: screw, extruder drive, barrel, feed hopper, and nozzle.

The helical structured extruder screw is the heart of an extruder, which includes transport, heating, melting and mixing functions for plastic. An extruder drive, an electrical motor, supplies power to rotate the screw. The stability and quality of products and highly dependent on the design of the screw. The extruder barrel is outside the screw providing heating and cooling capabilities. There is a feed throat connect feed hopper and barrel. The feed hopper is designed to hold the plastic pellets, and allows plastic pellets flow into the barrel steadily. The die is placed at the end of the extruder, and can determine the shape of the product.

Once the material and specification has been determined, we have used the knowledge of mechanical parts as well as SOLIDWORKS software to develop the plans and models to meet the project goals.

3.2 Proposed System Description a Specification

The first step in mechanical design is to know the whole operation of the system and to know how machine is band as shown in **figure 3.1** and **figure 3.2.**

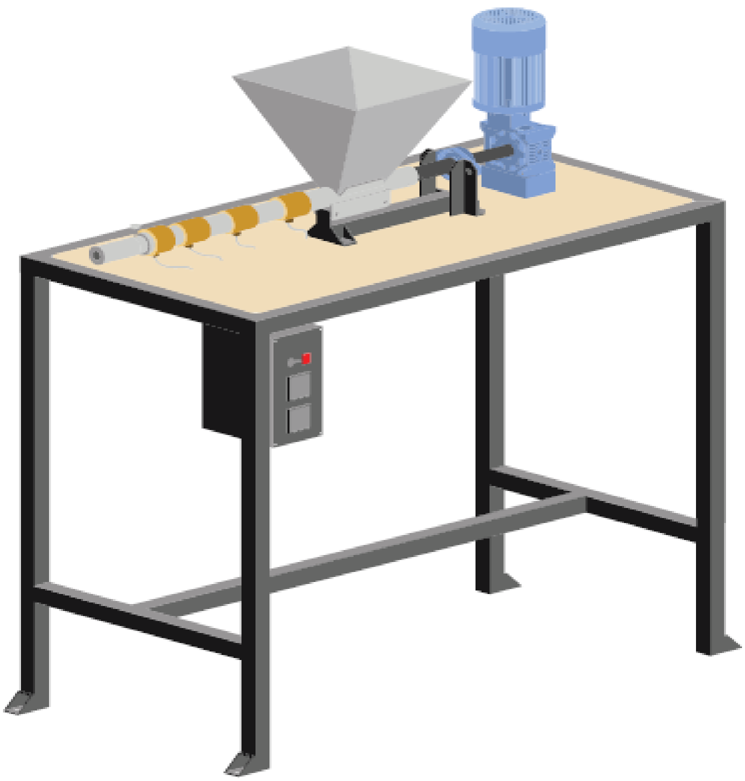

Figure 3.1: Structure Design of the Extruder Machine in 3D.

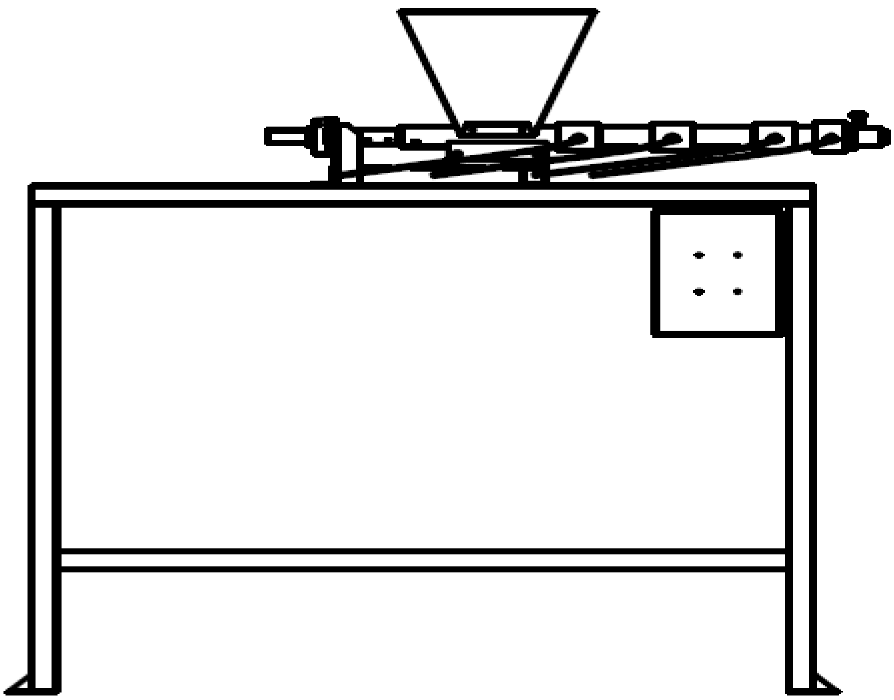

Figure 3.2: The machine in 2D.

In the next sections the parts of the machine will be describe in full details.

3.3 Mechanical Design

In this design the machine, is divided it into fore parts, which are connected to each other to Cover all stages needed, these parts are:

1) Hopper
2) Barrel
3) Screw
4) Nozzle

Since the machine is used for production of a Plastic and in order to get a good and clean product, most of the machine parts are made of steel that has resistance to corrosion; And in order to obtain a good and simple design a set of parameters must be considered, these parameters are related to the machine itself such as: safety, portability, cost, design simplicity, availability, work space, easy to move, volume occupied by the machine. On the other hand, the design must be able to produce a high quality Extruder machine related into the international standard.

3.3.2 Hopper

It is the first component of the machine, which the process starts through it as shown in **figure 3.4**, its capacity approximately about 5kg, which found by the calculation of its volume and through the density of the Plastic. This. Hopper produced from stainless steel (304L).

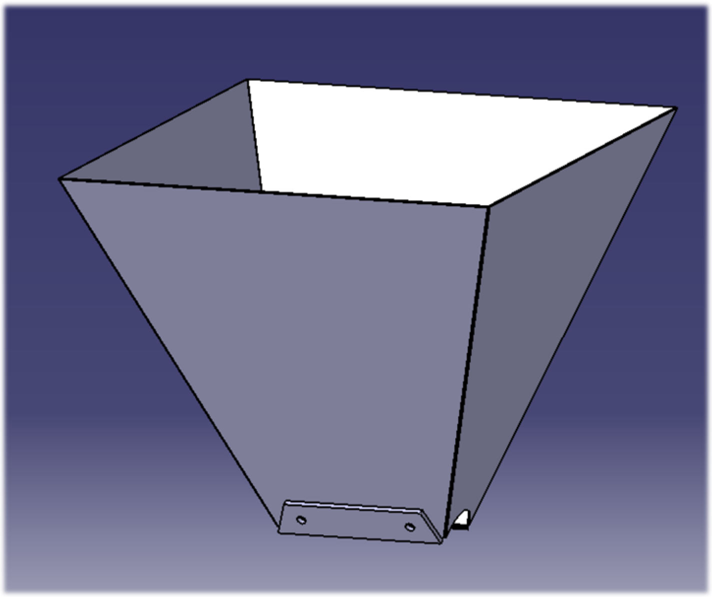

FIGURE 3.4*: Sketch Hopper*

To find a capacity of hopper of raw materials we can use the equation

$$\rho = \frac{M}{V} \quad (3.1)$$

Where:

ρ: Plastic density.

M: Mass of plastic.

V: volume of hopper.

Through we use LDPE-low density polyethylene Plastic the density is equal 0.917 g/cm^3, and the volume of hopper [19].

$$V= \frac{1}{3} * H * (s1 + s2) + \sqrt{s1 * s2} \quad (3.2)$$

Where:

H: height of hopper[mm].

S1: area of first base[mm^2].

S2: area of second base[mm^2].

From the **figure 3.5** can be determine the area of each base

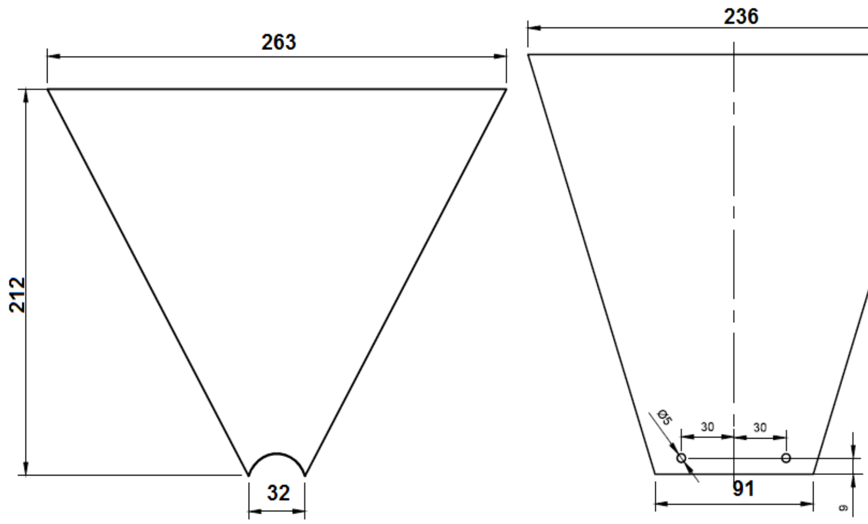

Figure 3.5: Dimension of Hopper.

S1=26, 3*23.6=620, 68cm^2

S2= 9.1*3, 2=29.12cm^2

$V_1 = \frac{1}{3} * 21.2 * (649.98 + \sqrt{18074.20})$

V_1=5543, 23 cm^3

By subtracts the size of half the cylinder:

$V_2 = (r^2 * \pi) * l$

=$(1.6^2 * 3.14 * 9.1) \div 2$

=36.57 cm^3

V_T=5506.66

M= $\rho * V_T = \frac{0.917g}{cm^3} * 5506.66cm^3$ (3.3)

M=5049.60 g

M=5.04 k

3.3.3. Screw

The extruder screw is one of the most important component of the machine, it design is crucial in the mixing and processability of the polymer in question, with respect to the type of polymer to be process. Screw extruders are classified as single or multiple screw extruders. In this project will choose Single conveying screw extruders are the most common type of extruders used in the polymer industry, because of it straight forward design, relatively low costing, and it reliability, they are most often used[17].

The screw is design in to three different sections known as zones. Different types of polymer may have different screw designs; some designs may not have the entire zone. Three zones are usually identified in most screw, which are [16, 17];

1. Feed zone: Transport and preheating of the solid material.
2. Transition zone: Compression and plastication of the polymer.
3. Metering zone: Melt conveying; melt mixing and pumping of the melt to the die.

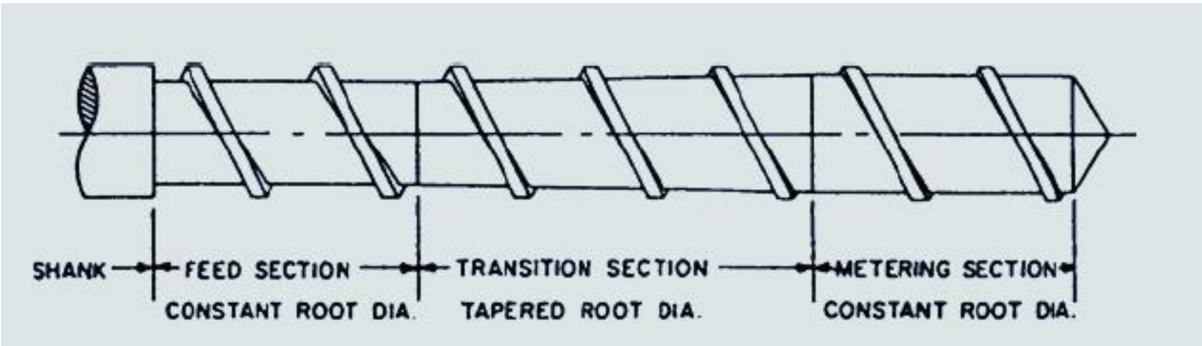

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Figure3.6: Three-zone screw

The L: D ratio of an extruder screw is define as the length of an extruder screw with respect to it diameter. An L: D ratio of 24: 1 is common, but some bigger machines go up to 32: 1 for faster mixing and additional output with no change in the diameter of the screw. Twin screws usually can measure about 36: 1 to account for the two extra zones [18, 17].

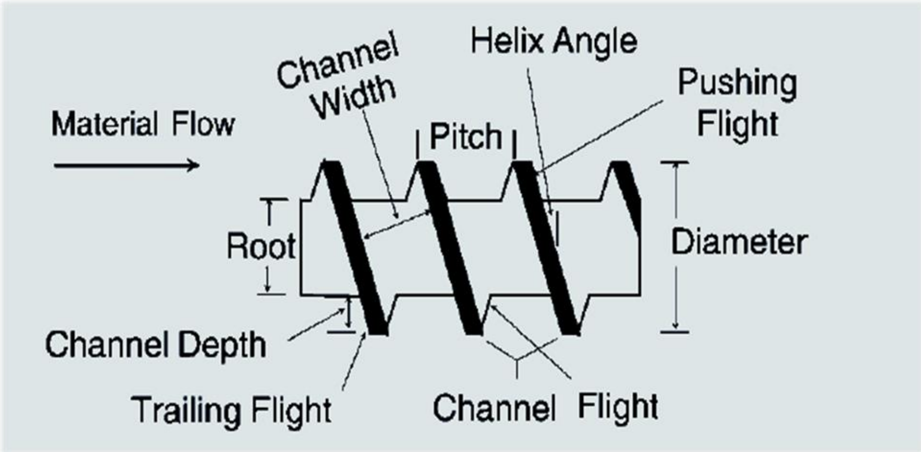


Figure3.7: Definition of screw elements.

Where:

1) Channel width: Space between flights.

2) Trailing flight flank: Back edge of flight.

3) Pushing flight flank: Front edge of flight.

4) Pitch: Distance between consecutive flights.

5) Helix angle: Angle flights make from a line perpendicular to the screw shaft.

6) Screw diameter: Distance between furthest flights across the screw shaft.

7) Keyway: End of screw containing the key that fits into the shaft surrounded by the Thrust bearing.

8) Root diameter: Distance from the channel bottom on one side to the bottom on the Channel bottom on the opposite side
.

9) Length: Distance from hopper to screw tip.

10) L/D ratio: Screw length divided by diameter Compression ratio: Ratio of the feed channel depth to the meter channel depth.

11) Channel depth: Distance from the top of the flight to the root.

Essential dimensions of extruder screws for processing thermoplastics are given in Table 3.2 for several screw diameters [16].

Table 3.2: Significant Screw Dimensions for Processing Thermoplastics [16].

Diameter (mm)	Flight depth (feed) h_F (mm)	Flight depth (metering) h_M (mm)	Flight depth ratio	Radial flight clearance (mm)
30	4.3	2.1	2 : 1	0.15
40	5.4	2.6	2.1 : 1	0.15
60	7.5	3.4	2.2 : 1	0.15
80	9.1	3.8	2.4 : 1	0.20
100	10.7	4.3	2.5 : 1	0.20
120	12	4.8	2.5 : 1	0.25
> 120	max 14	max 5.6	max 3 : 1	0.25

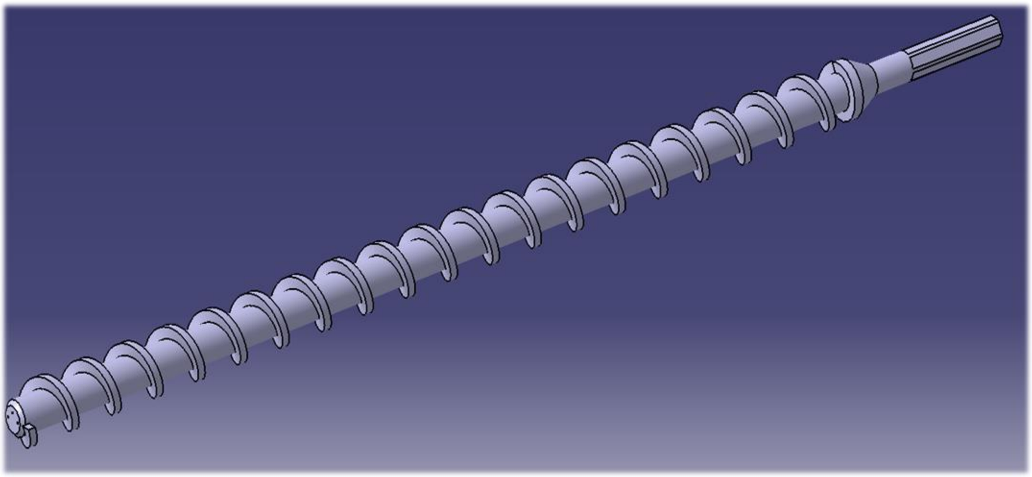


Figure3.9: Structure Design of Screw.

The solids transport is largely influenced by the frictional forces between the solid polymer and barrel and screw surfaces. The following example presents an empirical equation that provides good results in practice.

The geometry of the screw that used in project in (**Fig. 3.9**) is given by the following data:

Table 3.3: Geometry of the screw

Barrel diameter (D_b)	40mm
Screw lead (s)	24mm
Number of flights (υ)	1
Channel width (W)	22 mm
Flight width ((w_{FLT})	3 mm
Depth of the feed zone (H)	8 mm
Conveying efficiency (η_F)	0.436
Bulk density of the polymer(ρ_o)	800 kg/m3
Screw speed(N)	50rpm

The solids conveying rate in the feed zone of the extruder can be calculated according to equations in (**3.4**) *[*21].

$$\dot{m} = 60 \cdot \rho_o \cdot N \cdot \eta_F \cdot \pi^2 \cdot H \cdot D_b(D_b - H)\frac{W}{W + w_{FLT}} \cdot sin\phi \cdot cos\phi \quad (3.4)$$

Where

$\dot{m}$= solids conveying rate *(kg*/h*)*.

ρ_o= Bulk density of the polymer *(*kg/m3).

N = Screw speed (rpm).

η_F = Conveying efficiency.

H= Depth of the feed zone.

D_b = Barrel diameter.

W= Channel width.

w_{FLT} = Flight width

Φ= helix angle.

With the helix angle ϕ

$$\Phi = tan^{-1}[s/(\pi \cdot D_b)] \quad (3.5)$$

The conveying efficiency η_F in Eq. (3.4) as defined here is the ratio between the actual extrusion rate and the theoretical maximum extrusion rate attainable under the assumption of no friction between the solid polymer and the screw. It depends on the type of polymer, bulk density, barrel temperature, and the friction between the polymer, barrel and the screw. Experimental values of $\eta_F$for some polymers are given in Table 3.4.

Table3.4 conveying efficiency η_F for some polymers [21]

Polymer	Smooth barrel	Grooved barrel
LDPE	0.44	0.8
HDPE	0.35	0.75
PP	0.25	0.6
PVC-P	0.45	0.8
PA	0.2	0.5
PET	0.17	0.52
PC	0.18	0.51
PS	0.22	0.65

Using the values above with the dimensions in meters in Eq. (3.4) and Eq. (3.5) we get

ṁ = 60*800*50*0.25*3.14^2*0.008*0.04*0.032*0.88*0.187*0.98

=9.82 kg/h = $2.72\ g/s$

The maximum flow rate has been calculated for the screw parameter according to

$$Q_{max} = \frac{\dot{m}}{\rho} \qquad (3.6)$$

$$= \frac{2.72\ g/s}{0.915\ g/cm^3} = 2.89\ cm^3/s = 2.89 * 10^{-6}\ m^3/s$$

After that can be, calculated maximum pressure at Q = 0 from the equation (3.7)

$$Pmax = \frac{6 \cdot \pi \cdot D \cdot L \cdot N \cdot \eta}{H^2 \cdot tan\phi} \qquad (3.7)$$

Viscosity, η= $m(6)^{n-1}$ where n = 0.39 as shown in Table 3.5

Table 3.5. Power law parameters for some common plastics. Charles [16]

Polymer	$m(Pa\text{-}s)^n$	n	T(°C)
High density PE	2.00×10^4	0.41	180
Low density PE	6.00×10^3	0.39	160
PP	$7.5\ 0 \times 10^3$	0.38	200
PA 66	6.00×10^2	0.66	300
PC	6.00×10^2	0.98	300

In order to determine the shear rate in screw which is given by:

Shear rate (Ϭ) $=\frac{\pi * d * n}{60 * h}$ (3.8)

Where

Ϭ = shear rate in screw channel, is given in secs-1

d_{screw} = screw diameter in mm

n_{screw} = screw speed in revolutions/minute

h = channel depth in mm.

In this project, the extruder barrel diameter d = 40 mm, the screw speed n set at 50 rpm and the channel depth in mm was measured to be h= 8 mm. Then the shear rate at the barrel zone is given by (Eqn3.8);

Shear rate (Ϭ) $=\frac{\pi * d * n}{60 * h} = \frac{3.14 * 0.04 * 50}{60 * 0.008} = 13.08\ s^{-1}$

The rate at which polymers sheared between the end of the screw tip and the barrel wall is computed using (Eq3.8) above. The shear rates between the end of the screw flight and the barrel wall are high because the height is small, and low between the lowermost end of the screw channel and the inner barrel walls because the distance between them is large there.

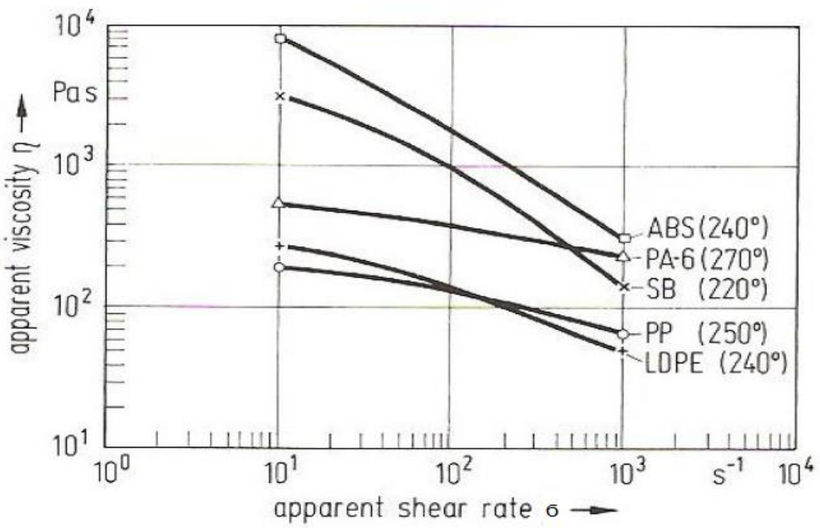
Therefore

η= $m(6)^{n-1}$ (3.9)

= (6*10^3 Pa.s) $(13.08s^{-1})^{0.39-1}$

=1250.31 Pa.s

Based on the viscosity-shear rate curve if figure below this value is too high. Since the maximum viscosity for LDPE at 240 ˚C is 300 Pa.s. The shear rate value of 13.08s^{-1}corresponds to approximately200 Pa.s.



And Frome Equ (3.7) can be determine the pressure max

$$Pmax = \frac{6 \cdot \pi \cdot D \cdot L \cdot N \cdot \eta}{H^2 \cdot tan\phi} \quad (3.7).$$

$$= \frac{6*3.14*0.04*1*50*200}{0.008^2*0.190}$$

$$= 3 * 10^5 \text{ Pa} \quad \text{When } Q = 0$$

This is the maximum pressure obtained when the flow rate is minimum.

3.3.4 Barrel

The extruder barrel hosts the screw internally and the heater and other components externally. In the feed section is equipped with a hopper design to prevent premature melting of the polymer resins. Along the length of the extruder barrel is covered a layer of protective material to prevent heat losses from the inlet. There may be several zones of heater bands to each section of the barrel wall [18].

Since the extruder barrel is the main component where the plastic is being process, they are designed to be large enough to hold the maximum possible amount of material, and also designed to prevent the screw from scraping the walls of the barrel that may cause damage to the barrel wall.

The change in temperature of each zone is detected by a sensor mounted beneath the barrel. There are two types of barrel heaters; band and cast. The band type is used for heating while the cast type has passages to house a flow of a cooling medium, and thus it can be used for both heating and cooling. The cooling medium is usually water but at time, oil can be used to prevent thermal shock to the barrel. The geometry of the Barrel with length 530mm and inner diameter 26mm, outer diameter 34mm as show in **Figure 3.10.**

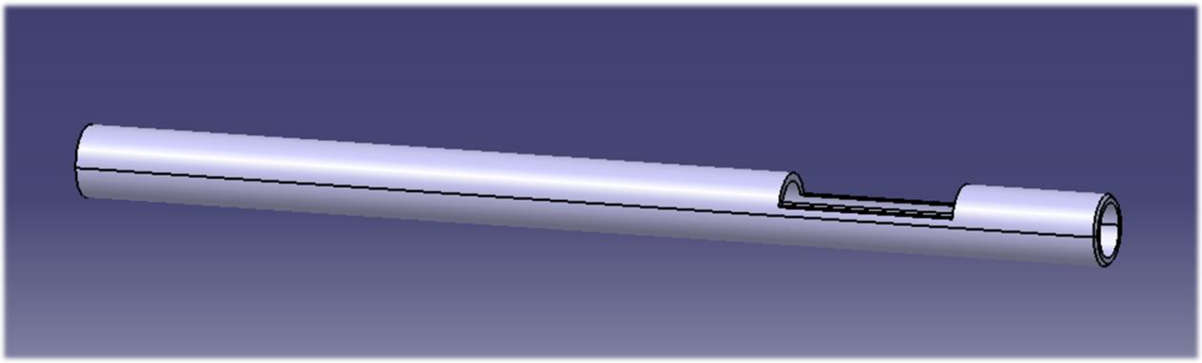


Figure 3.10: Extrusion barrel.

3.3.5. Barrel holder

Barrel holder use to hold barrel together in the framework, And are linked to each other by welding as show in **Figure 3.11.**

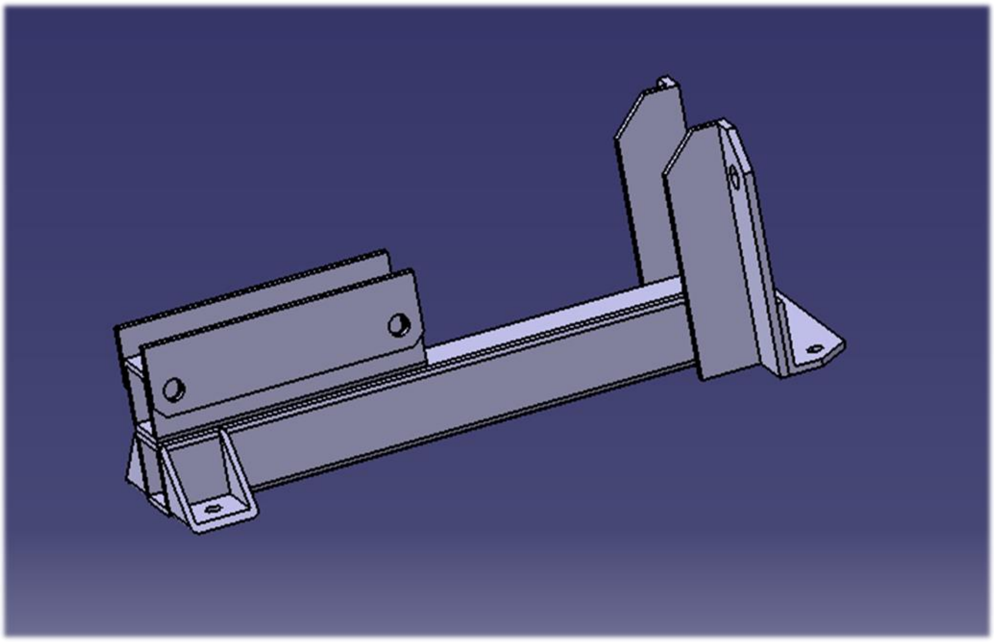


Figure 3.11: Barrel holder.

3.3.6. Flat

Used to connect between hopper and barrel by welding as show in **Figure 3.12.**

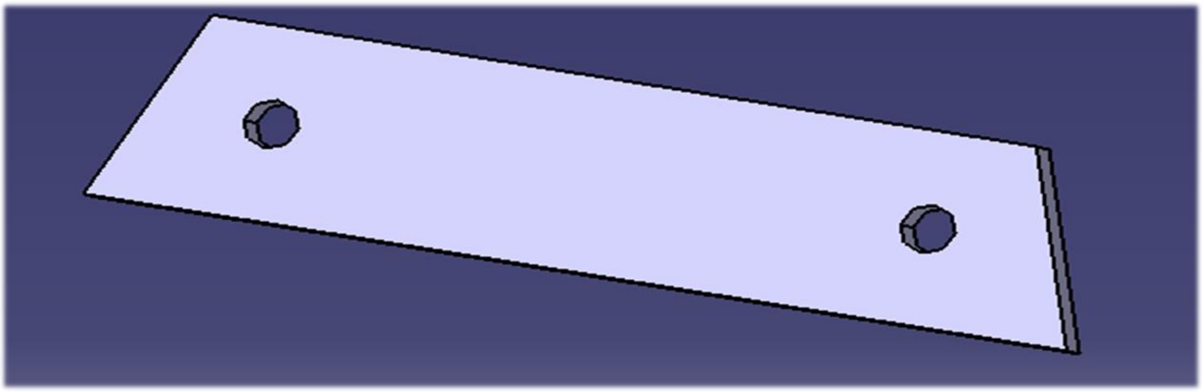


Figure 3.12: Flat.

3.3.7 Barrel holder-bearing shaft (shaft coupler)

Used to translate the motion from the electrical motor to the screw as show in **Figure 3.13**

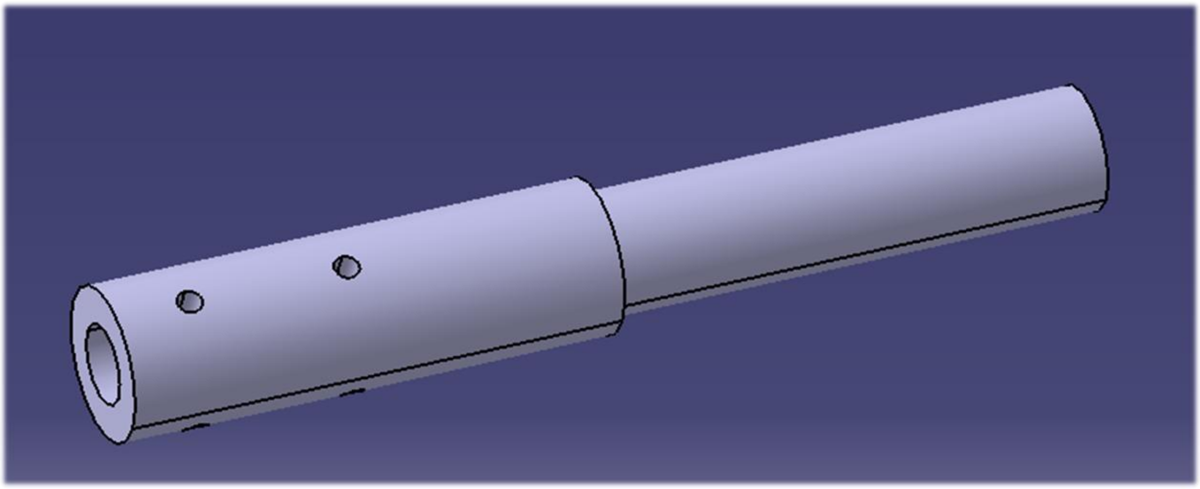


Figure 3.13: Shaft coupler.

3.3.8 Bearing

The bearing fixed between the shaft and the gearbox of the machine permit the rotational motion of the shaft without affecting the whole casing, so the isolate the shafts from the casing.

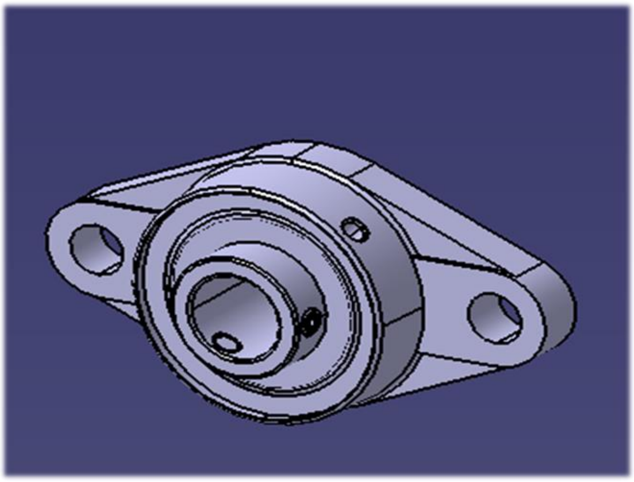


Figure 3.14: Bearing.

3.3.9 Nozzle

The Nozzle is placed at the end of the extruder, and can determine the shape of the product, and it can be used to control the output of Plastic.

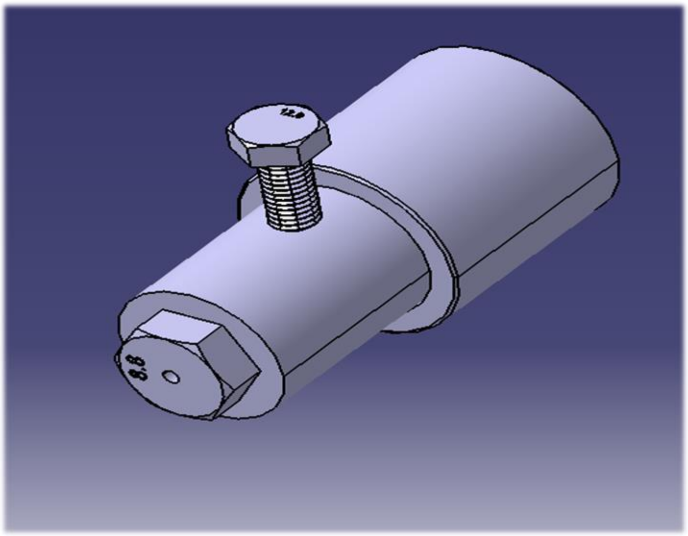


Figure 3.15: Nozzle

Figure 3.16 Explain the basic components of Nozzle.

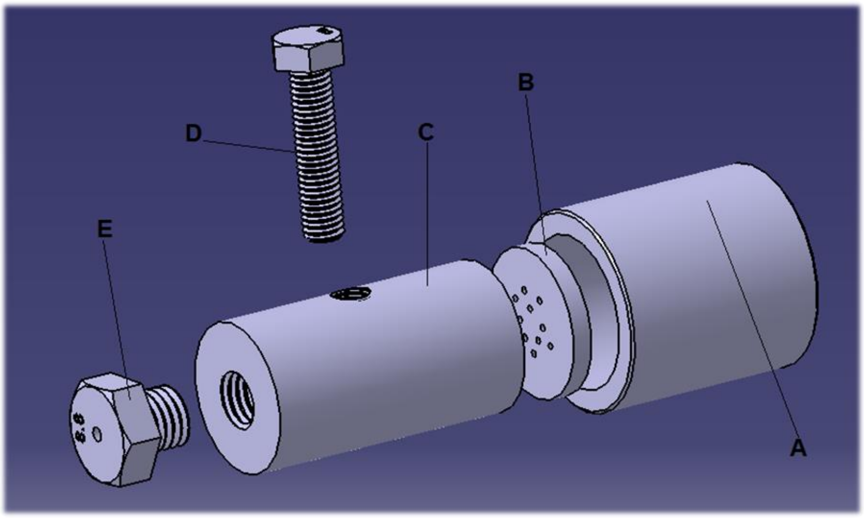


Figure 3.16: components of Nozzle

Table 3.4: Components of Nozzle.

symbol	*Name*	*Function*
A	Body	It use as a connector between the flow adjuster and Barrel, also it consists the filter in it bore.
B	Nozzle Filter	It has to make sure everything that comes out of the extrusion is smooth, molten and clean.
C	Nozzle flow adjuster	Used to adjust the amount of plastic output, and forms the link between Body and Nozzle screw, It also Contain a Bolt.
D	Bolt	It's used to control the amount of plastic output.
E	Nozzle screw	It's used to control the shape and diameter of the plastic output.

3.3.10. Framework

Framework carries the extruder machine, and it is installed in the ground by Bolts, the frame is made of steel and the surface is made of wood.

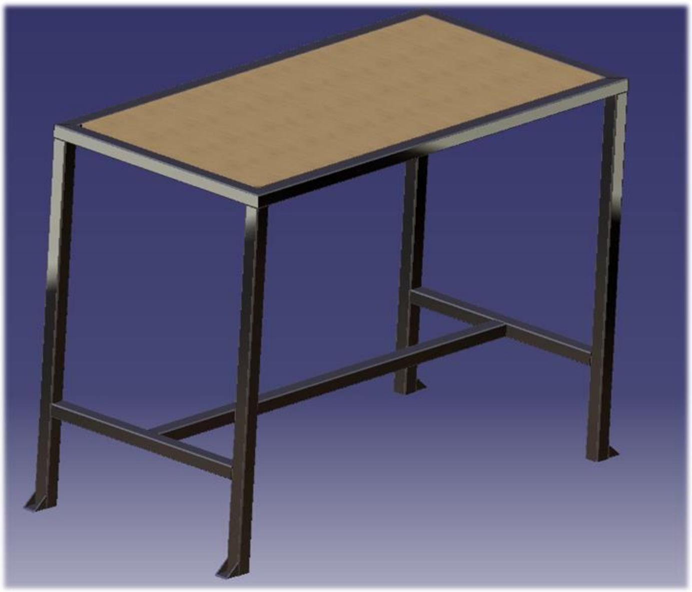


Figure 3.17: Framework

3.3.11. Electrical box

Electrical box contains all of the electrical parts in machine.

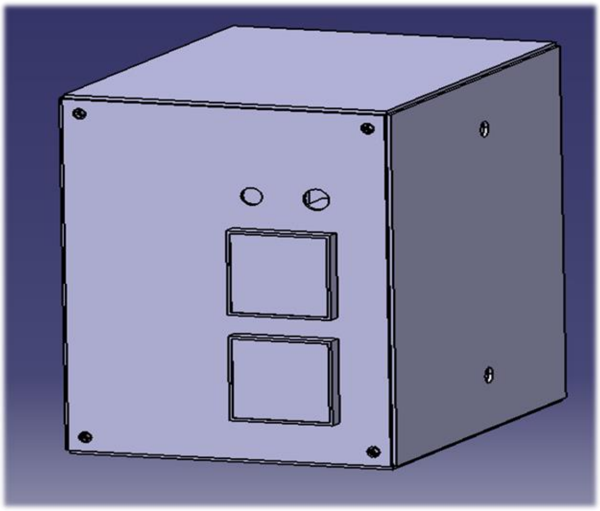
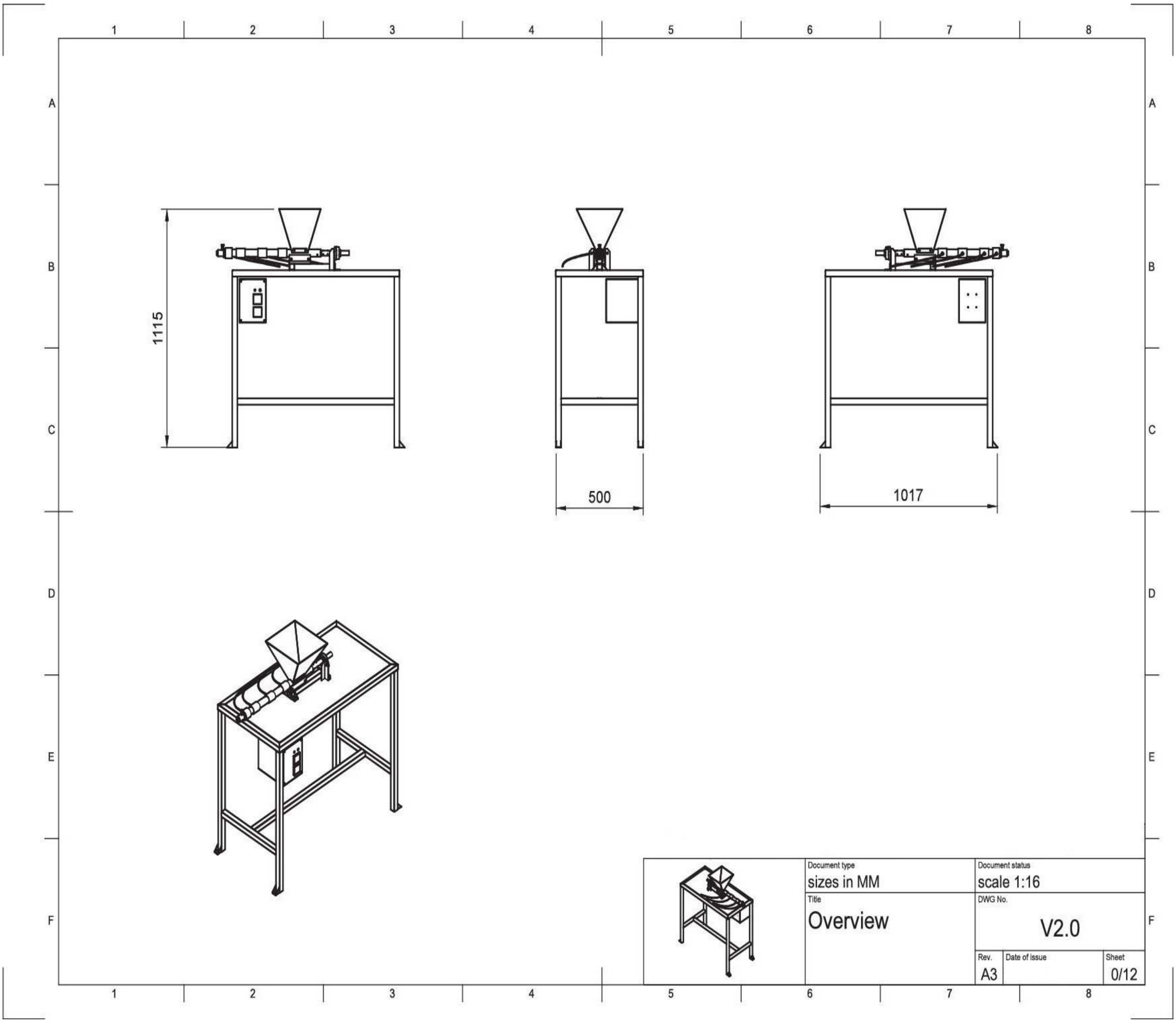
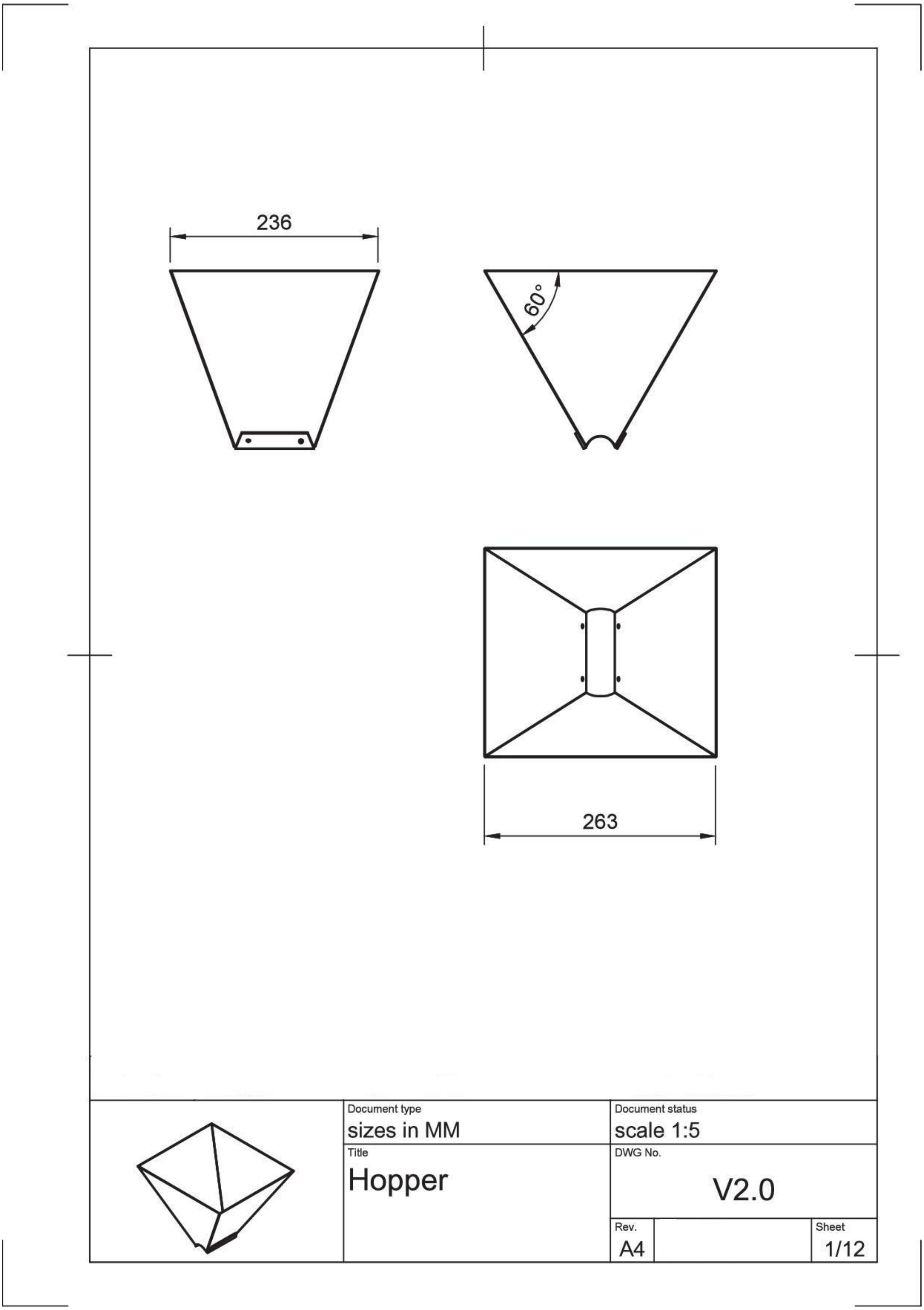


Figure 3.18: Electrical box.

The Machine designed using CATIA program. The dimensions and static analysis executed on it. The sheet metal package use to design model with all required features such as lathing, cutting and the metal thickness set on it. Appendix A discussed all designed parts in details.

Some of parts that designed illustrated in the following sheets:



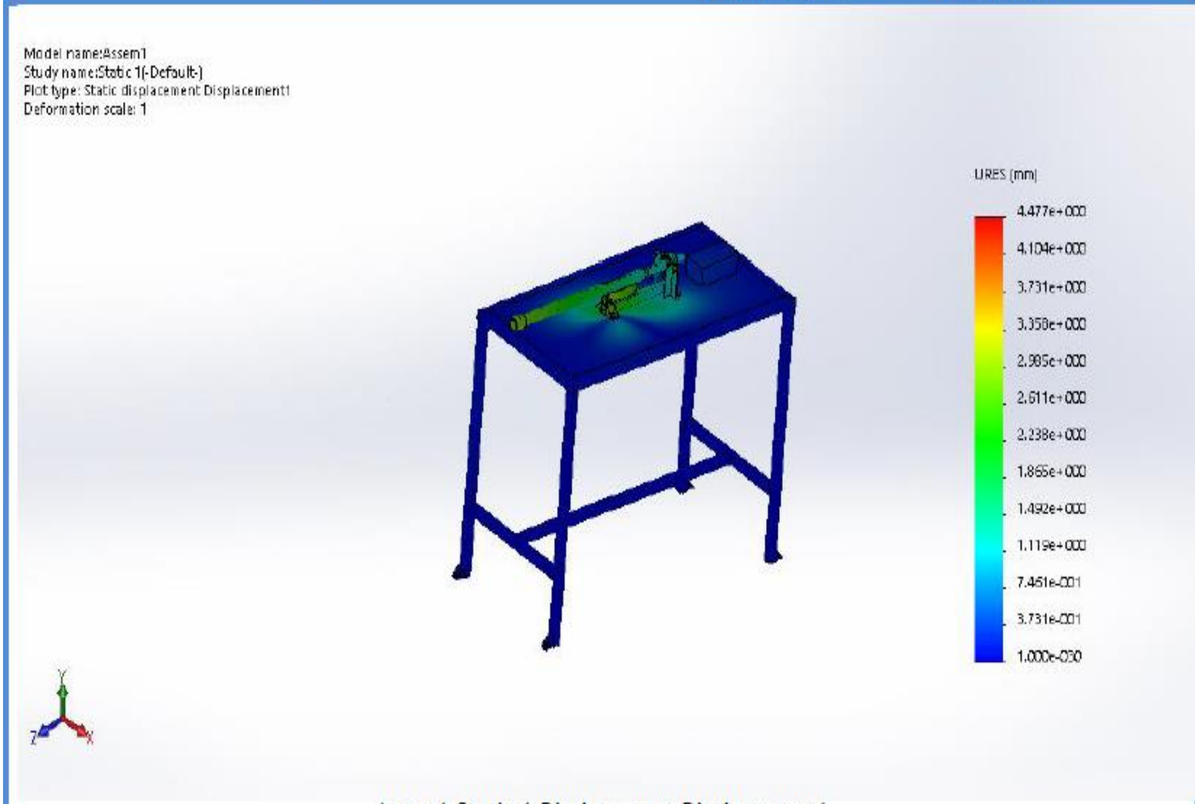

236
60°
263
Document type
sizes in MM
Document status
scale 1:5
Title
Hopper
DWG No.
V2.0
Rev.
A4
Sheet
1/12

3.4 Static analysis

The static analysis for fame executed on SOLIDWORKS .The results are good and no danger on frame and the frame reliable. Small tiny amount of deflection due to applied load appear and it can neglected. The stress does not make dangerous effect on frame. The Appendix C discuss the complete simulation report that generated by SOLIDWORKS. The report show the results with all details.

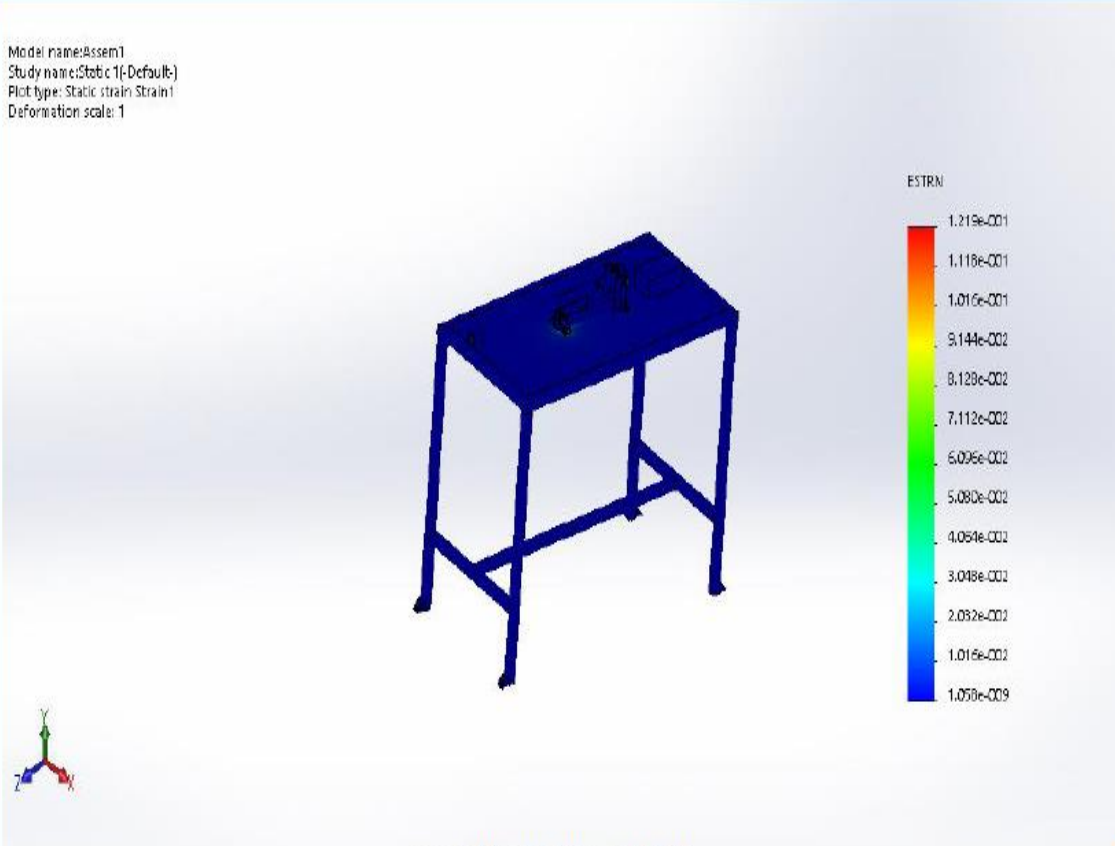
3.4.1. Study result

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 18523	4.47684 mm Node: 9602



Assem1-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.0582e-009 Element: 79668	0.121923 Element: 77821



Assem1-Static 1-Strain-Strain1

Mechanical Calculation

Calculation for force required to move the material along the power screw in order to choose the suitable motor.

The length of power screw equal 100cm, and the pitch equal2.4cm, the speed of motor is 1400 rev/min, and the rotational speed (W) equal 146.5 rad/sec, the radius of gear equal1.25cm.

Also by experiment, the required force equal 14kN.

F=14kN, W=146.5rad/sec

$$T=F*R \tag{3.11}$$

= 14*0.0125=175N.m

Where:

T: load torque. (N.m)

F: Force required for rotate the screw. (N)

R: screw radius. (m)

The chosen safety factor 1.67, so the used force equal 23.5KN.

T=F*R

=23.5*0.0125=294N.m

After this calculation chose gearbox (worm gear) has a reduction ratio equal to (1:30) has these specification:

Figure 3.19: Gearbox.

T before =T after*(1/30) (3.12)

=294/30=9.8(N.m)

Where:

T before: motor Torque

T after: load Torque

Pout=T*W (3.13)

=9.8*146.5=1435.7 WATT

Where:

P: power out of motor.

T: motor torque (N.m)

W: rotational speed (rad/sac).

Power in wat (Pin):

$$P\ in\ = 1.73 * V * I * PF\ = 1.7\ \text{kW} \tag{3.14}$$

Where:

Pin = Three-phase power in kW

V = voltage = 380V

I = current = 3.5A

PF = Power factor as = 0.9

Efficiency (%):

$$\eta = \frac{Pout}{Pin} x\ 100\% = 0.84 \tag{3.15}$$

Horse power = Pout/746 (3.16)

1435.7/746=1.92 hp.

Therefore, the chosen motor will be a 2 hp because there is no motor with 1.92 hp, the motor with this characteristic has been chosen to fit the calculation of the machine.

Table-3.4: Characteristics of Ac motor (Name- plate).

Type	**hp**	**Voltage (V)**	**Nrpm**	**Current (A)**	**Frequency (Hz)**	**Phase**
AC motor	2	230/400	1400	3.5/6.2	50	3 phase way connect

Chapter Four

Electrical Design & Protection

4.1 Introduction to Electrical Design

This section will explain all the electrical components will be used in this machine, Basic electronic components:

4.2 AC motor

Three phase AC motor with gear box, the reason to choose this motor because of its good self-starting capability, simple and rugged structure, low cost and more reliability,(to control it using inverter). The following table shows the characteristics of the motor.

Figure 4.1: Electrical motor

4.3 Gear box

Use gear box 1:30 to reducing the speed of the motor from 1400 rpm to 50 rpm.

*Figure 4.2***:** *Gearbox.*

4.4 CAM motor voltage frequency driver

The purpose of using the voltage frequency driver is to control the speed of CAM motor by using multifunction speed, the type of CAM Motor driver is Delta model VFD015EL21A shown in figure 4.3 The VFD-EL series is multiple function new generation micro type AC drive, high precision current detection, overload protection, and a built in keypad.

The calibration of inverter done by using the datasheet of it, (Appendix D).

Specifications

Nominal Input VAC: 208; 240 Volts AC

Input Range VAC: 200 to 240 Volts AC

Input Phase: 1

HP (CT): 2 Horsepower

Amps (CT): 7.5 Amps

Max. Frequency: 600 Hertz

Figure 4.3: CAM motor inverter.

To calculate power input of inverter:

P=I*V (4.1)

Where:

P: Power in put (W)

I: Measure current =5(A)

V: Voltage =220(V)

P=5*220=1100W

To calculate the amount of electricity consumption:

Electricity consumption=$Power\ input * price\ /1000W$ (4.2)

Where:

Power input=1100W

Price=0.5 NIS

Electricity consumption=1100*0.5/1000=0.55 NIS.

If don't use inverter the electricity consumption will be increase because the power input of motor 1700W، And with compensation in the Equ(**4.2**) find the electricity consumption before inverter

Electricity consumption=1700*0.5/1000=0.85 NIS.

The advantages of using an inverter

1. Inverter works to reduce electricity consumption.
2. Get three phase from one phase.

4.5 PID temperature control

PID is the device, which provides the Information to SSR when to turn on and when to turn off. ID reads the temperature of any system with the help of thermostat. It functions as the input panel to the system.

General purpose of temperature controllers are used to control most typical processes in industry. Typically, they come in a range of DIN sizes; have multiple outputs, and programmable output functions. These controllers can also perform PID control for excellent general control situations. They are traditionally placed in the front panel with the display for easy operator accessibility. These controllers have a pre-tune function to initially calculate the PID temperature for a process, and a continuous tune function to constantly refine the PID temperature, all details of this controller at appendix D.

*Figure 4.5**:** PID temperature control.*

4.6 Solid state relay (SSR)

SSR is the device in which the temperature can be controlled with the help of PID. For controlling the electric circuit to maintain the temperature. The temperature can be controlled by controlling electricity. So this device acts as the gate keeper for the electricity .Which means when the temperature is insufficient the SSR will transmit electricity to the heater and when the temperature reaches the required level it cuts of the electricity with the help of PID and thermostat.

Figure 4.6: Solid-state relay

4.7 Thermocouple sensor

The sensor which is used to measure the temperature is known as thermocouple.it consist of two wires made from different metals. When the two material are subjected to the heat, it produces some electric voltage, which determines the reading of the temperature in the system. The thermocouple are used for low cost, durable and high temperature range.

*Figure 4.7**:** Thermocouple sensor*

4.8 Band heater

Band heaters: of all types are used to heat cylinder. They are used on the plastic extruder, it consist from an electrical resistance ribbon, which are present between two sheets of mica, it are the combination of the material dielectric strength which are present between resistance ribbon and outer surface, of the component either mild steel or stainless steel.

Electric resistance heaters are widely use in extruder machines. The heat generated by the extruder heaters is made possible by passing a certain amount of current through a conductor of certain resistance, as the resistance creates barrier to the flow of electrons, heat is generated.

*Figure 4.8**:** Band heater*

To calculate the amount of current consumption:

I=P/V (4.3)

Where:
I: Current (A).
P: Power input (W).
V: Voltage (V).

I=500/220=2.27A for one band heater, and at five heater 2.27*5=11.36 this is all current consumption in heaters, to calculate the amount of electricity consumption:

Electricity consumption=$Power\ input * price\ /1000W$

=500*0.5/1000=0.25 NIS at one heater

At all heaters =0.25 *number of heaters
=0.25*5=1.25 NIS

4.9 Klemens

Used to connect wires and a range the connections as shown in **figure** (3.26).

*Figure 4.9**:** Klemens.*

4.10 Switches

The emergence switch are used to stop the machine immediately when something wrong happened with the machine as shown in Figure (4.10).The power switch used to select the system on/off, as shown in Figure(4.11).

Figure 4.10: Emergence switch

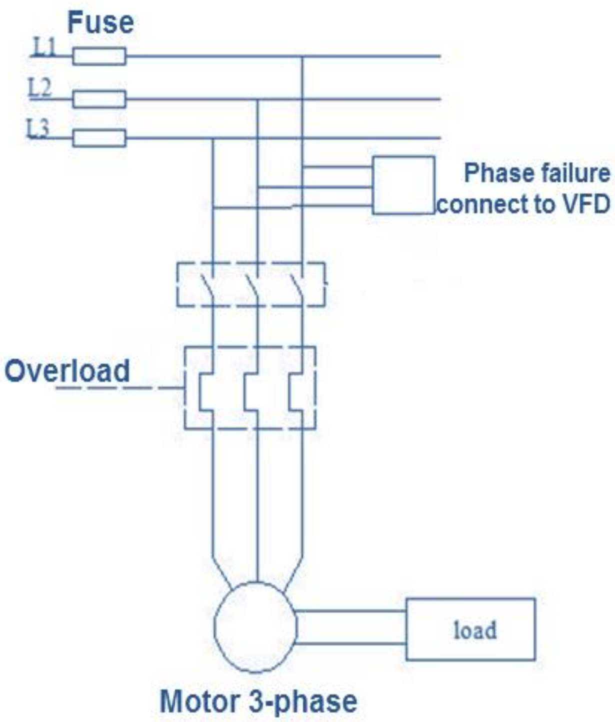
Figure 4.11: Power switch

4.11 Led indicator

The led as shown in **Figure** 4.12 are singed the machine operation mode.

Figure 4.12: Led indicator

4.12 Power circuit of motor



4.13 Electrical Panel and Protection.

The electrical panel shown in figure4.13and it is containing:

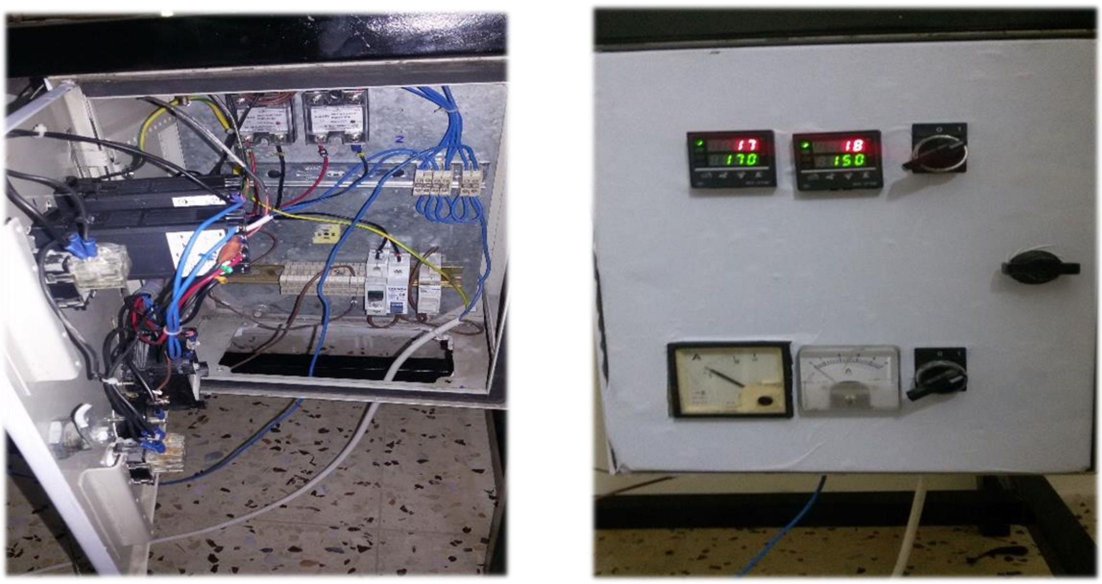


Figure4.13: Electrical Panel.

4.14 Circuit Breakers

Circuit breaker is an automatically operated electrical switch designed to protect An electrical circuit from damage caused by overcurrent or overload or short circuit. Its basic function is to interrupt current flow after protective relays detect a fault. Unlike a fuse, which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation. Circuit breakers are made in varying sizes, from small devices that protect an individual household appliance up to large switchgear designed to protect high voltage circuits feeding an entire city.

Use 3 circuit breakers in our panel, one of them is the main circuit breakers it have four poles two inter and two outer (line – neutral), and this breaker allows up to 25 amperes. The other two breakers each of them connected with the ***relay***s, one of breakers 10 ampere used it for motor and the rest one is 16 ampere and used it for heaters.

Figure 4.14: Circuit Breakers.

Chapter Five

Manufacturing and Assembly

5.1 Introduction

This chapter discuss the manufacturing technologies that used in project. The structure build using four manufacturing process and it is cutting, lathing, welding and coating. The mechanical parts such as screw, Also, the part assembly and part joined demonstrated.

5.2 Manufacturing

Two materials used to build the extruder. The first one, carbon steel metal that used for structure. The structure build in four stages and it cutting, lathing، welding and cutting. The second one is wood, which used for holding the parts of machine that uses for the frame.

5.2.1 Structure

The carbon steel metal used to build the structure, it uses due to four reasons. The first one, it is available in Palestinian market, so no need for import from aboard. The second one, it is low coast than other materials. For example, the aluminium is ten time expensive than steel. It is easy to manufacturing. The local factory have required high quality machines to cut, bend, weld and coating steel. The steel is robust material and have a chock resistance. In constraint, the plastic is easy to break. Due tis reasons the carbon steel is the best choice for stricter and cheapest one.

5.2.2 Cutting

The high quality-cutting machine is used to cut the metal (see Figure 5.1). It is have 0.1mm resolution. The structure parts designed in CATIA program using sheet metal module.

Figure 5.1: Nozzle during cutting the metal.

5.2.3 Lathing

This stage is one of the most important stages of building projects, through which the work of the most important parts such as screw, nozzle and coupler, also it is have 0.1mm resolution, (see **figure 5.2**).

Figure 5.2: Coupler during Lathing.

6.2.4 Welding

The MIG welding is used to assemble the part together after cutting and preparing the parts. This technology use Argon and CO_2 gas. After welding, the surfaces must gridding to get smooth surface finish (see **figure 5.3**).

Figure 5.3: Machine through welding.

6.2.5 Coating

The black-color and silver-color coating is useing to coat the surfaces (see **figure 5.4**, and **5.5**). It is give metal corrosion and wear resistance against environmental effect.

Figure 5.4: Machine after coating.

Figure 5.5: Frame after coating.

5.3 Construction Process

The extruder structure was installed with the frame by the bolts as shown in (**Figure 5.6)**

Figure 5.6: extruder structure installed with frame.

And then it was installed the hopper with the barrel by the bolts as shown in (Figure 5.7)

Figure 5.7 hopper installed with barrel of extruder.

The outer shell of gearbox of the motor was taken as the base of the extruder. The shaft was removed and replaced with the 16mm internal diameter and 20mm outer diameter threaded steel tube .The tube was perfectly pushed inside the shell of the gear box, The auger was attached with a coupler to the shaft of the motor as shown in (Figure 5.8).

*Figure 5.8**:** auger was attached with a coupler to the shaft of the motor***.**

The next stage is installing heaters with the tube by the cleats; an extruder that I am making is used five channel heating system extruder as shown in (**figure 5.9**).

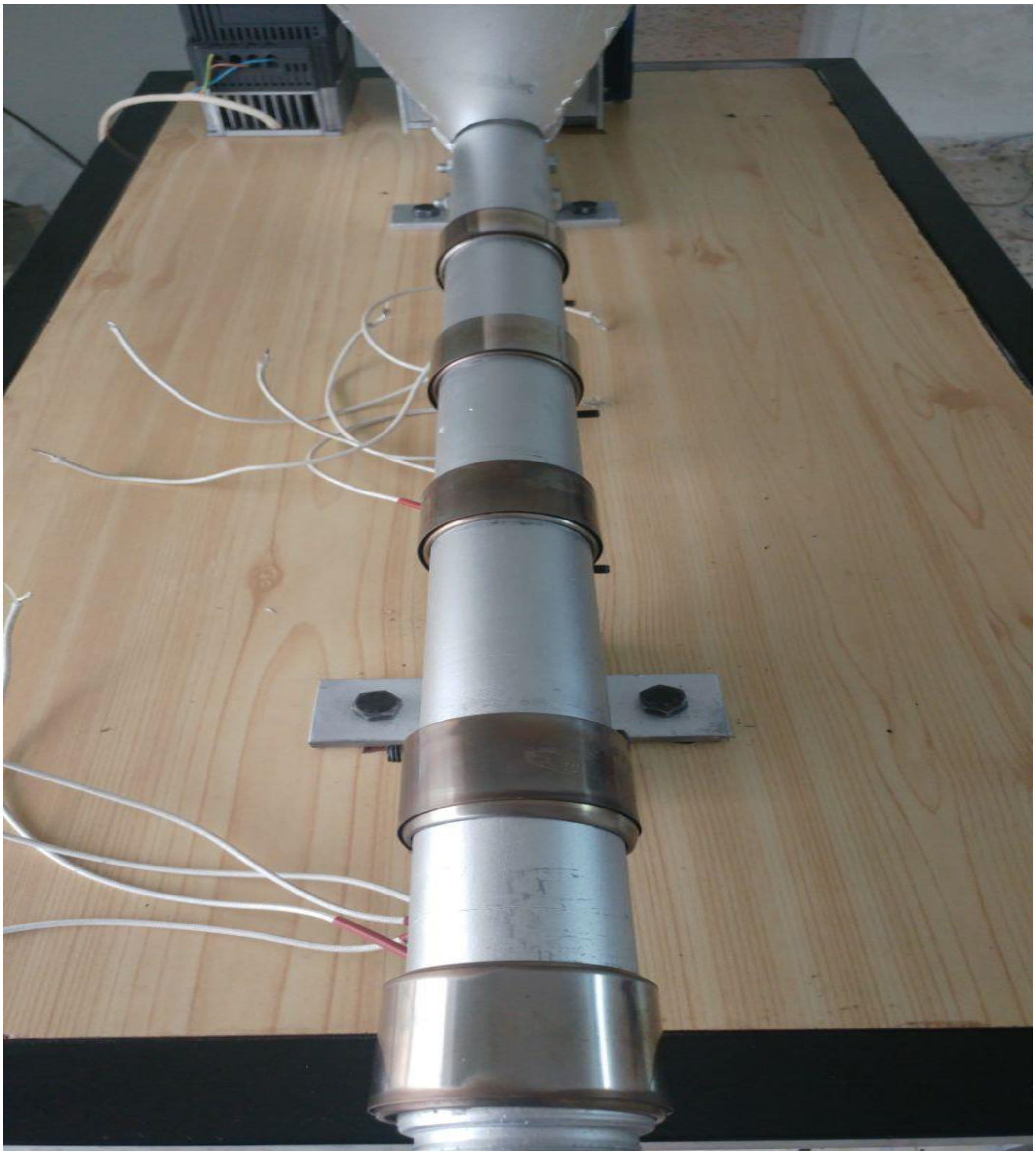


*Figure 5.9**:** five channel heating system extruder*.

The thermocouple was connected to the port 9 and port 10-.This port was the place where heat sensor was connected. It was able to read temperature of tube after connecting. SSR is connected on port 6 and port 7 according to polarity. This was able to switch the heater on and off after obtaining required temperature. The main power supply of this extruder is port 1 and port 2. The power supply for the heater was also supplied through port 1 and port 2.This completed the electronics wiring of the heat control mechanism as shown in (**figure 5.10**).

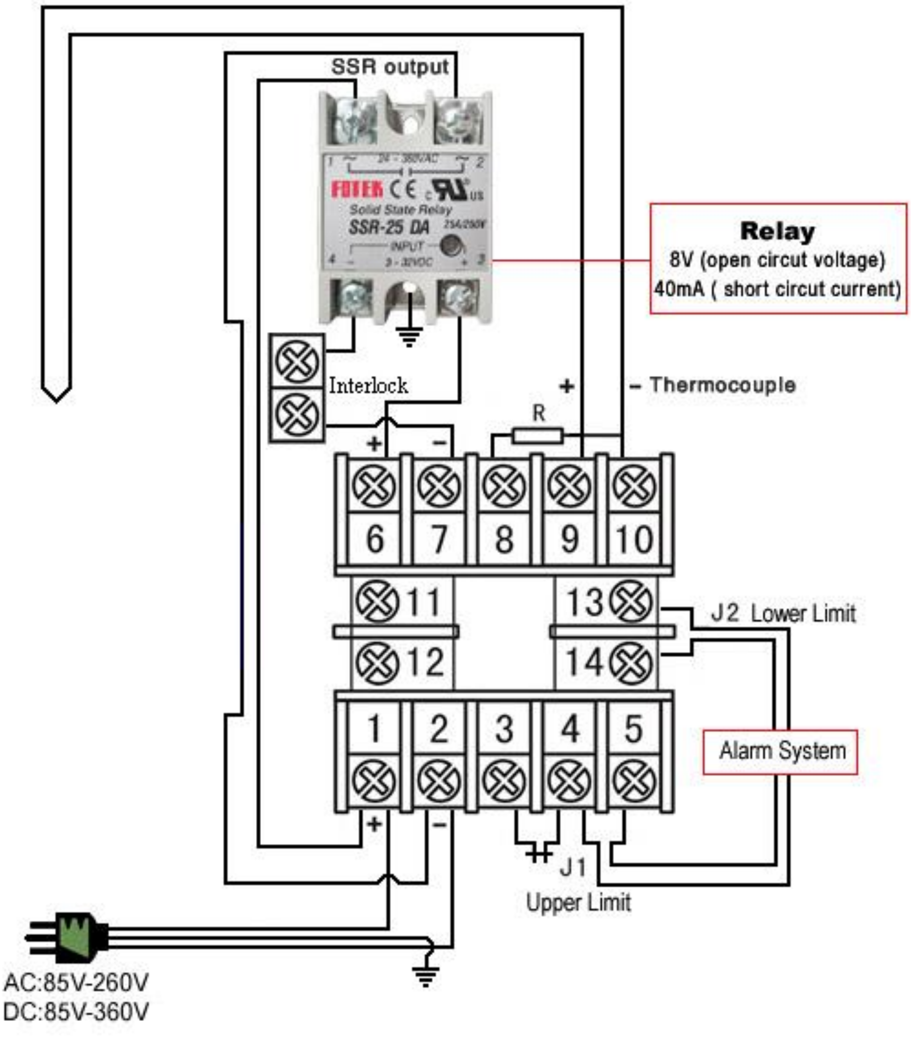


Figure 5.10 Electronics wiring of the heat control mechanism

After the assembly of the extruder parts was completed. The machine was left 15 min with turning on the heat of 180 ˚C. After acquiring the stable temperature, the motor in drive system was turned on .The pellets were then poured in to the hopper. The motor was on the speed of 50 RPM .the plastic were driven by the screw along the barrel. When the plastic reached the heating section, it started melting and the pressure was created inside the tube. Due to the friction inside the Steel tube and the additional heating from the heater rises the temperature and melted the plastic completely. The filament was extruded through the die hole of 3 mm in diameter.

Figure 5.11: Die with 3 mm hole

Chapter Six

Experimental Result & Recommendations

6.1 Introduction

This chapter provides experimental result, some recommendations from the work team for this project. In this chapter we are listing some goals hope to be accomplished or_ at least_ under attention.

6.2 Experimental Result

We made some experiments on parts of our project and these are some of results:

1) The structure stress, strain and deformation simulated using SOLIDWORKS program under simulation module. In addition, the results are as wished and show very tiny small of deformations due to applied forces. The stress on structure does not make a critical effect on it. Therefore, the machine can used without any problem under these results. On other hand, the machine assembled successfully without any problem. The frame rigid and does not show any dangerous behavior.

2) The hopper of machine contains about 5kg and the machine making a process on it and give output without any problem, as it should be.

3) The heating process with five channel heating system was enough for the melting process. In addition, the reasons are to set PID controller to desired temperature that should be for five heaters. At first the temperature about 150 ˚C for first three heaters, to increase the temperature of input plastic and making it homogeneous as possible, the temperature of the last two heaters is 180 ˚C, in order to make the input plastic more homogeneous and to output a continuous line of raw plastic in best shape.

4) The inside diameter of the barrel and the outside diameter of screw was 40 mm which assume to be perfect for the filament of 3 mm.

5) At the first experiment, we note that the final product of continuous line has a large diameter and High deformation as shown in **Fig** (**6.1.a**) after that we calibrate the nozzle screw to achieve the desired size of output diameter of raw plastic as shown in **fig 6.1.b.**

Figure 6.1.a: first experiment

Figure 6.1.b: product after calibration

The experiment as shown in **figure 6.2**.

Figure 6.2: Experiment result.

6.3 Recommendations

These recommendations are recorded by the tests on project and it should taking in account to modify it for better:

1) At first the selection of motor was 1hp but it doesn't work as it should be and consumes lots of power, and torque has not enough to rotate the screw, so by making a new calculation , the selection of motor is 2hp as the it shown in design chapter.

2) The project faced a problem to select the distance and the operation temperature of machine, so by making tuning and calibration of heaters through the experiments on machine, the distance between them about 10-11 cm expect the distance the haters in nozzle , which about 5 cm.

3) The operation time of machine about 15 minute to reach the desired temperature, because the cross section heaters not enough as required, so to reduce the time, the cross section should be larger than it was.

These recommendations are recorded to people who can create opportunities for student to make something new and useful, in order to make difference in our country Palestine:

1) Once the university administration financially supported graduation projects, this support must be provided at the beginning of the project work, to enable students to do their projects according to the time plan, and to test them at the proper time.

2) The university should provide the proper toolsets, which enable the Student to assemble his project and to test it the university campus, so he could get benefit of experiences in the university.

3) The metal workshops must have highly trained technician to read the plans, and to perform the design.

4) The Environment Department can using our project, to make a studies and tests on the output of this machine.

6.4 Conclusion

Extrusion is one of the most widely used polymer converting operations for manufacturing blown film, pipes, sheets, and laminations, to list the most significant industrial applications. Fig. 3.1 shows a machine for making blown film. The extruder, which constitutes the central unit of these machines, is shown in Fig. 1.5. The polymer is fed into the hopper in the form of granulate or powder. It is kept at the desired temperature and humidity by controlled air circulation. The solids are conveyed by the rotating screw and slowly melted, in part, by barrel heating but mainly by the frictional heat generated by the shear between the polymer and the barrel (Fig. 1.6). The melt at the desired temperature and pressure flows through the die, in which the shaping of the melt into the desired shape takes place.

6.5 Future Work

The project cover many of smart features can be added to this extruder machine, such as using SCADA systems, which uses computers, networked data communications and graphical user interfaces for making a best management, also it can using a cooling system for output, in order take a desired shape as it should be.

Appendix A

Extruder machine design sheet

Appendix B

Extrusion electrics schematics

Appendix C

Extruder structure static analysis report

Appendix D

Data sheet of inverter and temperature controller

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