Palestine Polytechnic University

College of Engineering and Technology
Mechanical Engineering Department

Graduation Project

Operation and Process analysis of PPU Plastic Factory

Project Team

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Jan, 2010

Palestine Polytechnic University
(PPU)
Hebron-Palestine

PROJECT NAME
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According to the project supervisor and according to the agreement of the Testing committee members, this project is submitted to the Department of Mechanical Engineering at college of engineering and technology in partial fulfillment of the requirements of (B.SC) degree.

Supervisor Signature

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Examine community Signature

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Jan, 2010

Abstract

The Palestine Polytechnic University Industrial Synergy Center (PPUISC) established an internal plastic factory as a local industrial facility within university campus, as a tool for "ice-breaking" between the engineering students and machines that they will operate in their practical life.

This project aimed at establishing a bridge between local Industry and engineering education at PPU.

The output from this project included technical analysis of hydraulic system, cooling tower, control system, molds, and including required design calculation.

In addition to that, the project required some kind of feasibility study of the products, to determine it's retrofit ability if being marketed within the local community.

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1.1 Project Background

Plastic is the general common term for a wide range of synthetic or semisynthetic organic amorphous solid materials suitable for the manufacture of industrial products. Plastics are typically polymers of high molecular weight, and may contain other substances to improve performance and/or reduce costs. Many countries produce plastic, but the most important of them are the United States of America and Japan. In Palestine there are various companies that are producing plastic such as Palestine Plastic Industries Company in Nablus which manufactures different types of products and Royal Industrial Trading Company in Hebron, which produces plastic pipes.

As part of its projects, Industry Synergy Center (ISC) established a new plastic factory as one of its activity in the ground flour-building C-Wad Alhariah.

The machine produces plastic by injection process, so it requires some steps to operate it. These steps will be explained in (section 1.5.1) as the main tasks and activities.

The project will answer the question on how to start and operate the factory and review the design process.

1.2 Project Scope

The scope of the project is to operate the plastic injection machine and explore the possibility to improve its product performance. This includes the following main topics:

- Literature review of the industrial operation for manufacturing plastic, and also a field study of the operation for making it in Royal Company.
- Reviewing the scientific background about the raw materials, processes and properties of plastics.
- Technical study and process analysis of existing factory at (ISC) including redesign of equipment components.

- Market study, marketing plan, and searching for possibility of a new products.
- Economic feasibility study, how to sell the products.
- Design new molds for new products.

1.3 Project Goals and Objectives

The overall aim of the project is to operate the factory and to explore the possibility to improve the production performance through engineering review of process design.

1.3.1 General Goals

- Operating the purchased factory by (ISC).
- Applying the mechanical engineering principles engineering on the various process components and systems.
- Creating bridges between engineering education and local industry.

1.3.2 Specific Objectives

1) Performing engineering review to process design involved in ISC plastic injection machine, this including :
    - Hydraulic system.
    - Cooling system.
    - Mechanical system-Truss.
    - Pasic concepts of control process.
2) Preparing` design document such as engineering flow sheets and plant layout.
3) Performing market survey to explore the potential for producing new plastic products.
4) Designing mold for a selected new products choose based on the market survey.
5) Performing economic feasibility study for the new factory at ISC.
6) Suggesting a management system for the factory focusing on products.
7) Creating aground for quality assurance system.

1.4 Project Choice Justification

1) ISC requires reviewing process design for the purchase plastic injection machine which is the focus of this project.
2) This project creates sufficient experience for the student, which assist them in having an employment opportunity after graduation.
3) Such a project provides the opportunity to apply what have been studied in five years in the engineering college.
4) The availability of obtaining funds from Industry Synergy Center (ISC) for purchasing the required project components.

1.5 Project Implementation Plan

This project intended to sustain a high level of scientific value, however, the project has got tasks, goals and objectives, in addition to the time table, thus when they are achieved; and then the project has accomplished that level.

1.5.1 Main Tasks and Activities

The main tasks for the first semester include;

- Literature review and gaining scientific background on plastic production, raw materials, processes and properties.
- Designing a suitable mechanical structure to be used for replacing the molds (Truss).
- Preparing engineering flow sheets and plant layout.
- Preparing a review about market study.
- Redesigning the mold.
- Preparing the report for the first stage.

1.5.2 Time Table

The time table for the first semester is illustrated in (Table 1.1).

Table 1.1: The time table for 1st semester

Objective	Week #															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Selecting project title	■	■	■	■												
Planning and Setting Project Concepts and Goals					■	■	■									
Establishing Scientific Background							■	■	■	■	■	■	■			
Design the Mechanical structure of Truss										■	■	■	■	■		
Preparing Engineering Flow Sheets and Plant Layout												■	■	■	■	
Marketing Survey Overview											■	■	■	■	■	
Redesign the mold														■	■	
Writing Report									■	■	■	■	■	■	■	
Presentation																■

The main tasks for the second semester include;

- Building and installing the mechanical structure that uses for replacing the molds.
- Redesign the cooling tower and the water cycle.
- Choosing the new product and design its mold.
- Prepare an economic feasibility study.
- Creating aground of suggesting material testing and quality assurance system.
- Analyzing control system.
- Analyzing the hydraulic system.
- Preparing documentation, summarizing the results and recommendations, and making presentation about the project.

Table 1.2: Time table for the 2nd semester

No.	Output	Output indicator	Activities	Milestone	Schedule (Weeks) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Build the structure	manufacture the deign	1.1Buy the components	Implementation																
			1.2Manufacturing																	
			1.3Testing																	
2	Analizing the hydraulic system	hydraulic system calculations	2.1Measure the pipes diameters and pressures	Full measurement results																
			2.2Prove the diameters by calculations																	
3	Analizing the cooling tower	Rate of heat tranfere and the efficiency of the machine	3.1Sketch of components	Possibility to improvement																
			3.2Calculate the heat transfere																	
			3.3Calculate the efficiency of machine																	
4	Control system	Electrical circuit used	4.1Drawing the electrical circuit	Control system																
			4.3The control system																	

5	Economic feasibility study	The Economic value of the products	5.1The amount of prodution 5.2Marketing plan 5.3Marketing	Economic feasibility of the factory
6	Flow sheet and plant layout	prepare a manual book about machine	6.1Prepare sheets for all steps we end it	Manual sheets
7	Testing the machine and products	operate the machine	7.1assembly all components and	Testing
8	Design the mold	Analize the mold componants and design a new one	8.1Background about components 8.2Design the new mold	Mold Design
9	Project presentation	Powerpoint presentation is prepared	9.1Presenting the project Activities that is achieved within the semester	Powerpoint presentation

1.6 Preliminary Budget

Preliminary estimates are made for the project components as listed in table (1.3)

Table 1.3: Preliminary budget

NO.	Item	Estimated Cost ($)
1	Truss -Material -Building	300
2	Raw Materials	500
3	The Mold	5000
4	Lubrication Oil	20
5	Hydraulic Oil	100
6	**Total coast**	**5920**

Chapter Two

Plastic Properties and Types

- Introduction to plastic.
- Chemistry and properties.
- Raw materials.
- Plastic processing.

2.1 Introduction

Plastic is one of the most important materials in our life, we use it in many subject in different shapes and types.

So, in this chapter we will discuss the plastic, meaning, chemistry, properties and types.

Plastic is the general common term for a wide range of synthetic or semisynthetic organic amorphous solid materials suitable for the manufacture of industrial products. Plastics are typically polymers of high molecular weight, and may contain other substances to improve performance and/or reduce costs.

The common word "plastic" should not be confused with the technical adjective "plastic", which is applied to any material which undergoes a permanent change of shape (a "plastic deformation") when strained beyond a certain point. Aluminum, for instance, is "plastic" in this sense, but not "a plastic" in the common sense; while some plastics, in their finished forms, will break before deforming and therefore are not "plastic" in the technical sense.

There are two types of plastics, thermoplastic and thermoset. Thermoplastics, if exposed to heat, will melt in two to seven minutes. Thermosets will keep their shape until they are a charred, smoking mess. Some examples of thermoplastics are grocery bags, piano keys and some automobile parts. Examples of thermosets are kid's dinner sets and circuit boards.

2.2 Chemistry and properties

Plastic formed by a collection of atoms which means polymers, plastic has multi chemical formulas depend on type and shape and structure.

2.2.1 Polymer and its Structures

Word Polymer constructed into two sections, poly means many and mer which means repeat unit.

The molecules in polymers are gigantic in comparison to the hydrocarbon molecules.

Polymer usually consists of monomers.

There are various types of polymers such as Polyethylene(PE), Polyvinyl chloride(PVC), and Polypropylene(PP).

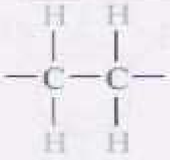
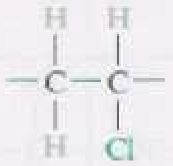
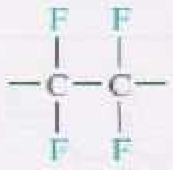
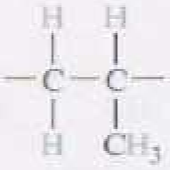
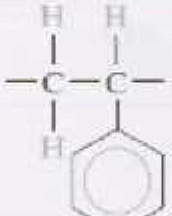
2.2.2 Polymer chemistry

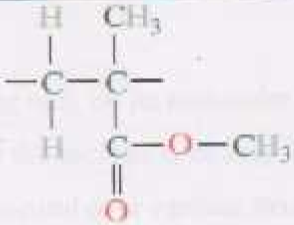
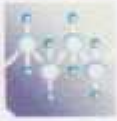
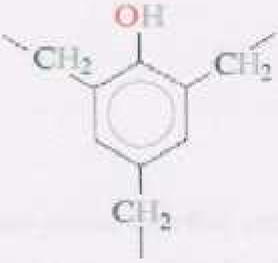
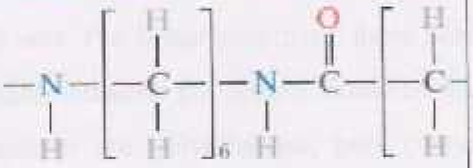
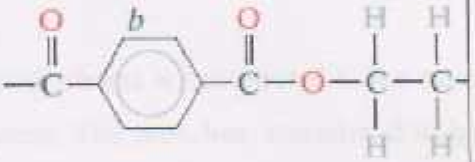
The repeating structural unit of most simple polymers not only reflects the monomer(s) from which the polymers are constructed, but also provides a concise means for drawing structures to represent these macromolecules. For polyethylene, arguably the simplest polymer, this is demonstrated by the following equation. Here ethylene (ethane) is the monomer, and the corresponding linear polymer is called high-density polyethylene (HDPE). HDPE is composed of macromolecules in which n ranges from 10,000 to 100,000 (molecular weight $2*10^5$ to $3*10^6$).

2.2.3 Bulk or Commodity Polymers

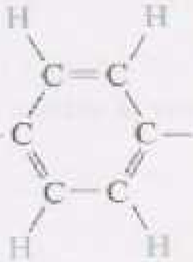
There are various types of commodity polymers making as shown in Table 2.1 .

Table 2.1 A Listing of Repeat Units for 10 of the More Common Polymeric Materials

Polymers	Repeat Unit
Polyethylene (PE)	
Poly(vinyl chloride) (PVC)	
Polytetrafluoroethylene (	
Polypropylene (PP)	
Polystyrene (PS)	

 Poly(methyl methacrylate)	
 Phenol-formaldehyde (Bak	
 Poly(hexamethylene adipamide) (nylon 6,6)	
 Poly(ethylene terephthalat (PET, a polyester)	
 Polycarbonate (PC)	

[b] The  symbol in the backbone chain denotes an aromatic ring as



2.2.4 Molecular Structure

The physical characteristics of a polymer depend not only on its molecular weight and shape but also on differences in the structure of the molecular chains. Modern polymer synthesis techniques permit considerable control over various structural possibilities.

2.2.5 Polymer types of Structure

1) Linear Polymers

Linear polymers are those in which the repeat units are joined together end to end in single chains. These long chains are flexible and may be thought of as a mass of spaghetti, where each circle represents a repeat unit. For linear polymers, there may be extensive van der Waals and hydrogen bonding between the chains. Some of the common polymers that form with linear structures are polyethylene, poly (vinyl chloride), polystyrene, poly (methylmethacrylate), nylon, and the fluorocarbons.

2) Branched Polymers

Polymers may be synthesized in which side-branch chains are connected to the main ones, these are fittingly called branched polymers. The branches, considered to be part of the main-chain molecule, may result from side reactions that occur during the synthesis of the polymer. The chain packing efficiency is reduced with the formation of side branches, which results in a lowering of the polymer density. Those polymers that form linear structures may also be branched. For example, high density polyethylene (HDPE) is primarily a linear polymer, while low density polyethylene (LDPE) contains short chain branches.

3) Crosslinked Polymers

In crosslinked polymers, adjacent linear chains are joined one to another at various positions by covalent bonds.

Circles designate individual repeat units.

Crosslinking is achieved either during synthesis or by a nonreversible chemical reaction.

Often, this crosslinking is accomplished by additive atoms or molecules that are covalently bonded to the chains. Many of the rubber elastic materials are crosslinked; in rubbers, this is called vulcanization.

4) Network Polymers

Multifunctional monomers forming three or more active covalent bonds make three-dimensional networks and are termed network polymers.

Actually, a polymer that is highly crosslinked may also be classified as a network polymer. These materials have distinctive mechanical and thermal properties; the epoxies, polyurethanes, and phenol-formaldehyde belong to this group.

Polymers are not usually of only one distinctive structural type. For example, a predominantly linear polymer might have limited branching and crosslinking.

2.2.6 Copolymers

Polymer chemists and scientists are continually searching for new materials that can be easily and economically synthesized and fabricated, with improved properties or better property combinations than are offered by the homopolymers previously discussed.

One group of these materials are the copolymers.

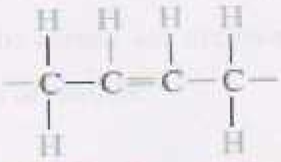
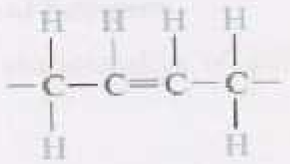
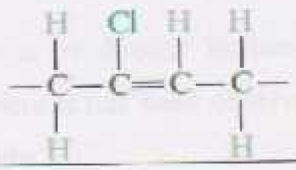
Consider a copolymer that is composed of two repeat units. Depending on the polymerization process and the relative fractions of these repeat unit types, different sequencing arrangements along the polymer chains are possible. For one, the two different units are randomly dispersed along the chain in what is termed a random copolymer.

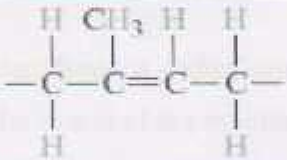
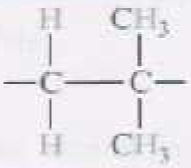
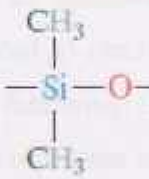
For an alternating copolymer, as the name suggests, the two repeat units alternate chain positions. A block copolymer is one in which identical repeat units are clustered in blocks along the chain. Finally, homopolymer side branches of one type may be grafted to homopolymer main chains that are composed of a different repeat unit; such a material is termed a graftcopolymer.

2.2.7 Polymer Crystallinity

The crystalline state may exist in polymeric materials. However, since it involves molecules instead of just atoms or ions, as with metals and ceramics, the atomic arrangements will be more complex for polymers. We think of polymer crystallinity as the packing of molecular chains to produce an ordered atomic array. Crystal structures may be specified in terms of unit cells, which are often quite complex.

Table 2.2 Chemical Repeat Units That Are Employed in Copolymer Rubbers

Repeat Unit Name	Repeat Unit Structure
Acrylonitrile	
Styrene	
Butadiene	
Chloroprene	 

Isoprene	
Isobutylene	
Dimethylsiloxane	

2.2.8 Polymer properties

The mechanical properties of polymers are specified with many of the same parameters that are used for metals that is, modulus of elasticity, and yield and tensile strengths. For many polymeric materials, the simple stress–strain test is employed for the characterization of some of these mechanical parameters. The mechanical characteristics of polymers, for the most part, are highly sensitive to the rate of deformation (strain rate), the temperature, and the chemical nature of the environment (the presence of water, oxygen, organic solvents, etc.). Some modifications of the testing techniques and specimen configurations used for metals are necessary with polymers, especially for the highly elastic materials, such as rubbers.

2.2.9 Factors that Influence the Mechanical Properties of Polymers

A number of factors influence the mechanical characteristics of polymeric materials, they are:

1.Molecular Weight

The magnitude of the tensile modulus does not seem to be directly influenced by molecular weight. On the other hand, for many polymers it has been observed that tensile strength increases with increasing molecular weight.

2. Degree of Crystallinity

For a specific polymer, the degree of crystallinity can have a rather significant influence on the mechanical properties, since it affects the extent of the intermolecular secondary bonding. Increasing the Crystallinity of polymer generally enhances its strength. In addition, the material tends to become more brittle.

3. Heat Treatment

Heat treating of semicrystalline polymers can lead to an increase in the percent crystallinity, and crystallite size and perfection, as well as modifications of the spherulite structure. For undrawn materials that are subjected to constant-time heat treatments, increasing the annealing temperature leads to the following: (1) an increase in tensile modulus, (2) an increase in yield strength, and (3) a reduction in ductility.

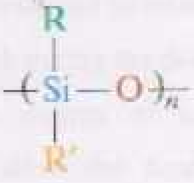
2.2.10 Polymer Types

1. Plastics

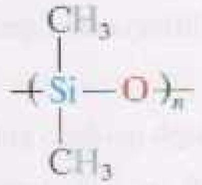
Plastics are materials that have some structural rigidity under load, and are used in general-purpose applications. Polyethylene, polypropylene, poly(vinylchloride), polystyrene, and the fluorocarbons, epoxies, phenolics, and polyesters may all be classified as plastics. They have a wide variety of combinations of properties. Plastic materials may be either thermoplastic or thermosetting; in fact, this is the manner in which they are usually subclassified. However, to be considered plastics, linear or branched polymers must be used below their glass transition temperatures (if amorphous) or below their melting temperatures (if semicrystalline), or must be crosslinked enough to maintain their shape.

2. Elastomers

Natural rubber is still utilized to a large degree because it has an outstanding combination of desirable properties. However, the most important synthetic elastomer is SBR, which is used predominantly in automobile tires, reinforced with carbon black. NBR, which is highly resistant to degradation and swelling, is another common synthetic elastomer. For many applications (e.g., automobile tires), the mechanical properties of even vulcanized rubbers are not satisfactory in terms of tensile strength, abrasion and tear resistance, and stiffness. These characteristics may be further improved by additives such as carbon black Finally, some mention should be made of the silicone rubbers. For these materials, the backbone chain is made of alternating silicon and oxygen atoms:



where R and R_ represent side-bonded atoms such as hydrogen or groups of atoms such as CH3. For example, polydimethylsiloxane has the repeat unit



as elastomers, these materials are crosslinked.

The silicone elastomers possess a high degree of flexibility at low temperatures and yet are stable to temperatures as high as In addition, they are resistant to weathering and lubricating oils, which makes them particularly desirable for applications in automobile engine compartments. Biocompatibility is another of their assets, and, therefore, they are often employed in medical applications such as blood tubing. A further attractive characteristic is that some silicone rubbers vulcanize at room temperature (RTV rubbers).

3. Fibers

The fiber polymers are capable of being drawn into long filaments having at least a 100:1 length-to-diameter ratio. Most commercial fiber polymers are utilized in the textile industry, being woven or knit into cloth or fabric. In addition, the aramid fibers are employed in composite materials, Section 16.8. To be useful as a textile material, a fiber polymer must have a host of rather restrictive physical and chemical properties. While in use, fibers may be subjected to a variety of mechanical deformations—stretching, twisting, shearing, and abrasion. Consequently, they must have a high tensile strength (over a relatively wide temperature range) and a high modulus of elasticity, as well as abrasion resistance. These properties are governed by the chemistry of the polymer chains and also by the fiber drawing process.

The molecular weight of fiber materials should be relatively high or the molten material will be too weak and will break during the drawing process. Also, because the tensile strength increases with degree of crystallinity, the structure and configuration of the chains should allow the production of a highly crystalline polymer.

That translates into a requirement for linear and unbranched chains that are symmetrical and have regular repeat units. Polar groups in the polymer also improve the fiber-forming properties by increasing both crystallinity and the intermolecular forces between the chains.

Convenience in washing and maintaining clothing depends primarily on the thermal properties of the fiber polymer, that is, its melting and glass transition temperatures.

Furthermore, fiber polymers must exhibit chemical stability to a rather extensive variety of environments, including acids, bases, bleaches, dry cleaning solvents, and sunlight. In addition, they must be relatively nonflammable and amenable to drying.

2.3 Processing of Plastic

The method used for a specific polymer depends on several factors: (1) whether the material is thermoplastic or thermosetting; (2) if thermoplastic, the temperature at which it softens; (3) the atmospheric stability of the material being formed; and (4) the geometry and size of the finished product. There are numerous similarities between some of these techniques and those utilized for fabricating metals and ceramics.

Fabrication of polymeric materials normally occurs at elevated temperatures and often by the application of pressure. Thermoplastics are formed above their glass transition temperatures, if amorphous, or above their melting temperatures, if semicrystalline.

An applied pressure must be maintained as the piece is cooled so that the formed article will retain its shape. One significant economic benefit of using thermoplastics is that they may be recycled; scrap thermoplastic pieces may be remelted and reformed into new shapes.

Fabrication of thermosetting polymers is ordinarily accomplished in two stages. First comes the preparation of a linear polymer (sometimes called a prepolymer) as a liquid, having a low molecular weight. This material is converted into the final hard and stiff product during the second stage, which is normally carried out in a mold having the desired shape. This second stage, termed "curing," may occur during heating and/or by the addition of catalysts, and often under pressure. During curing, chemical and structural changes occur on a molecular level: a crosslinked or a network structure forms. After curing, thermoset polymers may be removed from a mold while still hot, since they are now dimensionally stable. Thermosets are difficult to recycle, do not melt, are usable at higher temperatures than thermoplastics, and are often more chemically inert.

Molding is the most common method for forming plastic polymers. The several molding techniques used include compression, transfer, blow, injection, and extrusion molding. For each, a finely pelletized or granulized plastic is forced, at an elevated temperature and by pressure, to flow into, fill, and assume the shape of a mold cavity.

Compression and Transfer Molding

For compression molding, the appropriate amounts of thoroughly mixed polymer and necessary additives are placed between male and female mold members. Both mold pieces are heated; however, only one is movable.

The mold is closed, and heat and pressure are applied, causing the plastic to become viscous and flow to conform to the mold shape. Before molding, raw materials may be mixed and cold pressed into a disc, which is called a perform. Preheating of the perform reduces molding time and pressure, extends the die lifetime, and produces a more uniform finished piece. This molding technique lends itself to the fabrication of both thermoplastic and thermosetting polymers; however, its use with thermoplastics is more time-consuming and expensive than the more commonly used extrusion or injection molding techniques discussed below.

In transfer molding, a variation of compression molding, the solid ingredients are first melted in a heated transfer chamber. As the molten material is injected into the mold chamber, the pressure is distributed more uniformly over all surfaces. This process is used with thermosetting polymers and for pieces having complex geometries.

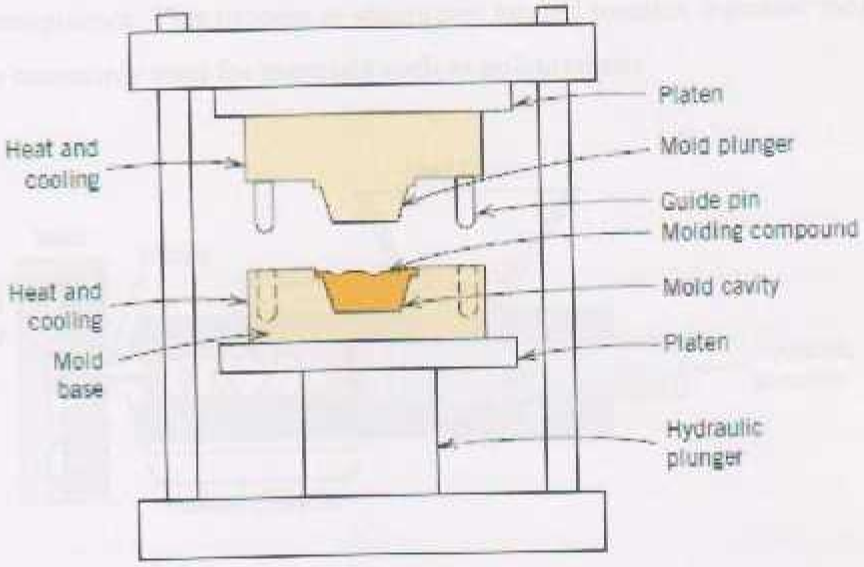


Figure 2.1:Schematic diagram of compression molding apparatus

Injection Molding

Injection molding, the polymer analogue of die casting for metals, is the most widely used technique for fabricating thermoplastic materials. The correct amount of pelletized material is fed from a feed hopper into a cylinder by the motion of a plunger or ram.

This charge is pushed forward into a heating chamber where it is forced around a spreader so as to make better contact with the heated wall. As a result, the thermoplastic material melts to form a viscous liquid. Next, the molten plastic is impelled, again by ram motion, through a nozzle into the enclosed mold cavity; pressure is maintained until the molding has solidified. Finally, the mold is opened, the piece is ejected, the mold is closed, and the entire cycle is repeated. Probably the most outstanding feature of this technique is the speed with which pieces may be produced.

For thermoplastics, solidification of the injected charge is almost immediate; consequently, cycle times for this process are short (commonly within the range of 10 to 30 s).

Thermosetting polymers may also be injection molded; curing takes place while the material is under pressure in a heated mold, which results in longer cycle times than for thermoplastics. This process is sometimes termed reaction injection molding (RIM) and is commonly used for materials such as polyurethane.

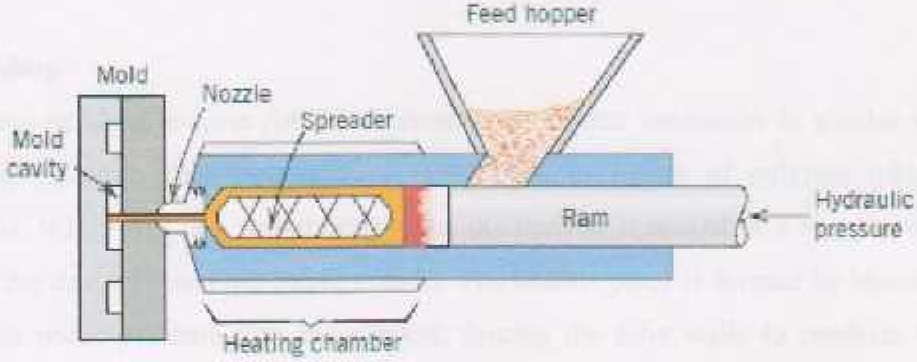


Figure 2.2:Schematic diagram of an injection molding apparatus

Extrusion

The extrusion process is the molding of a viscous thermoplastic under pressure through an open-ended die, similar to the extrusion of metals (Figure 2.3). A mechanical screw or auger propels through a chamber the pelletized material, which is successively compacted, melted, and formed into a continuous charge of viscous fluid. Extrusion takes place as this molten mass is forced through a die orifice. Solidification of the extruded length is expedited by blowers, a water spray, or bath. The technique is especially adapted to producing continuous lengths having constant cross-sectional geometries—for example, rods, tubes, hose channels, sheets, and filaments.

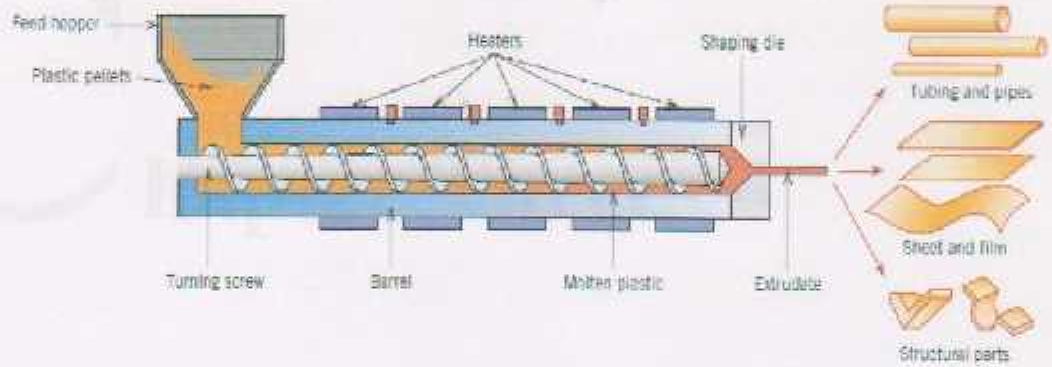


Figure 2.3:Schematic diagram of an extruder

Blow Molding

The blow-molding process for the fabrication of plastic containers is similar to that used for blowing glass bottles. First, a parison, or length of polymer tubing, is extruded. While still in a semimolten state, the parison is placed in a two-piece mold having the desired container configuration. The hollow piece is formed by blowing air or steam under pressure into the parison, forcing the tube walls to conform to the contours of the mold. Of course the temperature and viscosity of the parison must be carefully regulated.

Casting

Like metals, polymeric materials may be cast, as when a molten plastic material is poured into a mold and allowed to solidify. Both thermoplastic and thermosetting plastics may be cast. For thermoplastics, solidification occurs upon cooling from the molten state; however, for thermosets, hardening is a consequence of the actual polymerization or curing process, which is usually carried out at an elevated temperature.

Chapter Three

Plastic Injection Factory

- Introduction.
- Factory Layout.
- Factory Components.
- Injection Machine Cycles.
- Production Process Analyzing.

3.1 Introduction

This chapter will describe the factory components, each one and its objectives and properties, the factory building and the machines locations, the injection machine hydraulic and electrical circuits, and the production process line.

3.2 Factory Layout

The layout is shown in Figure 3.1 .It consists of the following components:

A. Facilities
   1) Management Office
   2) Training Room
   3) Storage Room
   4) Raw Materials Room
   5) W.C

B. Equipments
   1) Injection Machine
   2) Cooling Tower
   3) Mixer
   4) Crusher
   5) Loader
   6) Packaging Table
   7) Mechanical Truss
   8) Molds

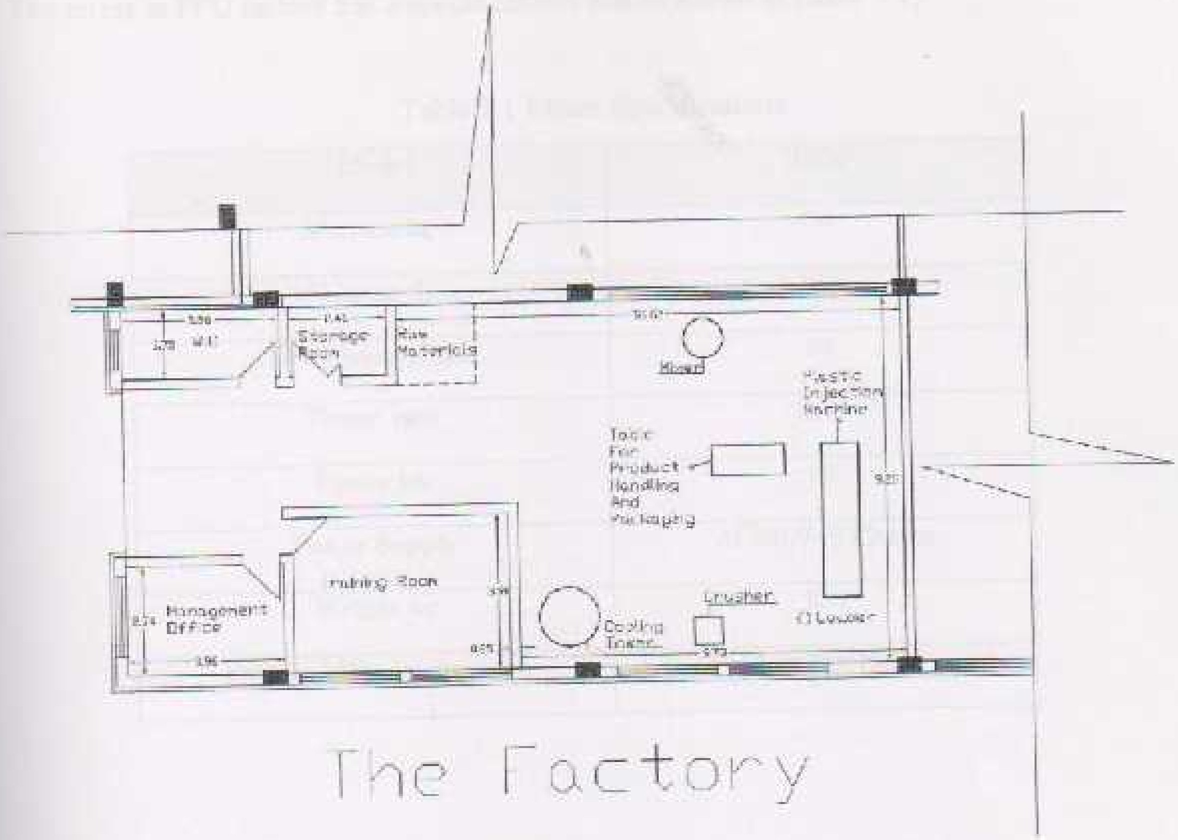


Figure 3.1 The Factory Layout

3.2.1 Factory Components

The factory or the production line contains components that the product goes through it. They are:

1) Mixer
2) Crusher
3) Autoloader
4) Injection machine

3.2.1.1 Mixer

It is one of the most important auxiliary equipment in the factory, which used to mixing the raw materials. this process make the plastic raw materials with a good blending with each others to handle the desired products.

The mixer in PPU factory has a specifications that as shown in (table 3.1):

Table 3.1 Mixer Specifications

Model	SH50
Mixture kg	50
Volume L	140
Revolution r/min	85
Timer min	3-20
Power kw	1.5
Power Supply	AC380V 3 Phases
Weight kg	250
External Dimensions mm	850x650x1200

Figure 3.2 The Mixer

3.2.1.2 Crusher

Crusher is another machine that used in the factory to recycling the defected products.

It crush the product into small pieces, then to repeat it into mixer.

PPU Factory crusher has a specifications that as shown in (table 3.2):

Table 3.2 Crusher Specifications

Model	XFS 180
Power	2.2kw
Quantity of rotating blades	٩
Quantity of fixed blades	٢
Screen Size	٦
Weight	240kg
Max.breaking capacity	100-150
Size of feeding inlet	180x125
Exterior dimension	730x440x900

3.2.1.3 Autoloader

The autoloader is an auxiliary equipment that used to support the injection machine with raw material. It can be in tow forms, either manually or vacuum.

Vacuum autoloader used because the injection machine is high, and its location is in the ground.

The manually one is in the top right side of the machine, and it exist in most of injection machines.

Table 3.3 The Manual Autoloader Specifications

Model	FHD-25
Diameter	350mm
Height	965mm
Capacity	25kg
Heater Power	2. 7kw
Blower Power	90w
Applicable injector	60g-250g

Figure 3.3 Manual Autoloader

Table 3.4 The Vacuum Autoloader Specifications

MODEL		XTL-300GN
Motor	Type	Carbon Brush
	Specification	1100w1
Conveying Capacity		400kg/gr
Static wind pressure (MAX)		1500mmAq
Filter		185x90H
Volume of Material Hopper		6L
Inside Diameter of Conveying Pipe		38mm
Exterior Dimension		430x440x295mm

Figure 3.4 Vacuum Autoloader

3.2.1.4 Injection Machine

Injection machine is the major part of the factory. It has three basic components: the injection unit, the mold, and the clamping system. The injection unit, prepares the proper plastic melt and via the injection unit transfers the melt into the next component that is the mold.

The clamping system closes and opens the mold.

This machine perform certain essential functions:

(1) Plasticizing: heating and melting of the plastic in the plasticator.

(2) Injection: injecting from the plasticator under pressure a controlled-volume shot of melt into a closed mold, with solidification of the plastics beginning on the mold's cavity wall.

(3) Afterjiilling: maintaining the injected material under pressure for a specified time to prevent back flow of melt and to compensate for the decrease in volume of melt during solidification.

(4) Cooling: cooling the thermoplastic (TP) molded part in the mold until it is sufficiently rigid to be ejected.

(5) Molded-part release: opening the mold, ejecting the part, and closing the mold so it is ready to start the next cycle with a shot of melt.

Figure 3.5 and 3.6 show the main parts of the machine and the basic cycle.

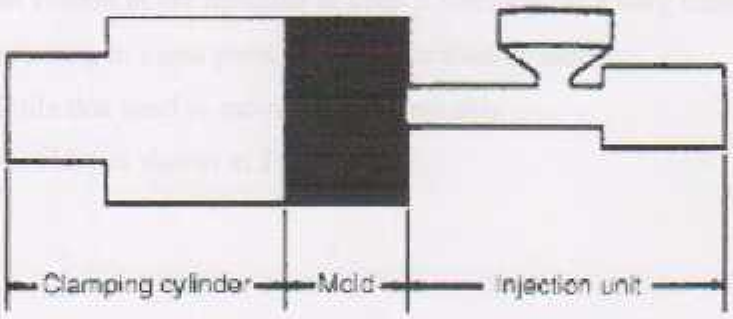


Figure 3.5 Basic Elements of Injection Molding

Figure 3.6 The Basic Cycle

3.3 Injection Machine Cycles

The process in the machine is depends on three circuits: The hydraulic, control, and electrical. Since the injection process requires a high pressure force to inject the plastic in the mold, and the melting plastic requires a pressure to clamp the tow parts of the mold to form a solid product, the hydraulic system is very important in the machine.

This system has many components to achieve the suitable pressure, such as main hydraulic motor, auxiliary hydraulic motors, different types of valves, vane pump, special oil, pressure gauges and pipes.

Another important system in the machine to keep it working for a long time without any deformations or wearing in metal parts, is the lubrication system.

A special kind of oils that used to moving parts smoothly .

This system is described as shown in Figure 3.7 .

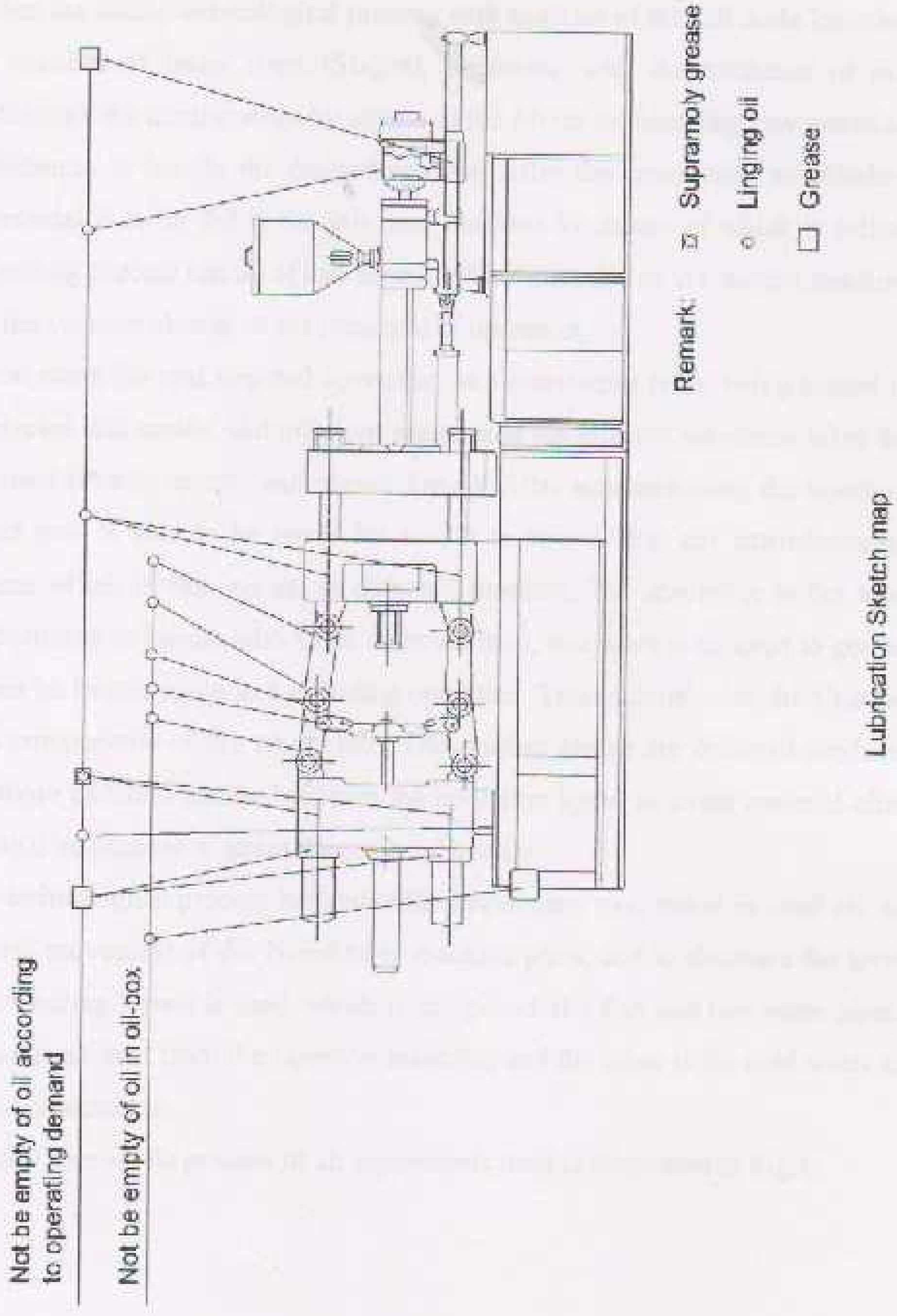


Figure 3.7 Lubrication Sketch Map

3.4 Production Process Analyzing

This section describes the whole technological process with analysis of the full scale Injection Line; the process consists of many steps (Stages), beginning with the existence of raw materials, passing through the mixing stage by means of the Mixer for blending raw materials with any other substances to handle the desired product. After the completion of blending stage, the mixed material is to be fed to the injection machine by means of which is called: Feeder (Loader). Feeding process can be of two forms; either manually or via suction machine which is similar to the vacuum cleaner in the principle of operation.

So now; the material starts the real targeted operation, and transferred (after being heated in the feeder) to be injected into molds, and injection means that the injected substance takes the shape of the mold used (Plastic spoons and plastic Trays). After accomplishing the injecting process, the product now is said to be ready for use. It is known that any manufacturing process has problems which in turn results in defected products, but according to the total line, there is an opportunity to handle with those defected item, that there is no need to get rid of them; but they can be treated again in a recycling operation. This is done using the Crusher as one of the main components of the whole line. The crusher grinds the defected products into tiny particles, those particles can be held into the operation again as a raw material after adding some additional substances to attain the required quality.

It is usual that any technological process hanged with temperature rise, either in used oil, or due to the mechanical movement of the Non-Stable machine parts, and to decrease the level of generated heat; a Cooling Tower is used, which is composed of a Fan and two water pipes, one for the hot water as an inlet from the injection machine, and the other is for cold water as an outlet to the injection machine.

For further explanation, the whole process of all equipments used is illustrated in Fig.8.

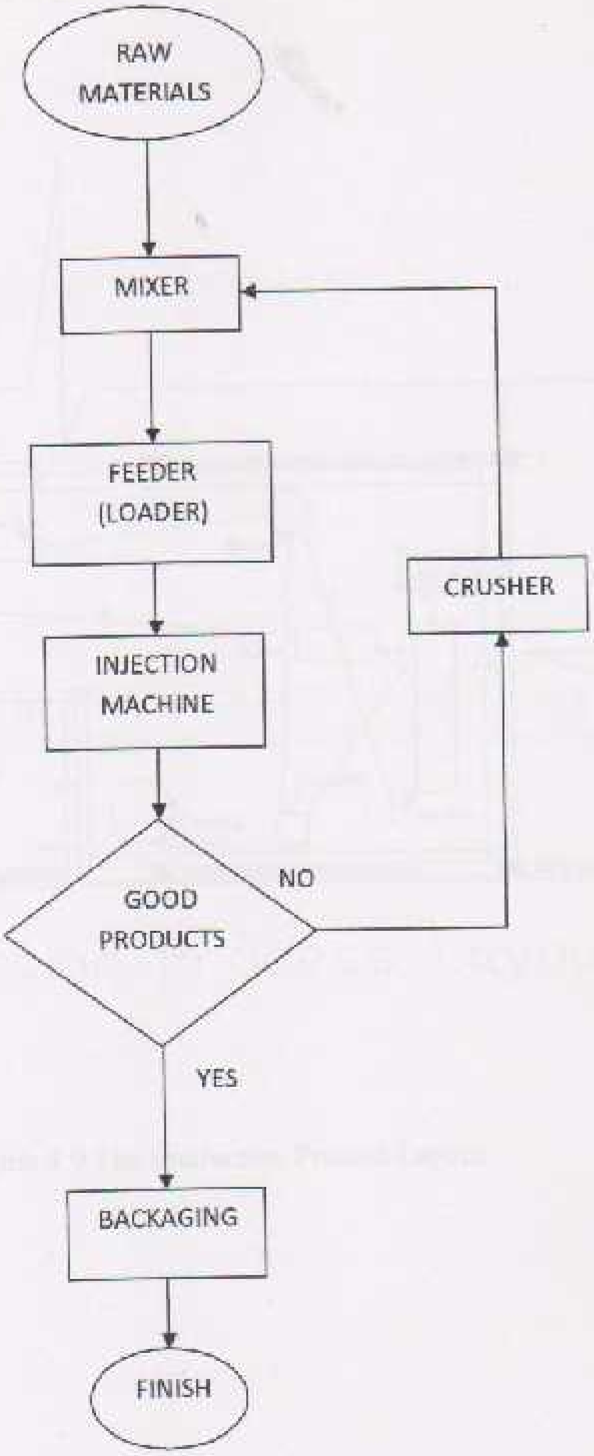


Figure 3.8 Production Process Flowchart

The production process layout as shown in Figure 3.9 .

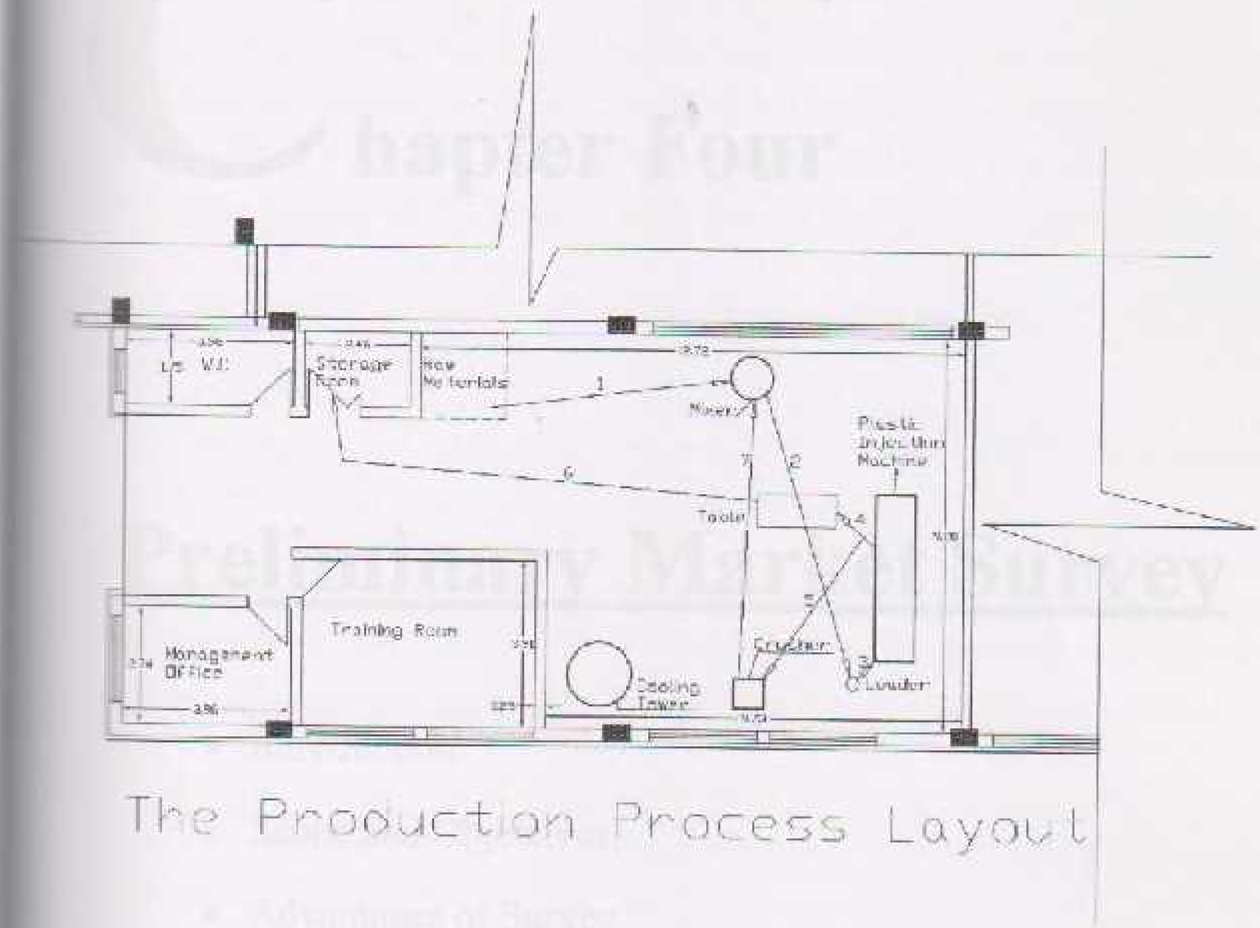


Figure 3.9 The Production Process Layout

Chapter Four

Preliminary Market Survey

- Introduction.
- Scope and Objectives.
- Advantages of Survey.
- Differentiation.

4.1 Introduction

- Marketing is identifying, anticipating, and satisfying customer requirements profitability.
- Marketing is defined by the American Marketing Association as the activity, set of institutions, and processes for creating, communicating, delivering, and exchanging offerings that have value for customers, clients, partners, and society at large. The term developed from the original meaning which referred literally to going to market, as in shopping, or going to a market to buy or sell goods or services.

Every research problem is unique in some way, and care must be taken to select the most appropriate set of approaches for the problem at hand.

Nevertheless, although every research problem may seem unique, there are usually enough similarities among such problems to allow decisions to be made in advance, as to the best plan to use to resolve the problem and there are some basic survey designs that can be matched to given problems.

There are three basic ways of obtaining primary data in marketing research: survey, observation, and experiment.

Surveys are the most widely used method of data collection in commercial marketing research.

Compared with observation or other qualitative methods, survey methods allow the collection of significant amounts of data in an economical and efficient manner, and they typically allow for much larger sample sizes.

4.2 Scope and Objectives

4.2.1 Economical Feasibility Study

The preparation of economical projects is considered as one of the main steps for those projects to be accomplished, that is the right planning for projects insures their success and efficiency, in addition to the good financial profit expected. So when deciding to deal with a certain project, it should have an economical feasibility study first.

Feasibility study is the process of collecting data and information about a proposed project, then the collected data is to be analyzed to determine whether the project is executable or not, also to decrease the expected risks, and so; the range of success or failure of a proposed project should be known in the contrast with the local market.

Hence, the local market should be studied and surveyed carefully regarding to so main elements such as: Market, Technical and financial studies.

To implement any economical feasibility study, there are some main points that should be considered, as follows:

First: Project's owner/s should realize the following:

(1) what experiences and skills they have to serve the project.

(2) What personal motives they have to insure the success of the project.

(3) What personal qualities they have which may enable them to be project's leaders.

So that; persons sharing the project, should be known, their skills (communication, ...etc) are to be determined, also their behaviors (cooperation, design, supervision, coordination, math, faith, enthusiasm, accuracy and maximum effort they can afford) have to be known, in hand with the academic level (scientific degree) they have with experience.

Second: Market study according to the type where the goods are marketed, share in the market, and to determine what actions that make the goods marketable.

Third: Technical study of the project according to fixed assets that the project requires, requirements of goods production process, the steps (stages) of the production process, transportations, machines, location, water and electricity, labors salaries and so on.

Forth: Financial study of the project according to whether the idea is profitable or not, the source of money (funds, grants, personal pocket, ...etc), and what is the total cost of the project.

So that, the total budget of the project, monthly and annual profit should be determined.

What is the feasibility study?

It is a method used for determining whether the requirements to execute and market a project are available or not, and to determine whether it is profitable or not.

Project's owners performs an economical feasibility study by means of a collection of series and successive six step, these steps forms data and information, discussion and analyze.

the previously mentioned steps are as follows:

Step No. 1: Choosing a product or a service to be sold. At this point there should be some kind of thinking about the appropriate idea of the project which seems meaningful via analyze, then can be determined what project should be implemented.

Step No. 2: To realize if the product is buyable or not. At this point there should be some kind of concentration, by which costumers (real or expected), needs requests should be recognized.

Step No. 3: To decide how the project is to be operated, That is it is necessary to make a serious decision of how the project is to implemented and operated.

Step No. 4: Calculating the costs of the project. The types of costs should be known and calculated, and should be taken into account when preparing the feasibility study. Costs are divided into the following two types:

(1) Fixed costs such as: salaries, rents, insurance and consumption.

(2) Variable costs such as: raw materials, maintenance, transportations, water and electricity.

Step No. 5: Evaluate the income of sales. This can be calculated by determining the amount the can be sold within the project during a certain period of time, in hand with determining the sale price.

Step No. 6: Determining whether the idea of the project is good or bad. To achieve this, the following points should be met:

(1) Project's profit size.

(2) How to calculate profits and cash flows.

(3) What other projects benefits could be achieved.

the preparation of a feasibility study of a project is necessary to make certain of project's success, and to obtain a load or grant for funding, and so, there should be clear highlights of the profitability, and the occurrence of adequate financial resources, skills and experiences.

4.2.2 Directions to perform a feasibility study

(1) Description of the project (Proposal), including the name, activities, owners and share holders, location and legal form.

(2) The market; depends on the market size, sales size and affordable services.

(3) Careers and their arrangement, that is role distribution in the production process is considered to be on the main factors of success,

(4) Project's requirements. Any project regardless to the size (small or big), has it's own requirements that should be available as a step in the way of success, and so; the production process should be known by recognizing the following.

- What the production process implies from the beginning to end.
- What resources required.
- What are the needed skills.
- Who will buy the goods and products (targeted slide of the society).
- Who are the responsible of production process and what is the production size (capacity).
- Who will be responsible of the financial transactions and who is responsible of sales and purchases (procurement department).
- Administration.

(5)Determining the total costs of the project (fixed and variable).

(6)Determining the competitive companies (prices).

4.3 Advantages of using survey methods.

4.3.1 Advantages

1)**Standardization**. Questions are preset and organized in a particular arrangement on a questionnaire, and survey methods ensure that all respondents are asked the same questions and are exposed to the same response options.

2) **Ease of administration**. Sometimes an interviewer is used, and survey modes are easily geared to such administration.

On the other hand, the respondent may fill out the questionnaire unattended (sometimes this approach is referred to as a self-explicated interview).

In either case, the administration aspects are much simpler than, for example, conducting a focus group or interviewing.

The simplest method is a postal survey in which questionnaires are sent to prospective respondents.

3)**Ability to tap the "unseen**." The four questions of what, why, how, and who help uncover "unseen" data.

For example, a working parent may be asked to explain ho\N important the location of a school was in his or her selection of the child's school.

A researcher can inquire as to how many different schools the parent seriously considered before deciding on one, and go on to gain an understanding of the person's financial or work circumstances with a few questions on income, occupation, and family size. Much information is unobservable and requires direct questions.

4)**Suitability to tabulation and statistical analysis**. The marketing researcher ultimately must interpret the patterns or themes sometimes hidden in the raw data collected.

Statistical analysis, both simple and complex, is the preferred means of achieving this goal, and large cross-sectional surveys perfectly complement these procedures.

Qualitative methods, in contrast, prove much more frustrating in this respect because of their necessarily small samples, need for interpretation, and general approach to answering marketing managers' questions.

Increasingly, questionnaire design software includes the ability to perform simple statistical analyses, such as tabulations of the answers to each question, as well as the ability to create graphs summarizing these tabulations.

5)**Sensitivity to subgroup differences**. Because surveys involve large numbers of respondents, it is relatively easy to "slice" up the sample into demographic groups or other subgroups and then to compare them for market segmentation implications.

The large sample sizes that characterize surveys facilitate subgroup analyses and comparisons of various groups in the sample.

4.3.2 Forms of market research

Market research surveys typically take one of five forms:

1)**Personal surveys**, in which face-to-face interviews are conducted at respondents' homes or offices.

2) **Intercept surveys**, in which face-to-face interviews are conducted with people who are stopped at a public location such as a shopping centre.

3) **Telephone surveys**, in which people are interviewed over the telephone.

4) **Postal surveys**, in which people complete self-administered questionnaires that are sent to them.

5) **Online surveys**, in which people fill out a questionnaire that is sent by e-mail.

4.3.3 Products is composed of three levels

Level 1 : Core benefit your product offers.

Level 2 : added features and benefits to ensure that your product offers a differential advantage from your competitors.

Level 3 : additional non-tangible benefits can you offer such as after sales service ,warranties, delivery.

4.3.4 Differentiation

Differentiation is the key to competitive advantage.

Innovation and best business practices are the key to differentiation.

There are six ways to differentiate product:

1) Low price
2) Shape
3) Weight
4) Packaging
5) Cycle life
6) Quality

Chapter Five

Mold Analysis and Truss Design

- Introduction.
- Mold Analysis.
- Truss design.

5.1 Introduction

The plastic Injection machine has many systems that must be redesigned.

One of them is the mold. It has the shape of the product and the molten plastic is injected inside it. It has a criteria to design it depending on the specifications of the machine.

Each injection machine has many molds to produce different shapes of products.

This mean that changing the mold need to a mechanical truss to carry it and replace it by another mold. This truss require a special design since it using to carry a high weight above the machine.

This chapter will describe these systems briefly.

5.2 The Mold

5.2.1 Introduction

Injection molding is the most commonly used manufacturing process for the fabrication of plastic parts. A wide variety of products are manufactured using injection molding, which vary greatly in their size, complexity, and application. The injection molding process requires the use of an injection molding machine, raw plastic material, and a mold. The plastic is melted in the injection molding machine and then injected into the mold, where it cools and solidifies into the final part. Figure 5.1 show the location of the mold in the injection machine.

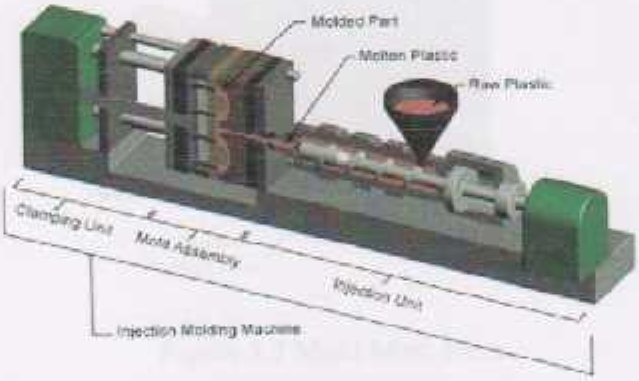


Figure 5.1 Mold Location in Machine.

5.2.2 Process cycle

The process cycle for injection molding is very short, typically between 2 seconds and 2 minutes, and consists of the following four stages:

1) Clamping.
2) Injection.
3) Cooling.
4) Ejection.

These processes happened in the mold part, this mean that the mold must be made from a very special materials that afforded a high stress at very high temperatures.

The injection molding process uses molds, typically made of steel or aluminum, as the custom tooling. The mold has many components, but can be split into two halves as shown in Figure 5.2 . Each half is attached inside the injection molding machine and the rear half is allowed to slide so that the mold can be opened and closed along the mold's parting line. The two main components of the mold are the mold core and the mold cavity. When the mold is closed, the space between the mold core and the mold cavity forms the part cavity, that will be filled with molten plastic to create the desired part. Multiple-cavity molds are sometimes used, in which the two mold halves form several identical part cavities.

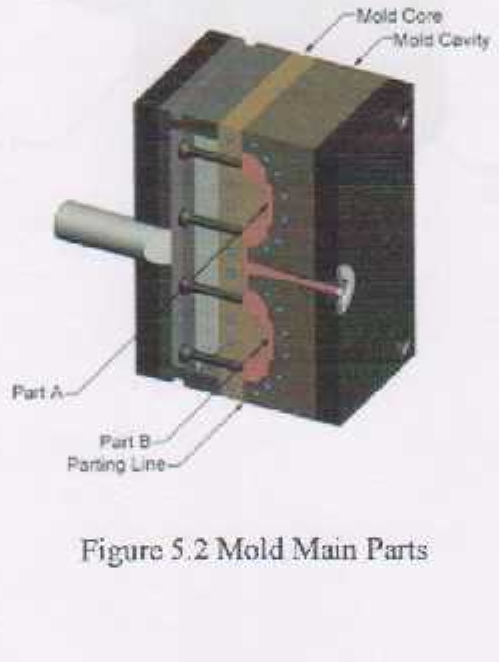


Figure 5.2 Mold Main Parts

5.2.3 Mold Base

The mold core and mold cavity are each mounted to the mold base, which is then fixed to the platens inside the injection molding machine. The front half of the mold base includes a support plate, to which the mold cavity is attached, the spur bushing, into which the material will flow from the nozzle, and a locating ring, in order to align the mold base with the nozzle. The rear half of the mold base includes the ejection system, to which the mold core is attached, and a support plate. When the clamping unit separates the mold halves, the ejector bar actuates the ejection system. The ejector bar pushes the ejector plate forward inside the ejector box, which in turn pushes the ejector pins into the molded part. The ejector pins push the solidified part out of the open mold cavity. Figure 5.3 and 5.4 show the mold base parts and components.

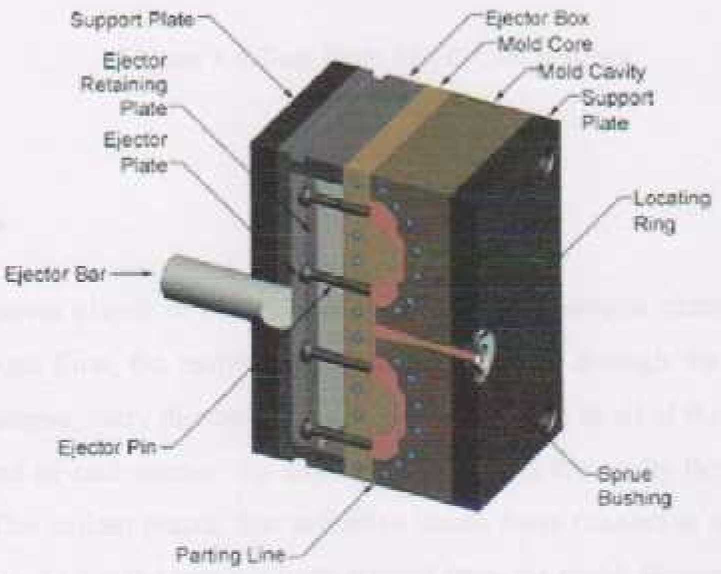


Figure 5.3 Mold Base

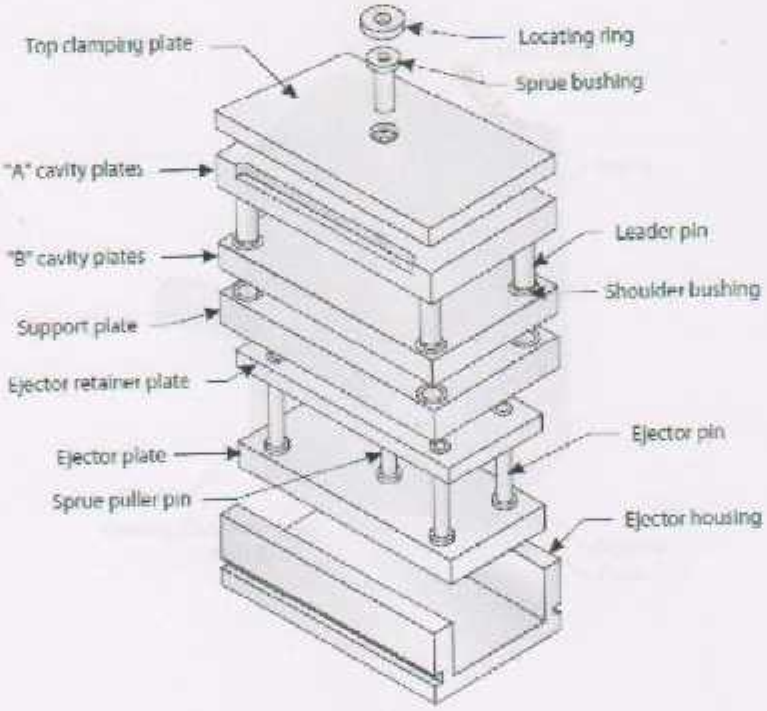


Figure 5.4 Two Plate Mold Components

5.2.4 Mold Channels

In order for the molten plastic to flow into the mold cavities, several channels are integrated into the mold design. First, the molten plastic enters the mold through the sprue. Additional channels, called runners, carry the molten plastic from the sprue to all of the cavities that must be filled. At the end of each runner, the molten plastic enters the cavity through a gate which directs the flow. The molten plastic that solidifies inside these runners is attached to the part and must be separated after the part has been ejected from the mold. However, sometimes hot runner systems are used which independently heat the channels, allowing the contained material to be melted and detached from the part. Another type of channel that is built into the mold is cooling channels. These channels allow water to flow through the mold walls, adjacent to the cavity, and cool the molten plastic.

Figure 5.4 show the mold channels.

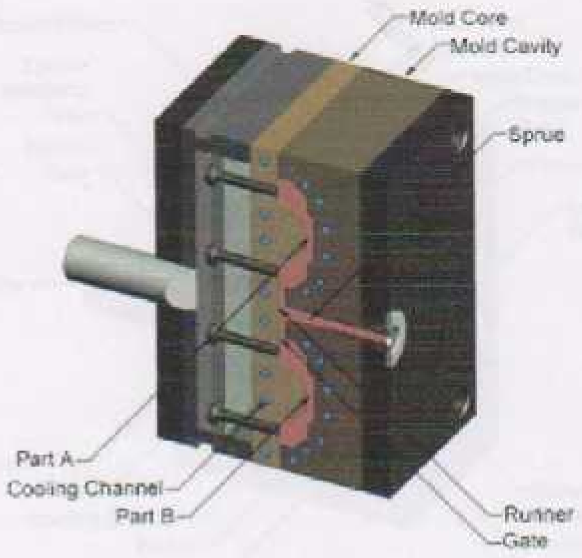
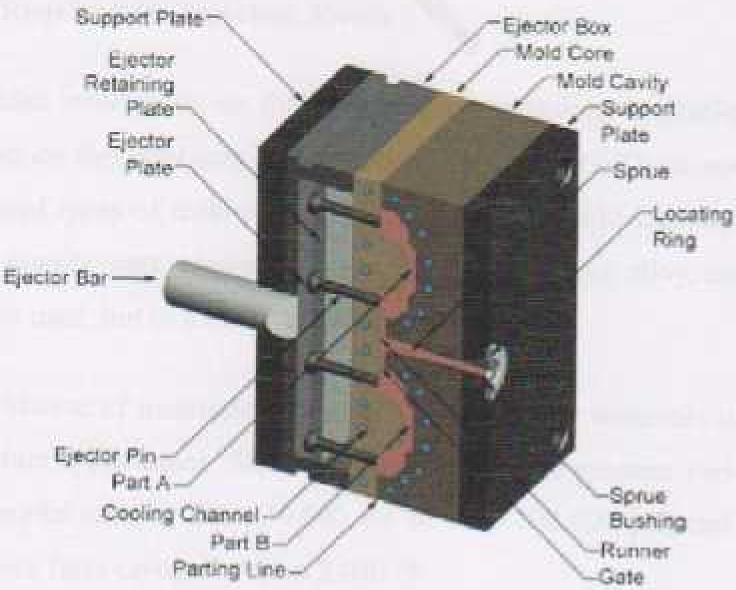


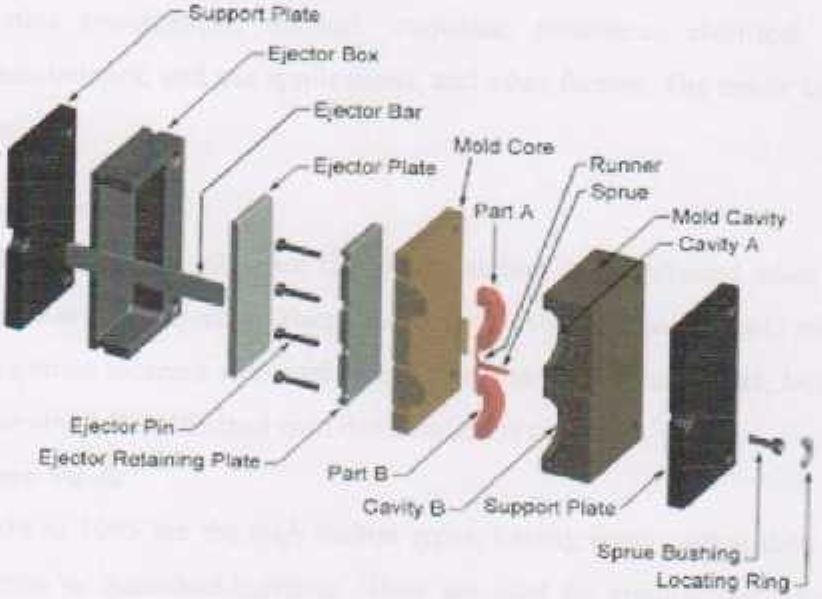
Figure 5.5 Mold Channels

5.2.5 Mold design

In addition to runners and gates, there are many other design issues that must be considered in the design of the molds. Firstly, the mold must allow the molten plastic to flow easily into all of the cavities. Equally important is the removal of the solidified part from the mold, so a draft angle must be applied to the mold walls. The design of the mold must also accommodate any complex features on the part, such as undercuts or threads, which will require additional mold pieces. Most of these devices slide into the part cavity through the side of the mold, and are therefore known as slides, or side-actions. The most common type of side-action is a side-core which enables an external undercut to be molded. Other devices enter through the end of the mold along the parting direction, such as internal core lifters, which can form an internal undercut. To mold threads into the part, an unscrewing device is needed, which can rotate out of the mold after the threads have been formed. Figure 5.5 show (a)the mold when it closed, and (b) the exploded view.



(a)



(b)

Figure 5.6 (a)Mold-Closed, (b)Exploded View

5.2.6 Types of Steel Required for Injection Molds

This section provides information on different steel compositions available to manufacture molds used to produce thermoplastic injection molded products. These steels constitute the most commonly used types of materials in the construction mold industry. Other materials such as beryllium-copper, cast aluminum alloy, forged aluminum alloy, cobalt-nickel alloy, and kirksite are also used, but to a lesser extent.

Steels are the workhorse of materials used in molds. No other materials offer comparable versatility for product applications. Steels are produced in the greatest variety of forms and finishes, have strengths ranging from 30,000 psi to over 300,000 psi, and can withstand a range of temperatures from cryogenic up to 2,000 °F.

Major Steel Families

Because of the great range of steel types, properties and applications, steels are categorized into many families based on the chemical composition, heat treatment, surface finishing, critical properties (mechanical, thermal, corrosion resistance, electrical, etc.), typical processing characteristics, end use applications, and other factors. The major families of steel are the following:

1. **Low Carbon Steels**

SAE 1008, 1010, 1015, and 1025 are the lowest carbon steels selected when cold forming ability is the primary prerequisite. These steels have relatively low tensile strength values. Strength and hardness increase with carbon addition and/or with cold work, but a decrease in toughness or the ability to withstand cold deformation is created.

2. **High Carbon Steels**

Steels SAE 1055 to 1095 are the high carbon types, having more carbon than is required to achieve maximum as quenched hardness. They are used for applications where the higher carbon is needed to improve wear resistance, higher strength characteristics for cutting edges, for springs, and for special purposes. Selection of a particular grade is affected by the nature of the part, its end use, and the manufacturing methods available. Cold forming is not always suitable and most parts are heat treated before use.

3. **Free Machining Carbon Steels**

Low and medium carbon steels, in which sulfur, sulfur-phosphorus combinations, and/or lead are purposely added to improve machinability, are termed free-machining carbon steels. Their designations are SAE 1108 to 1151 for resulfurized grades and SAE 1211 to 1215 for rephosphorized and resulfurized grades. Leaded grades are indicated by the letter "L" with the number.

Sulfur and phosphorus additions result in some sacrifice in cold forming ability, weldability, and forging ability. Lead additions have little effect on forming ability and forging ability, but impair weldability.

4. **Carburizing Carbon Steels**

This term is sometimes given to standard carbon steels, primarily low carbon grades, which are case hardened by various carburizing methods.

5. **Hardening Carbon Steels**
6. **Carbon Spring Steels**
7. **Low Temperature Carbon Steels**
8. **Carburizing Alloy Steels**
9. **H-Alloy Steels**
10. **Nitriding Steels**
11. **Low Temperature Alloy Steels**
12. **Tool Steels**
13. **Electrical Steels**
14. **Stainless Steels**
15. **Ultra High Strength Steels**

These are the highest strength steels produced. The designation is somewhat arbitrary, but generally refers to steels having yield strengths above 160,000 psi. The major types of ultra high strength steels are: medium carbon, low alloy, quenched, and tempered steels such as AISI 4130 and AISI 4340, 5Cr-Mo-V medium alloy air hardening steels, martensitic stainless steels, cold rolled austenitic stainless steels, precipitation hardening stainless steels, 12 and 18% nickel maraging steels, and 9Ni-4Co quenched and tempered steels.

5.2.7 Effects of Mold Design on the Injection Molding Process

Mold design is an important consideration in the injection molding process,

the following are general concepts for mold design

1. Runner System

Good runner design includes not only the correct geometry, size, and layout of the runner, but cooling, ejectability, and minimizing regrinds. A balanced runner system is required for filling all cavities at the same time; this minimizes cycle time and gives the best dimensional integrity to the molded product. Long and skinny or half-moon runners require higher injection pressures so the mold does not cool off prematurely causing incomplete parts. Long and thick runners increase the amount of regrinds, decreasing the efficiency of the molding process.

2. Mold Cooling System

Mold cooling is one of the most important parameters for controlling dimensional integrity, physical properties, surface finishing, warpage, weld line strength, and cycle time.

3. Ejector System

Uniform ejection is critical to control part warpage. Ejector pins, sleeves, rings, or plates must operate without obstructions. A guided ejector system allows ejector pins and cores to be precision aligned and will also bear the weight of the plates so that the pins do not wear and misalign. Early return systems should be provided as a safety feature.

4. Mold Venting

Mold venting of cavities and runner systems to remove the entrapped air and polymer melt volatiles is a must. A mold without venting causes many processing problems.

5. Other Mold Devices

Other mold design devices can also increase the cost of the mold, as well as create difficulty in injection molding the thermoplastic product. One example is the mechanically activated side cores or slides. Although sometimes necessary, side cores are expensive mold components and will have high maintenance costs.

5.2.8 Mold Cost

To calculate the mold cost is very difficult because of the complexity of the mold design, manufacturing tolerances, types of tool steels, hardness, finishing, part design, etc. For more details about molds. Injection molding is a high pressure process. There is a direct correlation between the process injection pressure and the mold cost. The mold must be ruggedly designed to withstand the large clamping forces and high internal pressures. A cost of $75,000 for a simple, small, high production mold is common. Complexities such as slides, core inserts, and hot runner mold systems will add to the cost of the mold.

It is not possible to give the product designer or estimator an accurate or infallible guide for estimating mold costs. Mold costs will vary widely depending on whether the mold is cast or machined, also on the choice of the construction material, the number of cavities, complexity and size of the cavities, the surface finishes on the mold, tolerances, and so forth. Products requiring retractable cores or threaded sections may be produced in molds designed with automatic core pulling or unscrewing devices. For the highest dimensional accuracy, machined and hardened tool steels are necessary, particularly for lifetime production runs. Such a mold design will increase mold cost, but it can usually be justified by reducing labor costs in the processing and finishing steps.

5.3 Mechanical Truss

The main objective of this truss is to replace the mold.

Because the mold and the machine are very sensitive, truss must be designed at high responsibility with a good factor of safety.

5.3.1Requirements

The truss design requires to know the machine dimensions, the maximum load that the truss to carry, and how to select the suitable material.

Machine Dimensions(**LxMxH**) ⟶ 4.08x1.15x1.7

Maximum Load ⟶ 15000 N

Material ⟶ H10

The material was selected is H10 because it available in the market, suitable cost, good shape, good mechanical properties, hardened, and do the specific objective.

The cross sectional area as shown in Figure 5.7 .

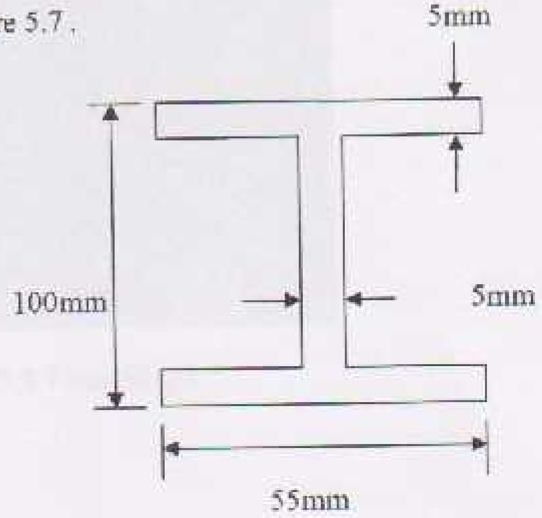


Figure 5.7 Cross Sectional Dimensions

5.3.2 Design Output

Drawing Shape

Figure 5.8 shows the truss shape after designing.

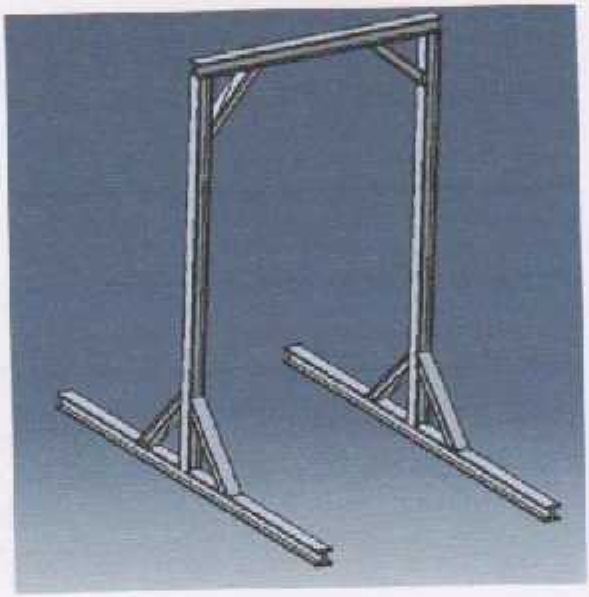
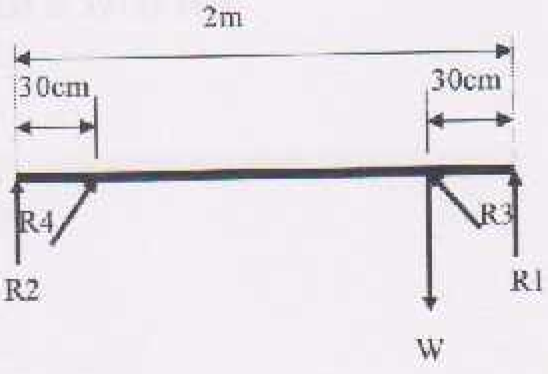


Figure 5.8 Truss Shape

Structure Design Calculations

By applying a mechanical engineering methods to design the structure, the result is:

Reactions Analysis



By applying static laws

$\sum M=0$

$\sum Fx=0$

$\sum Fy=0$

W=15000 N

Then R1=4375.7 N

R2=-8751.5 N

R3=13701 N

R4=13701 N

$$\sigma = \frac{MC}{I}$$

After analyzing the shear forces and moments the results are:

Mmax=5179 N.m

Vmax=10950 N

The second moment of inertia (I)=$2.979*10^{-6}$ m^4

$$\sigma = \frac{5179*.05}{2.979*10-6} = 87\ MPa$$

From Table A-24 the ultimate stress of A36 is 399.62 MPa.

That mean $\sigma < \sigma_{ut}$

Factor of Safety= $\frac{\sigma_{ut}}{\sigma} = \frac{399.62}{87} = 4.6$

Welding Design

As the weld is a line : d

A=0.707hd

=0.707*55*h=38.9h mm^2

$$\tau = \frac{F}{A} = \frac{13701}{38.9h} = \frac{352.2}{h}$$

From table (9.4) ⟶ $\tau = 0.3S_{ut}$

$\tau = 0.3 * 399.62$ =119.9 MPa

$$h = \frac{352.2}{119.9} = 2.94 \text{ mm.}$$

The electrode should be stronger than the material

The chosen material is E60XX since it was available.

Chapter Six

Cooling Tower

- Introduction.
- Sketch of Component.
- Rate of heat transfer.
- Efficiency of Cooling Tower.

6.1 Introduction

The plastic injection machine needs a device to cooling the mold after injection plastic through it and to decrease the hydraulic oil temperature. One of the most effective devices used is cooling towers.

Cooling towers are heat removal devices used to transfer process waste heat to the atmosphere. Cooling towers may either use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature or depend only on air to cool the working fluid to near the dry-bulb air temperature.

designing the suitable cooling tower, depends on the amount of drop temperature.

This chapter will analyses the cooling tower which exist at the factory, and see if it was the better justification or not.

6.2 Principle of Work

Cooling towers, in reference to chemical plants plants work by transferring heat from one source to another. Water will be circulated to cool the product, and that water goes to the cooling tower. There it cascades down a series of slanted steps forming waterfall. The cooler air is then drawn in at the bottom and evaporation takes place through the waterfalls. The cooler air then becomes wetter than before and is exhausted out the top of the cooling tower forming the all to familiar steam rising from the tower. The remaining cooler water is then collected at the bottom of the tower and recirculated through the chemical plant system.

This principle shown in the figure 6.1.

There are two main types of cooling towers:

- forced draught (using fans)
- natural draught

Both types are based on evaporative cooling.

-Natural draught cooling towers are more dependent on temperature gradients between air and water and the wind forces than forced draught cooling towers.

-The efficiency of natural draught towers are more variable over time and in general lower.

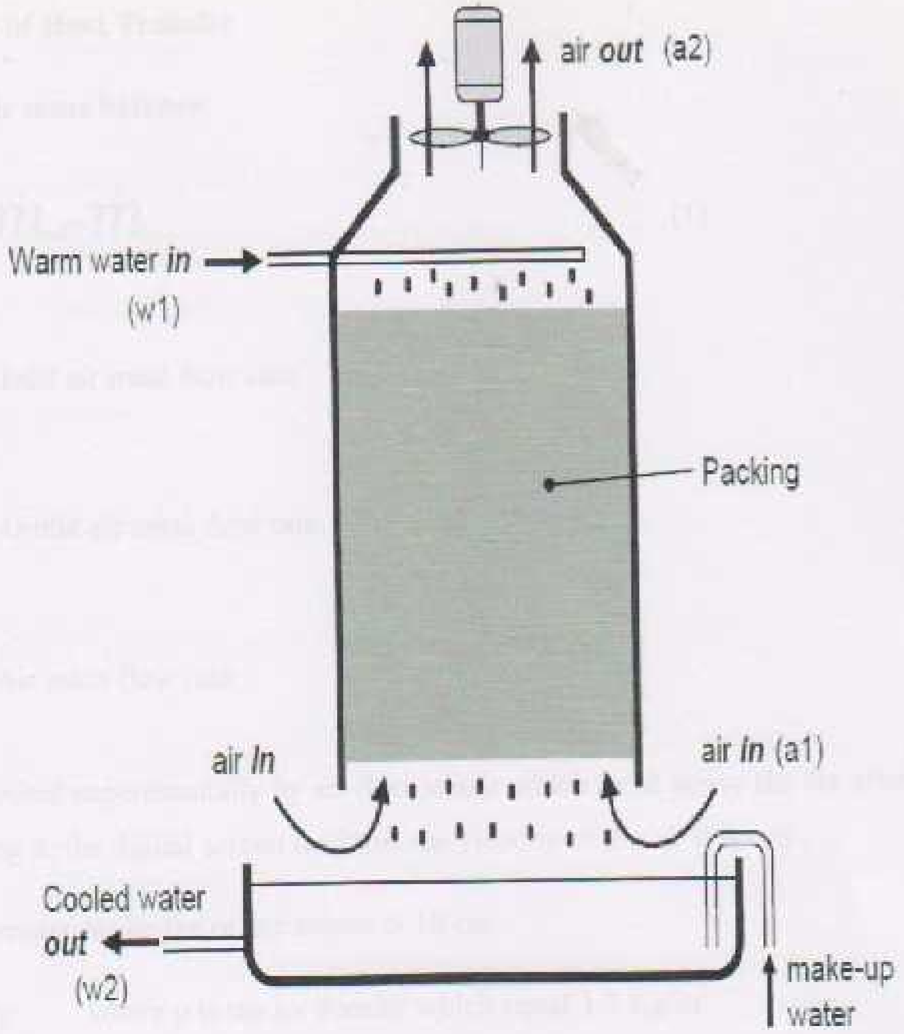


Figure 6.1: Sketch of Cooling Tower

6.3 Rate of Heat Transfer

1)Dry air mass balance

$\dot{m}_{a1}=\dot{m}_{a2}=\dot{m}_{a}$..(1)

$\dot{m}_{a1}$: Inlet air mass flow rate

$\dot{m}_{a2}$: Outlet air mass flow rate

$\dot{m}_{a}$ =Air mass flow rate

Its measured experimentally by air flow sensor which fixed above the fan after operating it, the digital screen read that the velocity of the air is 3 m/s .

The diameter of the fan of the sensor is 10 cm .

$\dot{m}_a=Q*\rho$ where ρ is the air density which equal 1.3 Kg/m^3

$Q=V*A=V*\pi D^2/4$

$=3*\pi*0.1^2/4=3\pi/400$ m^3/s

$\dot{m}_a=(3\pi/400)*1.3=0.03$ Kg/s

2)Water balance

$\dot{m}_{w1}+\omega_{a1}\dot{m}_a=\dot{m}_{w2}+\omega_{a2}\dot{m}_a$....................(2)

$\dot{m}_{w1}-\dot{m}_{w2}=\dot{m}_a(\omega_{a2}-\omega_{a1})$=make up water...(2)*

$\dot{m}_{w1}$: Inlet water mass flow rate , its measured experimentally by using a could its volume is known and a stop watch to measure the period that the could filling and then calculate the inlet water flow rate, which equal(2/3 Kg/s) .

$\dot{m}_{w2}$: Outlet water mass flow rate

ω_{a1} : Inlet Air Specific Humidity

ω_{a2} : Outlet Air Specific Humidity

3)Energy balance

$$\dot{m}_{w1} h_{w1} + \dot{m}_a h_{a1} = \dot{m}_{w2} h_{w2} + \dot{m}_a h_{a2} \ldots\ldots\ldots\ldots\ldots(3)$$

$$\dot{m}_{w1} h_{w1} - \dot{m}_{w2} h_{w2} = \dot{m}_a (h_{a2} - h_{a1}) \ldots\ldots\ldots\ldots\ldots(3)^*$$

$$\dot{m}_{w1} h_{w1} - (\dot{m}_{w1} - \dot{m}_{m.up}) hw2 = \dot{m}_a (h_{a2} - h_{a1}) \ldots(3)^{**}$$

h_{a1} :Inlet Air specific Enthalpy

h_{a2}: Outlet Air specific Enthalpy

h_{w1}: Inlet Water specific Enthalpy

h_{w2}: Outlet Water specific Enthalpy

To find specific humidity and enthalpy values , others parameters needs to be founded experimentally as below:

1. Inlet Dry bulb air temperature (T_{d1}=25 C)
2. Inlet Wet bulb air temperature (T_{w1}=20 C)
3. Outlet Dry bulb air temperature (T_{d2}=28 C)
4. Outlet Wet bulb air temperature (T_{w2}=28 C)

*After this by using psychometric chart the values are:

ω_{a1} = 0.0136 Kg H_2O/Kg Dry Air

ω_{a2} =0.015 Kg H_2O/Kg Dry Air

h_{a1}=57 Kj/Kg

h_{a2}=65 Kj/Kg

From steam tables of thermodynamics (A5) :

h_{w1}=210 Kj/Kg

h_{w2}=?? To be founded

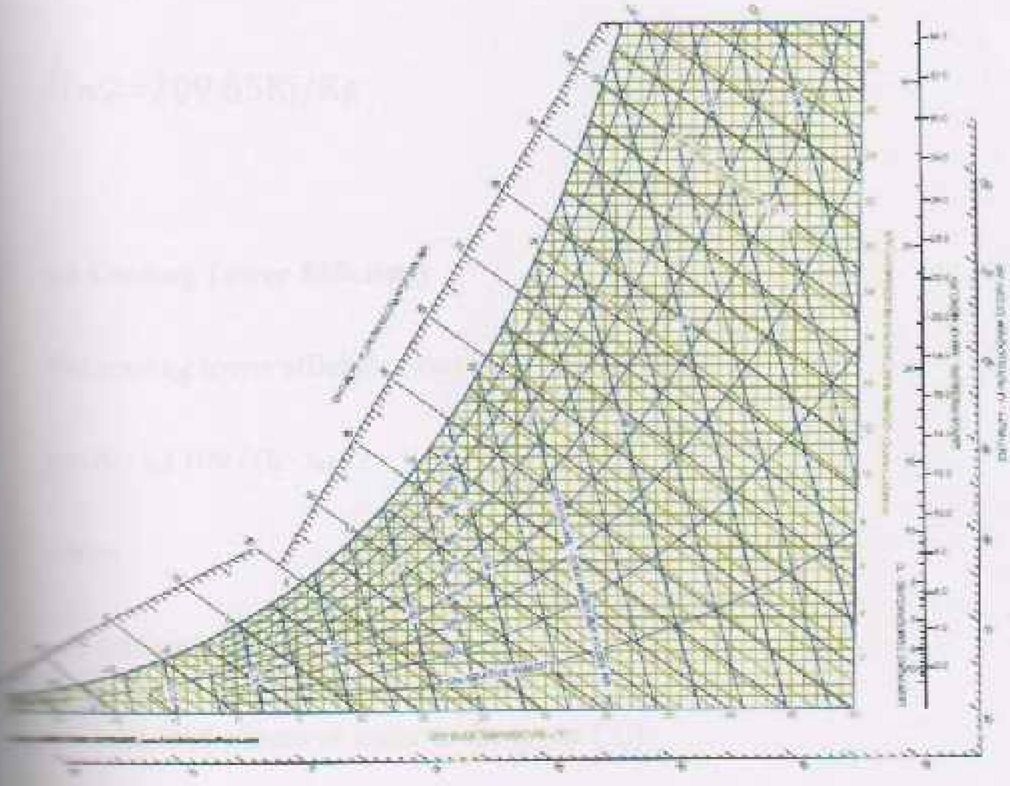


Figure 6.2 Psychometric Chart

The amount of water lost by evaporation is typically only a very small percentage of the water inlet flow, therefore :

$$\dot{m}_{w1} Cp_w (t_{w1}-t_{w2}) = \dot{m}_a (h_{a2}-h_{a1}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Cp_w: Water specific Heat Capacity =4.18 Kj/Kg.K

t_{w1} : Inlet Water Temperature =50 C

t_{w2} : Outlet Water Temperature

From equation (2)* :

Make up water flow rate = $4.3*10^{-5}$ Kg/s

From equation (3)** :

$$h_{w2}=209.65 Kj/Kg$$

6.4 Cooling Tower Efficiency

The cooling tower efficiency can be expressed as

$\mu = (t_i - t_o)\ 100 / (t_i - t_{wb})$

where

μ = cooling tower efficiency.

t_i = inlet temperature of water to the tower (°C)

t_o = outlet temperature of water from the tower (°C)

t_{wb} = wet bulb temperature of air (°C)

t_i =50 °C

t_o =25 °C

t_{wb} =20 °C

η =(50-25)100/(50-20)=83.33%

Chapter Seven

Hydraulic System

- Introduction.
- The main parts of the hydraulic system.
- Diameters of pipes and pressure.
- Prove the diameters by calculations.

7.1 Introduction:

One of the most important parts of the project is the hydraulic system, the main function of this part is the motivation of the parts, The principle of work depends on creating force by the fluid to act on the parts and achieve the desired movement.

The extensive use of hydraulics to transmit power is due to the fact that a properly constructed hydraulic system possesses a number of favorable characteristics. These are as follows :

1. Eliminates the need for complicated systems using gears, cams, and levers
2. Motion can be transmitted without the slack inherent in the use of solid machine parts.
3. The fluids used are not subject to breakage as are mechanical parts.
4. Hydraulic system mechanisms are not subjected to great wear.

The basic principles of hydraulics are few and simple and are as follows:

* Liquids have no shape of their own.
* Liquids are incompressible.
* Liquids transmit applied pressure in all directions.
* Liquids provide great increase in work force.

7.2 Main Components of the Hydraulic System

The components of the hydraulic system are:

1. Electric motor which drives the main pump, it has a 970 rpm and 13 kW.
2. The main pump.
3. Two hydraulic motors, one to drive screw and the other is to adjust the mold within the specified space.
4. Oil tank, its capacity is 220 L.
5. Hydraulic fluid, its number is 46-48.
6. Control valves.
7. Different types of pipes.

7.3 Pipes design

Main hydraulic pump specification.

power= 13 kW

rpm =970

the working pressure (WP) of hydraulic system =16Mpa .

and it's the maximum safe operating fluid pressure and is defined .

Wp=Bp/Fs .... (7-1)

where Wp........ working pressure

Bp....... Burst pressure.

Fs......... Factor of safety .

A factor of safety ensures the integrity of the conductor by determining the maximum safe level of working pressure as

Fs =6 For working pressure from 7 to 17.5 µpa.

To find the burst pressure for the tubing by uses equation (7-1) .

Bp = Wp*Fs

= 16*6 = 96 Mpa.

The burst pressure (Bp) it's the fluid pressure that will cause the pipe to burst.

From hydraulic pump specification

Pump power = 13 Kw & Wp = 16 Mpa

Hydraulic fluid Mass flow rate = pump power*Efficiency/ hydraulic pressure .

Q =Power* 0.80 / pressure.................................(7-2)

= 13Kw *0.80 /16 Mpa =39 L/min.

$Di = \sqrt{4Q/\pi v}$ ....(7-3)

Where Di .... pipe inner diameter .

Q.......... Hydraulic fluid Mass flow rate .

v........... average fluid velocity.

$$Di = \sqrt{4 * 39 * \frac{10^{-3}}{\pi} * 3}$$

=16.6 mm

The selected pipe is Rubber Pipe (DIN EN 853 2SN SAE 100 R2 AT)

Figure 7-1

Product Description

Tube: Oil resistant synthetic rubber
Reinforcement: One high tensile steel wire braid
Cover: Abrasion, ozone and weather resistant synthetic rubber
Temperature range (medium): -40° C to +121° C

The selected standard size conductor with an inside diameter equal to or greater than the value calculated based in flow rate requirements.

Table 7.1 : standard diameter of rubber pipe

Nominal	Inside	Braid	Outside	Working pressure	Test pressure	Burst pressure	Bend radius	Weight
mm	mm	mm	mm	Mpa	Mpa	Mpa	mm	kg/m
19	19.0	27.0	29.3	21.5	51.5	100	240	0.86

$\sigma = p*Di/2t$........................ (7-4)

Where σ .... tensile stress in the pie material.

P .... Burst pressure .

Di .... inner pipe diameter .

t .... conductor wall thickness.

σ = 100 Mp*19mm/10.3

= 184.5 Mpa

Wp = Bp /Fs

=100 Mpa/6

= 16.67 Mpa

This pressure is Adequate (greater than the operating pressure of 16 Mp)&
This result is acceptable.
This design for the main supply of hydraulic lines & any design for any other line will be defined as the before calculations .

Chapter Eight

Economic Feasibility Study

- Introduction.
- Choosing The Product.
- Calculation of Feasibility Study.

8.1 Introduction

To establish a project, economic feasibility study must be done before, to determine whether this project is successful or not. Economic feasibility is usually based on several factors which are:

1. Provide the necessary construction to contain the project.
2. The provision of machinery, equipments and costs.
3. Raw materials to provide what prices are.
4. Choose an appropriate product and what are the conditions of his choice.
5. How to market this product after production.

The University provided a place to the factory which is now located in Wadi Al – Hariyyah, building C.

And therefore, in this chapter the study concentrated on choosing the product and design the appropriate mold for it, and then calculate the economic feasibility of the project.

8.2 Choosing The Product

To choose the right product, some conditions must be realized, and they are as follows:

1. The way of manufacturing, injection or whatever.
2. Form in terms to be produced, regarding their simplicity and size.
3. The raw materials used, and whether is it available in the market or not.
4. The availability of the new product within the local market.

A sample of different products were captured as photos, those items are available within the market, and after taking into account the conditions of the choosing process. Six products have been chosen regarding that they have achieved the required conditions. Those products are:

Figure 8.1: Selected product

	Raw material	Size, Simplicity	Price, Marketing	salable	Total
A	5	6	8	6	25
B	4	9	9	4	26
C	9	4	7	9	29
D	6	7	4	5	22
E	8	8	5	7	28
F	7	5	6	8	26

Note: all these products manufactured by injection.

Since dish is a wide available in the market, the choice is the product E

8.3 Calculation of Feasibility Study

The types of costs should be known and calculated, and should be taken into account when preparing the feasibility study. Costs are divided into the following two types:

1)Fixed costs such as: machine cost, salaries, rents, insurance and consumption.

2)Variable costs such as: raw materials, maintenance, transportations, water, packaging and electricity.

The calculations of the breakeven point :

It's have been supposed that the machine produce four products in a minute and the machine producing time is five hours in a day and so twenty day at a month 288,000 units/year, this number

Machine cost : 183,000 NIS

Salaries : 36,000 NIS/year

Rents : 12,000 NIS/year

Insurance : 3000 NIS/year

Consumption : 18,000 NIS/year

Raw material : 263,808 NIS/year

Maintenance : 5,000 NIS/year

Let find the breakeven point by superposition (present worth(purchasing pries), and annual worth(maintenance, rents, etc.)

1. Purchasing pries

   Fixed cost = 183,000 NIS.

   Variable cost = (18,000 + 263,808 + 5,000)/ 288,000 = .995 NIS/unit.

   Pries = 5 NIS/unit.

   Breakeven point(NIS) = fixed coast / 1 - (variable cost / pries) = 228,464.4 NIS

   Breakeven point (unit) = Breakeven point(NIS)/ pries = 45,693 units.

2. annual worth(maintenance, rents, etc)

   fixed cost = 36,000 + 12,000 + 3,000 = 51,000 NIS.

   Variable cost = .995 NIS/unit.

   Pries = 5 NIS/unit

   Breakeven point(NIS) = fixed coast / 1 - (variable cost / pries) = 63,670.4.

   Breakeven point (unit) = Breakeven point(NIS)/ pries = 12,735 units.

Chapter Nine

Process Control Criteria

- Introduction
- Factors Affecting Product Quality
- Process Control Techniques
- Forms of Process Control in the Injection Molding Machine
- Analysis of the control system in the existing machine

9.1 Introduction

The operational process requires process control technology to provide an acceptable operation at economic cost, and to provide a consistent product within demanded specifications. This chapter presents an overview of process control strategy used in the injection molding machine.

Process control technology in polymer processing simply is an adjustment and calibration of machine operational conditions to keep plastic behavior and products of consistent properties.

The process control improves machine performance in response to external perturbation and gives more consistent results than the normal process. Manufactured plastic of the injection molding machine should concern about the process control technology in order to improve production quality.

9.2 Factors Affecting Product Quality

The properties of injection molded products are not always the same. Factors affecting product properties can be classified as follows:

Environmental Factors: Such as ambient temperature and humidity, those can affect the performance of the injection molding machine and also the condition of the molding material. Ambient temperature may affect temperature of the water used for mold cooling, feed hopper throat and hydraulic system. In addition to that, Humidity, that is; the molding material may absorb water and this will affect Product properties.

Raw Material: The material used in the injection molding process must be clean and free of impurities like metal, water and volatiles. If the polymer is contaminated, this may affect the viscosity of the polymer melting point, and thus; will affect the mold filling phase. Some materials need to be dried before being processed; water in the case of Nylon will influence the properties in the product. Metal contamination to the polymer could cause serious machine damage if it passes through the injection unit.

Machine Variations: Machine performance affects the repeatability of product properties. Machine variations arise due to water, decomposition of polymer and hydraulic system problems.

Wear generally occurs when two component of the machine are moving relative to each other. Wear can occur in the injection unit, clamping unit and mold. Generally the wear in all these components is caused by abrasive material such as the glass fiber in glass-fiber-reinforced thermoplastics.

Decomposition of the polymer, for example PVC, the problem may arise as a result of the acidic nature of the degradation products.

Electric problems can arise as a result of voltage variations. Voltage variations can occur where extra loaded areas are exists. The variation can affect the performance of induction motors, heating devices and solenoids. Such factors affect the performance of the molding machine.

Hydraulic problems include the contamination of the hydraulic fluid with dust. The contamination will affect the performance of the hydraulic system and thus the machine. Also when the hydraulic fluid gets hot, the viscosity of the hydraulic fluid will fall and the performance of the hydraulic system will also fall. If the hydraulic fluid is too cold, the viscosity will rise and it will affect the movement of the fluid in the hydraulic system, meanwhile; affecting the whole operational process.

9.3 Process Control Techniques

9.3.1 Relay Logic

Relay logic was the earliest type of the sequence control for injection molding machine and still widely used. Relay logic uses electromechanical relay and hard wiring to affect the proper sequencing of various functions of the molding machine.

The disadvantages of relay logic are:
Life Time: The electromechanical contacts and the solenoids, which switch them, have a limited life due to the continuous use.
Lack of Flexibility: The relay technology can only be used for sequencing; it is not capable of being used as a feedback control element.

9.3.2 Solid State Machine Logic

Solid state logic consists of electric components such as resistors and transistors mounted onto printed circuit boards (PCB's). Such boards contain a variety of circuits, for example those used for timing, machine sequencing and switching. In general, such solid-state circuitry are more reliable than the electromechanical devices, and this is partially due to the reduced number of the electromechanical devices they replace, and this is regarding the types of systems which are difficult to troubleshoot.

9.3.3 Microprocessors

A microprocessor-based controller performs tasks in a sequential manner and is guided through its various tasks by a software program (Algorithm). The software is located in the memory of the microprocessor in the form of a Read Only Memory (ROM), Program Read Only Memory (PROM) or Random Access Memory (RAM).

The advantages of microprocessor control is that it not only performs the logical functions, but also interprets data from sensors such as a thermocouple on the machine, analyzes this information and produces outputs or actions. The design of the microprocessor-based control system provides a flexible process control of high capability. As a result, the use of microprocessor control has developed rapidly.

9.4 Forms of Process Control in the Injection Molding Machine

Individual closed-loop process control systems are required in order to ensure that an injection molding machine operates consistently. All of the individual process control closed-loop systems need a sensor to provide a feed back signal. The following are some examples of the forms of process control in an injection molding machine.

9.4.1 Injection speed control

In the closed-loop control of the injection speed (Figure 9.1), there is a positional transducer attached to the injection screw and a proportional valve in the hydraulic system, this regulates the hydraulic flow to the injection cylinder. The screw position versus time profile is compared to set point injection speed, and the difference between two values is amplified and serves as a command for the proportional valve. The repeatability of the injection speed of filling possibly raises the variations in component properties.

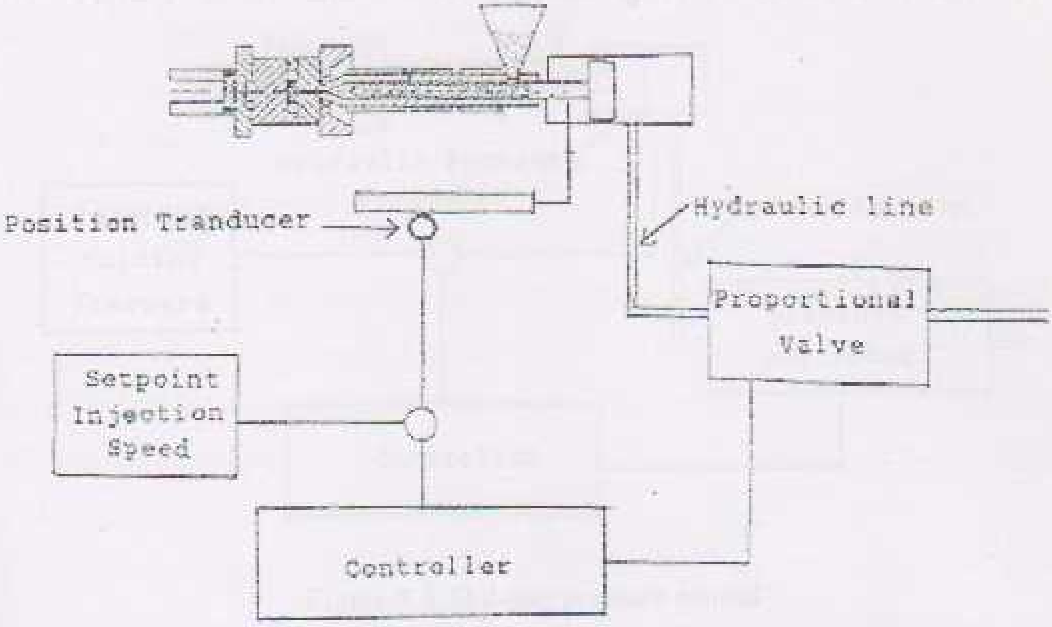


Figure 9.1: Injection speed control

9.4.2 Holding Pressure Control

The holding pressure closed-loop control system (Figure 9.2) Consists of a hydraulic pressure transducer and an electrical-pressure regulator on the principal hydraulic circuit. The holding pressure versus time profile is measured and compared to a set point. Any difference in two valves causes a correction to the system and a signal is sent to the electrical-pressure regulator. The stability of the holding pressure affects the repeatability to the packing phase, variations possibly raises to over packing of the mold components.

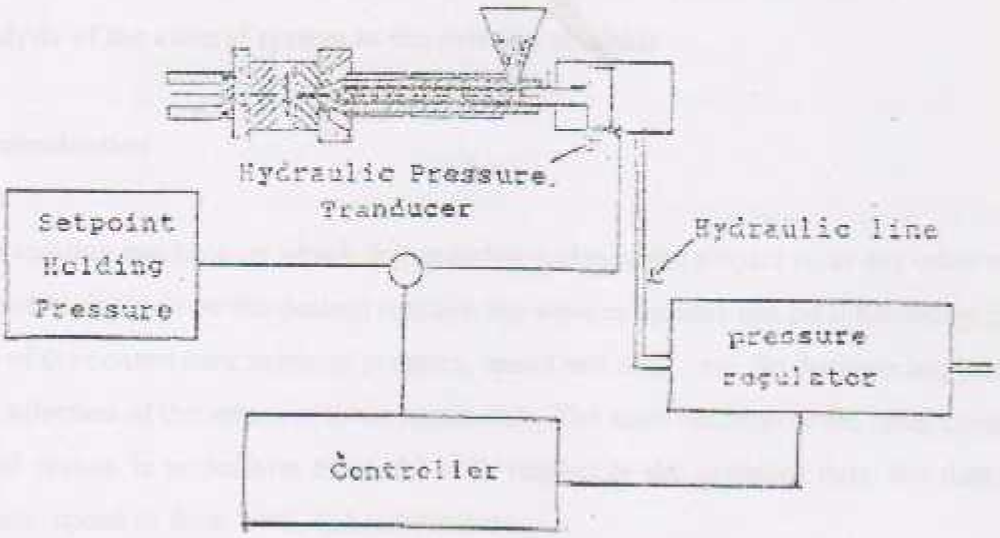


Figure 9.2: Holding pressure control

9.4.3 Temperature Control System

Temperature control systems are usually installed for the control of barrel and mold temperature. The temperature of various parts of the machine is generally sensed using thermocouples and is compared to a set point temperature. Any deviation will cause the controller to produce a suitable response.

9.5 Analysis of the control system in the existing machine

9.5.1 Introduction

In the existing machine on which the underlying idea of the project is, as any other machine, the control depends on the desired options, the various options can be achieved by changing some of the control parameters as pressure, speed and time…etc. So the main important thing is the selection of the values of these parameters. The main function of the components of the control system is to perform the tasks with respect to the installed data; the data include pressure, speed or flow, time, and temperature.

This section focuses on explaining the inputs, outputs, and their role in the operational sequence, the main components of the machine, and the control elements.

9.5.2 Main component of the machine

To build up the control system, first, whole the parts of the machine should be known, so; the machine consists of the following main components:

1. motors

   The machine contains three motors, main motor which drives the pump, two hydraulic motors, one for adjusting molds within installing space, and the other for driving the screw.

2. valves

   The machine contains seven valves and each valve has specific tasks as follows:

   - Two spot four way valve for controlling the act of plasticizing hydraulic motor.
   - *Three spot four way valve for controlling injection salivating* protection.

- Three spot four way valve for controlling ejector forward / back motion.
- Three spot four way valve for controlling the process of opening and clamping.
- Three spot four way valve for controlling the adjustment of the hydraulic motor on / off operations.
- Three spot four way valve for controlling injection seat advance / back process.
- Double sealing hydraulic valve for adjusting system's pressure and flow.

3. Heaters

   Three heaters (Heating Regions) fixed on the group to melt the material as desired.
4. Various mechanical parts like jacks, arms and cores.
5. Hydraulic cylinders and tubes.
6. Sensors, various sensors for multifunction as protection, detection, and electric rulers. The protection sensor as limit switches to ensure closing the door for safety, and lower-pressure mold protector, the detection sensors as thermocouples, and rulers for detecting the position and to provide an input signal to the controller.
7. Integrate controller includes timers, memory, conditional circuits, microprocessor, and relays.
8. Control panel by which the operators can manage all the operations, especially, for changing the parameters required for the operational process.

9.5.3 Main components of control criteria

1. Valves:

The machine contains seven main valves, one of them is a servo valve and the others are directional valves. *The servo valve is the main control element among these valves and it* is responsible for achieving all machine operations, because any operation needs certain values of pressure and flow and this is done by means of that element. The desired values of the pressure and flow are installed in the microcontroller and can be changed by the operator to achieve the desired characteristics. Take into consideration that at the same time only one operation can be done, and so; the servo valve controls the pressure and flow of all the operations with respect to the data installed in the controller.

2. Control Unit :

The control unit is an intermediate part between the input and the output, it receives signals and processes these signals in order to make a decision with respect to the installed data, and send signals to the interested parts. This unit consists of:

- Microprocessor:

  This is the brain (Heart) of the unit, all decisions are made in this part, the other parts of the control unit are assistants, and the processing depends on the programming of the processor and the data installed in the memory, so it only executes the program.

- Timers:

  Each operation in the machine is limited with a certain time, it should not exceed the set value, and if it exceeds, this means that there is an error and the machine automatically do not go on running, and disable the current operation. For example; if the time of closing of the mold was set to be 20 seconds, and this Operation exceeded this value, that means there is an error occurred, and the machine stops closing / opening the mold, then by default stops the machine providing an alarming signal.

- Memory:

  This part stores the program of the processor, and the data stored are set points for pressure, speed, time, and temperature.

- Conditional circuits:

  These circuits process the signals to make it suitable for driving.

- Relays :

The main function of them is to isolate the microprocessor and protect it, in addition to being responsible for control missions.

3. Sensors:
   - Limit switches for safety doors to protect the operator, and to avoid any thing to access the area of the mold and cause some problems in the clamping and opening the mold. Other limit switches are installed in the clamping unit for pre installing a new mold, and to determine the end positions of it.
   - Photo sensor: this sensor is used in the "auto" operation. At the end of each cycle, the photo sensor will verify whether the product has been properly ejected from the mold within 4 seconds. If the product is still in the mold area, the machine will automatically stop and the alarm lamp will light. The control display will show an "Ejection Failure" error message.
   - Rulers to limit the movement of the mechanical parts and the hydraulic cylinders. The distance by which any part is going to move, is already stored in the controller and the controller sends signals to these rulers to control the movement of these parts.
   - Lower-pressure mold protector.
   - Thermocouple for detecting the temperature of the group, the machine generates an error message if the temperature is not suitable for the operation.

These components are the main control components that control the machine. The controller makes the decisions due to the data stored in it, and due to orders from operators, so to open the mold; the operator should press the opening key "Mold Open", then the controller checks up the data for opening the mold and then sends a certain signal to required component. The following example will clarify the concept.
The injection operation is divided into injection and pressure holding, the following table shows the values of pressure, speed, time, and position.

Table 9.1 injection parameters

	Pressure	Speed	Time	End-position
Inject #1	50	50		50.0
Inject #2	60	50		20.0
Inject #3	70	50		15.0
Inject #4	80	50	6.0	10.0
Hold #1	20	50	2.0	
Hold #2	30	50	0.0	
Hold #3	40	50	0.0	

Injection part has four phases, each phase has its own hydraulic pressure and speed, changes between each phase use the position distance, at the same time changes the pressure and speed, suitable for any complicated, highly accurate mold. Changes for injection hold pressure can be changed by using time control and position control; its operations depend on the mold structure, material, fluidity, and the efficiency.

The hold pressure uses three pressure phases, and three speeds. The changes of the holding pressure can be controlled by means of time control, the last phase timing indicates that the whole injection procedure is completed.

9.5.4 Operational Modes

1. Manual Mode: Pressing command key according to the designation on the panel of electrical control box can achieve the corresponding mechanical act. The act will not stop if the button is reset during the act itself. This method is often used in adjustment and production. Operators must abide prescriptive act in turn if using manual method.
2. Semi-Automatic: The machine can accomplish a work circulation to the process in the action sequence chart by pressing the button on the position of semi-automatic and close safety door on the base of preselecting dictating switch, time relay and stroke switch.

When act finished, open safety door to take out products and close safety door again, then another work circulation will take the place.

In semi-automatic operation, all stroke switch position, all relays time and the switch of the process method have direct effect to products quality productive efficiency.

3. Full Automatic: The machine executes automatic method by pressing the button on the position of automation after clamping. When a work circulation is done, photoelectric switch detect products drop, and clamp mold automatically begins another circulation. If products can't be ejected in certain time, the machine will stop and alarm automatically.

The manual operation method lets the operator to check up if the parameters give the desired options, if not; the parameters should be changed to get the perfect product, then it is possible to switch the machine to work on the automatic mode.

9.5.5 Operational steps

Operational steps can be summarized as follows:

- Before switching the machine on, the cooling tower should be switched on.
- Turn on the machine (Main power switch ON).
- Turn on the Heaters (Control Screen).
- Supply the raw material to the machine feeding unit, either manually, or through the vacuum suction instrument.
- Charge material to be transferred from the feeding region to the Nozzle region (Nozzle has three different regions classified due to their temperature difference).
- The heating process should last for about 30-40 minutes to ensure that the raw material have been completely melted, this time period is when using standard raw material, while for a recycled material, it needs about 1 – 1.5 Hours, depending on the used material purity.
- Turn on the main motor by means of a button on the Control Screen (at least 20-30 minutes before starting the injection process).

- Advance the nozzle (Forward towards the mold region).
- Inject the material.
- Open the mold.
- Eject the product.
- Close the mold.

This is the complete cycle for producing one piece, while producing three to four pieces, check the quality of the product, if it has no defects, then turn the machine to operate under the full automated mode, if there where defects or any undesired measures, then change the settings of some parameters to get the desired quality (Like pressure or temperature or both).

9.5.6 Block Diagram

The following diagram shows the whole process and the operations to be controlled, control elements, input signals, and control unit.

The input signals are:

- Inputs from control panel, the control panel is the interfacing device between the operator and the machine, any function and any compensation in the values of the parameters can be obtained by means of the control panel using the proper key.
- Rulers

  The rulers give a signal voltage representing the positions of the various parts, these signals are very important because determining the proper values of pressure or speed depends on the position of the part, for example; in the opening process of the mold, the distance should be within 30 cm.

  At the end position of the distance, the mold should stop without shocking the cores, so the controller should send a signal to decelerate the responsible cylinder and the mold stops without occurring any damage, so, when reaching to the last 10 cm, the rulers give a special signal to the controller indicating that the part reached the last 10 cm, and the controller then sends a signal to the valves to decelerate the interested part and stops exactly in the final specified position.

- Protection elements.

  Limit switches and lower-pressure protectors usually are used for safety matters.

- Feedback signals

  In the machine, it had been noticed that there is only a one feedback signal that comes from a thermocouple, indicating the temperature of the nozzle region.

The output signals are:

- Signals to switch the motor on/off.
- Signals to switch the heater on/off.
- Signals to control the directional valves.
- Signals to control the proportional valve.
- Diagnosis signals.

Referring to the block diagram seen below (Fig. 9.3), the detailed process can be explained. To achieve any of the necessary operations, this is only can be done using the control panel, whereas, pressing any key means a signal that is being sent to the brain of the machine which is the processor, though, the processor in turns sends the required order to the required parts or actuators, so that the intended output is being achieved.

For example, to switch the heaters on or off, the specified button on the control panel called "Heaters On/off" should be pressed, and then the processor operates the heaters due to a signal sent through a solid state relay. And hence, there should be a feed back signal to correct what faults may occur, meanwhile, when the heaters temperature exceeds the stored value in the memory of the processor, a sensor which is a temperature sensor, sends a signal as a feed back to the system, so that an error message appears on the panel, and so, this blocks all others related movements or operations.

In the same way, if the intention is to operate the injection process, a signal is set through the panel to the processor, the processor makes a decision in respect to the values of pressure and flow stored in the memory, and sends a signal to the proportional valve, align with a signal to the directional valve specified for this operation and then rulers provides required signals due to the preset values, to operate the injection process as needed, and so on.

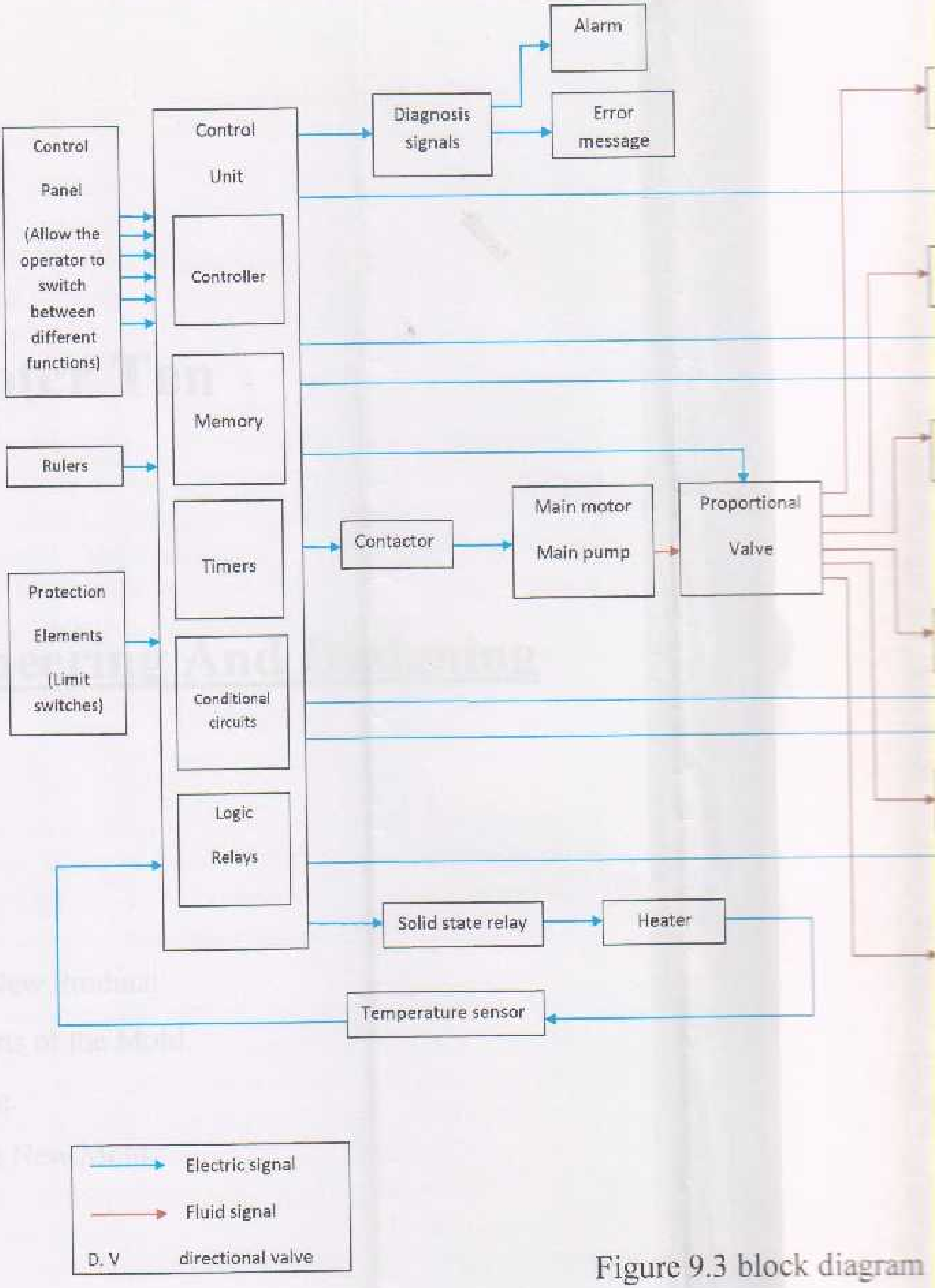
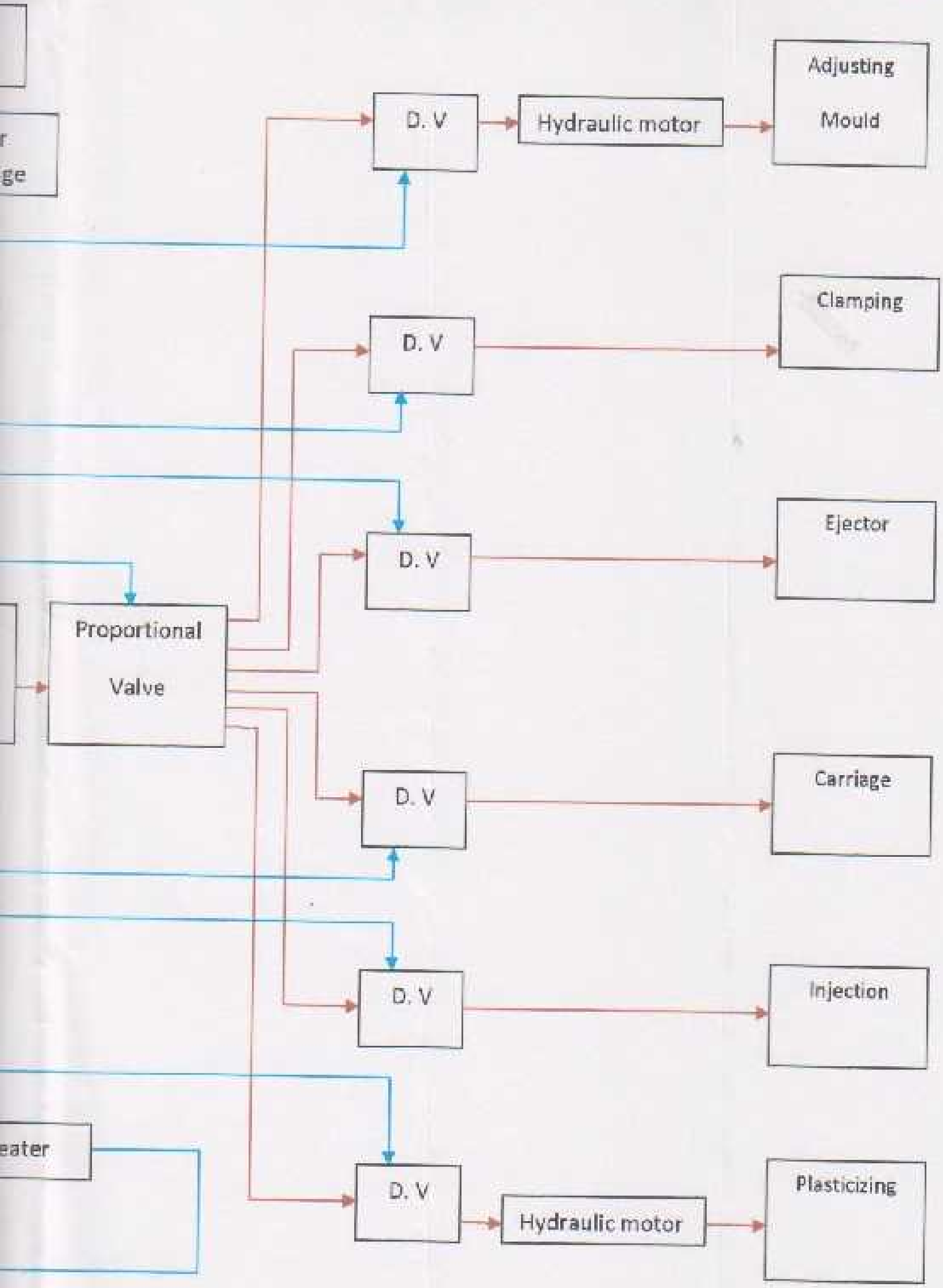


Figure 9.3 block diagram



re 9.3 block diagram

Chapter Ten

Mold Engineering And Designing

- Introduction.
- Design The New Product.
- The Main Parts of the Mold.
- Mold Cooling.
- Design of the New Mold.

10.1 Introduction:

Plastic injection machine contains the mold which the product formed inside it.

It is the most important part of the machine, and its design very complex and it depends on many parameters, this part of machine take especial importance because it has a direct affect on the quality of the products.

Traditionally, molds have been expensive to manufacture. They were usually only used in mass production where thousands of parts were being produced. Molds are typically constructed from hardened steel, pre-hardened steel, aluminum, and/or beryllium-copper alloy. The choice of material to build a mold from is primarily one of economics, steel molds generally cost more to construct, but their longer lifespan will offset the higher initial cost over a higher number of parts made before wearing out. Pre-hardened steel molds are less wear resistant and are used for lower volume requirements or larger components. The molds can be manufactured by either CNC machining or by using Electrical Discharge Machining processes.

10.2 Design the product

The product designer must have knowledge of the part geometry, because it may create problems during the molding process; he must also be familiar with the properties of thermoplastic materials, the injection molding process in general, mold design, and the quality of mold construction and product design required to produce functional thermoplastic molded parts.

Producing quality thermoplastic parts requires converting the functional requirement of the application into a design. The product design's geometrical configurations should not only satisfy functionally, but it also has to meet the conditions required by mold design and construction and operation of the mold in order to produce quality parts and guarantee efficient molding operation.

When designing injection molded thermoplastic parts, the product designer must also be aware of some part configurations that pose potential problems during the injection molding process. The part design requirements include uniform wall thickness, parting line location to balance the heat removal from both sides of the cavities, smooth internal corners, draft walls (to facilitate part removal from the cavity), elimination of feather edges, elimination of fragile deep pockets (long thin cores), provide location for the gate, allow large permissible surface area for ejection, specify typical part dimension tolerances for plastics, and avoid the use of high-gloss surface finishing for the product.

10.2.1 Effects of Product Design on the Injection Molding Process

1) Uniform Wall Thickness

Products that incorporate abrupt changes in wall thickness will create major mold design problems regarding the temperature control system of the mold. Abrupt changes in wall thickness make it difficult to maintain a uniform temperature throughout the mold cavities during the molding cycle. After the thermoplastic melt has been injected, variations in part wall thickness do not allow the walls to cool at consistent rates. Thick walls will shrink more than thin walls, causing part warpage, voids on thicker wall cross sections, poor dimensional control,long cycle times, poor surface finish, and structural defects.

2) Balance Geometrical Configuration

The positioning of the cavity should be balanced on both sides of the mold parting line. Both halves of the cavity should be subjected to the same volume of polymer melt for uniform cooling in the mold cavity. If one side of the cavity is injected with more melt than the other side, this side will become hotter. The hotter side of the cavity will have the tendency to stick on the deep hot spots, causing warpage, poor surface finish of the molded part, and long cycle times.

3) Smooth Internal Sharp Corners

Sharp corners create high stress concentrations on the thermoplastic part; they are also stress concentrators within the mold cavity. These sharp corner areas fail under high loads. Internal radii of at least 0.031 in should replace sharp corners in thermoplastic part design wherever possible. If a sharp corner is unavoidable, reduce the radii and polish this surface area; in addition, these mold cavity areas should be designed with removable inserts to facilitate ease of repair.

4) Draft Walls

Thermoplastic parts should be designed with positive draft walls. Minimum positive draft is required on all walls in the direction of mold opening or core pulling. Without draft, thermoplastic molded parts adhere to the mold cavity surface, causing drag marks and surface finishing defects. In many cases, the part will not be fully ejected so that the mold may close on it and cause damage. Lack of positive draft also increases cycle time and molding costs.

5) Feather Edges

Avoid the use of feather-shaped edges that require thin and fragile steel.

Within the mold cavity, feather edges tend to break and chip, resulting in mold maintenance and downtime. Undetected broken and chipped feather edges will cause flashing problems as the thermoplastic melt fills into the mold vents.

Feather edges become extremely hot and take longer to cool because cooling water channels cannot be brought to the feather edge, thus increasing cycle time.

6) Proportional Boss Geometries

Avoid the use of long narrow cores. The height of the unsupported core should not exceed four times the core base thickness. During the molding process, the injection pressure will deflect long narrow cores, because they act as cantilever beams, causing parting line openings and possible early failure of the mold core insert. In critical cases, a structural analysis of the mold can be made based on expected forces and allowable deflection. Cores of greater height must be fully supported using core inserts to decrease the chance of failure and to ease repair.

7) Gate Type and Location

The gate is an important component in the injection molding process. The gate influences the type of mold needed for the application (two-plate, three-plate, hot runner, and automation). The location of the gate determines the mold shrinkage, the melt flow, part dimension, warpage, and weld line strength.

The gate functions as a thermo-valve between the runner and the cavity. The temperature is increased around the gate area by the melt injection speed, pressure, and temperature. The hot gate allows the melt to enter the cavity with out shearing off the polymer; the gate cools off when the melt stops moving, closing the gate while the melt inside the cavity cools off under packing pressure.

8) Molded Product Ejection Surface Area

The mold ejection system automatically provides a uniform force to extract the molded product from the cavities. The ejection force breaks the vacuum between the internal surface wall of the part and the cavity core and ejects the parts from the mold. The ejection surface area of the product should be located in the direction of the moving half of the mold, where the ejector system is generally placed. The product designer should specify large ejection surface areas with heavy cross sections that are not critical for the functionality of the product.

The type of ejection system depends on the molded product's geometrical configuration and the permissible ejection surface area wall thickness, the stiffness, crystallinity rate, and melts temperature of the thermoplastic resin.

For example, punctuation holes or indentation defect marks on the external surface of a molded product may be produced by small diameter ejector pins pushing against a flexible and thin-walled cross section of a thermoplastic molded product during the ejection cycle.

9) Molded Product Tolerances

A realistic view of the cost of tolerances often helps avoid high molding costs without affecting the performance of the part. It may be unreasonable to specify close production tolerances on a part when it is designed to operate within a wide range of environmental conditions. Temperature-induced dimensional changes alone can be three to four times as great as the specified tolerances. The tolerances for injection molded thermoplastic parts have been developed by the plastic molding industry. The purpose of these specifications is to assist the part designer in obtaining a quick and preliminary analysis for the different molding tolerance factors found in a generic injection molded thermoplastic part.

Understanding the limitations of this process and knowing how to control fine tolerances are the result of applying thermoplastic part design principles, working with molds and mold designers, being aware of the governing rules in polymer technology, and applying the latest technologies available for the injection molding process.

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10) Surface Finish of Molded Product

Surface finish affects part quality, mold cost, mold cycle, and delivery time.

Surface finishing is used to enhance surface clarity for appearance of the molded product. The standard steel finishes range from a number one (mirror finish) to a number six (grit blast finish). Any finish specifications on the part print must reference the molded product and not the mold itself. Specifying the mold surface finish does not necessarily produce the expected result on the finished molded product. Although a requirement for a part with a high-gloss finish requires a high-gloss finish on the mold cavity, other factors, such as resin, gating, melt and mold temperature, injection speed, and mold venting affect the surface finishing of the part. For extremely high-gloss finishing, the types of steel used in the cavities may need to be specified to ensure reasonable life of the polished cavity in production.

10.2.2 The New Product

The new product which designed is Cigarette extinguisher. a new form of it that designed by CATIA program for mechanical design.

The shapes of the design as shown in the figures (10.1-10.5) below:

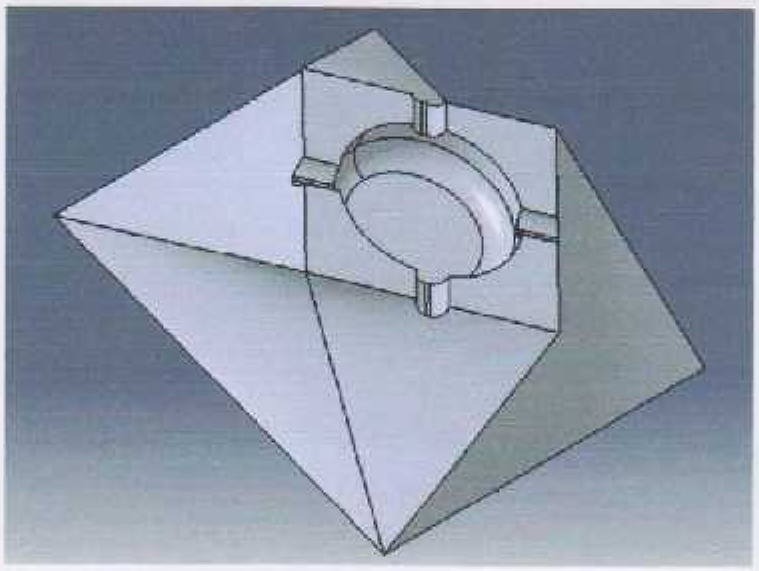

Figure 10.1

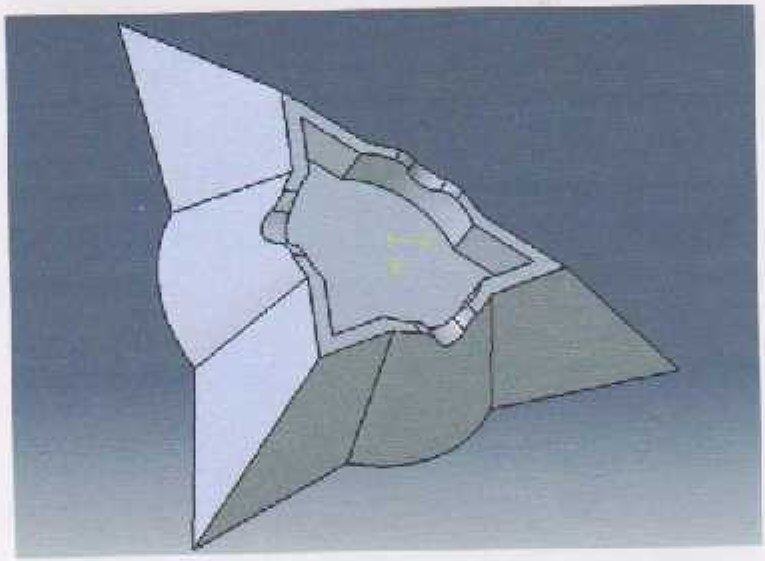

Figure 10.2

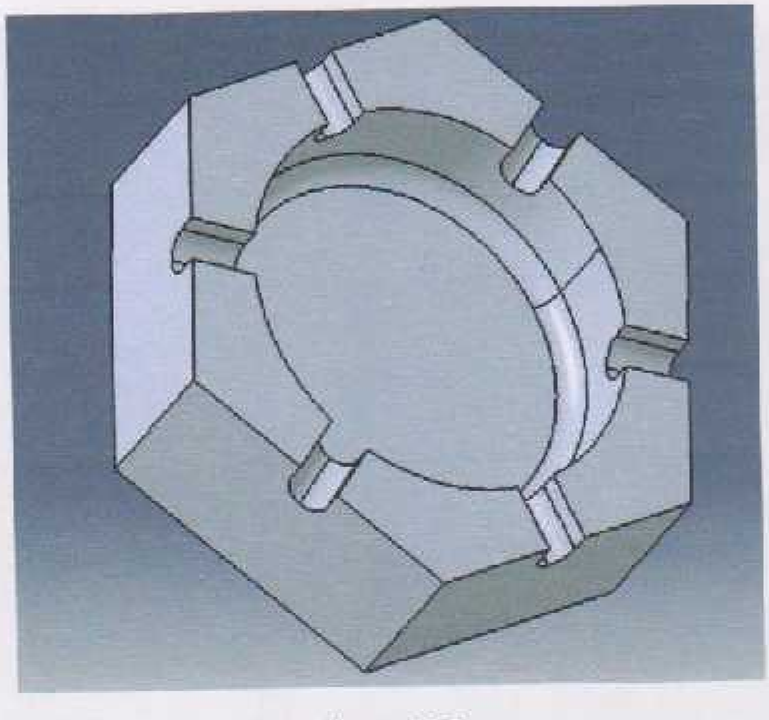

Figure 10.3

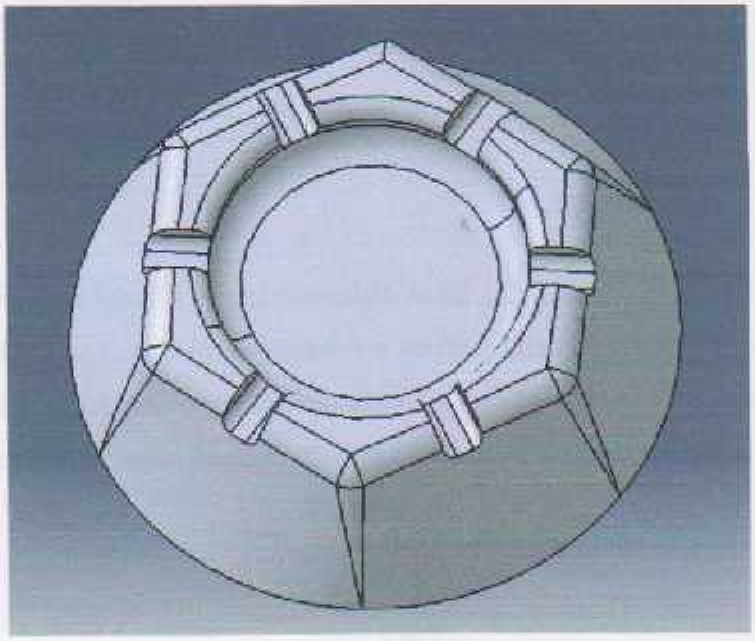

Figure 10.4

Figure 10.5

The product that a choice to design its mold is the latest one (figure 10.5) because of the new shape of it and a mechanical concept.

10.3.1 Mold main parts

Because of the similarities in the two-plate mold construction, it is desirable to have some standard mold base available to permit the thermoplastic injection molds to be produced in quantity, with a short delivery time, thereby reducing manufacturing costs.

The main parts of the mold explained by figure 10.6 .

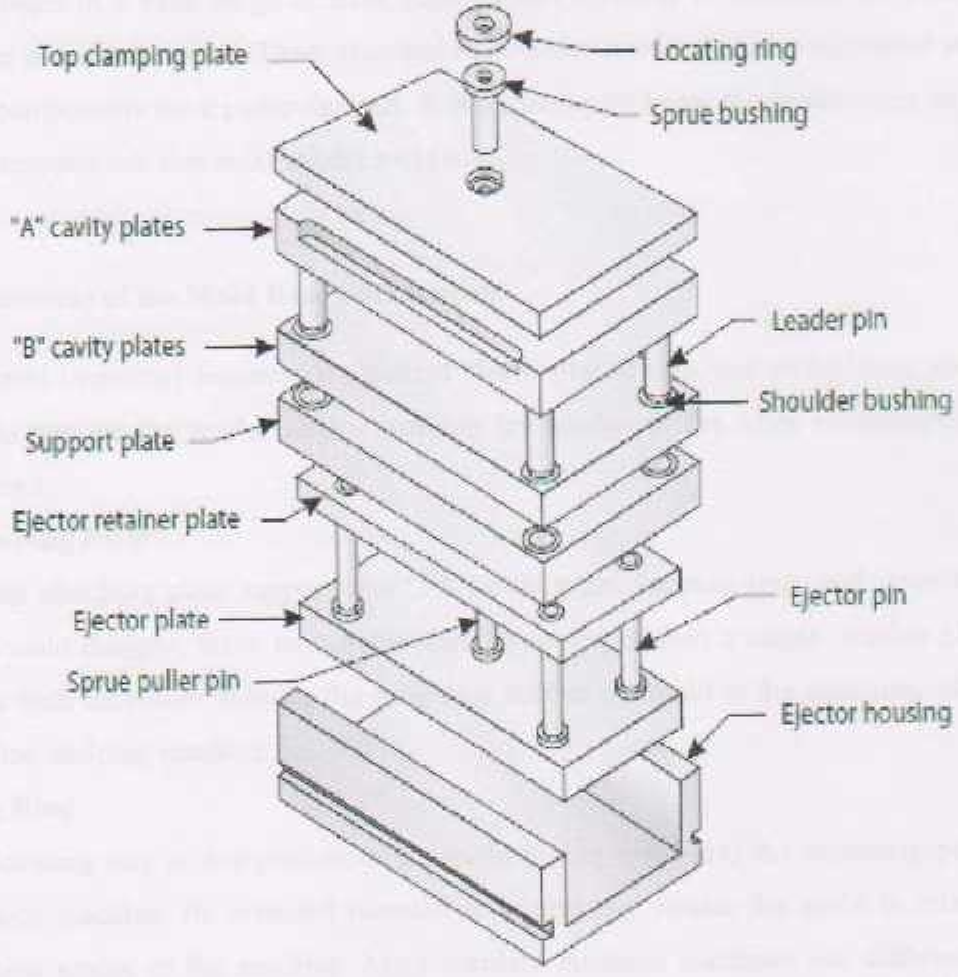

Figure 10.6 Mold Parts

A thermoplastic injection mold base may be defined as an assembly of mold components that conforms to an accepted structural shape and size. The proper type of mold base is specified by the number of plates, premachining of the plates (if desired), steel selection, dimensions, ejection travel distance, size and type of locating ring and sprue bushing required by the injection molding machine. The remaining mold base components are suitably attached together and guidance system incorporated. Of course, the mold base does not include runners, cavities, cooling, venting, hardness, finishing etc.; these aspects of mold manufacturing must be left to a specialized mold maker.

The thermoplastic injection two-plate mold has been adopted as the standard mold base by mold component manufacturers because this particular mold construction is the most widely used design in industrial practice.

Mold bases in a wide range of sizes made to suit a variety of purposes are produced by a number of manufacturers. These standard mold bases need only to be machined to make the mold components for a particular part. It is necessary to know the terminology and function of the components that make up the mold base.

10.2.2 Functions of the Mold Base Components

The most important features of standard thermoplastic injection mold bases are reviewed here to provide the reader with a working knowledge of the basic components and their functions.

Top Clamping Plate

The top clamping plate supports the "A" cavity plate, locating ring, and sprue bushing. In some mold designs, these two plates may be combined into a single, thicker plate, which serves both functions. It holds the stationary half of the mold to the stationary platen of the injection molding machine.

Locating Ring

The locating ring is that portion of the mold that is fitted into the stationary platen of the injection machine. Its intended purpose is to properly situate the mold in relation to the injection nozzle of the machine. Most standard injection machines use different diameters with a variety of design features to accommodate the platen entry for the nozzle. The correct sizes of locating rings are provided in the molds to fit a particular type of injection machine. Where relatively thin-walled parts are being molded and injection pressures may be high, the locating ring may be required to retain the sprue bushing within the mold, so the nozzle and sprue bushing are aligned.

Sprue Bushing

The sprue bushing seals off the melt from the injection nozzle conveying the melt through a conical shaped internal channel and forcing it into the sprue puller, runner, gate, and cavity confines of the mold itself. The sprue bushing has a tapered internal round channel that can vary in size as needed. In proper mold design, the sprue is made as short as possible, consistent with a given part design, thereby reducing the injection pressure drop in the runner system.

Both, the locating ring and the sprue bushing, are usually supported by the top clamping plate, which is used to support the stationary half of the mold.

"A"Cavity Plate

The "A" cavity plate contains and supports the cavity or cavities or the core insert, sprue bushing, and the runners for the parts to be molded. In some cases, the cavity may be cut directly into the solid steel plate, while in others the cavities can be constructed separately and inserted into pockets within the cavity plate.

The "A" cavity plate is part of the stationary section of the mold half, this plate is where the leader pins are mounted.

"B"Cavity Plate

The "B" cavity plate contains or supports the other half of the cavity or a core section of the molded part and also contains the leader pin bushings. The plane between these two plates is the normal parting line of the mold, which separates the two halves of the tool. The "B" cavity plate is the top plate of the movable section of the mold half. It is used to hold the sprue puller and ejector pins as well as the core inserts, or the cavity inserts.

Support Plate

The "B" cavity plate is mounted on top of the support plate. The support plate is used to provide strength to the cavities to avoid deflection during melt injection inside the cavities.

Ejector Housing

The ejector housing parallel blocks are added to provide the height required for the movement of the ejector system. The base plate of the ejector housing is used for clamping the moving half of the mold to the moving platen of the machine.

The ejector housing is a single unit for the ejection system. The injection mold base is manufactured with the parallels (vertical supports) welded to the bottom

Clamping plate

Bottom Clamping Plate

A bottom clamping plate secures the movable half of the mold to the movable platen of the injection molding machine. If the mold is exceptionally large, the ejector system may require additional support, provided by the insertion of support pillars that bear the load between the bottom support plate and bottom

Clamping plate.

Ejector Retainer Plate

Mounted on top of the ejector plate, this plate retains the ejector head pins, ejector return pins, and sprue puller pin through counter bored holes.

Ejector Plate

The ejector plate is bolted together with the ejector retainer plate to form a unit.

It acts as a back support plate for the ejector pins, return pins, and the knockout bar. These pins pass through drilled holes in the "B" cavity plate, insert cavity, and support plate.

Stop Pins

The stop pins are mounted on top of the bottom clamping plate; they are used as stops for the ejector housing when the ejector system returns as the mold closes.

Support Pillars

The support pillars are round bars placed between the support plate and the bottom clamping plate; they have the same height as the parallels. Bolted to the bottom clamping plate, they are used as additional support to avoid deflection of the "B" cavity plate

Sprue Puller Pin

Pin located below the main runner, directly under the large diameter of the sprue channel. It is used to pull the solid sprue out of the bushing automatically when the mold opens and the molded parts and runner system are ejected.

Ejector Pins

The ejector pins enter the cavity to make contact with the molded part.

Return Pins

The return pins contact the stationary cavity plate and prompt the movement of the ejector plates back to the normal position prior to the next injection shot

Leader Pins

The leader pins, used to align the plates on the closing of the mold, are hardened and ground steel pins mounted into one of the mold halves. One of the leader pins is offset so that the mold halves can only be closed when the leader pins are in the correct relative position.

Shoulder Bushings

Hardened and ground steel bushings are mounted into the other half of the mold, in-line with the leader pins. They serve as bearing surfaces for the leader pins.

10.3 Mold Cooling

One fundamental principle of the thermoplastic injection molding process is that hot melt enters the mold cavity, where it cools rapidly to a temperature at which it solidifies sufficiently to retain the shape of the cavity. While the melt flows more freely in a mold cavity, a longer cooling period is required before the solidified molded parts can be ejected. On the other hand, while the melt solidifies quickly in a cold mold, it may not reach the extremities of the cavity.

A compromise between the two extremes must be made to obtain the optimum molding cycle.

The thermoplastic injection molding process embodies the technological ability, innovation, and efficiency required for injection molding a product, while maximizing the amount of profit.

The thermoplastic injection molding process efficiency is affected by the mold cooling design. The difference in productivity between a correct and incorrect mold cooling design can represent an increase of 20 to 40% in the molding process costs.

The term mold cooling means lowering the temperature of the thermoplastic melt in the cavity to form a molded product. When molds require heat for proper operation they are being practically cooled as the temperature of the mold is lower than the thermoplastic melt temperature. The heat transfer flows from a high temperature source to a contacting element of lower temperature.

The main source of heat removal or mold cooling is obtained by an adequate circulation temperature control and volume control of the cooling fluid. If an adequate amount of properly treated water is available at any temperature and volume required by the molding process, the mold will be properly cooled.

Heat removal depends on temperature, pressure, viscosity, thermal diffusivity, and thermal conductivity. The heat transfer calculations are based on steady state or equilibrium conditions. In the thermoplastic injection molding process, the temperature, pressure, and viscosity are constantly changing as the melt flows and cools in the mold cavity. The complexities of the shapes of the molded products are beyond analytical determination. The molecular weight, molecular structure, and distribution of the thermoplastic melt are not constant.

In spite of all these variables, several mold cooling computer analysis programs have been developed by making many heat transfer assumptions to simulate the mold cooling process and the thermal behavior of the thermoplastic melt.

These mold cooling programs are approximations and have some technical value in the development of new products and for a novice engineer who is learning thermoplastic injection mold cooling technology.

During the cavity filling stage, the hottest material will be near the entry point,

i.e., the gate, and the coolest material will be at the point farthest from the entry.

The temperature of the coolant fluid, however, increases as it passes through the mold. Therefore, to achieve an even cooling rate over the molding surface, it is necessary to place the incoming coolant fluid next to the mold cavity surfaces.

Ultimately, adopting the idealized approach is not always practical and the mold designer must use a fair amount of common sense when laying out coolant circuits to avoid unnecessarily expensive molds.

The layout of a circuit is often complicated by the fact that the cooling channels must not be drilled too close to any other hole in the same mold plate. The mold plate has several holes or recesses, to fit ejector pins, support pillars, guide bushings, sprue bushing, cavity, and core inserts, etc.

To obtain the best possible position for a mold cooling circuit, it is good practice to lay the circuit in at the earliest opportunity in the mold design. The other mold components such as ejector pins, bushings, vents, etc., can then be positioned accordingly.

10.3.1 Mold Temperature Control

The thermoplastic injection molding process requires the rapid removal of heat from the mold cavities, so that the molded parts can be removed from the mold in the shortest time and in a condition that the parts meet the quality control requirements.

The mold temperature control system includes the mold, the cooling channels, the different mold cooling systems used in the mold design, the type of fluid with adequate capacity for its circulation, and the method of temperature control.

Predicting the best temperature conditions for a given mold and thermoplastic material is neither possible nor necessary. In many applications there will be several different temperatures maintained for different mold components to meet the quality control specifications. These process settings should be evaluated to select the best balance between economics and part quality.

The mold cavity surface temperature is measured at the beginning of the molding cycle, for example 140 °F.When the hot thermoplastic melt is injected into the mold cavity, the mold temperature increases to 160 °F. At the end of each molding cycle, the mold temperature decreases to 140 °F. A constant mold temperature means that the amount of heat removed per shot by the total cooling system is the same as the amount of heat provided by the hot thermoplastic melt. Mold temperature fluctuations will affect the dimensional control of the molded part, warp age, flashing, surface finishing, and reduce physical properties.

The mold cavity reaches its maximum temperature very quickly and the mold cooling stage of the cycle is used to reduce this temperature to the base operating temperature. This rate depends on the temperature differences, the area of the cooling surfaces in the mold and in the cooling channels, the transfer rates of the heat from the thermoplastic melt to the thermoplastic/ metal interface through the metal and through the metal/water interface. The heat removed by the mold and radiated into the operating molding area is relatively constant.

It is important that a mold cooling system produces a uniform temperature over the entire surface of the mold cavity at the same level as the cooling channels.

It will remove heat from the thermoplastic melt at the highest possible rate consistent with the quality and properties required in the molded part.

10.3.2 Factors Affecting Mold Cooling

The mold temperature is affected by several thermoplastic injection molding process factors related to mold cooling:

- Thermoplastic material (process melt temperature, crystallization rates, modulus of elasticity)
- Part wall thickness, size, complexity, dimensional control, and finish
- Shot weight, process automation, cooling time
- Mold base, cavity, and core material
- Size and shape of the mold, cavity, and core
- Efficiency of mold cooling systems
- Size and location of cooling channels
- Velocity, capacity, pressure drop, and temperature of cooling fluid
- Operating ambient conditions (temperature, moisture, and air flow)

10.3.3 Mold Heat Transfer Methods

There are three methods for transferring heat in the injection molding process: radiation, convection, and conduction. The hot thermoplastic melt from the plastifying unit nozzle is transferred into the mold sprue bushing. The heat from the thermoplastic melt moves by convection through the polymer until it reaches the cavity surface of the mold. The heat is then conducted through the mold cavities to the mold cooling system and the cooling channels. The heat is then transferred to the cooling fluid. A substantial amount of the heat reaches outside the mold surface, where the heat is lost by radiation.

Of the heat added by the plastifying unit to the thermoplastic melt in the injection molding process, approximately 60% is removed by the mold; however, some heat is left in the molded parts after they are removed from the mold cavities after ejection. Approximately 35% of the heat is removed by radiation from the mold and 25% is removed by the cooling fluid that controls the mold cavity surface temperature. The percentages vary, depending on the thermoplastic material, melt process temperature, mold temperature control efficiency, molding cycle, molded product wall thickness, application requirements, size and complexity of the product design.

These basic principles lead to very simple procedures for designing efficient mold cooling systems.

- Place the cooling channels at a proper distance from the mold cavity surface
- The minimum cooling channel center distance to be three to four diameters in length
- Do not use small diameters for cooling channels, specify 0.4375 in diameter minimum
- Cool directly in the cavity and core inserts
- Cool auxiliary mold plates if required
- Drill through cooling channels and use pipe plugs
- Be sure that the Reynolds flow will occur throughout the mold. The Reynolds number should not be less than 3,500
- Treat the cooling channels with electroless nickel or equivalent. If not possible, clean them regularly
- The cooling fluid should be a blend of distilled water and special corrosion resistant additive (25% minimum to 65% maximum) so that no scale deposits are found in the cooling channels.

10.4.1 Mould Design

Design Considerations for Injection Molds

The main parameters for the design of a thermoplastic injection mold are: type, size, number of cavities, tolerances, runner layout, gating, venting, parting line, ejection system, surface finishing, steel hardness, and mold cooling among others. The geometrical design of an injection mold, the type of resin, the dimensional tolerances of the product, the part quality, and the volume of part production influence the selection of the steel for the mold because of considerations involving cavity forming and difficulties in heat treatment. Too great a difference in the wall thicknesses of mold cavity inserts necessitates greater care during heat treatment, because the time to heat the thickest wall section uniformly may result in over heating the thinnest wall section. Quenching from high temperatures, cracking, or distortion may occur where a thin section adjoins a thick section.

Injection mold design is also important from the standpoint of service performance.

If mold walls are made too thin, excessive elastic deflection and even cracking can result from service stresses. Overcoming excessive mold deflection that results in flashing problems, dimensional control problems, poor part surface finishing, and incomplete molded parts can only be accomplished by increasing the wall section size of the mold.

It is of extreme importance that any injection mold be designed and built by a qualified mold maker to the exacting standards demanded by the industry.

Typical mold development procedures are as follows:

- The product design has been completed and approved for molding
- Mold planning process, where the product designer, tooling engineer, process engineer, mold designer, mold builder, and resin supplier's technical
- representative review the needs of the product and provide recommendations for the design and construction of the mold
- Development of a preliminary mold design proposal is the responsibility of the mold designer
- Review of the mold layout proposal by the product designer, tooling engineer, process engineer, mold designer, and purchasing, recommending mold changes if needed and providing authorization to finalize the mold design

- Completing the mold design details
- Reviewing the final mold design by the product designer, tooling engineer, process engineer, mold designer, and mold builder
- Construction of the mold
- First molding run evaluation to produce samples at the mold maker's shop, end user tool engineer and process engineer should be present.
- Inspection and documentation of all product samples whether they meet
- print dimensions (end user)
- Debugging of the mold if needed
- Approval of molded products and pre-production run (mold maker's shop)
- Surface treatment and polishing of the cavities and cores.

By following the mold considerations and criteria, the new mold that designed for the product shown in figures below. It designed by CATIA program for mechanical design.

10.4.2 Types of Steels Required for Injection Molds

This section provides information on different steel compositions available to manufacture molds used to produce thermoplastic injection molded products.

These steels constitute the most commonly used types of materials in the construction mold industry. Other materials such as beryllium-copper, cast aluminum alloy, forged aluminum alloy, cobalt-nickel alloy, and kirksite are also used, but to a lesser extent.

Steels are the workhorse of materials used in molds. No other materials offer comparable versatility for product applications. Steels are produced in the greatest variety of forms and finishes, have strengths ranging from 30,000 psi to over 300,000 psi, and can withstand a range of temperatures from cryogenic up to 2,000 °F

10.4.2.1 Major Steel Families

Because of the great range of steel types, properties and applications, steels are categorized into many families based on the chemical composition, heat treatment, surface finishing, critical properties (mechanical, thermal, corrosion resistance, electrical, etc.), typical processing characteristics, end use applications, and other factors. The major families of steel are the following:

1. **Low Carbon Steels**

SAE 1008, 1010, 1015, and 1025 are the lowest carbon steels selected when cold forming ability is the primary prerequisite. These steels have relatively low tensile strength values. Strength and hardness increase with carbon addition and/or with cold work, but a decrease in toughness or the ability to withstand cold deformation is created. Low carbon steels are nearly pure iron in structure, they are readily welded, but do not machine freely, producing poor smooth finishes.

SAE 1016 to 1025 provide increased strength and hardness and reduced cold forming ability. Carburizing or case hardening is possible in some grades. Increase in carbon gives greater core hardness in thicker sections. Increase in manganese improves the hardening ability and also improves machining. SAE 1025 is used for larger sections or where greater core hardness is needed.

All of these steels may be readily welded or brazed. SAE 1020 is frequently used for welded tubing. These steels are used for forged parts; they usually machine better in the "as forged" condition without annealing, or after normalizing.

2. **Medium Carbon Steels**

The medium carbon steels, SAE 1030 to 1052, are selected for uses where higher mechanical properties are needed and frequent further hardening and strengthening by heat treatment or by cold work is done. The carbon and manganese levels selected increase the mechanical properties required in section thickness or in depth of hardening. The heat treatment preferred for any of the grades over 0.30% carbon allows selective hardening by induction or flame methods.

All of these groups of steels are used for forging, the section being governed by the section size and the physical properties desired after heat treatment. Medium carbon steels are popular for forging and general uses requiring greater strength than low carbon steels.

3. **High Carbon Steels**

Steels SAE 1055 to 1095 are the high carbon types, having more carbon than is required to achieve maximum as quenched hardness. They are used for applications where the higher carbon is needed to improve wear resistance, higher strength characteristics for cutting edges, for springs, and for special purposes.

Selection of a particular grade is affected by the nature of the part, its end use, and the manufacturing methods available. Cold forming is not always suitable and most parts are heat treated before use.

4. **Free Machining Carbon Steels**
5. **Carburizing Carbon Steels**
6. **Hardening Carbon Steels**
7. **Carbon Spring Steels**
8. **Low Temperature Carbon Steels**
9. **High Strength Low Alloy Steels**
10. **Carburizing Alloy Steels**
11. **H-Alloy Steels**
12. **Boron Alloy Steels**
13. **Nitriding Steels**
14. **Low Temperature Alloy Steels**
15. **Tool Steels**
16. **Electrical Steels**
17. **Stainless Steels**
18. **High Temperature Steels**
19. **Ultra High Strength Steels**

10.4.3 The Design of the New Molds

The first mold

The new mold is designed by CATIA program for mechanical design

The figures below (10.7-10.12) show mold parts.

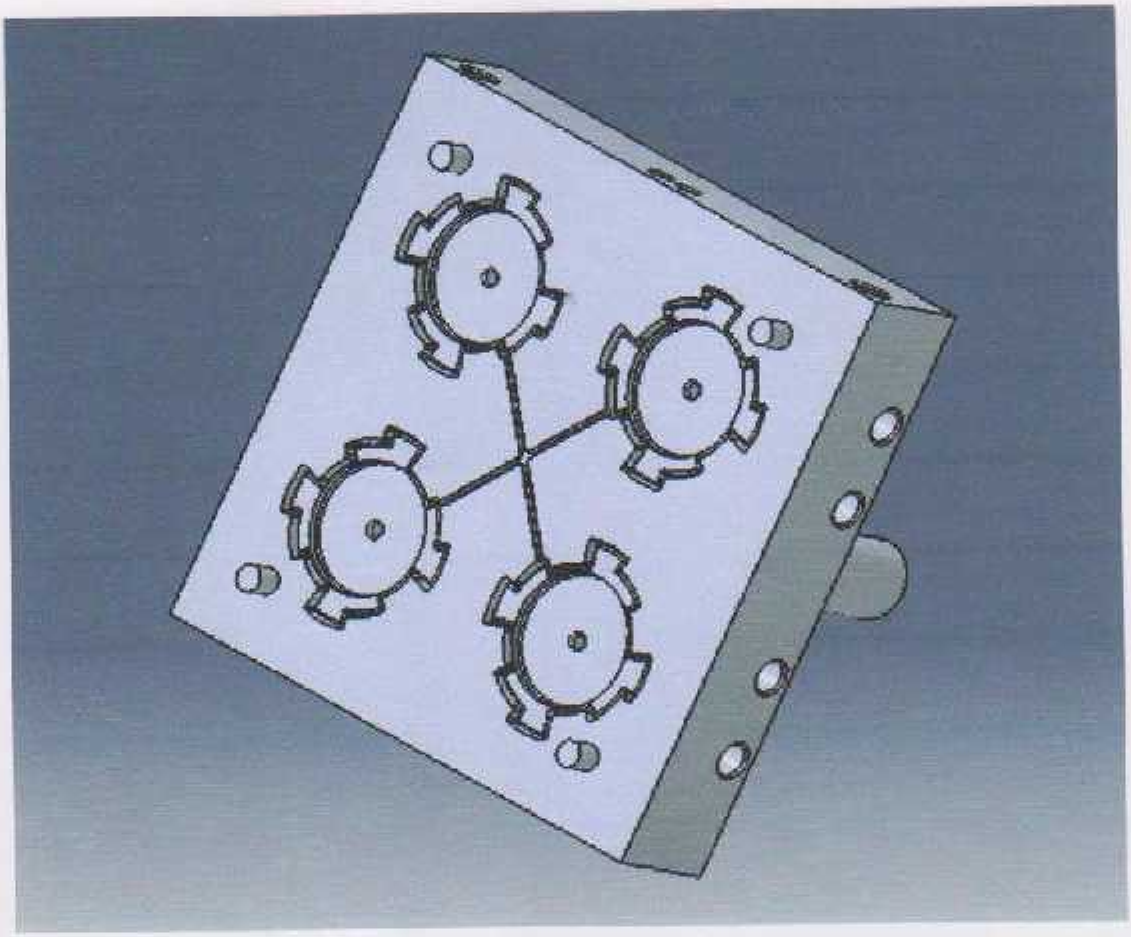

Figure 10.7

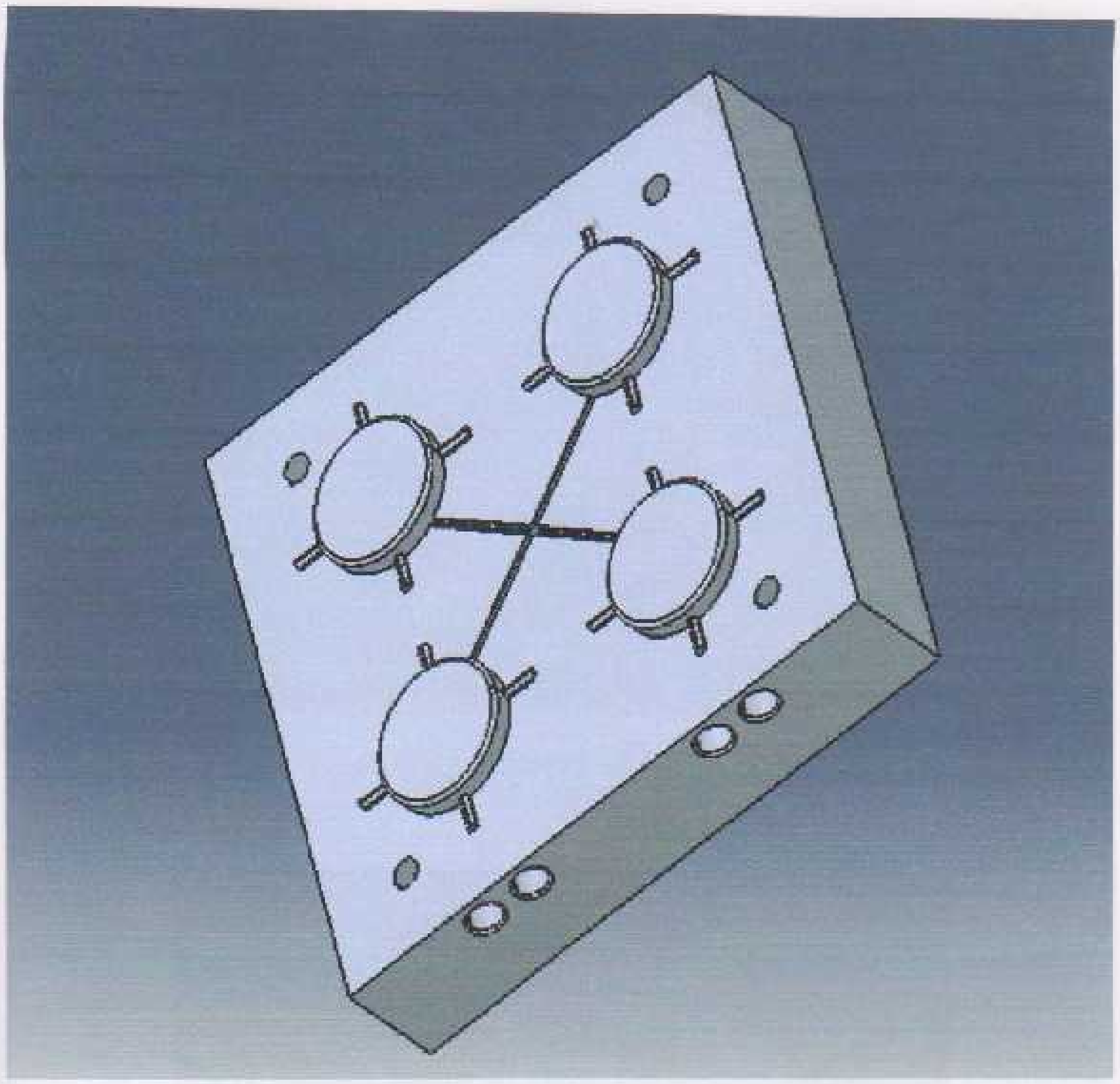

Figure 10.8

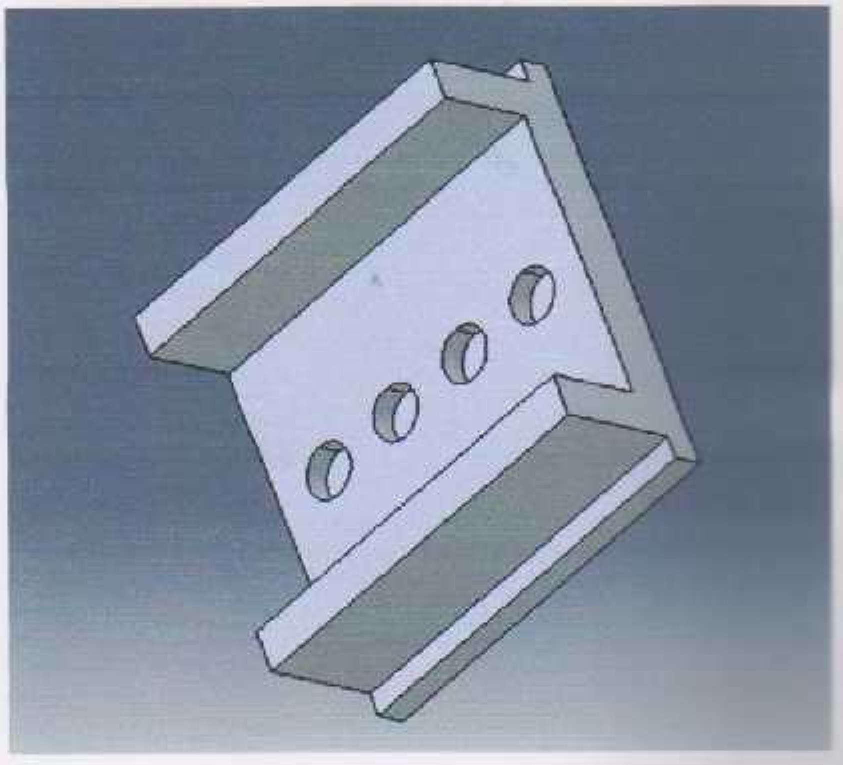

Figure 10.9

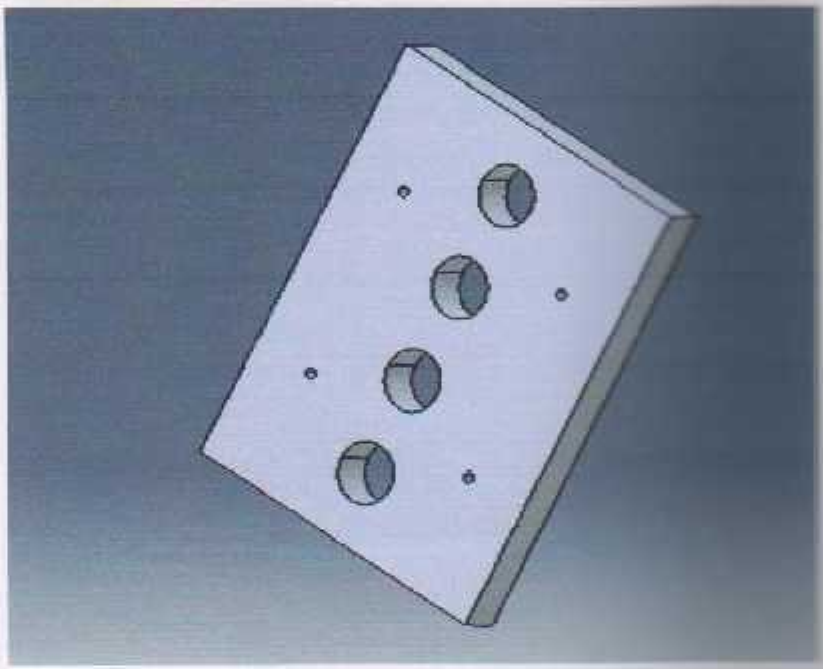

Figure 10.10

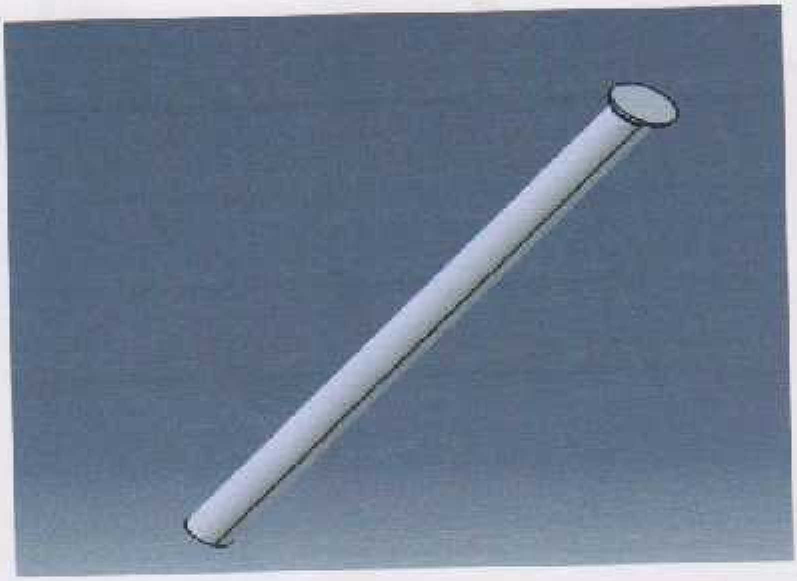

Figure 10.11

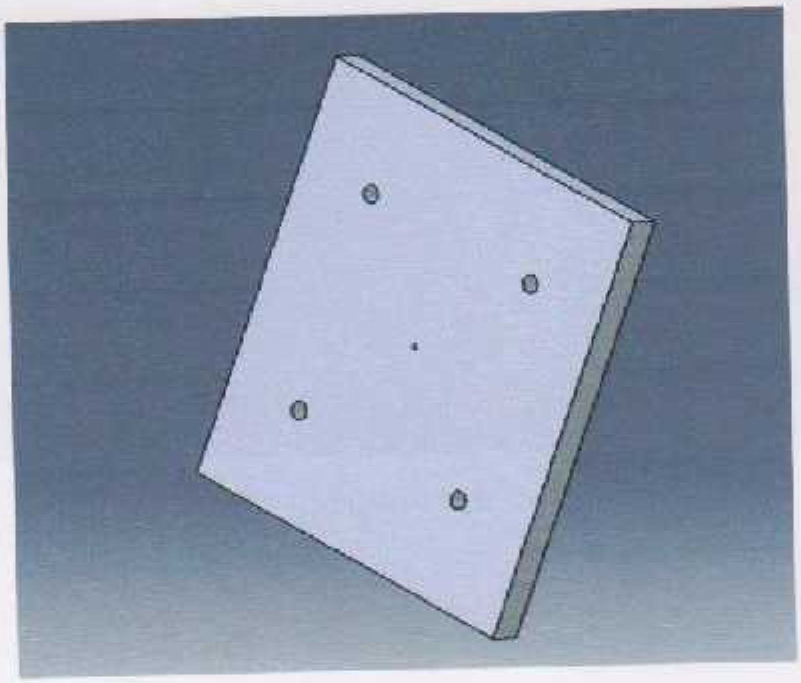

Figure 10.12

Figures 10.7-10.12 Mold Parts

Now all the previous parts are combined together to formulate the final shape of the mold. Figures(10.13-10.16).

Figure 10.13

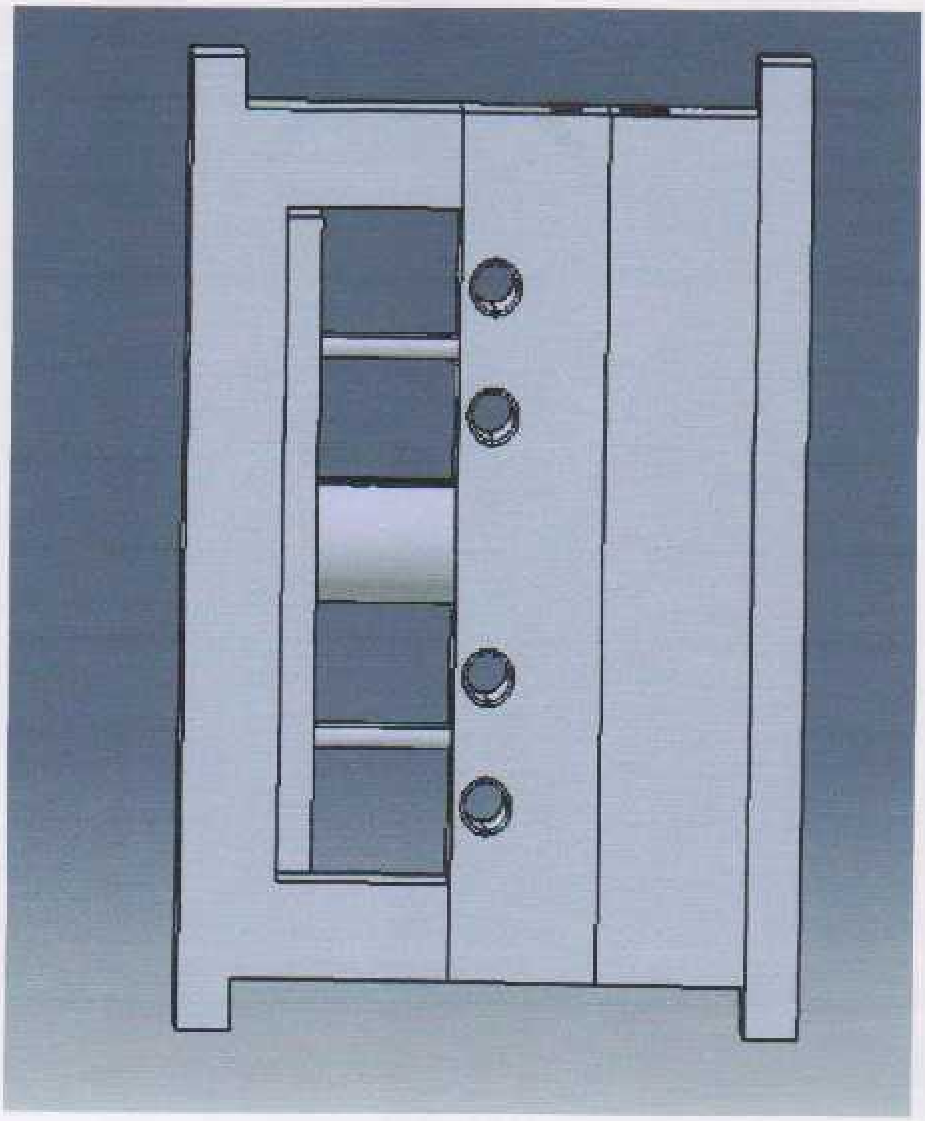

Figure 10.14

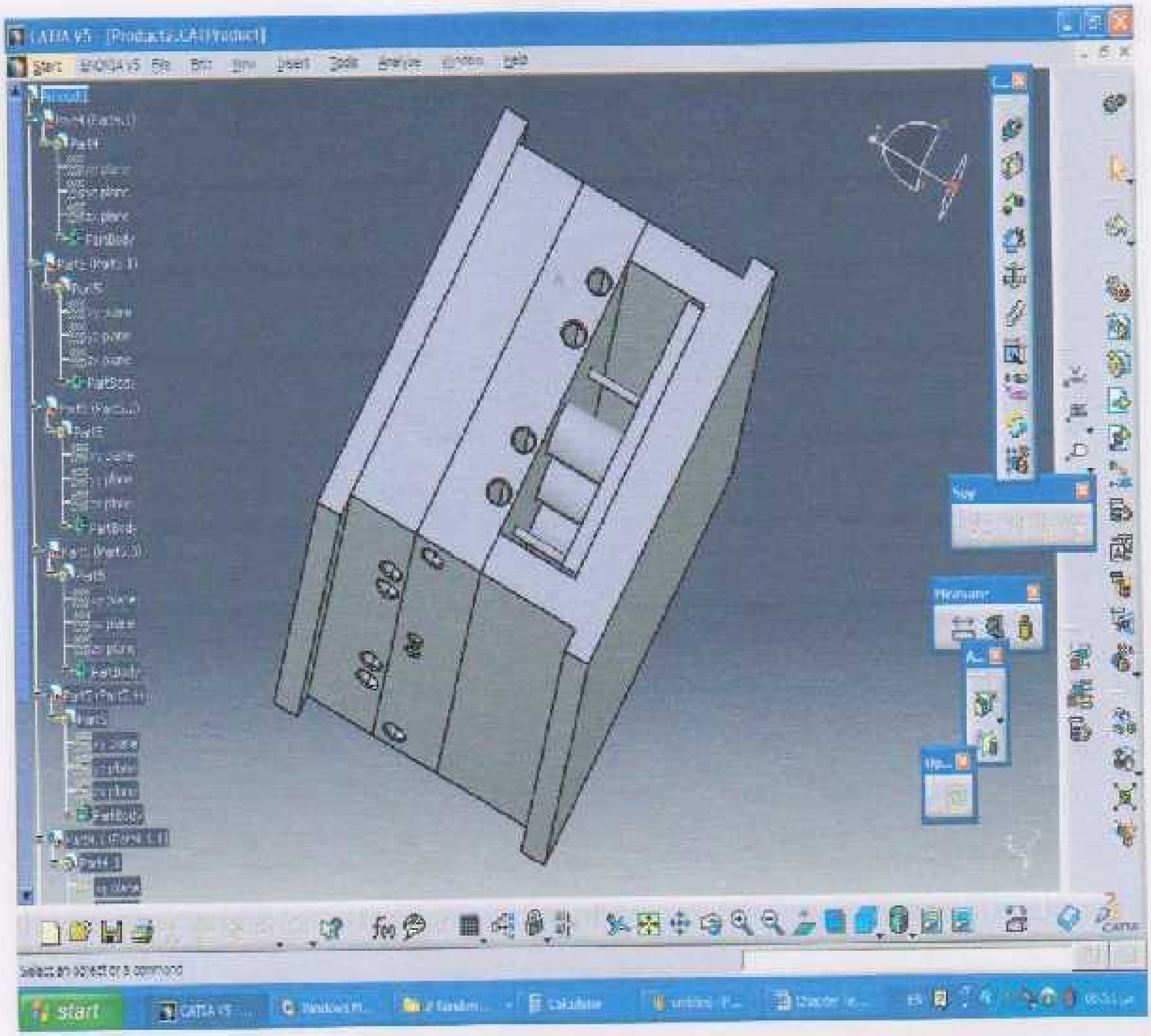

Figure 10.15

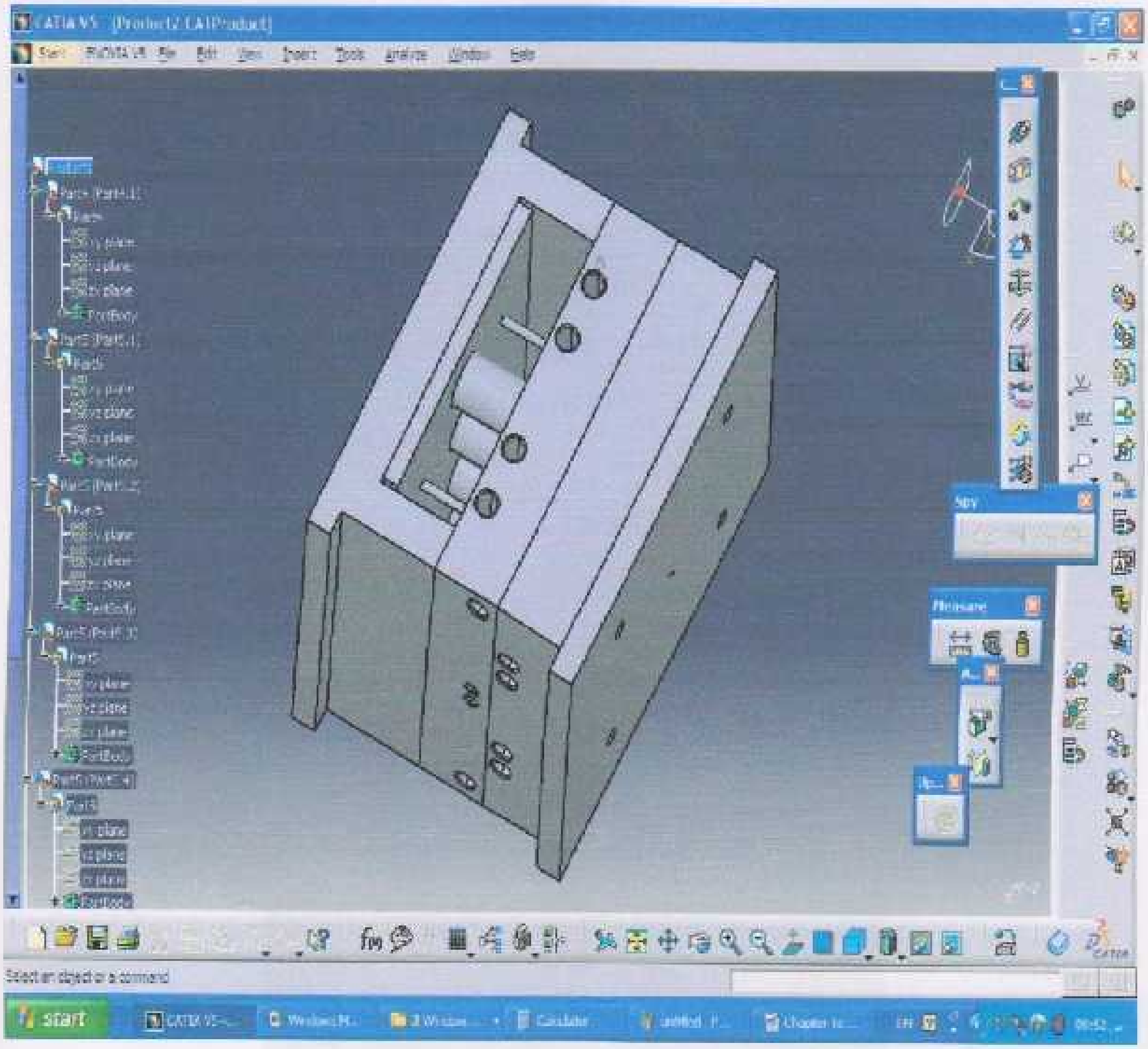

Figure 10.16

Figures 10.13-10.16 Mold Assembly

The second mold

The new mold is designed by CATIA program for mechanical design

The figures below (10.17-10.12) show mold parts:

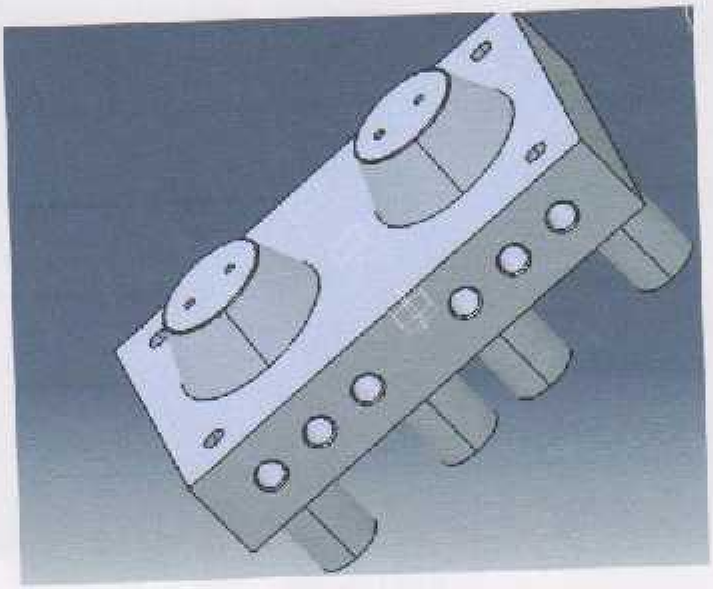

Figure 10.17

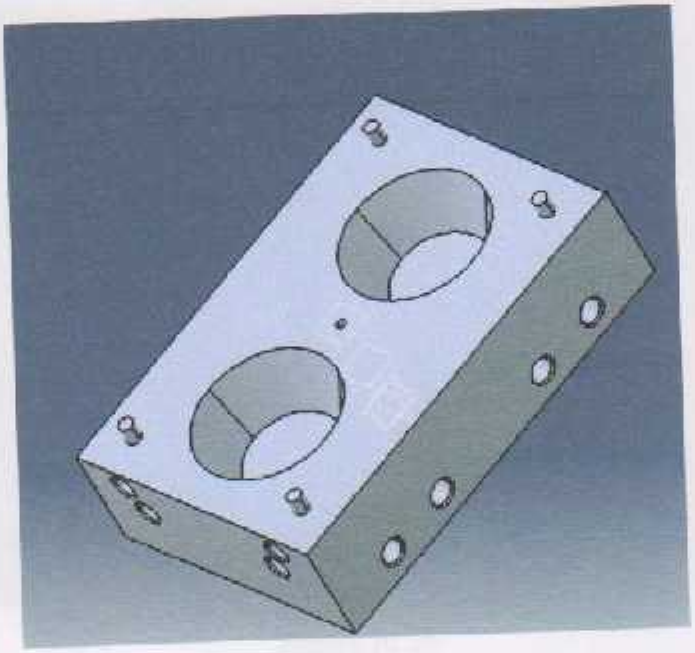

Figure 10.18

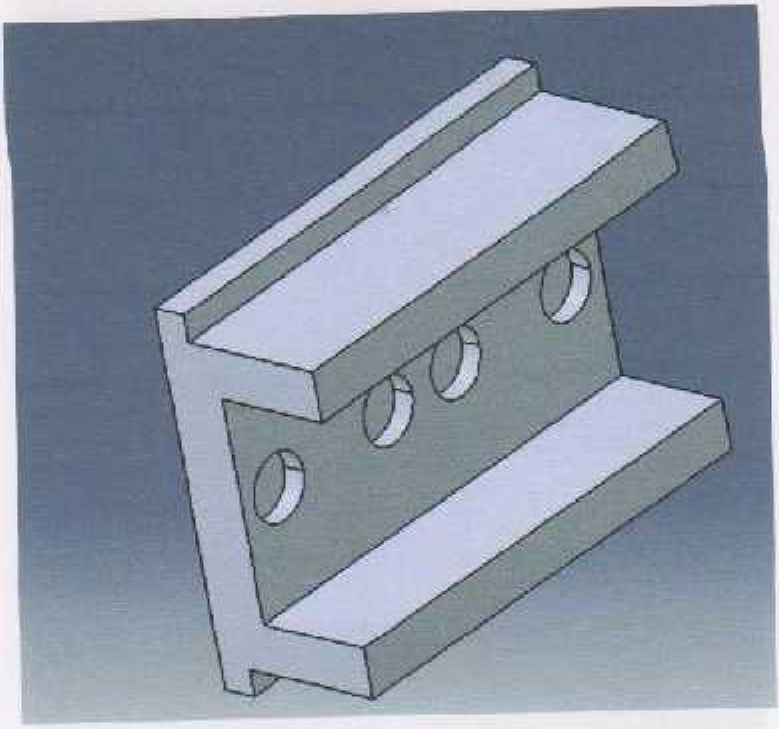

Figure 10.19

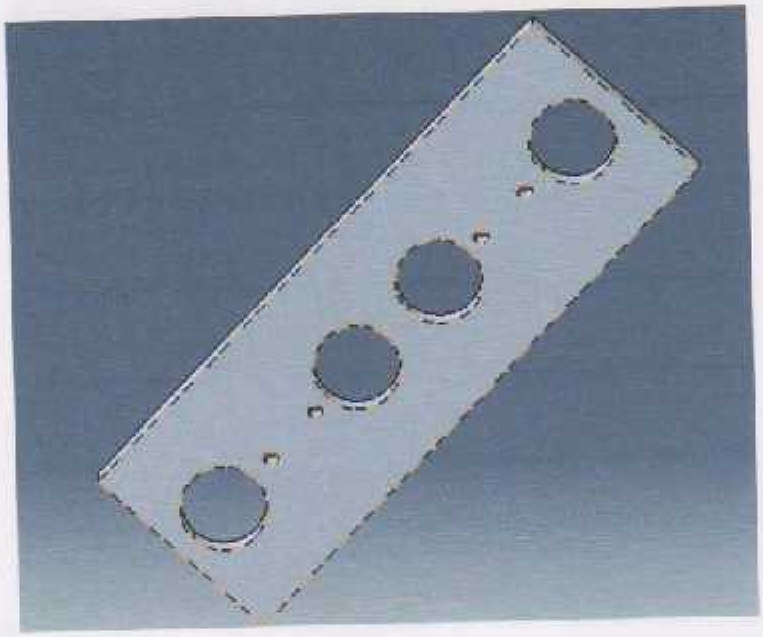

Figure 10.20

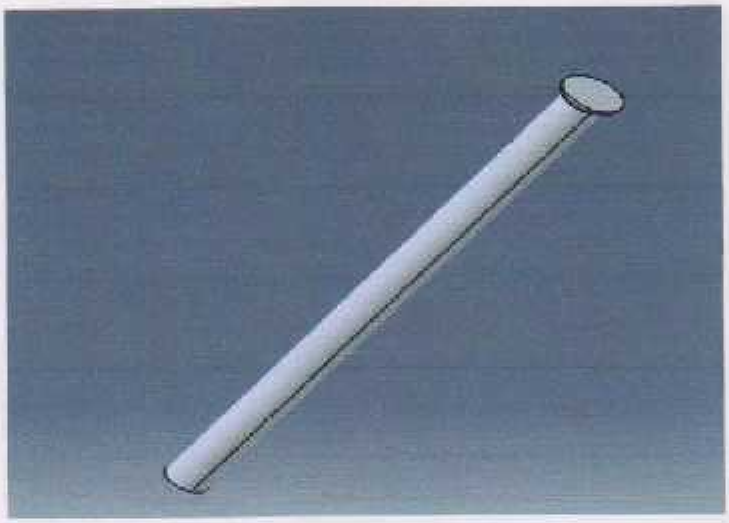

Figure 10.21

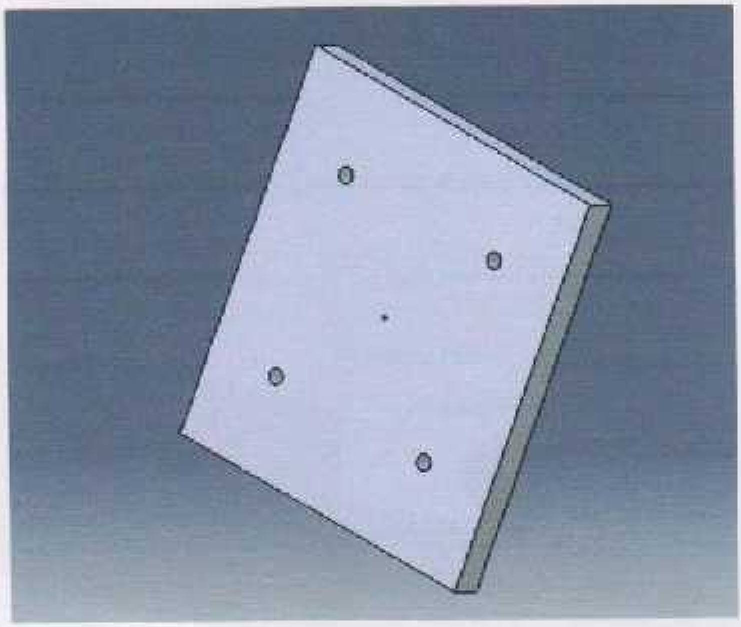

Figure 10.22

Figures 10.17-10.22 Mold Parts

Now all the previous parts are combined together to formulate the final shape of the mold Figure (10.13).

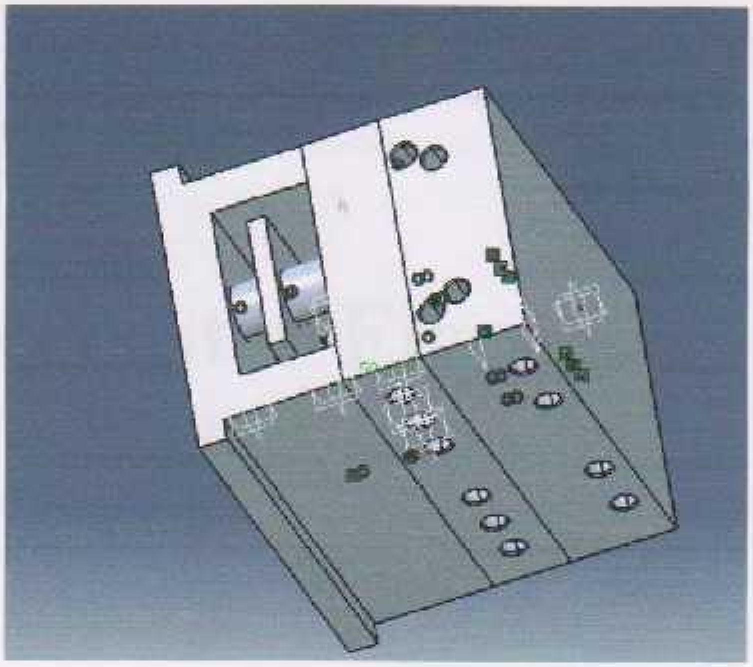

Figure 10.23 Mold Assembly

The mold location in plastic injection machine as shown in figure 10.17

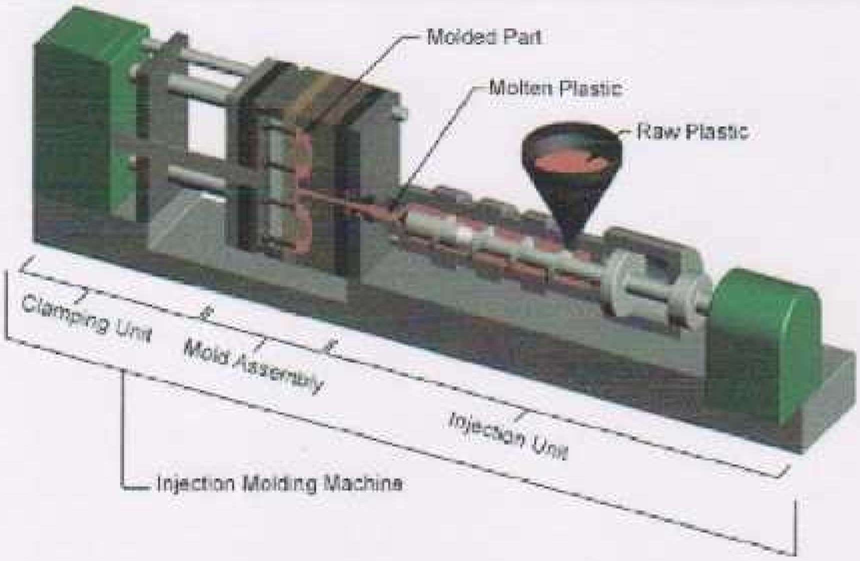

Figure 10.24 Mold Locations in the Machine

Chapter Eleven

Failure and Maintenance

The machine failure and work life have close connection with operation maintenance, so operator must abide the regulation in specification strictly. Machine failure is more than mechanical, oil way and electric failure, these are some failures.

1. Pump motor drives with difficultly

- Power has been shut off: phase voltage is too low, line voltage drops too great, the tip of conductor burn loss, and so forth wither the supply of three phases power is natural, automatic breaker is shut off, the relay to control motor in electric box is close.
- The motor is burnt with burned taste and smoke, find out burnet cause and take measure to change or replace.
- Pump locks, repair or change pump.

2. Oil way has no pressure

- Sundries choke damp orifice of the proportional valve.
- Electromagnetic plug of the proportional valve loosens.
- Impurity or scrape iron chocks oil retain hole of the proportional valve.
- Proportional valve locks , remove and clean valve and replace seal ring to prevent impregnating.
- The height of oil level is lower than oil absorber, so pump has no oil to absorb; supply enough hydraulic oil.
- Some directing valves leaks too sharp or inner spring breaks, repair or replace the valve.
- Hydraulic oil is not clean and oil taking filter is choked, clean filter and replace hydraulic oil.
- Pump damaged, repair or replace pump.
- Some valve cannot switch and seal ring of cylinder is damage, remove and clean the valve and replace seal ring .

3. **Unable to clamp**

- The connection of stroke switch for safety door loosens or damage, safety door does not close, the contact of low pressure dwelling is adjusted improperly, join the connection or replace the stroke switch, check the cooperation of stroke and switch for safety door, adjust the contact at proper position.
- Clamping magnet valve locks or plug of it loosens low pressure and low speed knob turns to low, clean valve, fix plug of magnet valve turn up concerned knob.
- Hydraulic system has no pressure, repair according to previous note.

4. **Unable to inject**

- Injecting pressure and speed is too low, turn up injecting pressure and speed.
- The heating temperature is too low
- Muzzle chocked
- Remove muzzle for heating and cleaning.

- The connection of combined switch for injection loosens or damage; injecting time and relay time too low; check and repair; adjust time

5. **Unable to plasticizing or its speed is too low**

- Electric ruler position; adjust time.
- Back-pressure turns too high; readjust it.
- The heating temperature of the material barrel is not enough and make hydraulic motor aver load; check and replace heating ring.
- Hydraulic motor damage and axis locks;
- Plasticizing pressure is too low; turn the pressure 1 Mpa higher than plasticizing pressure.

6. **Material could not forward even screw turning**

    - There is not enough cooling water at feed port; there is material in feed port; adjust flooding quantity; take out plastic block.
    - There is no material in feed at feed port; charge material.

7. **The level of the hydraulic oil is too low**

    - Pump pressure is too high; adjust according the specifications.
    - Pump damage or the viscidity of hydraulic is too low; check pump and quality of oil.
    - Shortage of oil in oil-box; put on enough oil.

8. **Semi-automatic is out of order**

    - The automatic circulation is achieved by stroke switches and time relays controlling hydraulic elements. If each act in natural method, it is likely because stroke switches and time relay have not work. Check and repair the failure control element refer to electric and hydraulic principle diagram.

9. **Automatic method is out of order**

    - The products have not pass through photoelectric switches after moulds opened.
    - Photoelectric send or receive are in poor position.
    - Photoelectric equipment is damages.
    - Photoelectric signal is too strong.

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Appendix A

Table A.1 A Commonly plastic materials are used

Material name	Abbreviation	Trade names	Description	Applications
Acetal	POM	Celcon, Delrin, Hostaform, Lucel	Strong, rigid, excellent fatigue resistance, excellent creep resistance, chemical resistance, moisture resistance, naturally opaque white, low/medium cost	Bearings, cams, gears, handles, plumbing components, rollers, rotors, slide guides, valves
Acrylic	PMMA	Diakon, Oroglas, Lucite, Plexiglas	Rigid, brittle, scratch resistant, transparent, optical clarity, low/medium cost	Display stands, knobs, lenses, light housings, panels, reflectors, signs, shelves, trays
Acrylonitrile Butadiene Styrene	ABS	Cycolac, Magnum, Novodur, Terluran	Strong, flexible, low mold shrinkage (tight tolerances), chemical resistance, electroplating capability, naturally opaque, low/medium cost	Automotive (consoles, panels, trim, vents), boxes, gauges, housings, inhalors, toys
Cellulose Acetate	CA	Dexel, Cellidor, Setilithe	Tough, transparent, high cost	Handles, eyeglass frames

Polyamide 6 (Nylon)	PA6	Akulon, Ultramid, Grilon	High strength, fatigue resistance, chemical resistance, low creep, low friction, almost opaque/white, medium/high cost	Bearings, bushings, gears, rollers, wheels
Polyamide 6/6 (Nylon)	PA6/6	Kopa, Zytel, Radilon	High strength, fatigue resistance, chemical resistance, low creep, low friction, almost opaque/white, medium/high cost	Handles, levers, small housings, zip ties
Polyamide 11+12 (Nylon)	PA11+12	Rilsan, Grilamid	High strength, fatigue resistance, chemical resistance, low creep, low friction, almost opaque to clear, very high cost	Air filters, eyeglass frames, safety masks
Polycarbonate	PC	Calibre, Lexan, Makrolon	Very tough, temperature resistance, dimensional stability, transparent, high cost	Automotive (panels, lenses, consoles), bottles, containers, housings, light covers, reflectors, safety helmets and shields
Polyester -	PBT, PET	Celanex,	Rigid, heat	Automotive

Thermoplastic		Crastin, Lupox, Rynite, Valox	resistance, chemical resistance, medium/high cost	(filters, handles, pumps), bearings, cams, electrical components (connectors, sensors), gears, housings, rollers, switches, valves
Polyether Sulphone	PES	Victrex, Udel	Tough, very high chemical resistance, clear, very high cost	Valves
Polyetheretherketone	PEEKEEK		Strong, thermal stability, chemical resistance, abrasion resistance, low moisture absorption	Aircraft components, electrical connectors, pump impellers, seals
Polyetherimide	PEI	Ultem	Heat resistance, flame resistance, transparent (amber color)	Electrical components (connectors, boards, switches), covers, sheilds, surgical tools
Polyethylene - Low Density	LDPE	Alkathene, Escorene, Novex	Lightweight, tough and flexible, excellent chemical resistance, natural waxy appearance, low cost	Kitchenware, housings, covers, and containers
Polyethylene - High Density	HDPE	Eraclene, Hostalen, Stamylan	Tough and stiff, excellent	Chair seats, housings, covers, and

			chemical resistance, natural waxy appearance, low cost	containers
Polyphenylene Oxide	PPO	Noryl, Thermocomp, Vamporan	Tough, heat resistance, flame resistance, dimensional stability, low water absorption, electroplating capability, high cost	Automotive (housings, panels), electrical components, housings, plumbing components
Polyphenylene Sulphide	PPS	Ryton, Fortron	Very high strength, heat resistance, brown, very high cost	Bearings, covers, fuel system components, guides, switches, and shields
Polypropylene	PP	Novolen, Appryl, Escorene	Lightweight, heat resistance, high chemical resistance, scratch resistance, natural waxy appearance, tough and stiff, low cost.	Automotive (bumpers, covers, trim), bottles, caps, crates, handles, housings
Polystyrene - General purpose	GPPS	Lacqrene, Styron, Solarene	Brittle, transparent, low cost	Cosmetics packaging, pens
Polystyrene - High impact	HIPS	Polystyrol, Kostil, Polystar	Impact strength, rigidity, toughness, dimensional stability, naturally translucent, low cost	Electronic housings, food containers, toys
Polyvinyl Chloride -	PVC	Welvic,	Tough,	Electrical

Plasticised		Varlan	flexible, flame resistance, transparent or opaque, low cost	insulation, housewares, medical tubing, shoe soles, toys
Polyvinyl Chloride - Rigid	UPVC	Polycol, Trosiplast	Tough, flexible, flame resistance, transparent or opaque, low cost	Outdoor applications (drains, fittings, gutters)
Styrene Acrylonitrile	SAN	Luran, Arpylene, Starex	Stiff, brittle, chemical resistance, heat resistance, hydrolytically stable, transparent, low cost	Housewares, knobs, syringes