



Universidad Popular Autónoma del Estado de Puebla

Centro Interdisciplinario de Posgrados

e Investigación

Escuela de Ingeniería

Maestría en Sistemas Integrados de Manufactura y Estrategias de Calidad

ADVANTAGES OF THE DESIGN AND MANUFACTURE OF A BLOW MOLD

Tesis que para obtener el Grado de Maestro

En Sistemas Integrados de Manufactura y Estrategias de Calidad

Presenta

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Puebla, México.

Noviembre, 2017



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Maestría en Sistemas Integrados de Manufactura y Estrategias de Calidad

Se aprueba la Tesis:

Advantages of the Design and Manufacture of a Blow Mold

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## ABSTRACT

### THE KEY WORDS

MOLDS, EXTRACTION, BLOWING, COMPUTER NUMERICAL CONTROL, PACKAGING, PLASTICS, MANUFACTURING, COMPUTER AIDED DESIGN, COMPUTER AIDED MANUFACTURING.

The first chapter includes theoretical and specific information on blow molds, and a viewpoint that gives us the situation of Mexico in the area of plastics.

In chapter 2 it is proposed how the computer design of a blow mold should be carried out, starting from the design of the required plastic bottle.

The third chapter contains information regarding the companies that manufacture in Mexico, and the way in which the total cost of the blow mold is calculated.

Master thesis contains 80 pages, 33 figures, 19 tables, 35 sources.

## **Introduction**

### **Contribution of research**

This document seeks to provide insight into the current state of plastic packaging, focusing on plastic bottles manufactured by blow molds. It tries to expose the forms of execution, method of manufacture and the possibility of production. To solve this task a small design, systematic figures, and process representations were chosen, which make it easy to understand the manufacturing process of a "Plastic blow mold." It must be clarified that the word packaging is used here as a concept General, comprising container, box, bottle, bag, etc. Products that are manufactured thanks to the blowing of plastics.

### **Problem Statement**

At present most of the problems that the technology aims to solve is to have the adequate means and knowledge to be able to satisfy the demand of plastics. To focus on a specific problem will take as an example the need for a customer who needs a body to pack a liquid so it can be transported and sold.

The client will seek to solve their needs in the existing industrial means so that they can supply them with such containers, their need will be solved with: "the manufacture of exclusive packaging for your business."

The problem will be solved with the manufacture of a blow mold with the characteristics and attributes that the client requires for its exclusivity.

### **Justification**

The technological development that exists today allows us to create a "blow mold" that meets the needs of a small or medium-sized company. In this way these companies will be able to create their plastic bottles at a low cost and with features they need, giving them a level of customization according to the needs of each product. Granting them a competitive advantage. In order to successfully solve this problem, a "blow mold" manufacturing project will be developed. The blow mold will be built with CNC machines are high-tech working tools, which have reduced the delivery time in mold machining jobs, these machines are operated with the help of CAD-CAM. Providing a competitively high level of quality. Remembering that this type of plastic packaging is also part of the image of the product.

## ADVANTAGES OF USING THE BLOW MOLD.

- Variety of products.
- Multiple production methods.
- Automation of blow molding.
- Environmental impact.
- The process manufactures articles with full endings and without necessity cuts.
- The high quality of the neck model provides precision in dimensions and finishes "for children"
- High productivity.

### **General objective**

Represent in the project the manufacturing process necessary for the manufacture of blow molds through the use of CAD-CAM technology together with the machining of a CNC machine.

### **Specific objectives**

Generate the blow mold in specialized CAD software. Get the knowledge of conventional machine tools and CNC machinery. After obtaining the 3-dimensional design, the CAM software will be used. Which will provide us with the necessary coding to manufacture a blow mold using a computerized numerical control machine.

# CHAPTER ONE

## THE PLASTIC INDUSTRY IN MEXICO AND INTRODUCTION TO BLOW MOLDS.

### 1 Plastic industry in Mexico

This chapter addressed the importance of the plastic industry, and the role of the use of polymer mold by injection at an industrial level.

#### 1.1 Plastic industry.

Plastic material is the material of modern society, thanks to this material technological innovation has been so important in industries such as automotive, packaging, construction. However, the total transformation of plastic in Mexico, a year represents only 2% of total global production, so it is an industry with great potential to exploit in our country. As shown in Figure 1.1

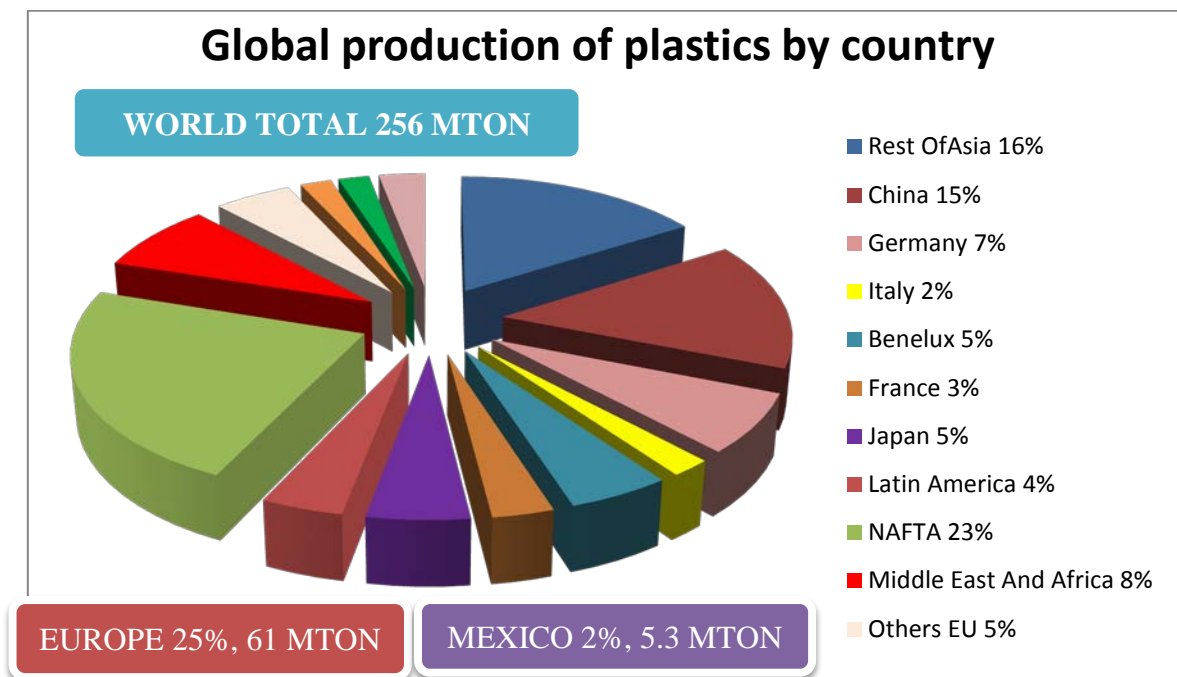


Figure 1.1 Global production of plastics by country and region [10] [Conde, 2012]

The current situation of the plastic processing industry in our country lies in the backwardness of technology, entrepreneurs who are not willing to invest in favor of the renovation of machinery, or investment for the training of personnel in this industry works. This situation can be deduced from the following figures:

In Mexico, according to Conde, there are 15 companies producing plastic resins for the generation of plastic products. 90 companies. Manufacturers of molds 50 companies registered in ANIPAP (National Association of Plastic Industry), with capacity and skills to develop a mold of injection of good quality. Marketing of plastics and resins 250 companies. Plastic products manufacturers 2700 companies, 55% of the total of these companies handle the injection process, 1,485 companies [10] [Conde, 2012] . With this data the companies of plastic articles have a weakness for the small number of companies that are dedicated to a supplier of resins, molds or machinery.

The final consumer of plastic products is divided into 4 major items, home, industry, government and products for export. Figure 1.2 shows the segments of the plastic industry in Mexico.

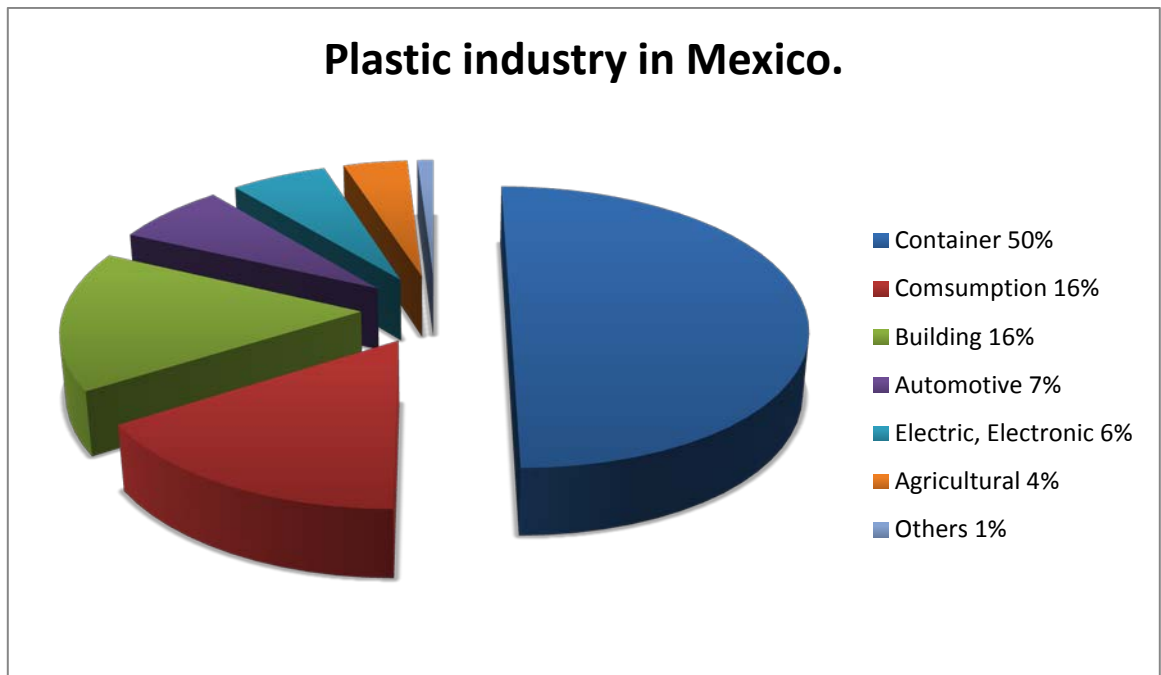


Figure 1.2 Consumption of plastic by industry [10] [Conde, 2012]

When talking about the plastic industry, we can not ignore the question of sustainability and recycling, an issue that becomes important in our country, since only 12% to 14% of the total consumption is recycled, the industry's little exploited competitive advantage Of plastic.

The processes that exist for the transformation of the plastic are: extrusion, injection, blowing, rotomolding, compression, etc. This dissertation focuses on the plastic injection process that in the national industry represents 55% of the total.

Companies engaged in the processing of plastic 1,485 companies engaged in the injection process, accounting for 27% of the total volume of plastic processed[10] [Conde, 2012].

Figure 1.3 shows the importance of the injection molding industry in Mexico. As one of the industries with the largest number of companies dedicated to the transformation of plastic, it is the second industry to contribute the total volume of processed plastic. [10] [Conde, 2012]

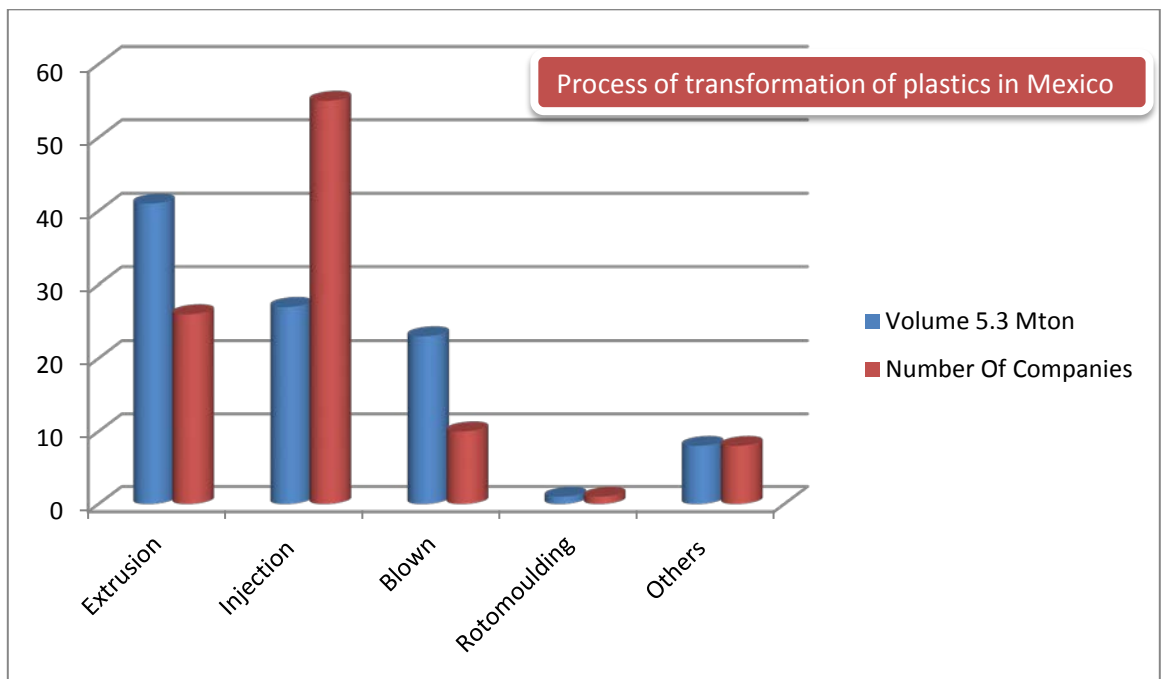


Figure 1.3 Processes of plastics transformation in Mexico 2011. [10] [Conde, 2012]

Currently there is a shortage of tooling producers for the plastic processing industry, compared to the number of companies engaged in the injection process in total 1,485 registered companies. This problem is illustrated in the amount of tools and machinery that this industry has to import year after year.

Derived from this situation in the professional practice have been found metalworking workshops that have the possibility to present developments at low prices of injection molds, without having experience in the design of blow molds and also in the design of blowing systems. The practices that are carried out are to

reproduce existing molds, generally developed outside of Mexico, without taking into account aspects of design. This situation results in blow molds with problems to produce the final product, due to excess burr, or incomplete pieces.

## **1.2 Mold production in Mexico.**

Mexico imports more than 2,600 million dollars in molds, dies and tools. At present, this sector is one of the ones that offers the most opportunities for the metal-mechanic workshops that want to migrate to this area. Training the right employees is one of the great challenges.

According to the Innovation Agenda of the National Council of Science and Technology (Conacyt), Mexico presents business opportunities in the supply chain for 16 metal-mechanical processes in the automotive, auto parts, electrical, consumer electronics and household appliances industries. "The seven main metalworking processes in Mexico with the greatest opportunities are stamping, casting, forging, machining, injection of plastics, casting of pressure molds, molds and dies," the document states.

However, Mexico imports more than \$ 2.6 billion worth of molds, dies and tooling, because there is no comparable local industry from which to purchase, according to an analysis by ProMexico's Business Intelligence Unit. In fact, according to the Ministry of Economy, more than 90% of the tools used in Mexican industry are imported, mainly from the United States (43%), South Korea (10%), Canada (9.3%), China (8.4%) and Japan (8%). On the other hand, in the country there are 230 manufacturers of machinery and equipment for the metalworking sector (most related to molds and dies); There are also 335 manufacturers of forged and die-cut metal products and 725 manufacturers of metal coatings and finishes, according to updated data from the National Statistical Directory of Economic Units (Denue) of the National Institute of Statistics and Geography [28] Manufacturing companies (Inegi). <http://www.beta.inegi.org.mx/>

Although many industrialists, particularly SMEs, do not know about financing that favors their development, modernization and innovation, the federal government offers programs of support through instances such as the Ministry of Economy, the National Institute of Entrepreneurs and ProMéxico.

Molds for the automotive industry Recently, the National Council of Science and Technology (CONACYT) and the Ministry of Economy (SE), through the Sectoral Fund for Innovation Ministry of Economy-Conacyt launched a call for innovative development of suppliers in the automotive sector.

The objective is to promote integration and domestic production in the automotive sector's value chains in the country, through the development of a pilot project that involves the technological assimilation of tooling (molds and dies), molds and dies, preferably for Processes of stamping, forging, casting and injection of plastics, as well as the documentation of said pilot project with the purpose of identifying the value of replicating the model for the development of the national supply and the integration of these suppliers in the chain of Value, the Conacyt statement said.

In this sense, an ATKearney study on automotive technological development and the current situation of technological development in Mexico refers to the need for competences in geometric tolerances, 3D modeling (OEM) design systems; Specialists in molds and dies; Technicians with knowledge of CNC machines and automation engineers, among others.

### **1.3 Conventional Machine Tools of the Mold Factory.**

The parallel or mechanical lathe evolved from the old lathes when it was incorporated new equipment that managed to turn it into one of the most important machine tools that have ever existed. However, today this type of lathe is being relegated to perform minor tasks, to be used in apprentices workshops and maintenance workshops to carry out specific or special jobs. For serial and precision production have been replaced by copying lathes, revolver, automatic and CNC. Proper handling of these lathes requires the expertise of highly qualified professionals, since the manual handling of their carriages can often cause errors in the geometry of the turned parts Several types of lathes are currently used in the machining industry, whose application depends on the number of pieces to be machined per series, the complexity of the parts and the size of the parts.

A milling machine is a machine tool used to perform machining by chip removal by the movement of a rotary tool with several cutting edges called a milling cutter. In traditional milling machines, the part moves by bringing the zones to be machined to the tool, allowing to obtain diverse forms, from flat surfaces to more complex ones.

Radial drills of the stationary type, horizontal spindle, and universal head type are designed to accommodate large parts where the cost of preparation is an important factor. These machines are arranged so that the spindle can be positioned to drill anywhere within the reach of the machine by means of the movements provided by the head, the arm and the rotation of the arm around the spine. Some types of radial drills, as well as horizontal portable machines, are arranged so that the whole machine can be moved to the part rather than the part being raised to the machine.

Conventional machine tools still form an important part of the mold factory despite having state-of-the-art CNC machinery. The theory that exists of machined differs in many cases within the practices of the same reason why the machine operator has to improvise and apply manual techniques in the development of its work.

#### **1.4 Plastic containers and packaging.**

Among the tasks of using a packaging is facilitating the industrial processes of filling and closing, the easy opening of a plastic bottle. It is important to be able to provide a durable, lightweight and economical and non-tarnable plastic bottle, the containers that have to make the return path from the consumer to the producer, through the merchant not only reloads on the transport routes and demand a valuable space Are in no case rational, since they must be administered, stored, transported, cleaned, controlled and classified. A careful calculation shows that returnable packages are always more expensive than single use containers. The search for "optimal" packaging that meets the maximum of the requirements imposed, leads to commitment. The multiplicity of these tasks, the realization of which was no longer possible with simple means, has led to the development of an extensive packaging industry. This development was supported by the introduction and the increasing use of plastics, whose wide possibilities of elaboration opened many new ways. The proper use of the plastics leads in most cases to a modification to the shape of the package, which can then be configured optimally. The change of traditional packaging materials by plastic, without adaptation to the particularities and behavior of the new material, is almost always an incomplete and unsatisfactory solution.

##### **1.4.1 Hollow bodies for packaging**

The concept "Hollow bodies for packaging" covers containers with capacities between approximately 1 ml up to about 800 lt. In the form of blisters as well as tubes, tubes, bottles, drums and barrels, containers called

"reverse conicity" can also be counted here. In Germany, the maximum limit for the concept "bottles" is 2 lt. According to the usual distribution in statistics, in contrast in the USA stands at 1 gal = 3.84 lt. The hollow bodies with capacity up to 5 lt. They are almost always packaging without return, for greater volumes increases the percentage of packages with return. [6] (Sánchez Valdés, Fernández, Oliverio, Flores, 2003.)

### 1.5 Extrusion and blow molding.

It is the oldest and still most important procedure for manufacturing hollow bodies of blown plastics (better: blow molding) and its beginnings go back to the year 1938 obtaining already a great expansion for packaging purposes from 1950. For the extrusion molding And blowing, a plastic thermoplastic is first plasticized in an extruder, from which it comes out in the form of a hose, generally vertically and more rarely horizontally (Fig. 1.4). The hose piece hanging from the extruder nozzle is placed between the Halves of a blow mold and cut below the nozzle upon closure of the mold are stressed portions of the hose protruding from the bottom or sides; these fragments are automatically cut or ejected upon opening of the mold in modern blow molding facilities

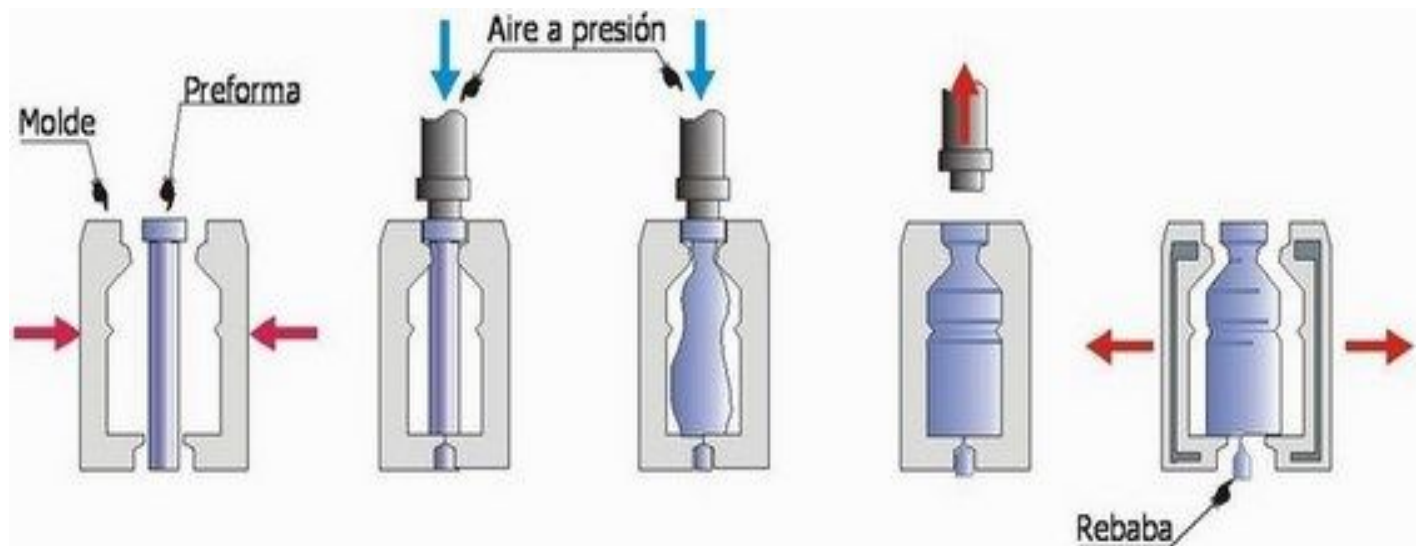


Fig.1.4 Schematic representation of extrusion-blow molding.

A blowing head inserted into the mold by an upper or lower opening (Fig. 1.5) or a hollow needle penetrating transversely into a "runner" blows air at a pressure of 3 to 10 bar inside the hose. Still warm, and therefore plastic. The hose is widened until its surface contacts the outer cavity of the mold, to cool and solidify in contact with the cooled metal. The air overpressure is then eliminated and after opening the mold the hollow body obtained is withdrawn or expelled.

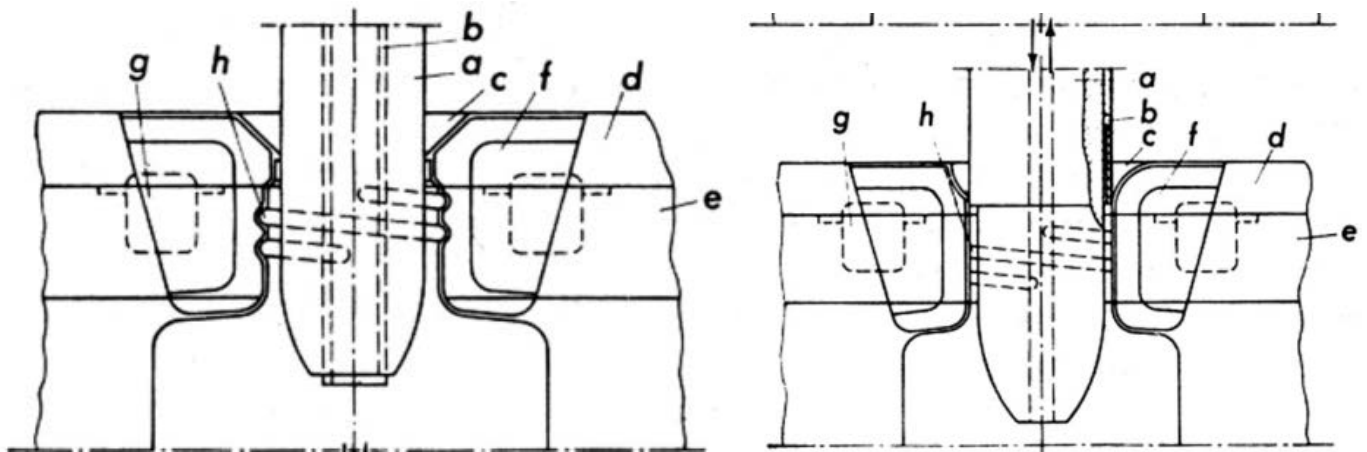


Fig.1.5 Blowing and calibrating chuck of the neck.

The speed of the process is the number of pieces that can be obtained in a mold of this type per unit time, and provided that the extruder has a sufficient plastification efficiency, depends on the cooling rate of the hot plastic. The low thermal conductivity of the plastic, which can not be modified, depends also on the temperature of the material, the hose wall thickness, the mold temperature, and the thermal transfer conditions. Careful construction of the mold cooling system and forced cooling with water maintained at constant temperature (usually +4 and +8 ° C) are therefore very important conditions for cost-effective work. [7] (Tim Osswald, Giménez. 2008).

Another way of increasing the performance, not of the molds, but of the machine, is the feeding of several molds with the same machine (simultaneously and / or successively), which will have to possess a suitably superior power. The extrusion-blow molding or market-offering facilities are very similar in their way of working, although they differ in performance, size and construction. These differences lie for example in:

- The size of the extruder (spindle diameter, drive power, plastification performance, etc.)
- The extruder arrangement (horizontal or vertical cylinder).
- The outlet direction of the hose (vertical in vertical extruders, horizontal or also vertical by means of an angular head in the horizontal extruders).
- The dimensions of the mold-holding plates and therefore of the molds themselves.
- The strength of the closure.
- The number of extruder nozzles usually one or two or rarely more.
- The number of molding stations (usually one or two).
- The number of molds per station (one or two, although they can be up to eight).
- The degree of automation.
- The direction of blowing (from above, down or laterally).
- The type of transport direction from the hose to the blowing station, etc.

In machines where medium and large hollow bodies are to be manufactured, the cooling time is necessarily long, it would be necessary for the next hose part to cool for a few minutes in the nozzle before it can be introduced into the mold. The front (bottom) would then cool much more than the posterior (close to the nozzle). There would also be a longitudinal stretch because of its own weight (drums for making drums can be up to one meter in length). On the other hand, it is also not possible or inexpensive to extrude the large and thick hose pieces necessary for large hollow bodies in a few seconds. This would require an extraordinarily large extruder whose operation would be intermittent and therefore of poor performance.

For this reason, all large blow molding plants have the so-called accumulator, which is well insulated thermally and is slowly charged by the extruder during the entire blowing and cooling period the amount of mass accumulated (up to about 150 Kg) is driven through the extrusion nozzle by a hydraulically operated plunger or by a plastification spindle in a short time (several kg / s) passing immediately to the blow mold. Another device present in almost all modern blow molding machines is the so-called wall thickness control, which is used both for the manufacture of small and large hollow bodies.

By controlled or programmed modification of the nozzle outlet slit, it is possible to extrude hoses which longitudinally represent annular stepped wall thicknesses. In this way, the thickness of the hollow bodies blown by this process can be prevented from being necessarily finer at the points with the highest blowing

ratio (gap-to-hose ratio). This rule is true for hoses with uniform wall thickness. However, with thickness control material can be accumulated at the points that are to be widened and save at points where the diameter will be reduced (for example, in a bottleneck). This control therefore provides hollow bodies with better balanced mechanical strengths, saving material and often also shorter cooling times because of the generally smaller wall thickness of the hose, gives us a higher performance.

### 1.5.1 Obtaining the precursor.

The first step in getting a piece of suitable final characteristics is to obtain the precursor. Figure 1.6 shows the front view of a nozzle of an extrusion machine used in this type of process.

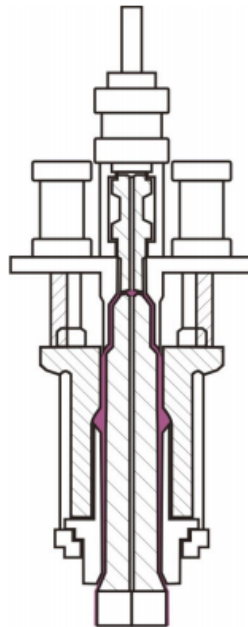


Fig. 1.6 Frontal view of a typical extrusion head used for the manufacture of preforms.

The wall thickness of the precursor will depend on the size of the nozzle and the mandrel of the extruder, so the design of these extruder parts must be very precise. In most of the extruders used to obtain blow molding preforms, the ends of the nozzle and the central mandrel are adjustable, so that the internal diameter of the precursor, and hence its thickness, can be modified Programming of the precursor (Figures 1.7 and 1.8). In

this system the mandrel moves with respect to the nozzle, which remains fixed, so that the wall thickness of the precursor is varied during each cycle, thus a distribution of constant thickness can be obtained in the wall of the products one Molded to contain more material the parts of the piece that will stretch more during the blowing (figure 1.8). Modern extrusion machines are now ready to modify the wall thickness more than 100 times in a single precursor.

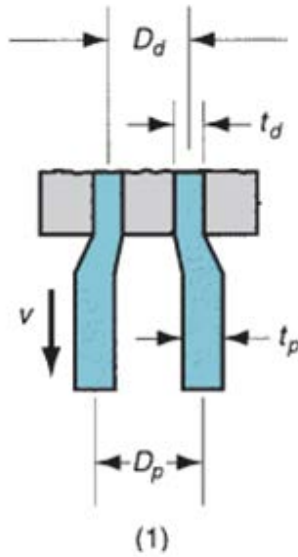


Figure 1.7 Programming the precursor.

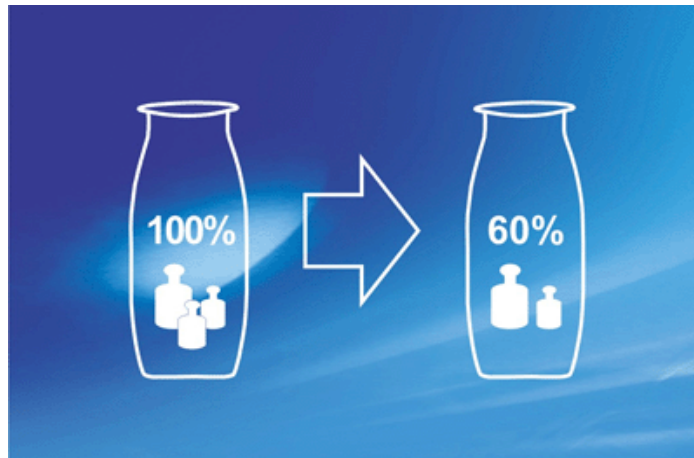


Figure 1.8 Distribution of thicknesses obtained in a normal bottle and one with programmed precursor.

There are other possibilities for modifying the thickness of the precursor, and therefore achieving a more uniform thickness distribution of the molded part, such as:

- Vary the extrusion speed.
- Vary the pressure in the extruder.

- Modify the nozzle size by keeping the mandrel size constant.

The type of material is a factor that will greatly condition the quality of the product obtained. The resins used in extrusion-blowing must have a high viscosity in the molten state and furthermore the melt must develop a high resistance, so that the deformation suffered by the material when it leaves the extrusion machine until the blowing is minimal. Otherwise, the swelling that the material undergoes when it leaves the extrusion die together with the deformation caused by the effect of gravity when the precursor hangs down will cause a very great thickness in the lower part of the precursor and deficient in The upper part, which in some cases could be compensated for by proper precursor programming, but which would in most cases lead to pieces of Poor quality. In general the resins used in extrusion-blowing must have a high molecular weight, which provides high viscosity and high melt strength, as well as high impact resistance. Another important feature of the resin is its extensibility which delimits the maximum blowing ratio that can be achieved and whether the corners and angles can be molded properly.

### 1.5.2 The blowing bolt.

In blow molding, the air is pressurized into the precursor so that it expands against the walls of the mold with such pressure that it captures the details of the surface of the mold. For this reason it is very important to control the air inlet, which is done by a suitable size of the air inlet orifice since if the inlet channel is too small, the required blowing time will be too long or the pressure exerted On the precursor will not be adequate to reproduce details of the surface of the mold. To avoid this, general rules have been established in determining the optimum size of the air inlet orifice, depending on the size of the part, as shown in Table 1.1.

Diameter of the hole mm.	Capacity of piece lts.
1.6	1
4	1 a 4
13	4 a 200

Table 1.1 Dimensions of the blowing bolt according to the size of the par

Typically, the air pressure used to blow the precursors is between 250 and 1000 kg / cm<sup>2</sup>. Sometimes, if too much air pressure is used, the precursor may leak, whereas if the pressure is too low the precursor does not accurately reproduce the shape of the mold. In general it can be said that a high blowing air pressure is

concerned so that a minimum blowing time (resulting in higher production rates) and finished pieces can be achieved which faithfully reproduce the surface of the mold. However, this blowing air can cause stresses and cooling in the area of the plastic on which it acts.

Another factor to take into account is the humidity of the blowing air as this can cause marks on the inner surface of the product. This defective appearance is particularly unpleasant in thin-walled articles such as milk cans. Dry air is often used to prevent this problem.

Finally the blowing bolt must have the proper length. If it is too long it can happen that the air "focuses" against a hot zone of the determined plastic, causing defects in this zone.

To produce high quality blow molded bottlenecks, bolts have been developed which compress the material in this mold region. In these processes, the blowing pin is introduced into the hot precursor by overcompressing the plastic inside the neck, filling the inside of the channels of the mold, and forming a smooth surface therein, as shown in (Figure 1.9)

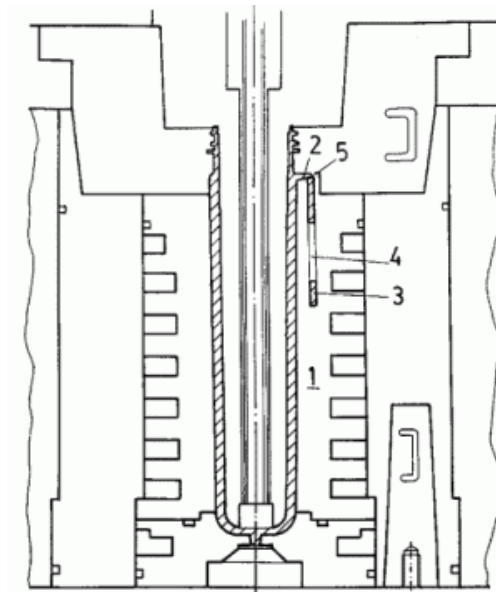


Figure 1.9 Blowing mold and bottle neck production by compression of the material by the blowing bolt.

### **1.6 Blow molded injection molding.**

A hose is not extruded here, but a shaped part is injected that oscillates between the bell and the test tube. However, the mold is not as cooled as in the normal injection because it is maintained at temperatures

ranging from 70 to 100 ° C. After opening the mold, the core with the piece still hot and plastic moves by advance or turn to the blowing station. Where it penetrates into a blow mold with a desired cavity. Air is then introduced through the core, which has a valve; The material is then separated from the mold, where it cools and acquires its definitive shape. [7] (Tim Osswald, Giménez. 2008).

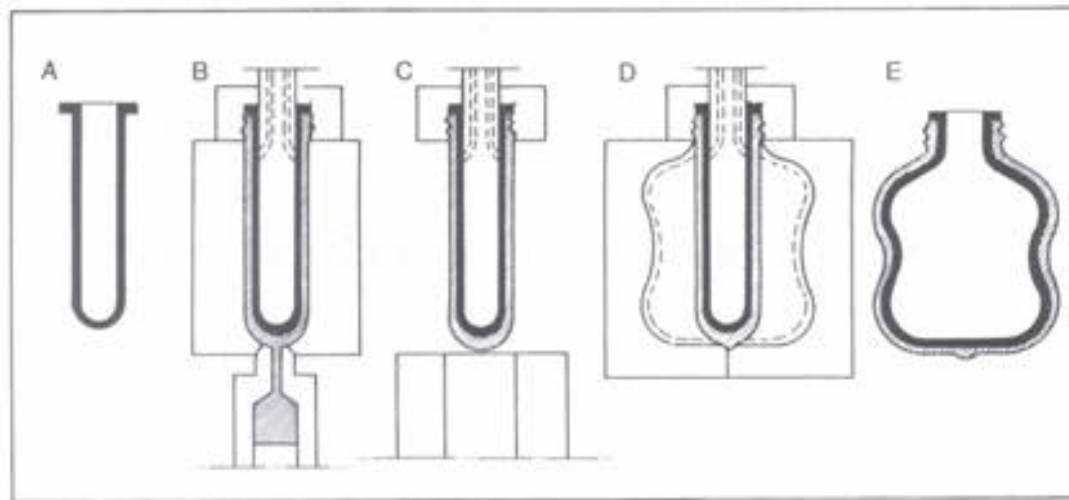


Fig 28

Fig. 1.10 Scheme of injection-blowing procedure.

Its main advantages with respect to extrusion are:

- More constant weight of the parts, since the filling of a high pressure closed injection mold can be performed with narrower tolerances than the extrusion of a hose.
- More constant dimensions of the pieces, since the preformed part is not only configured by its outer surface, as the extruded and blown parts but is surrounded by metal molding walls, both the exterior and interior surfaces.
- There are no dumplings or other debris.
- Increased tenacity (resistance to falling) of the plastic due to the biaxial elongation produced when blowing; This is very important for brittle plastics such as polystyrene and rigid PVC.

In contrast, the following disadvantages of injection-blowing are mentioned:

- Since the core of the injection mold requires enough stability to prevent the high injection pressure from moving it to the side, it must have a minimum diameter of about 15 mm, and the finished hollow body can not be longer than 10 times The inside diameter of the neck.

- For each piece two molds are required (injection mold for the preformed piece and blow mold for the hollow body) which has its coincidence in the calculations.
- The weight of the pieces, their wall thickness and their thickness distribution can not be varied by a simple correction of the nozzle as the case of blown extrusion, but the molds must be rectified.

For such reasons, the process is used instead for reduced bodies, for wide neck bodies and for not too small production runs.

### **1.7 Stretch blow molding.**

The tension-blowing process is basically used to produce bottles for carbonated beverages that must be impermeable to CO<sub>2</sub>, and must therefore withstand the pressures that could develop in their interior (up to 5 atm) and also have a very good transparency. The idea of making this type of bottle came from Coca-Cola, who had observed that the consumption of the product increased if sold in large bottles, and in principle began packing in glass bottles of 2 lt. These bottles were too heavy, and on the other hand the oil crisis of the 1970s led to the development of the tension-blown process. It is curious to note that although plastics are obtained directly from petroleum, other materials such as aluminum or glass consume much larger amounts of oil, because large amounts of energy are required during processing.

The packaging intended for Coca-Cola (highly carbonated beverage containing 4 volumes of CO<sub>2</sub> per volume of liquid) should have a number of important requirements. On the one hand it had to withstand the high pressures that can develop in such a bottle without breaking, deforming or suffering pressure losses. A boat of this type is really a pressure vessel, for which the best design would be a sphere, which would not be practical. The next best shape is a cylinder with semi-spherical corners. In addition, this packaging should not be delayed for long periods of storage or lose the shape, taste of the liquid contained or the CO<sub>2</sub> content. It must also be highly transparent. The process to manufacture these containers was finally developed and patented by DuPont in the 70's, and until relatively recently only bottles were manufactured using this process for Coca-Cola.

In the tension-blowing process the preform is obtained by injection, although occasionally it can be obtained by extrusion. The preform is tempered in a mold.

Very cold, so that the polymer is not crystallized. The polymer should then be heated to a temperature above its T<sub>g</sub>. (Temperature at which the amorphous region of the polymer reaches the thermodynamic equilibrium

and behaves like a fluid.) Once this temperature is reached, the workpiece is tensioned in the axial and radial directions. To do this, on the one hand the central bar of the machine on which the preform is obtained is lengthened and simultaneously the blowing air is introduced into the part, as shown in figure 1.8

After obtaining the preform, the crystallization of the material must be prevented to prevent opaque areas from appearing, so the cooling to which the preform is subjected must be very fast. Once the fully amorphous preform is obtained, it is heated to a temperature slightly higher than  $T_g$  (95-100 ° C for PET) and subjected to tension, which induces the formation of small lamellae of crystals, sufficiently Small to maintain transparency.

A material processed in this way is much more tenacious and resistant than the same amorphous or crystalline. PET is the one that presents a greater improvement of properties due to the type and size of the crystals obtained when stressing it. The barrier properties and the transparency of the plastics can also be improved by orienting the polymer molecules. The blow-molding molding normally allows a saving of at least 10% of the weight per package and more than 30% in sizes above one liter for the same mechanical properties.

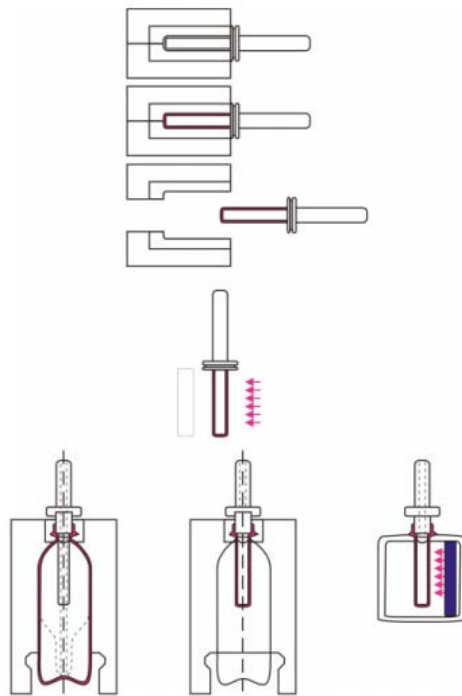


Figure 1.11 Tension-blowing process.

The polymer that is most used in this process is PET. Other polymers such as PVC, SAN, PAN, nylon or PP also perform well in this process, however PET is used by far in the millions of carbonated beverage bottles made daily. There are basically two methods for obtaining parts through tension-blowing. In the two-step method the preforms are obtained by injection and stored, and then reheated at the orientation temperature to tension and blow them.

This two-stage system is known as a reheat-tension-blow process. The second method is a continuous process in which the molded precursors are immediately conditioned at the orientation temperature and then tensioned and blown (1 step process).

In the case of tension-blowing machines in one stage the necessary equipment consists of:

- Injection machine, generally with plasticizer spindle.
- Injection mold to obtain the preform.
- Conditioning station.
- Tension-blow station.
- Demoulding station.

These machines offer the advantage that they are the least expensive way to enter the market, and that they subject the material to the least possible heating. As for disadvantages, it is a relatively slow system since it is the injection cycle which controls the performance of the machine and the part can not reach the higher levels of orientation since the blowing takes place at a relatively high temperature.

In the two-stage blow-molding system the precursors are introduced into a furnace on a plate which rotates at a speed of about 60 rpm at a constant temperature, so that the temperature distribution is adequate. The precursors are then transported to the blow-up zone, where they are blown in two stages (blown air is first introduced at about 200 psi, followed by 450 psi or more). Finally they are taken to the demolding station, sent to another area where the base is hollowed and labeled. The machines used for the tension-blowing system in two stages consist of a conventional injection machine, with which the preforms are obtained and of a reheating unit where the preform is conditioned, tensioned and blown. [7] (Tim Osswald, Giménez. 2008).

The advantages of the two-stage process are:

- Offers the lowest total cost.
- Produces smaller bottles.

- Precursors can be designed to optimize bottle properties.
- The precursors can be produced in an independent stage and stored, according to the needs of production and demand.
- It allows the highest efficiency of production of both precursors and bottles.

The main disadvantage of the two-state process is the cost of investment.

### **1.8 Other procedures.**

Other processes derived from blow-molding and others, used on a reduced scale for the manufacture of hollow bodies in the two-stage extrusion process, a tube is first extruded which cools and cuts into fragments longer than the part to be manufactured, these fragments can be stored for an unlimited time or even dispatched. In the second stage of manufacture, these parts are placed on studs fixed to an endless chain, which leads them through a preheating furnace, from where they are extracted upon reaching the thermoset state to be introduced into blow molds and to perform said operation .

It is also possible to preheat the two ends of the tube and apply a bead and a dome-shaped bottom by pressing, or also leave the transport studs in the pieces and use them as blow nozzles.

The tube segments used in this process are produced in an extrusion line independent of the blowing plant; This installation can also be fed by several extruders working in parallel, it is possible to achieve high performance of the blowing installation (up to 10000 pzs / hr.).

In the two-stage blow-injection process, the injection-preformed parts do not move directly into the blow mold, but are completely cooled, expelled, stored and dispatched. Subsequently they are treated in a similar way to the extrusion-blowing process in two stages by preheating them in 2 stages, preheating them in an oven, to blow them next.

The Renopac procedure represents a modification of the thermoformed. A rigid PVC sheet, folded U-shaped in the longitudinal direction, is heated on both sides by heat sources, such as infrared radiators, and is then fixed between the halves of a blown mold. During blowing a high frequency welding is applied all around the external contour, except for the neck. When cutting the part by punching, the welding protrudes in the form of a rib and is a typical characteristic of all Renopac containers.

In the process Cubitainer is made of sheets an extruder with double nozzle produces two bands of parallel polyethylene sheet, which then pass from a kind of blow mold and, by means of overpressure and / or reduced pressure acting from the outside, each Band in one half of a cube split diagonally. At the same time the outer edges of both parts are soldered, resulting in a completely closed container shape with the exception of the filling opening. When it is empty, one part of the die can be folded, on the other, which allows to save volume of transport; When filling, the pressure or weight of the merchandise causes the die to regain its shape. As the material has to be relatively soft these packagings are usually made with LD-PE, they are frequently used as external coating of carton boxes. The rotation molding process consists in heating thermoplastic powder (provided its molecular weight is not excessive) until it reaches the melting range, whereby a compact layer is formed even without external pressure acting.

Hollow molds of two or more pieces are used, which fit perfectly. The molds are placed in a frame that allows the simultaneous rotation on two axes, generally perpendicular to each other with equal or different speeds. The twisting movement is started once dosed and loaded the amount of powder necessary for the piece, after closing the mold. The mold is then heated from the outside; When the wall thereof has reached the melting range of the plastic, a certain amount of powder is adhered thereto and as the rotation continues, the thickness of this still porous layer increases, which in the course of the process becomes compact, After heating time and experimentally determined rotation (generally preserving the rotation movement), it is cooled from the outside until the mold is opened and the part is removed.

The molds may be relatively light, as they will not withstand any pressure; For example in light metal or even sheet metal. Finally, there remains a process for the manufacture of hollow bodies in exceptional cases, which consists in gluing or welding two halves produced by injection to constitute a closed vessel. These halves may be identical or differ to form one top and one bottom.

### **1.9 Injection molding.**

Injection molding is one of the most famous plastic processing technologies since it represents a relatively simple way to manufacture components with highly complex geometric shapes. This requires an injection machine that includes a mold. In the latter, a cavity is manufactured whose shape is identical to that of the part to be obtained and for its size a contraction factor is applied which is added in the measurements of the

cavity so that when the molded part is cooled, The desired dimensions. The cavity is filled with molten plastic, which solidifies, maintaining the molded form.

The polymers retain their three-dimensional shape when cooled below their  $T_g$  (glass transition temperature) and thus also their melting temperature for semi-crystalline polymers. Amorphous polymers, whose useful temperature is lower than their  $T_g$ , are in a thermodynamic state of pseudo-equilibrium. In this state, there are no rotation and relaxation movements (chain unraveling) of the polymer. It is for this reason that, in the absence of efforts, the three-dimensional shape is maintained. Semicrystalline polymers also have the characteristic of forming crystals. These crystals provide dimensional stability to the molecule, which is also (in the crystalline region) thermodynamically stable. The entropy of the molecules of the plastic diminishes drastically due to the order of the molecules in the crystals.

The mold (also called tool) is the space where the piece is generated; To produce a different product, the mold is simply changed, being an interchangeable part that is screwed into the closure unit. There are several types of mold, to inject plastics, metal, etc.

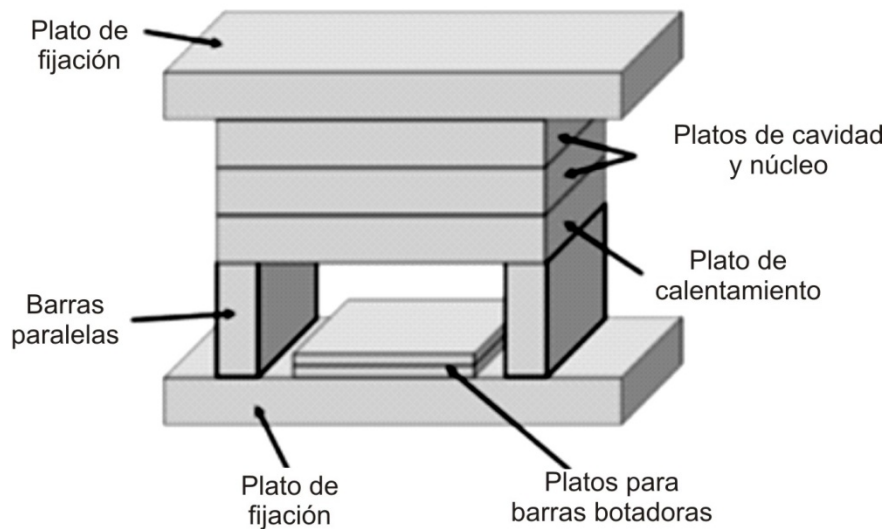


Figure 1.12 Schematic of a prefabricated mold, which only lacks the cavity for the desired part.

Mold parts:

- Cavity: is the volume in which the piece will be molded.

- Channels or ducts: are ducts through which the molten polymer flows due to the injection pressure. The feed channel is filled through the nozzle, the following channels are the so-called troughs and finally the gate is located.
- Cooling channels: These are channels through which refrigerant (the most common water) circulates to regulate the temperature of the mold. Its design is complex and specific for each piece and mold, in view of the fact that the cooling must be as homogeneous as possible in the whole cavity and in the fixed part as in the moving part, in order to avoid the effects of contraction differential. It should be noted that when designing a mold, the cooling system is the last thing to be designed.
- Ejector bars: when opening the mold, these rods expel the molded part out of the cavity, sometimes being able to count on the help of a robot to perform this operation.

Commonly used is steel (tempered and tempered) that some know as P20 steel, because of the American standard AISI. This steel is a material in which it can be easily polished, since it can be worked in the state of supply (turning, milling, etc.) Has a hardness similar to that of steels 705 and 709. This material is ideal as a mold as it is effective with any type of corrosive plastic. [6] (Sánchez Valdés, Fernández, Oliverio, Flores, 2003.).

### **1.10 Molding cycle.**

In the molding cycle 6 main steps are distinguished (although some authors can distinguish up to 9 steps):

- Mold closed and empty. The injection unit loads material and is filled with molten polymer.
- The polymer is injected by opening the valve and, with the spindle acting as a piston, the material is passed through the nozzle into the mold cavities.
- The pressure is kept constant to ensure that the piece has the proper dimensions, because when it cools it tends to contract.
- The pressure is eliminated. The valve closes and the spindle rotates to load material; when turning it also recedes.
- The part in the mold finishes cooling (this time is the most expensive because it is long and interrupts the continuous process), the press releases the pressure and the mold opens; the bars expel the molded part out of the cavity.
- The closing unit closes the mold again and the cycle can be reset.

### **1.11 Packaging finishing operations.**

Sometimes it is necessary to mechanize the inside of the neck of the blown parts to obtain an exact diameter or the upper edge of the neck for an exact height, a complete smoothness and deburring, the necessary, often automated apparatuses can be incorporated into the machine Blowing or working independently.

Another finishing machining is the stamping of the window between the body and the handle of the bottles that have it. However, this operation is attempted in the blow mold to avoid the finishing process.

The majority of hollow bodies used for packaging are decorated, not so much to beautify them as to increase the advertising effect and the purchase stimulus. This point of view is of extreme importance, especially in non-return containers that are sold in the self-service stores. Since most blow molding methods, as well as injection and rotation, there is no manageable intermediate product between the raw material and the finished part, only the partial printing path of the finished products remains.

### **1.12 Raw Materials.**

For the blowing of hollow bodies only thermoplastics are used, and specifically for packaging, in particular the main types: polyolefin polyethylene and polypropylene, polyvinyl chloride (PVC) and styrene polymerizes (normal polystyrene, anti-shock polystyrene, ABS etc.). The main thermoplastics used depend on the technique used, for extrusion-blowing are; LDPE, HDPE, PVC-U, PS, PP, PA and ABS.

Those used in the blow-injection technique are; All employees in extrusion-blown and also PE crystal and PET.

### **1.13 Types of closure.**

The closure of a container is the most important component only with this element results a complete container its missions are multiple.

- Avoid uncontrolled spillage of the merchandise.
- Take care of the opening function and often again closing.
- Ensure protection against influences, such as moisture inlet, temperature change, etc.
- Be well able to meet the demands of pressure, heat, movement, shock and impact on the container.

It distinguishes between standard closures and guaranteed closures. A standard closure can be opened and closed for an unlimited number of times including traction and displacement pressure closures, such as cap plugs and threaded closures. Locks with a guarantee can not be closed again after the first opening, so that the operation is not noticed. In most cases, they can not be closed again All its effectiveness. In this group all seals are glued, sealed and welded, as well as crown caps "pilfer proof" (pilfer: steal, proof) and rolled caps.

### **1.13.1 Closures for bottles and hollow bodies.**

We must distinguish:

- Standard and standard locks
- Welded seals applied only to plastic bottles and tubes.
- Rolled closures for hoods and wide neck containers.

### **1.13.2 Threaded fasteners**

The number of variants of threaded closures for drums, tubes, and wide neck containers is immeasurable. They are distinguished by the shape of the thread, the diameter of the thread, type of joint and external shape. The standard forms are those of round thread and saw (Fig. 1.13). The vectors marked on the drawing show that in the round thread the normal force  $P_n$ , which always acts perpendicular to the contact line of the thread contours, is decomposed into an axial force  $P_a$  and a radial force  $P_r$ .

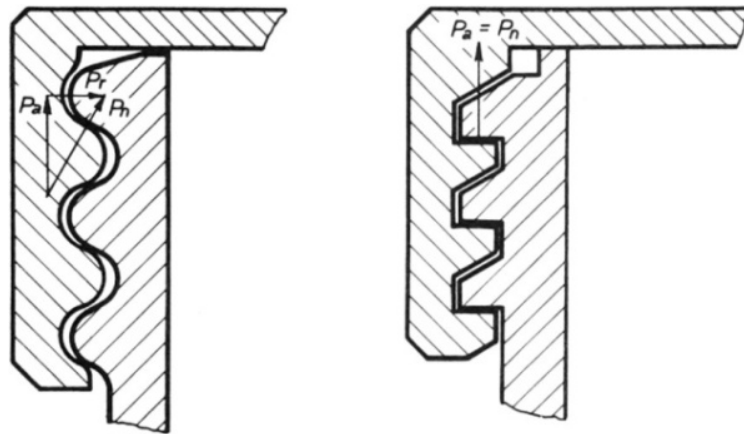


Figure 1.13 Screw forms for locking caps.  $P_a$  = axial force;  $P_r$  = radial force;  $P_n$  = Resulting force.

The axial force  $P_a$  determines the pressure of the cap on the nozzle gasket surface at  $a$ . The partial force  $P_r$  is usually undesired as it attempts to widen the cap. The greater the inclination of the flanks of the thread, the greater the angle between  $P_a$  and  $P_r$ . In a saw thread with rectangular flanks, no transverse force  $P_r$  originates; In this case it is  $P_a = P_n$ , that is to say all surface tension of the thread is used as joint force in  $a$ . The number of thread steps is not necessarily decisive for the joint force, since all steps can not be expected to act with their entire surface. However, for plastic parts the threads should not be less than a full weight, with a certain excess  $\ddot{u}$  (figure 1.14). In the hollow bodies blown the screw passages in the area of the separating line of the mold which may prove to be defective and result in problems in threading the cap. In order to overcome these difficulties, the threads are often split in half passages, so that in each half of the mold the threads reach only a few mm from the line of separation, in these cases it is indispensable to have at least two , And better than 3 steps [4] (M. A. Ramos Carpio., Ruiz.,1988)

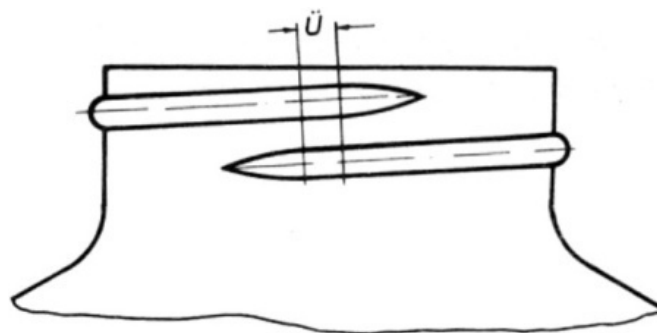


Fig. 1.14 One-step thread  $\ddot{u}$ , necessary overlap

### **1.14 Design of the blow mold.**

Since blow molds do not have to withstand high pressures the amount of materials available for their construction is large. For small parts aluminum, steel, copper-beryllium alloys are used. The aluminum molds have very good thermal conductivity, they are easy to manufacture but their durability is not very high. In comparison steel molds are more durable and rigid, and Cu / Be are those with better thermal conductivity. Aluminum molds are the most used since they have the best balance between thermal conductivity, duration and cost:

Most of the blow molds are not capable of providing as high cooling capacity as the molds used in injection, which goes through a suitable design of the cooling channels of the mold. In blowing, as was done in rotational molding, the part is cooled only by the external surface, apart from the small contribution to the cooling performed by the blowing air, so that the cooling is quite poor compared to the process of injection. In the company for the elaboration of a blow mold can be started in different ways and as long as the quotation is approved and authorized by the customer, the factors on which the quote depends are:

- The customer only has the idea of a mold for a certain volume, the quotation starts from the development of engineering, design, machining to the finished mold.
- That the customer has only one bottle and wants to modify their design or have their drawings in 2D, then the quotation starts from the design, machined to the finished mold.
- That the client already has a 3D design of his bottle, then the quotation starts from the programming for machining to the finished mold.

### **1.15 Methodology for the design of mold.**

The methodology for the design of mold is presented below, the methodology is proposed as a result of the approach that gives the concurrent engineering to the technological design, as well as the experience acquired in the industry of manufacture of Molds. Concurrent engineering poses parallel tasks during the technological development, allowing to improve project delivery times, or manufacturing times. In the case of molds the methodology to be managed shown in Figure 1.15

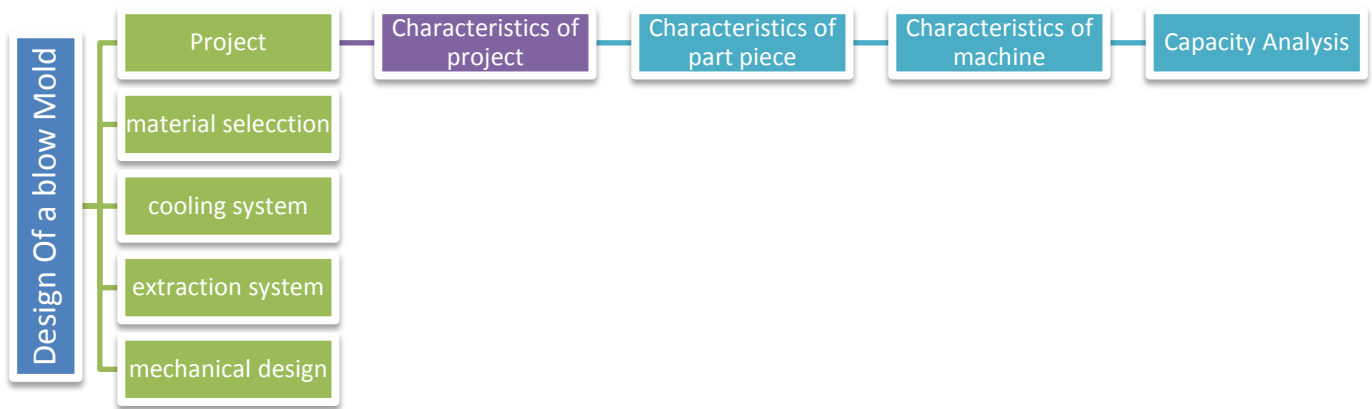


Figure 1.15 Design of an injection mold

### 1.15.1 Project.

This phase describes the parameters from which the design project of an injection mold will start, the customer will go with an injection mold supplier to indicate the characteristics of the project which starts with the needs of injecting a plastic part , Depending on the number of plastic parts to be produced (production volume), the number of cavities will be determined and the time required to start production (delivery time). The characteristics of the part must be specified by the customer including, the type of plastic required, dimensions of the piece, estimated weight of the piece.

The customer must indicate the type of plastic used for the injection of the part to determine the dimensions of the injection channels (hot wash), mold operating temperatures, and variables related to cooling, all these parameters according to specifications of the material.

The injection mold supplier must have the characteristics of the injection machine where the injection mold will be placed, this is important to evaluate the capacity of the injection machine and determine the dimensions of the injection mold. This description generally applies to any design and construction of an injection mold.

With the required information, the injection mold manufacturer will make an analysis as to the injection capacity, this analysis consists of comparing the injection capacity of the machine against the material needed to fill the injection mold cavity, also It includes closing force analysis, and analysis of machinery dimensions and mold height, this dimensional analysis of the injection machine will be the initial variable to determine the size of injection mold.

### **1.15.2 Selection of materials**

This classification in the mold design will not be addressed in this thesis work, but depends mainly on the type of plastic to be used, if it is corrosive, the pressure it generates and the number of shots that must be applied against cracks in The steel which will determine the type of alloy applied for the manufacture of the mold.

### **1.15.3 Cooling system, Extraction system and Mechanical design**

**Cooling system:** In any mold design the cooling system is necessary to ensure that the heat from the molten plastic dissipates, at each injection cycle the plastic will heat the steel forming the cavity, so behind the cavities the steel is drilled to generate Cooling circuits through which water will flow.

**Extraction system:** The extraction or ejection system serves to guarantee the exit of the already molded plastic part from the mold without risk of rupture or superficial damages.

**Mechanical design:** The mechanical design includes the calculation of the mechanical stresses to which the steel of the injection mold will be subjected, caused by the injection of the material, closure of the mold, in this sub-item the thicknesses with which will count the elements that will support those efforts Mechanics.

### 1.16 Main features of the markets and the plastic industry in Mexico

The plastics industry in Mexico is highly dependent on the exterior in resins and additives and capital for plastics processing, the plastics market in Mexico has grown based on the displacement of other materials, mainly packaging required by the manufacturing industry for both the domestic and export, as in resins, the production of plastics in Mexico is insufficient to supply the local market and market share is lost each year. More than 35% of the consumption of plastic.

Industry has a high concentration of companies in markets with low quality but high price, its profit margin is very low. The average size of the companies in Mexico corresponds to "small company" with less than 50 employees and a production of less than 100 tons per month, Mexico's plastic transformers are unprotected in the face of unfair competition, foreign competitors and smuggling of plastic products, the plastic industry has potential for growth, but actions are required to make it more efficient its processes and favor the competitiveness to attend growing markets such as agro plastics, the maquiladora (IMMEX), the automotive industry and the pharmaceutical industry.

The plastic industry is made up of 500 suppliers of resins and additives, machinery and services; and more than 4,180 plastic transformers

Various suppliers 500 companies	Transformadores de plástico: 4180 empresas	Consumidores
Producers and distributors of resins and additives: 100 producers and 150 distribution companies	Integrated transformers	Food, beverages, industrial products, construction
Machinery and equipment manufacturers and distributors: 150 companies	Independent transformers	Intermediate users, end consumer
service providers 50 companies	Transformers of the maquiladora industry (IMMEX)	Electronics, Appliances and Automotive

Table 1.2 The plastic industry

- The plastic industry chain is made up of producers and distributors of resins and additives, manufacturers and distributors of machinery and equipment, specialized service companies, plastic transformers and intermediate and final consumers
- More than 80% of the companies in the plastic industry in Mexico are mainly micro and small companies; the 54% are micro enterprises with less than 10 employees, 27% are small with memos of 50 employees, 15% are medium-sized companies and only 5% are large with more than 250 employees
- The processes most used by the companies are mainly; extrusion, injection and blowing

In 2011 there was a production of plastic products greater than 5.8 million tons, which represents 80% of total consumption

- Among the injection products which stand out by their volume and growth are as follows
- Containers and containers of PE, PP and PS
- PP, ABS and PS components for industrial use
- In the case of blown packages representing 23% of the volume produced in 2015 includes
- PET bottle for beverages
- HDPE and PP containers for various products
- Films in their various applications with low-moderate growth
- Film, bag and food bags
- Film, bag and sacks for various products
- Stretchable and shrinkable film
- Film for agricultural use and sanitary use
- Piping with moderate growth
- PVC pipe for hydraulic use
- HDPE pipe for gas, water and industrial use
- Wire and wire and other extrusion products
- Includes wire and PVC wire and PE
- Profiles and sheets of various materials
- Rotomoldeo is a low volume but high market increase
- Includes water tanks, tanks and cisterns of HDPE

Production of Plastics in Mexico (volume in thousands of tons)		
	2011	2015
Blown	1,070	1,280
Food packaging	323	394
Commercial and industrial film	385	435
Movies, other uses	133	180
Pipeline	275	336
Cable and wire	40	52
Extrusion, others	583	708
Injection	1,131	1,902
Rotomoulding	45	63
Other uses	247	244
Total	4,232	5,596

Table 1.3 The plastic industry Production of Plastics in Mexico (Elaboration with data of Secretary of Economy)

Electronics and home appliances, automotive and household goods are markets with greater growth potential

- The main markets for general purpose resins are related to packaging and packaging in their different forms and represents more than 47% of the total \_ Includes bottles, containers, films, bags and boxes among others
- Durable applications such as construction represent 10% of production in 2015
- Includes pipe, drums, water tanks, tanks, profiles, etc.
- Products related to goods industries consumption and semi-durable, including components for automotive use, appliances, electronics, home and medical use, among others
- A joint participation in the order of 23% of the total
- Products for use in agriculture are estimated at 4% and other applications 14%
- Rotomolding, injection and blowing products have boosted growth over the past five years
- The end products related to electronic, appliances and automotive will drive growth in the next five years

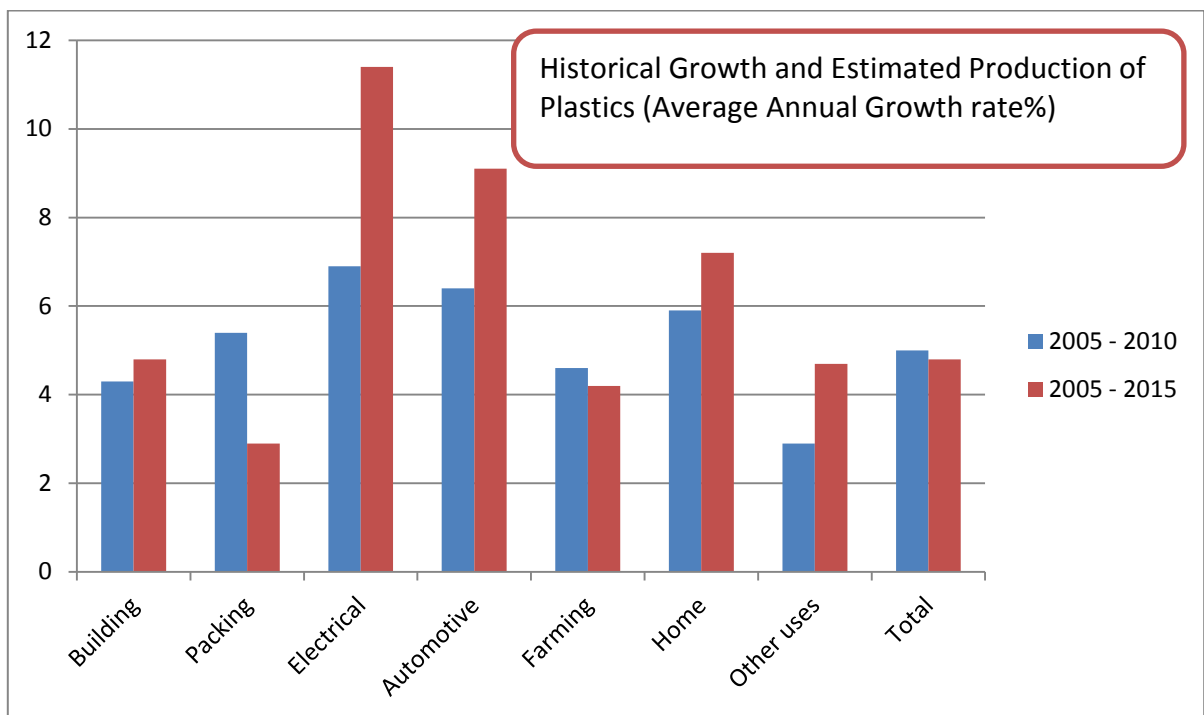


Figure 1.16 Historical Growth and Estimated Production of Plastics

With the entry into force of the IMMEX decree, the statistics of the Maquiladora Export Industry ceased to be published in 2007

Balance Demand for Plastics in Mexico (volume in thousands of tons)							
PRODUCT	2009	2010	2011	2012	2013	2014	2015
<b>Production</b>	4,737	5,093	5,197	5,326	5,298	5,490	5,624
<b>National</b>	4,231	4,548	4,651	4,807	4,798	4,978	5,092
<b>IMMEX</b>	505	545	547	519	500	513	532
<b>Production</b>	2,452	2,573	2,630	2,459	2,072	2,465	2,717
<b>National</b>	1,189	1,225	1,304	1,248	985	1,177	1,346
<b>IMMEX</b>	1,283	1,348	1,326	1,210	1,087	1,288	1,370
<b>Production</b>	967	1,041	1,062	1,005	953	1,117	1,206
<b>National</b>	461	466	482	472	453	579	651
<b>IMMEX</b>	506	575	580	533	500	538	554
<b>Production</b>	6,222	6,624	6,765	6,780	6,417	6,839	7,135
<b>National</b>	4,939	5,307	5,472	5,583	5,331	5,576	5,787
<b>IMMEX</b>	1,283	1,317	1,293	1,196	1,087	1,262	1,348

Table 1.4 Production of Plastics in Mexico Balance Demand (Elaboration with data from WTA and S. Economy)

In order to guarantee the supply of the market demand, more than 2.2 tons of plastics are imported for each ton that is exported

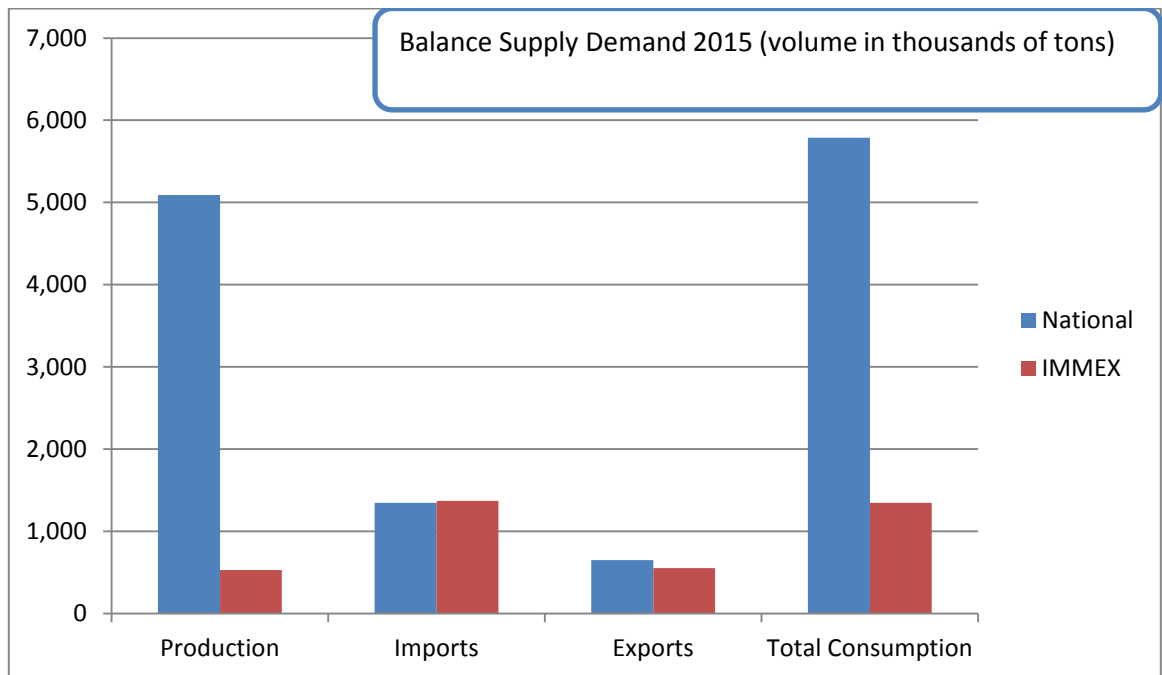


Figure 1.17 Balance Supply Demand 2015 (Elaboration with data of Secretary of Economy)

Mexico has an industry oriented to the production of packaging, but the production of injected parts is taking off

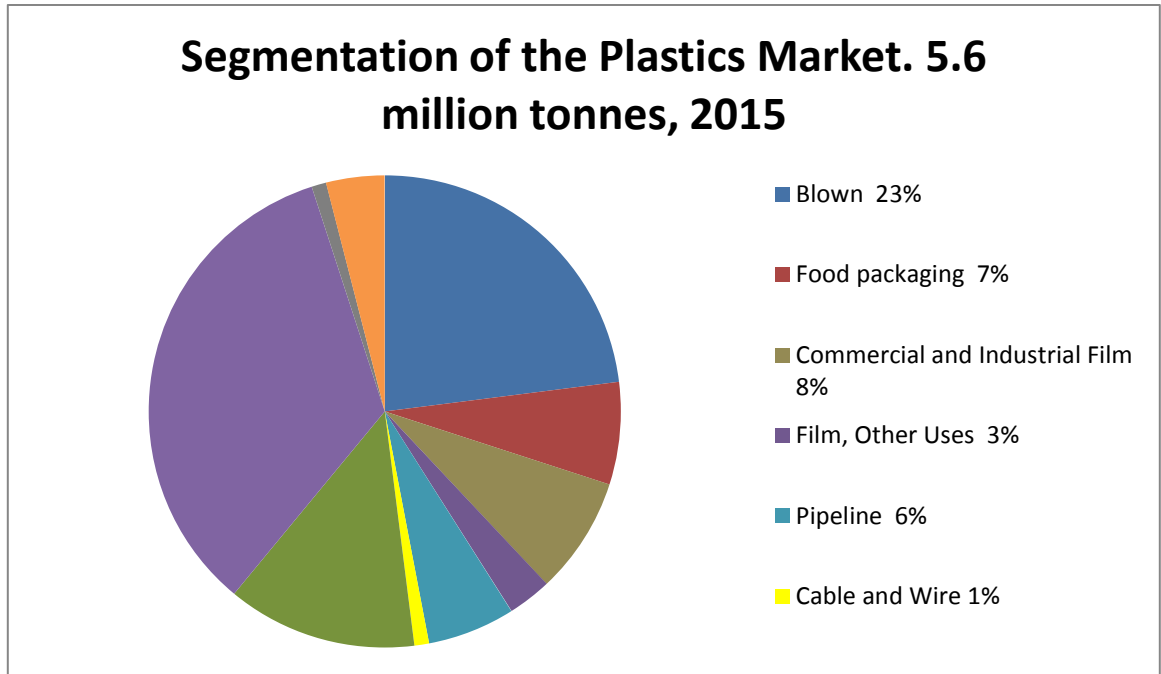


Figure 1.18 Design of an injection mold (Elaboration with data of Secretary of Economy)

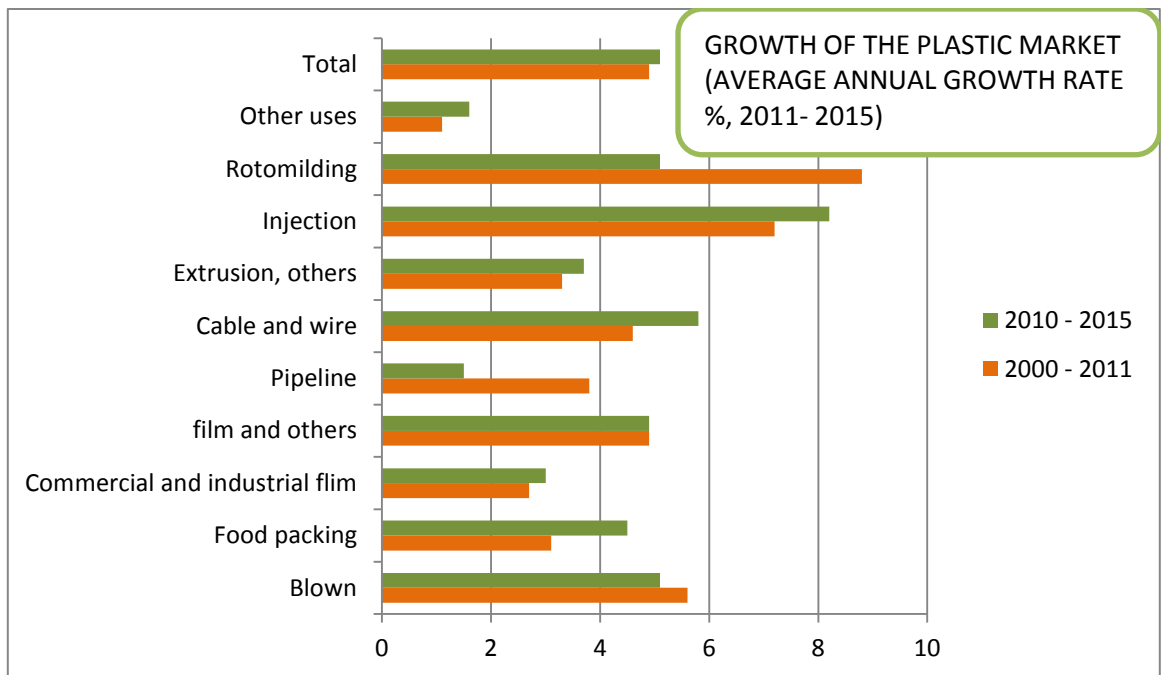


Figure 1.15 Design of an injection mold (Elaboration with data of Secretary of Economy)

The market by final application is dominated by packaging with more than 48% of the total, but smaller markets have greater potential

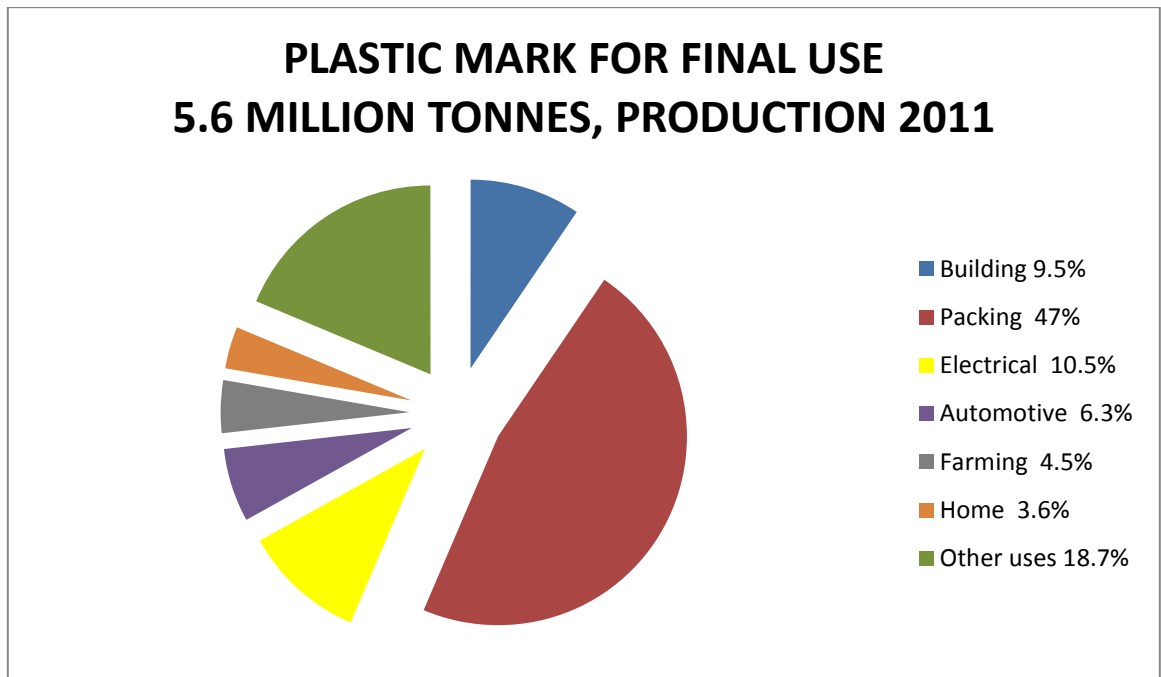


Figure 1.19 Design of an injection mold

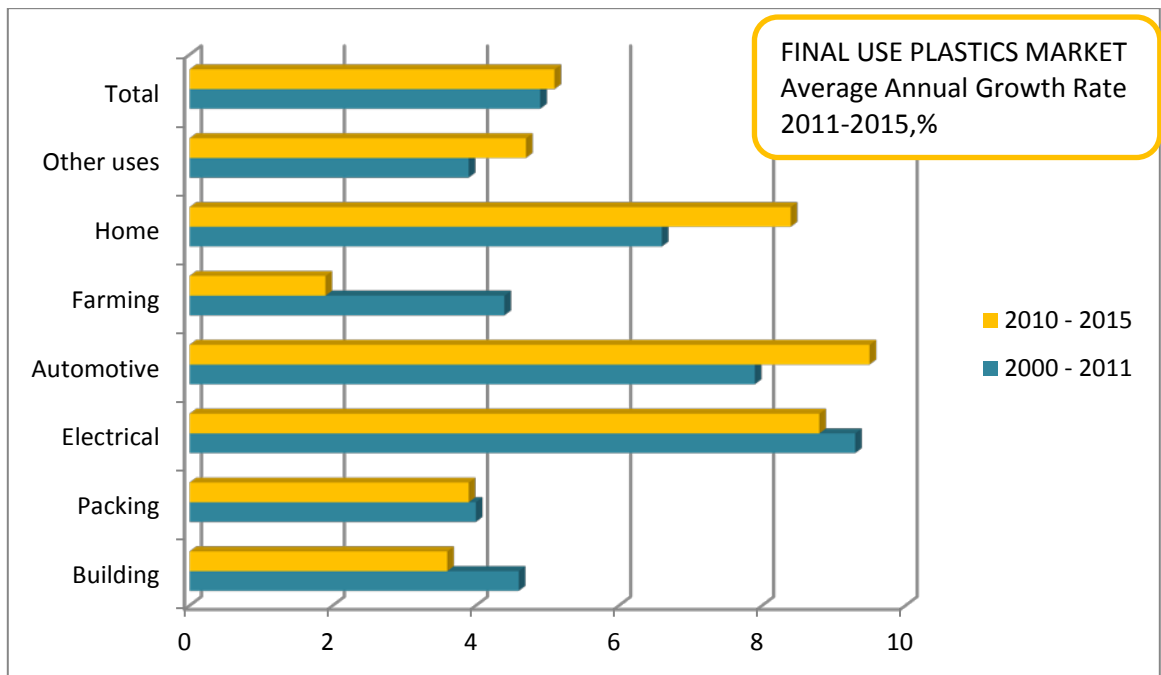


Figure 1.20 Design of an injection mold (Elaboration with data of Secretary of Economy)

Extrusion is the main process employed by the industry, followed by injection and blowing with higher and lower growth respectively

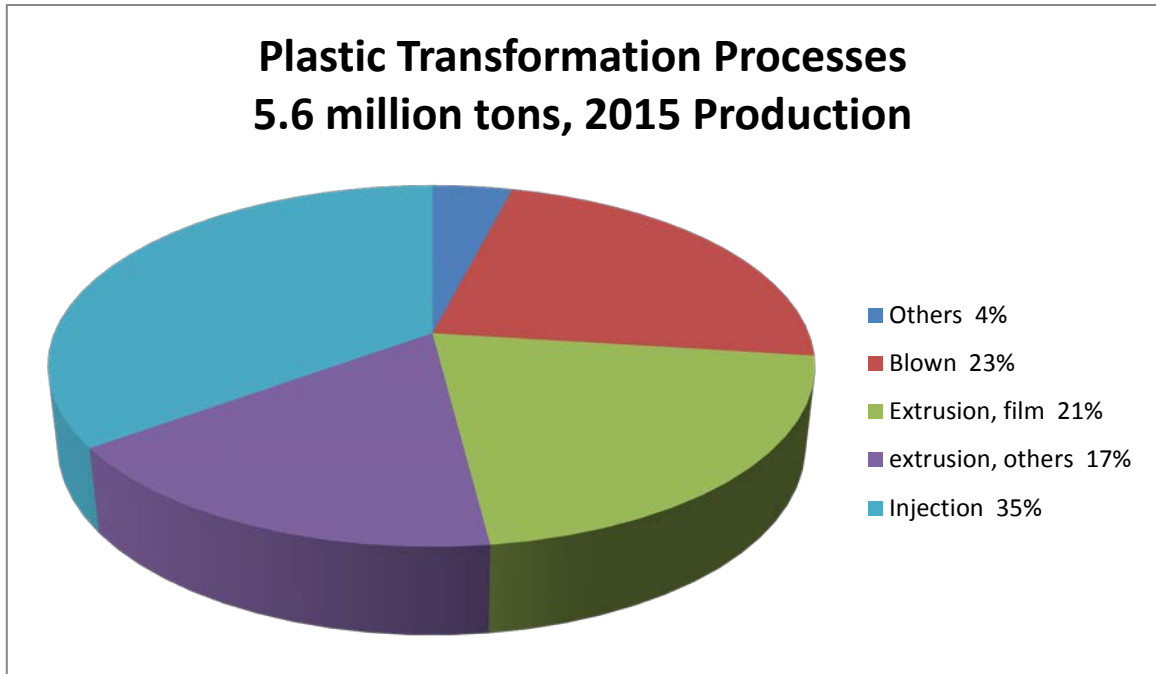


Figure 1.21 Design of an injection mold

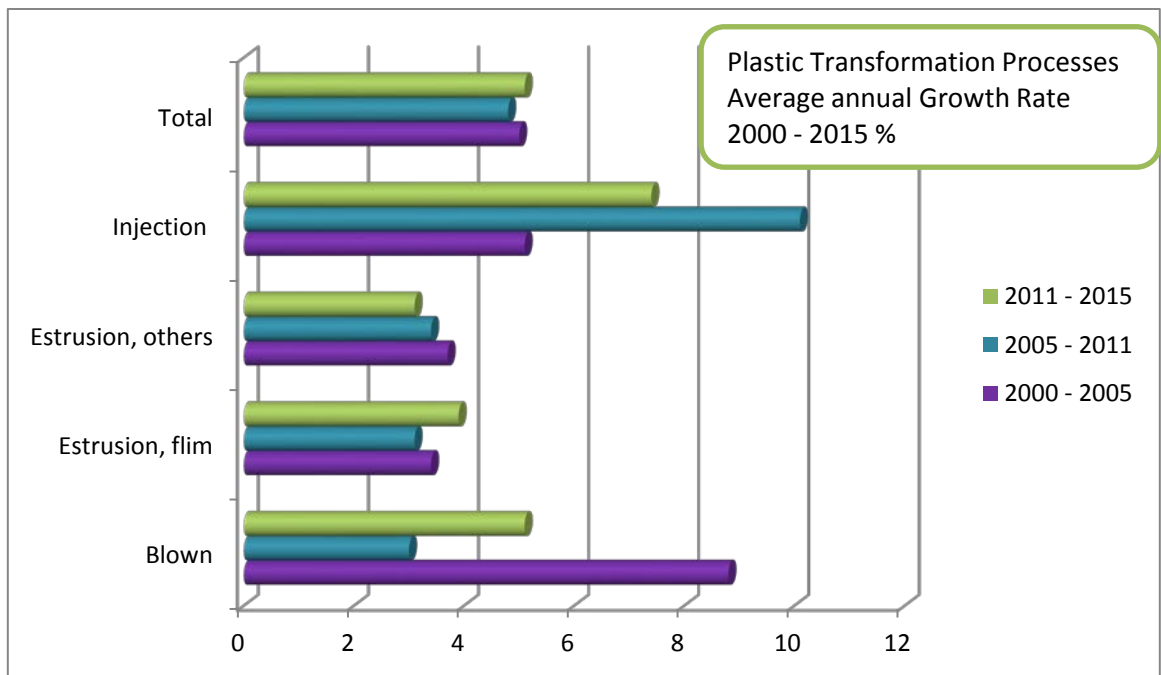


Figure 1.22 Design of an injection mold (Elaboration with data of Secretary of Economy)

## Main findings and challenges of the Mexican plastic industry

The main strengths of the plastics industry are related to the size of the domestic market and free trade agreements with more than 40 countries, export markets and maquiladora supply (IMMEX) are an opportunity for the plastic must take advantage. In terms of weaknesses we can mention the insufficient production of grades of resins and additives in Mexico and the limited development of higher value-added plastic products.

Among the threats that the plastic industry will continue to face are unfair competition, contraband, and environmental regulation related to plastics, although the natural growth of the plastic industry has been lower in the last ten years compared with the past, has a broad potential for local development and positioning. To strengthen its position and increase the productivity of the plastic industry, it is necessary to design a plan with actions in five main aspects:

- Education and training, develop human capital, specialists in plastics
- Infrastructure services mainly associated with transport
- Market efficiency, less informal market, tariff protection
- Promotion of investment projects in petrochemicals
- Foster innovation and development of technology, product and process

The importation of boxes, bags and sacks, films and sheets of PVC and self-adhesive tapes, were those that marked the growth

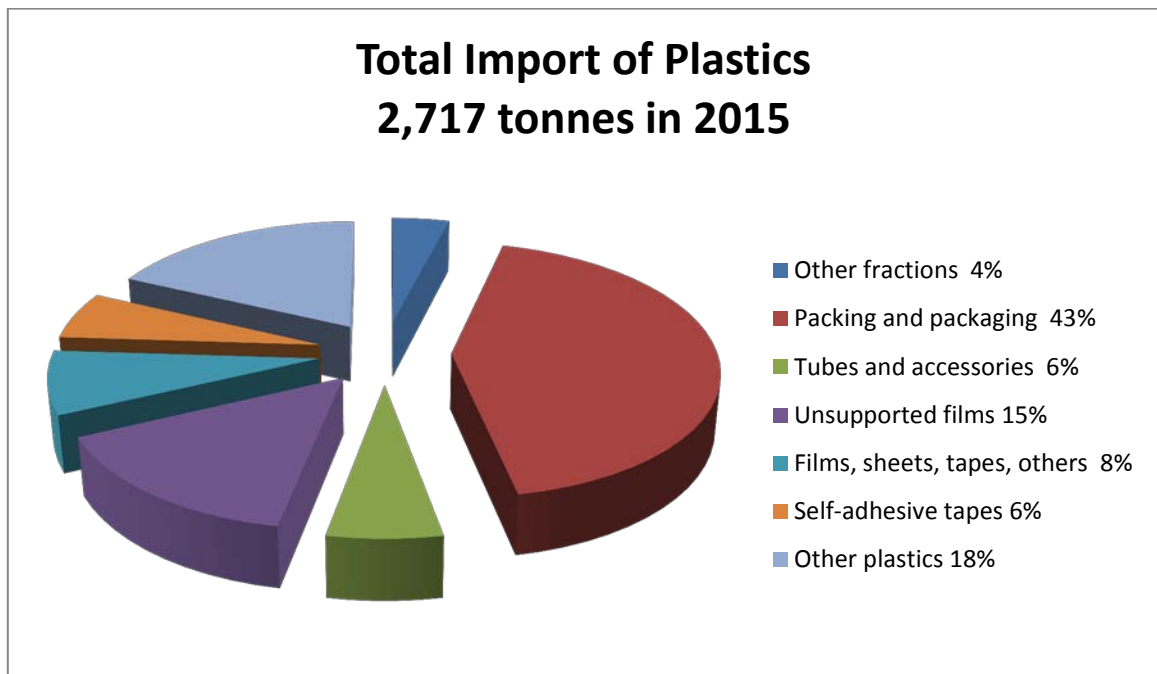


Figure 1.23 Design of an injection mold

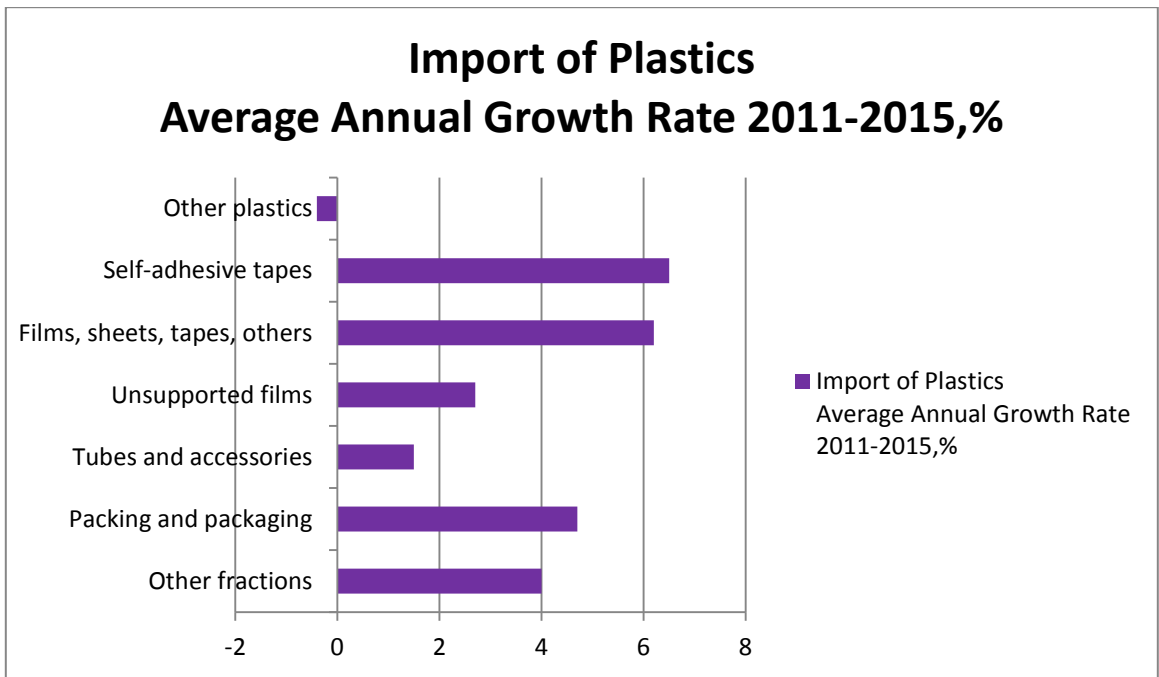


Figure 1.24 Design of an injection mold (Elaboration with data of Secretary of Economy)

70% of the volume corresponds to films of polyethylene, PP and PVC, but the growth is greater in acrylic and PC / PET films

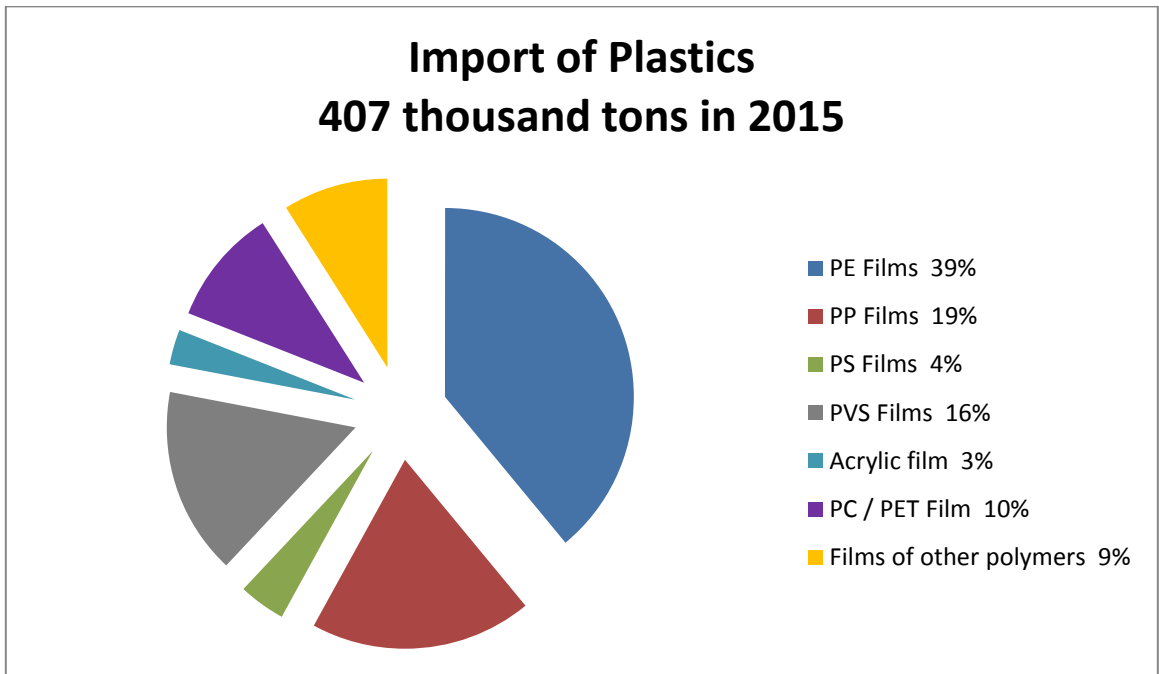


Figure 1.25 Design of an injection mold

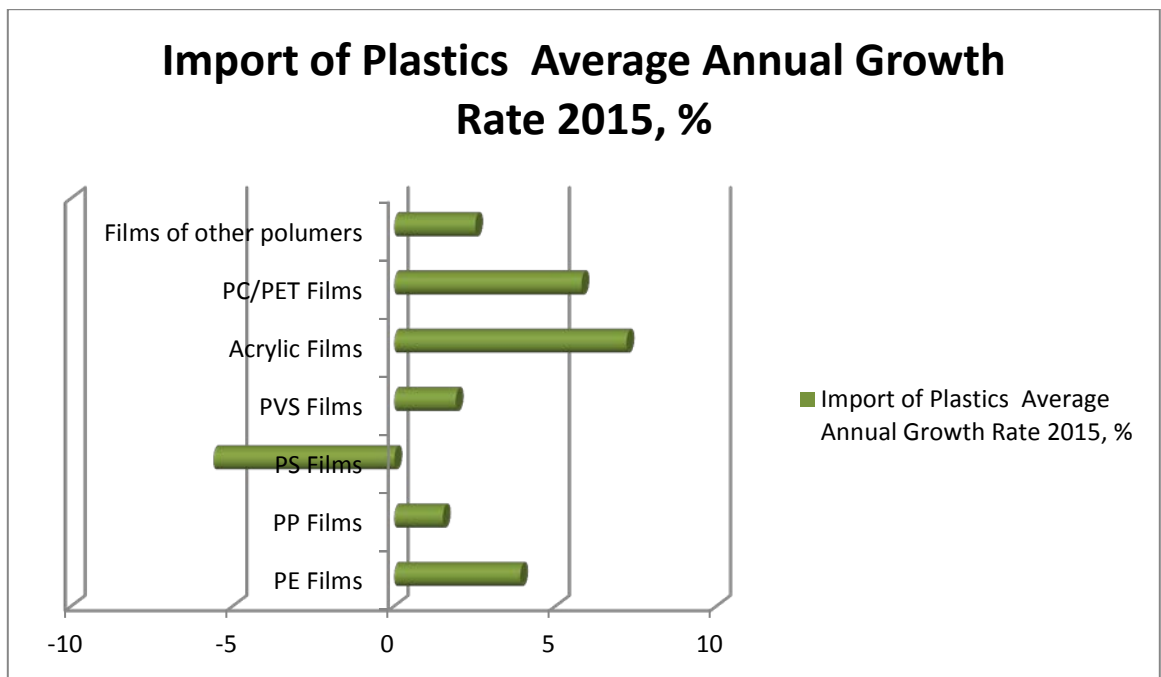


Figure 1.26 Design of an injection mold (Elaboration with data of Secretary of Economy)

In this information presented we can observe how there is a tendency in the increase of the production of plastic articles and which are their main area of application. so that we can come to somehow show the opportunity that exists in the Mexican market to be able to realize an innovation like the one raised in this thesis work, since we can observe a clear trend in the production line that means that with the advance of the years the technology for the production of plastic in Mexico will continue advancing and becoming increasingly competitive, with respect to the world, and to achieve this goal has to constantly innovate to be able to lead the market.

# **CHAPTER TWO**

## **APPLICATION OF CAD, CAM AND CAM, IN THE MANUFACTURE OF A BLOW MOLD.**

### **2.1 CAD-CAM.**

- Computer-Aided Design (CAD).
- Computer-Aided Manufacturing (CAM).

CAD / CAM, a process in which computers or computers are used to improve the manufacture, development and design of products. These can be manufactured faster, more accurately or at a lower price, with the appropriate application of computer technology. Computer Aided Design (CAD) systems can be used to generate models with many if not all of the characteristics of a particular product.

These features could be the size, outline and shape of each component, stored as 2D and 3D drawings. Once these dimensional data have been entered and stored in the computer system, the designer can manipulate them or modify the design ideas more easily to advance the development of the product. In addition, the combined ideas of various designers can be shared and integrated, since it is possible to move data within computer networks, so that designers and engineers located in distant locations can work as a team. CAD systems also allow you to simulate the operation of a product. They make it possible to verify whether a proposed electronic circuit will operate as intended, whether a bridge will be able to withstand the hazards predicted loads and even if a tomato sauce will flow adequately from a newly designed container.

When CAD systems are connected to computer-controlled manufacturing equipment, they form an integrated CAD / CAM system (CAM, acronym for Computer Aided Manufacturing). Computer-aided manufacturing offers significant advantages over more traditional manufacturing equipment control methods. In general, CAM equipment involves the elimination of operator errors and the reduction of labor costs. However, the constant accuracy and optimum use of the equipment represent even greater advantages. For example, blades and cutting tools will wear out more slowly and break down less frequently, which would further reduce manufacturing costs. Faced with this saving can be argued the higher costs of capital goods or the possible social implications of maintaining productivity with a reduction in the workforce.

CAM equipment is based on a series of codes Numerical, stored in computer files, to control the manufacturing tasks. This Computer Numerical Control (CNC) is obtained by describing the operations of

the machine in terms of the special codes and shape geometry of the components, creating specialized computer files or part programs. The creation of these parts programs is a task that, to a large extent, is carried out today by special computer software that creates the link between CAD and CAM systems.

The characteristics of CAD / CAM systems are used by designers, engineers and manufacturers to adapt them to the specific needs of their situations. For example, a designer can use the system to quickly create a first prototype and analyze the feasibility of a product, while a manufacturer may use the system because it is the only way to be able to accurately fabricate a complex component. The range of features offered to CAD / CAM users is constantly expanding. Clothing manufacturers can design the pattern of a garment in a CAD system, which is automatically placed on the fabric to minimize material waste when cut with a CNC saw or laser. In addition to CAD information describing the contour of an engineering component, it is possible to choose the most suitable material for manufacturing in the computer database, and employ a variety of CNC machines combined to produce it. Computer Integrated Manufacturing (CIM) fully exploits the potential of this technology by combining a wide range of computer-assisted activities, which may include stock control, costing of materials and total control of each production process.

This offers greater flexibility to the manufacturer, allowing the company to respond with greater agility to the demands of the market and the development of new products. Future developments will include even greater integration of virtual reality systems, which will allow designers to interact with virtual prototypes of products via the computer, rather than having to build costly models or simulators to test their viability.

Also the Rapid Prototypes area is an evolution of CAD / CAM techniques, in which three-dimensional computerized images are converted into real models using specialized manufacturing equipment, such as a stereolithography system.

## **2.2 Uses.**

- Scheduling for numerical control, computer numerical control and industrial robots.
- Design of die casting molds in which, for example, shrinkage tolerances are reprogrammed.
- Data for metal working operations, eg complicated dice for sheet forming, and progressive die stamping data.
- Design of tools and electrodes for EDM.

- Quality control and inspection; For example, coordinate measuring machines programmed in a CAD / CAM workstation.
- Planning and scheduling of process.
- Distribution plant.

In this case the blow mold starts from the need of a customer who only had a 2D plane and a bottle shows which would serve to make the new bottle design.

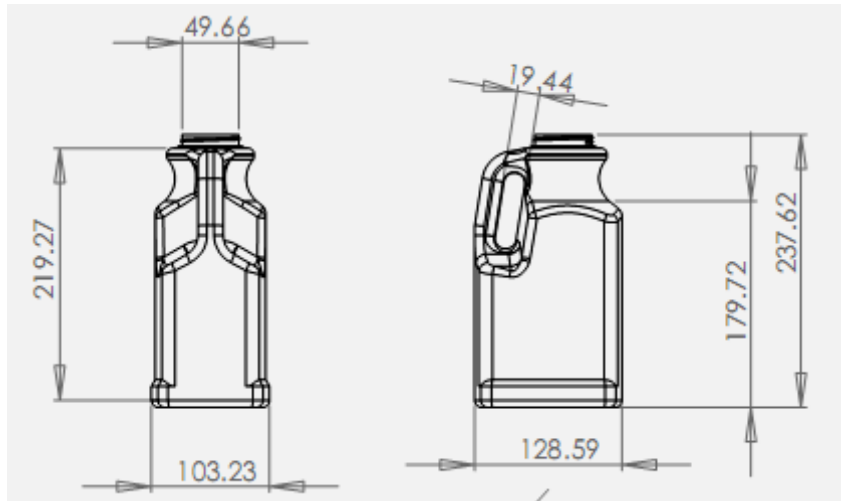


Figure 2.1 Left and front side view.

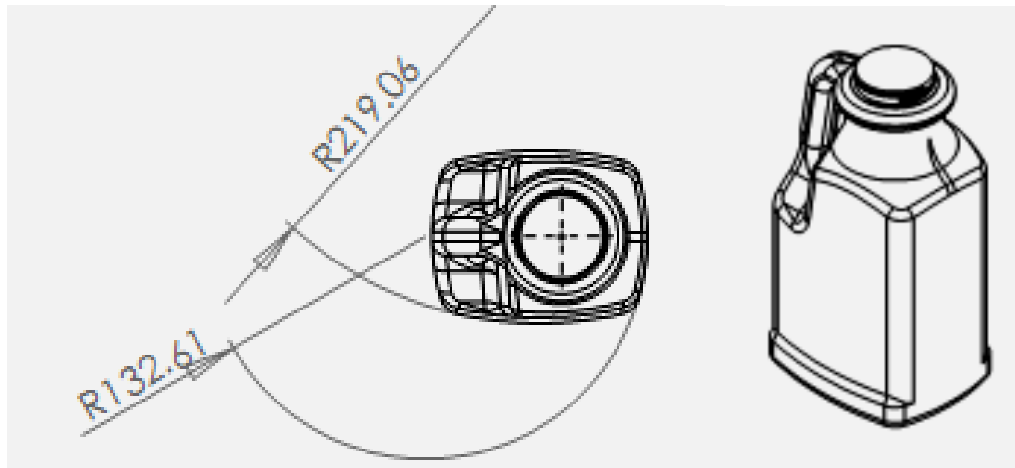


Figure 2.2 Top view and isometric.

## 2.3 Design in SOLID EDGE.

Solid Edge is a parametrized program of computer-aided design of three-dimensional pieces. It allows the modeling of pieces of different materials, folding of sheets, assembly of assemblies, welding, drawing functions in plane for engineers.

This is one of the packages urged to bury the massive use of 2D CAD giving way to 3D CAD, with the consequent advantages at all levels of work. Through third-party software, it is compatible with other PLM technologies. It also brings "Insight", written in PDM and with CPD functionalities based on Microsoft technology.

Taking the figures in point 1.12 proceed to begin redesigning the bottle in a 3D format as shown in the following figures. Selecting in the program SOLID EDGE the lateral and frontal planes to later make an association of the model sent by the client.

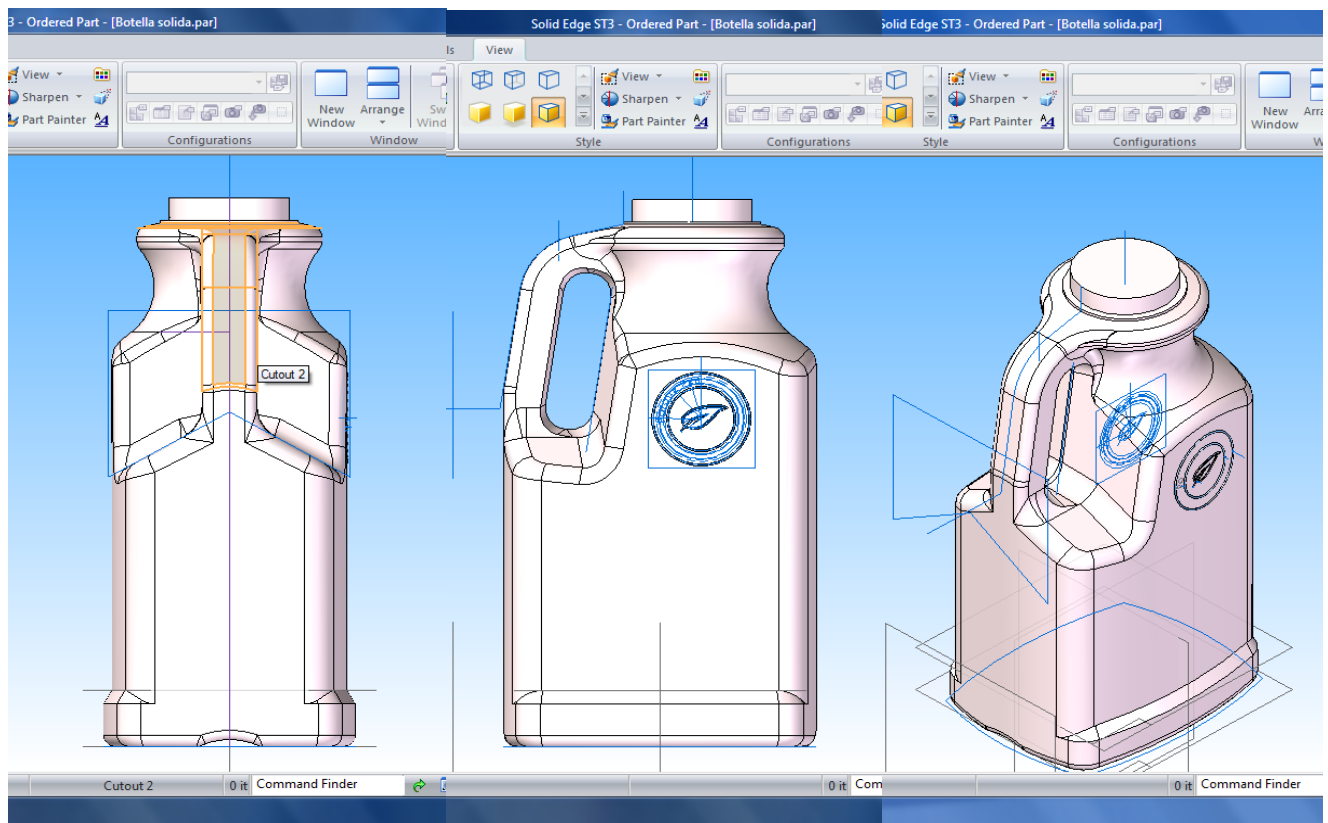


Figure 2.3 3D container design

Fig. 2.3 Selected views already designed in the design program until obtaining the solid model with which the required operations will be done to obtain the cavities to be machined.

## 2.4 External dimension of the blow mold.

To determine the dimensions of the blow mold it is necessary to know the type of machine that will manufacture the containers mainly statistics of minimum and maximum closure and opening of the machine. With this statistic it will be possible to define the volume that will occupy the mold in the machine blower. Having the volume mentioned above can be known the amount of material that is needed to manufacture the mold cavity as well as the cutter and its crown.

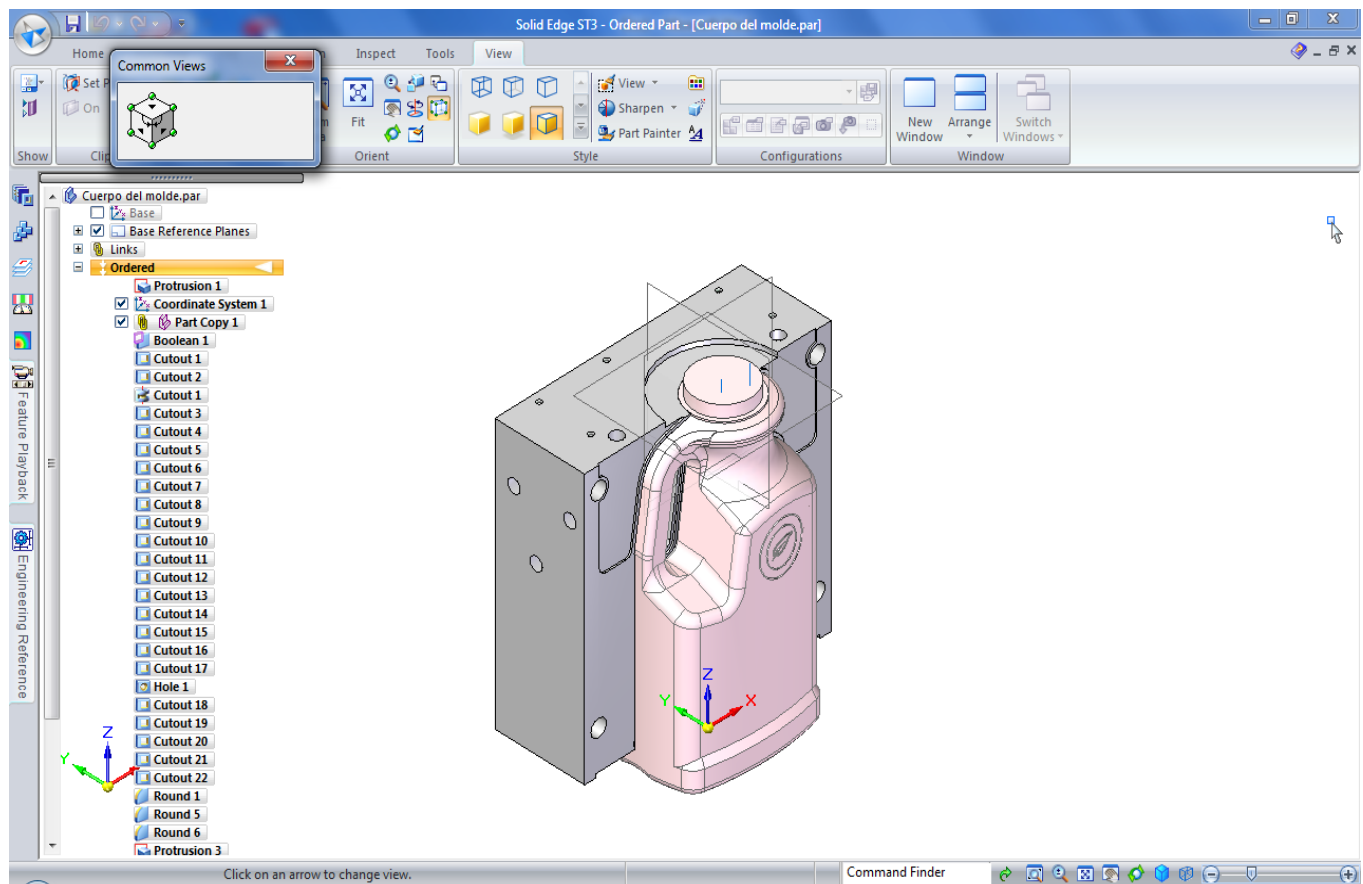


Figure 2.4. Creating the mold cavity

To create the mold virtually relate the bottle drawn in 3D with the pieces created to contain the cavity, the necessary operations are applied to obtain in this case a boolean and the part that occupies the bottle with respect to the solid material will be extracted and with it The casting of the mold will quickly be created as

shown in Figure 1.16, in the extraction procedure for the mold cavity it must be ensured that the partition line is exactly at the middle of the bottle although this is very easy with the aid of Program.

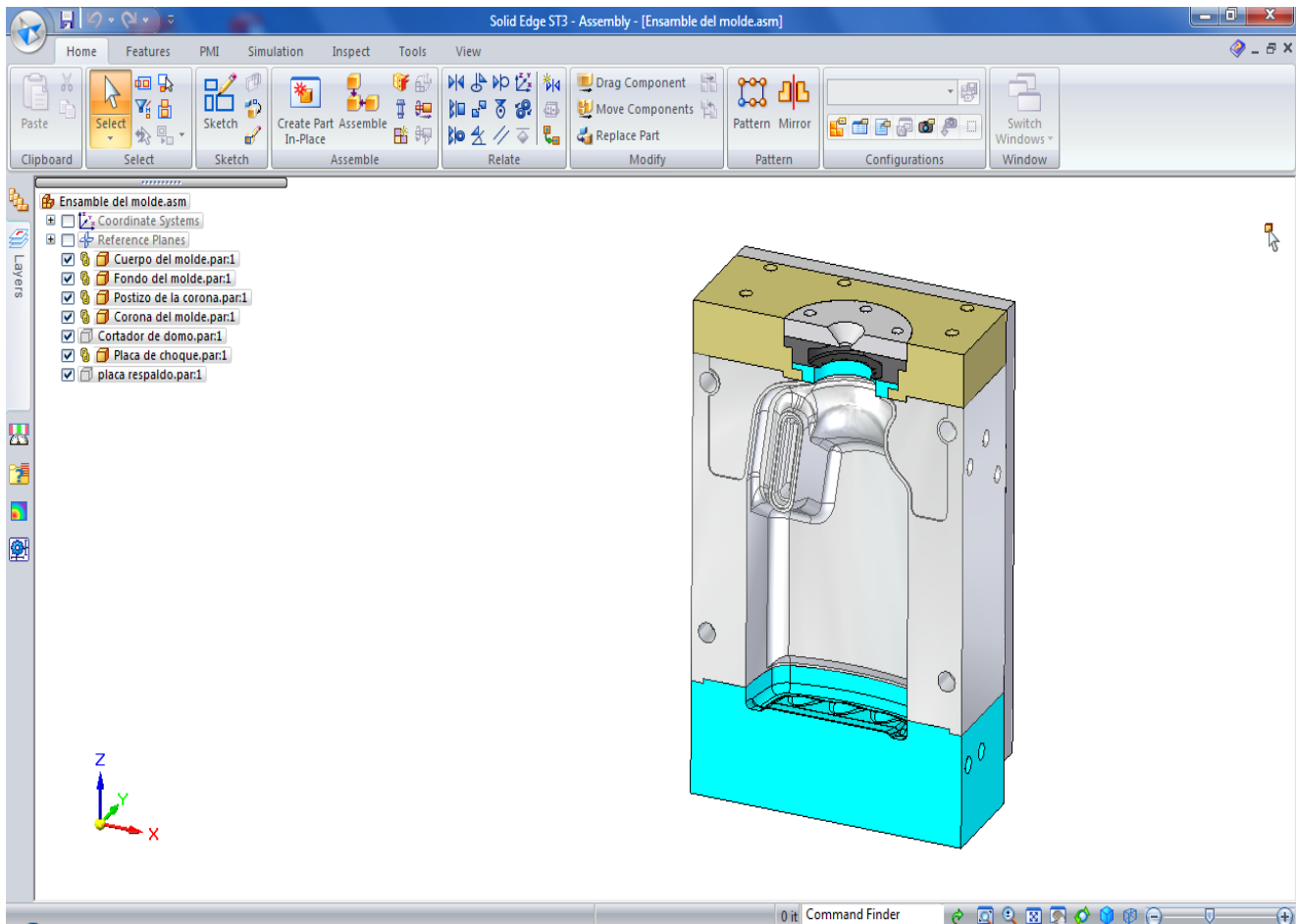


Figure 2.5. 3D preview of the mold cavity

Figure 2.5 clearly shows half of the blow mold and you can also see the color separation of each of the parts that make up the mold, in the program SOLID EDGE will be done only once this operation because the other Part is obtained directly from the machining program of the parts.

The parts that can be distinguished in the previous figure are the bottom, body, crown and cutter although the process still does not finish because the lines of exit of air and cooling are still missing.

## 2.5 Mold Cooling.

All blow molds, however simple, should carry their cooling lines. These are designed in the same program. Drills are made on the sides and laterally to be joined together, so that no leaks from the holes are plugged

and are sealed with silicone. When the top of the mold is assembled both the crown and the crown insert is inserted an oring to prevent refrigerant leaks and mold malfunction.

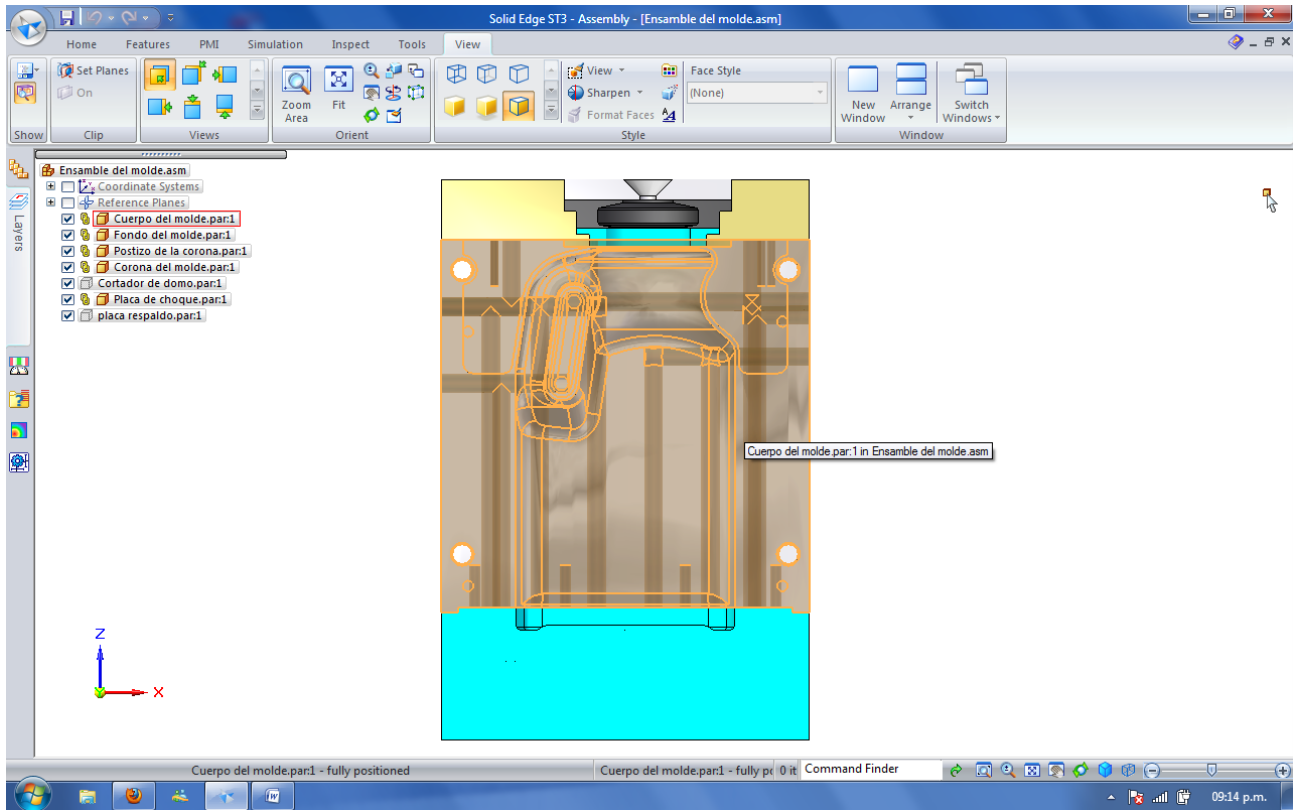


Figure 2.6. Cooling lines

## 2.6 Programming and mold machining.

### 2.6.1 Introduction to Numerical Control and Computer Numerical Control.

Numerical control (NC) is a machine tool automation system that is operated by commands programmed in a storage medium, compared to manual control by means of handwheels or levers.

The first numerical control machines were built in the 1940s and 1950s, based on existing machines with modified motors whose controls were automatically operated following the instructions given in a perforated card system. These servo mechanisms were developed quickly with analog and digital equipment. The cheapening and miniaturization of microprocessors has generalized the digital electronics in the machine

tools, which gave rise to the denomination numerical control by computer or numerical control by computer (CNC), to differentiate them from the machines that did not have computer.

### **2.6.2 Principle of operation.**

For machining a part, a coordinate system is used to specify the movement of the cutting tool.

The system is based on the control of the movements of the working tool in relation to the coordinate axes of the machine, using a computer program executed by a computer.

In the case of a lathe, it is necessary to control the movements of the tool in two axes of coordinates: the X axis for the lateral displacements of the carriage and the Z axis for the transversal displacements of the tower. In the case of milling machines, the vertical displacements, which correspond to the Z axis, are controlled. For this purpose, servomotors are incorporated in the movement mechanisms of the carriage and the turret, in the case of lathes, and in the table in the case of the milling machine; Depending on the capacity of the machine, this may not be limited to only three axes.

The application of CNC systems in machine tools has greatly increased production, while making it possible to carry out forming operations which were difficult to do with conventional machines, for example realization of spherical surfaces maintaining a high degree of dimensional accuracy. Finally, the use of CNC has a favorable impact on production costs, as it leads to lower production costs of many machines, maintaining or improving their quality.

### **2.6.3 Programming in the numerical control.**

Two methods can be used, manual programming and digitized programming using CAD-CAM software. It is now recommended to use the programming provided by specialized software. Because these tools facilitate and decrease the percentage of human error. Within the environment of CNC programming. The CNC program is a language which contains the instructions that the CNC machine must follow. This is the most important reason implying that the error in the encoding should be null. To be able to guarantee that the manufacturing process is carried out correctly.

#### 2.6.4 Manual programming.

In this case, the part program is written only by reasoning and calculations performed by an operator. The machining program comprises the entire set of data that the control needs for the machining of the part.

The set of information corresponding to the same phase of the machining is called block or sequence, which are numbered to facilitate its search. This set of information is interpreted by the order interpreter. A sequence or program block must contain all the geometric functions, machine functions and technological functions of the machining. Thus, a program block consists of several instructions.

The beginning of numerical control has been characterized by an anarchic development of programming codes. Each builder used his own. Subsequently, there was a need to standardize programming codes as an indispensable condition for the same program to be used for different machines provided they were of the same type. Commonly used characters governed by DIN 66024 and 66025 are the following:

- N: is the address corresponding to the block number or sequence. This address is normally followed by a number of three or four digits. In the case of the N03 format, the maximum number of blocks that can be programmed is 1000 (N000 to N999).
- X, Y, Z: are the addresses corresponding to the dimensions according to the X, Y, Z axes of the machine tool (and Cartesian planes). These dimensions can be programmed in absolute or relative form, ie with respect to the zero part or with respect to the last dimension respectively.
- G: is the address corresponding to the preparatory functions. They are used to inform the control of the characteristics of the machining functions, for example, path form, tool correction type, timed stop, automatic cycles, absolute and relative programming, etc. The G function is followed by a two-digit number that allows programming up to 100 different preparatory functions.
- M: is the address corresponding to the auxiliary or complementary functions. They are used to indicate to the machine tool that operations must be performed such as shutdown, right or left rotation of the spindle, change of tool, etc. Address M is followed by a two-digit number that allows programming up to 100 different auxiliary functions.
- F: is the direction corresponding to the forward speed. It is followed by a four-digit number indicating the feedrate in mm / min.
- S is the direction corresponding to the speed of rotation of the main spindle. It is programmed directly in revolutions per minute, using four digits.

- I, J, K are directions used to program circumferential arcs. When interpolation is performed in the X-Y plane, directions I and J are used. Similarly, in the X-Z plane, directions I and K are used, and in the Y-Z plane, the J and K directions are used.
- T is the address corresponding to the tool number. It is followed by a four-digit number in which the first two indicate the number of tool and the last two the number of correction of the same.

### **2.6.5 Scheduling.**

In this case, the calculations are performed by a computer, which outputs the program of the piece in G and M code language. The codes G are all the main operations performed by the CNC machine. These operations G the girls indicating to the machine as the type, type of cycle, etc. While the M codes are secondary codes which complement the G codes. The M codes reprecise the special machining operations.

### **2.7 Haas CNC Control - Triple 32-bit processor.**

It has been well-known to the owners and users of Haas machines for years, but now everyone is aware of it. A market survey of Freelance has proven that professionals like you have rated Haas control as the simplest handling of all they have ever worked with.

Haas designs and manufactures its own CNC system, both hardware and software, specially optimized for Haas machine tools. This system uses three high-speed Motorola processors, which allow for up to 4,000 control loop calculations per second for each of the six motors and offer up to 1,000 blocks per second of program execution speed.

Static RAM powered by battery is used exclusively for storing programs. Optional equipment up to 16 MB is also available for storing large files or saving jobs to the machine. Unlike the dynamic RAM of a PC, which only retains memory while it is receiving power, battery-powered static RAM preserves changes instantly and permanently. In addition to program storage in RAM, other storage options including floppy floppy drive, Ethernet connectivity, and hard disk storage up to 20 GB

All Haas controls also come standard with a high-contrast color LCD-TFT display and are available with the new Intuitive Turning System (Intuitive Milling System) software. This software guides the operator through basic machining functions and general machining operations using a single-chip screen, without the need for G code knowledge.

### **2.7.1 Exclusive Closed System.**

Our aim is to provide Haas users with robust and reliable control that is easy to use and fully integrated in the machine. Our closed system is not based on PC-based controls or independent CNC suppliers. If you go to Haas, you will find a company that takes full responsibility for the entire machine.

### **2.7.2 Ease of use.**

An important idea in Haas designed controls is the standardization of keyboards of all HAAS controls (turning centers have some specific keys for their functioning). Thus, if one learns to use a keyboard of a Haas control, one learns to use, to turn on and to program the rest, whether of vertical centers, horizontal, lathes or even machines of 5 axes. In addition, Haas offers CNC simulators for training centers and schools and specialization courses

Haas Automation offers a wide variety of vertical machining centers (VMC): an ideal solution to meet the demands of the machining shop.

The Toolroom Mills combine the power of the CNC with the simplicity of manual control. Haas CNC Vertical Centers have 406 x 305 x 254 mm (X, Y, Z.) travels in the Mini Mill and the Super Mini Mill (up to 3048 x 1016 x 762 mm) in the huge VF-11. The range of sizes of pieces accepted is also diverse, with tables available from 305 x 914 mm up to 711 x 3048 mm.

The range of possible applications is as wide as the capacities: the Mini Mill of 5.6 kW, the Super Mini Mill of 11.2 kW, spindles of 14.9 and 22.4 kW for the line VF; Speed ranges ranging from 0 to 7500 rpm, with options for 10000, 15000 and 30000 rpm; And torque values up to 610 Nm. These machines are flexible enough to guarantee rough machining with high pairs of large parts as well as high precision machining operations at high speed.

The legendary Haas control makes our VMCs easy to use. With unique Haas features such as word processor editing, one-button activation of functions, multifunctional remote control and programming with Visual Quick Code, you will discover that the Haas control is the easiest to use CNC control in the market. Using the machine could equate to driving your favorite sports car: it will take you where you want. It is easy to drive. And you can not say no.

Haas machines offer extensive menus of options, accessories and dividers that allow you to customize the machine completely according to the specific needs. But before focusing on the options, it impresses the long

list of functions and capacities of series that includes each machine of Haas. These functions and abilities are usually typical of machines, some functions are not available on any other machine.

Each Haas VMC has been designed to provide the necessary functions and performance, making them a good investment that guarantees comfort, flexibility and productivity difficult to imagine.

Haas CNC lathes offer a range of power options with drive systems of 11.2, 14.9, 22.4 or 29.9 kW and up to 7000 rpm. All models incorporate a vector drive system manufactured by Haas to provide high torque and maximum performance during machining of large parts. In addition, ultra-fast switching offers high torque values and a wide range of constant power. The working environments of the SL series lathes range from 279 x 356 mm of the SL-10 small size and the maximum capacity of the long bench lathe SL-40L of 635 x 2032 mm, The new Haas Toolroom lathes, with a functional range from manual to full CNC operation, incorporate the Haas Intuitive Turning System, an exclusive conversational operating system that simplifies to the maximum the machining of parts and the creation of CNC programs. Toolroom lathes have four modes of operation: manual, semi-automatic, fully automatic or full CNC. The high-precision digital reading facilitates manual positioning and the Haas conversational programming system further simplifies, if possible, programming using the G-codes

All SL models feature brushless drive shafts, which provide high reliability and are available with programmable counterpoints (the SL-10 has a manual adjustment counter with hydraulic shank). SL series lathes feature 10 or 12 position turrets that index the next tool in less than 1 second. The Big-Bore models offer more power and allow more bars to be housed without switching to a larger machine. On the other hand, the options of motorized tools and axis C are available in the majority of models to drive tools dividers VDI of standard 40 mm and to realize secondary operations without having to reuse the pieces.

These machines are made in USA. With gray cast iron and ribbed design for high rigidity and high structural damping against vibrations. The design of the tubular anti-torsion bench (Haas exclusive), with more than twice the mass of the competing models, is used for greater rigidity. The result is greater precision, repeatability and extraordinary surface finishes, while maintaining reliability and competitive prices.

All Haas SL series CNC lathes include functions and capabilities that are usually typical of machines that cost a lot more money; Some functions are not Still available on any other machine. A wide range of options, such as a spindle at 7000 rpm, high performance gearbox, complete C axis, power tools, parts extractor, servo bar and tool gauge, allow you to tailor your new machine According to their specific needs.

## **2.8 Machining of mold parts.**

The parts of the mold are individually machined to an approximate measure so that torque is then accurately measured, that is to say, at the moment of the mold assembly, the pieces that are machined in pair perfectly match.

In the process of selection and machining of parts is done in an orderly and precise, it is worth mentioning that in the SOLID EDGE program only one half of the blow mold is worked, the part that will be responsible for forming the complete cavity will be obtained from carrying out In the MASTERCAM program a reflection of the parts already obtained in SOLID EDGE.

### **2.8.1 Machining of the mold body.**

The machining of the mold body as shown in figure 1.16 is done as follows and already having a 3D emptied part is passed to MASTERCAM apply the tools available in the workshop and in this case has a variety of tools , It is arranged to place the material to be machined in any available machining center, the program created by MASTERCAM is sent through the network and the relevant modifications are made to the program so that no errors occur when the machine places the tool Selected in the program.

In order to start with the machining of the part it must have been aligned on the X, Y and Z axes. With a tolerance of 0 +/- 0.0005 "the face to be machined the cavity must be rectified, this is necessary for the parts of the Cavity to be joined do not present variations or displacement in the cavity. If alignment and grinding are not properly done, errors in the mold may occur, such that they would only be seen when the mold is working.

The zero part is placed as the programmer indicates.

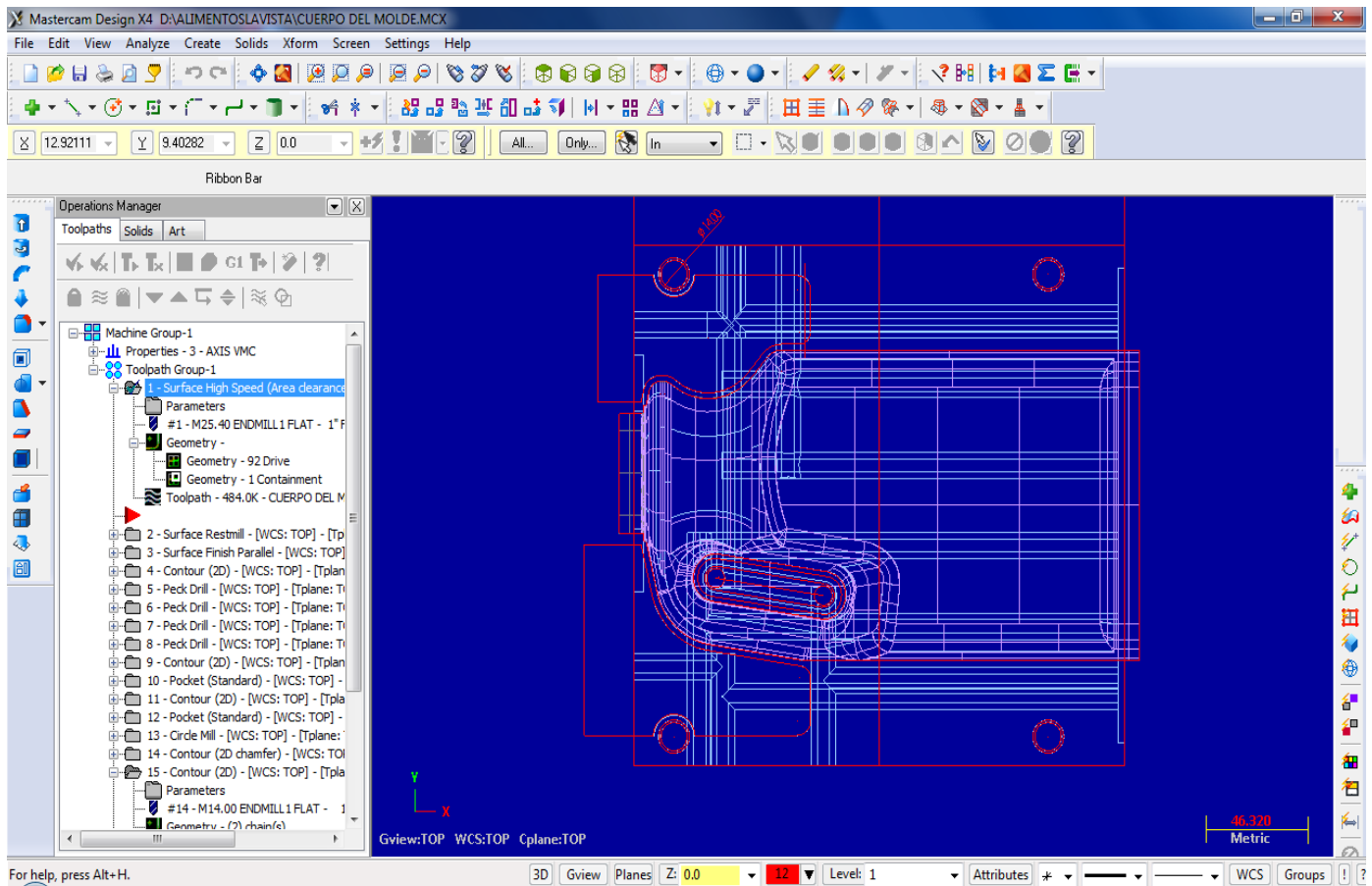


Figure 2.7 Mold Body View

Figure 1.18 shows the cavity of the mold body. It is worth mentioning that in order to create the opposite cavity, only a mirroring is performed in the program, thus saving a lot of work automatically, since the tools used would be the same. Also this action allows that at the time of the closing of the mold does not have displacement one cavity with another.

## 2.8.2 Mold crown.

For the machining of the crown of the mold are made two pieces like the one shown in figure 1.19 are made with an approximate measurement in the center of machining and its process ends joining the two moon stockings and turning them to an exact measurement, it has to Match the body of the mold. This piece will serve to make the threaded part of the bottle.

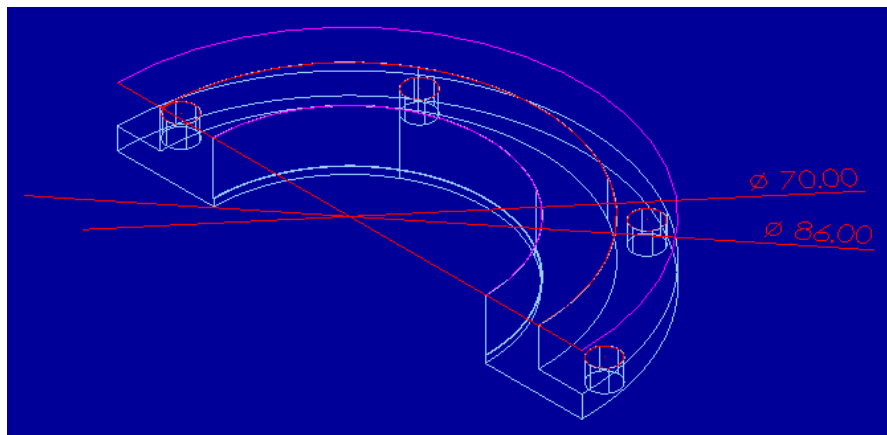
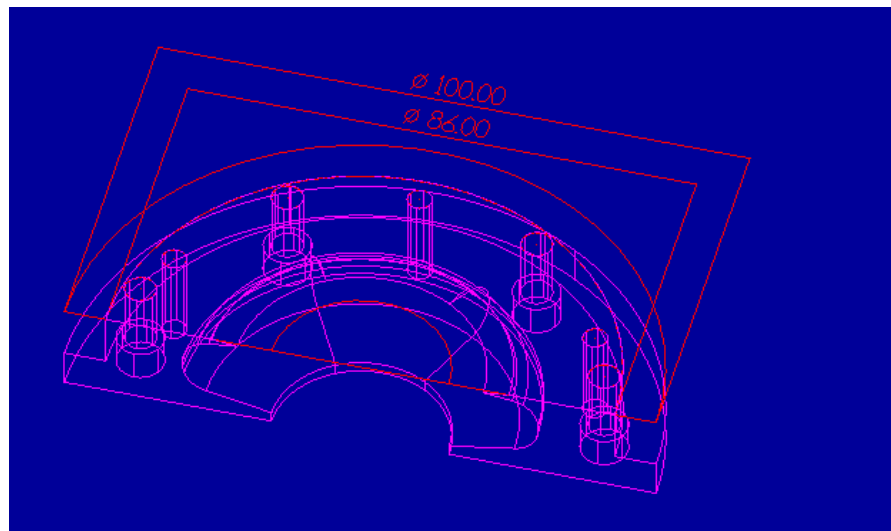


Figure 2.8 Mold crown

### 2.8.3 Dome Cutter.

This piece has a process similar to that of the crown, its function in the mold is to leave in the crown of the container a stretch of extra material so that it does not have imperfections in the threaded part.



2.9 Dome cutter

### 2.8.4 Crown stud.

This piece like the previous ones will be machined individually each one and will be united with similar one to give the inner diameter. Its function is to protect and bring cooling to the surface of the cavity.

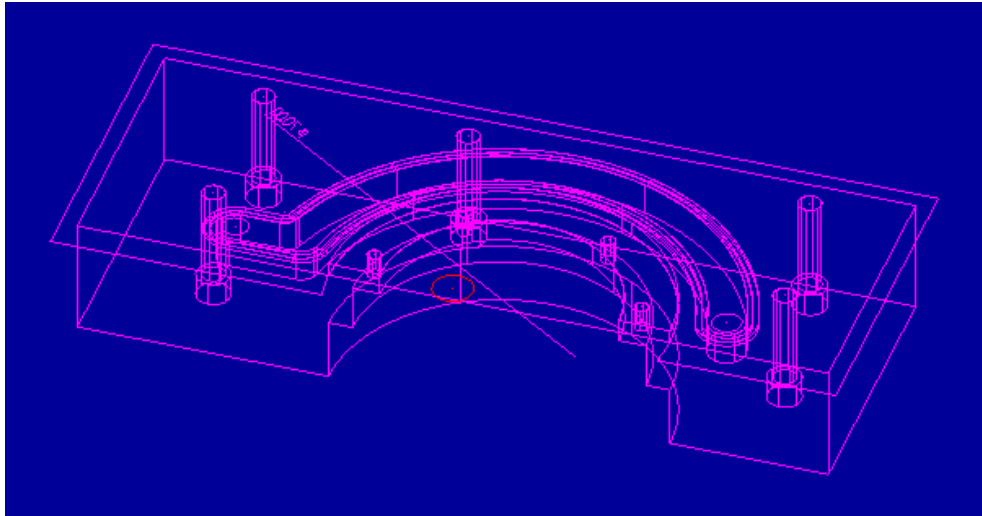


Figure 2.10 Crown plug

### 2.8.5 Mold Background.

This piece unlike the previous ones is machined with its other half so that at the moment of closing the displacement errors are minimal.

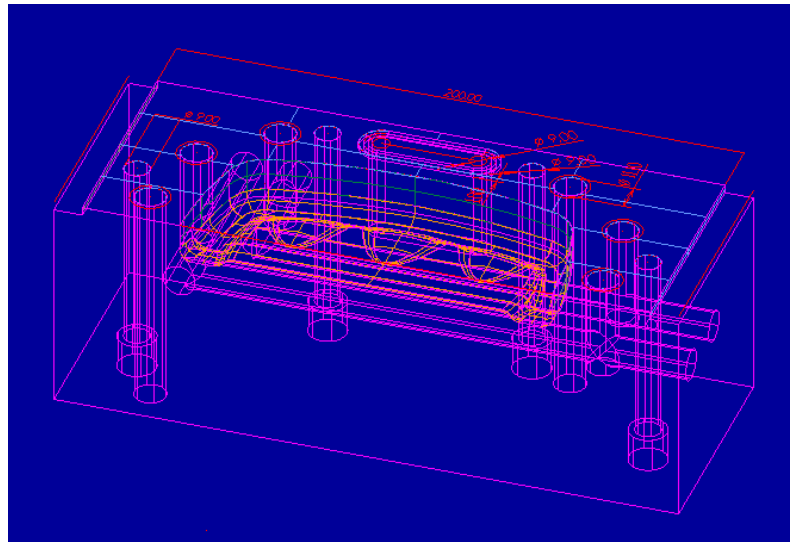


Figure 2.11 Mold Background

### 2.8.6 Cooling Boreholes.

Cooling holes are made once the mold body has been joined with its counter cavity, will be placed in the machine in so many ways is required for the chill guides to join with the respective inlet or outlet.

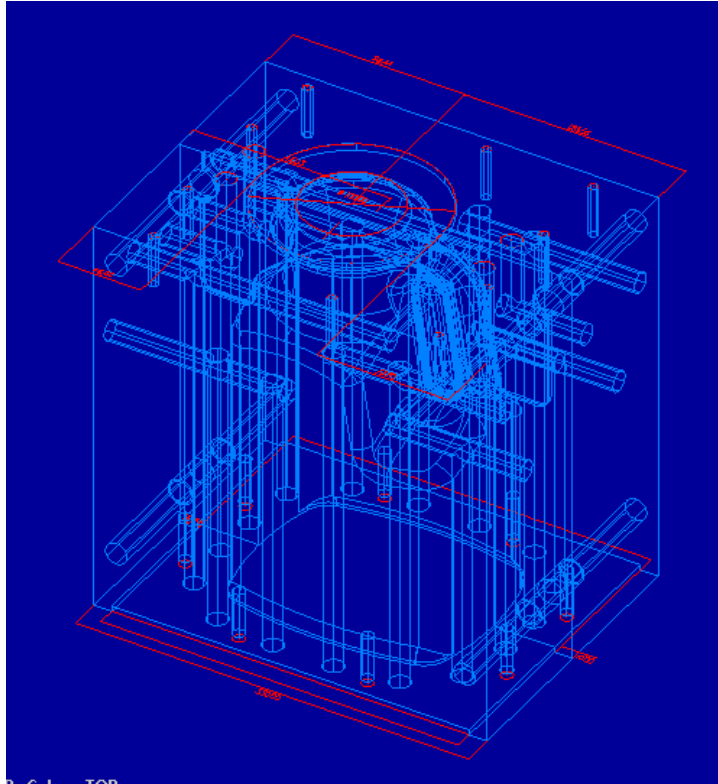


Figure 2.12 Cooling bores

### 2.9 Materials used

Table 2.1 Ratio of materials used

Mold Body	Aluminum
Crown	Aluminum
Dome cutter	AISI 8620
Background	Aluminum
Crown Bolt	Aluminum
Guide bolts	AISI 8620

### Features Steel AISI 8620

Steel grade nickel-chromium-molybdenum machinery for cementing. It offers very good surface hardness and great toughness to the core.

The cementing process is applied to increase the carbon content in the surface so that with a suitable heat treatment the surface is substantially harder than the core.

Table 2.2 AISI Applications 8620

Tornillos sin fín	Flechas	Engranés
Pernos	Piñones	Engranés para
Pistones	Cigüeñales	Reductores

### Features Duralumin 5083 = Magna 45 - Aluminum magnesium alloy

Very high alloy characteristics and tensile strength, very high mechanical strength.

Good mechanization, resistance and corrosion.

Table 2.3 Applications of duralumin

Molds for the textile industry	Utensils
Chemistry	Mechanization.

- Aluminum absorbs heat very quickly, which saves energy.
- Crown aluminum transmits heat to the molds, shortening the cycle.
- Duralumin does not suffer from corrosion or electrolysis.
- The weight of a duralumin crown is 1/3 of a steel crown.
- The life span of a duralumin crown is much longer.

## **2.10 materials for the manufacture of molds.**

These molds are currently manufactured in steels, non-ferrous metals such as aluminum, non-metallic casting materials, galvanically obtained or other a base of ceramic materials.

The type of mold with which you want to make a piece depends on several factors such as son:

- The demands that are asked of the piece.
- The costs of manufacturing the mold.
- The cycle time.
- The number of pieces to be made with the mold. (Useful life).

Choosing the best material that adapts to the needs of the mold, ensures the final quality of the mold from the initial step.

It is understood that a material can not present all the properties it needs. Therefore, before manufacturing the mold, it is necessary to expose and debate the indispensable properties. These properties can be classified in 4 following points of view:

- Type of molding compound to be manufactured (requirements relating to corrosion, abrasion, Thermal conductivity and viscosity).
- Type and magnitude of predictable mechanical stress (cavity size, Injection, shape variations, residual pressure).
- Method of obtaining the casting of the block (chip picking, stamping, erosion).
- Required heat treatment.

### **2.10.1 steels.**

### **2.10.2 Cementation steels.**

Cementing steels have optimum characteristics for the construction of molds. Its main advantage is that by carburizing the surface it obtains a great superficial hardness, and, in addition, a resistant and tenacious nucleus. The high surface hardness makes the molds resistant to abrasion and the resistant core consisting of resistance to bending stresses.

### **2.10.3. Boned steel.**

The bonus gives high tensile strength and toughness throughout the steel section. They have little abrasion resistance and poor surface quality of the mold, which usually requires a surface treatment such as chromium or nitrided. The steels are subsidized in the metallurgical industry where they are subjected to a tempering treatment after tempering.

### **2.10.4. Full tempered steels.**

When it is desired to increase the hardness this is achieved by heating the steel to an elevated temperature and rapidly cooling it with oil, water or air. In this way, we allow the formation of martensite increasing the hardness. Depending on the desired hardness, a different cooling agent is used, the water being the one that provides a faster cooling, whereby, the hardness achieved depends on the cooling rate. Molds made of this type of steel have high abrasion resistance due to their high hardness but are more sensitive to cracking and deformation compared to cementation or bonus steels and this is due to their lower tenacity. For this reason, total tempering steels are only used for small or medium molds.

### **2.10.5. Nitrided steels.**

Mainly steels whose alloy has additives that form nitrides that can be nitrided. These alloying additives are chromium, aluminum, vanadium and molybdenum. The steels to be nitrided, subjected to an annealing in a saline bath, which varies according to the application of a nitrided, a diffusion of nitrogen occurs on the surface of the mold and the additives of the alloy form nitrides, which form a nitrided layer Of a variable hardness, according to the type of steel and the procedure used. Unlike other treatments, the maximum hardness is achieved inside the nitrided layer. For this reason it is necessary to polish the surface after nitriding.

### **2.10.6. Steel of second fusion.**

The quality of an injected part depends on the surface quality of the mold. Reason valid for parts obtained from transparent materials, such as glasses, lenses, etc. The quality of the surface of a mold is higher

depending on the quality of the polishing operation employed. The polishing capacity of the steels is influenced by the degree of purity, depending on the percentage of non-metallic materials found in the steel, such as oxides, sulphides and silicates. These inclusions, which can not be avoided in a first melt steel, can be removed with the second melt steels obtained in high vacuum induction furnaces or in electric arc furnaces. Vacuum cast steels have the maximum degree of purity. As a result, a maximum polishing quality can be obtained.

### **2.10.7. Alloys of aluminum.**

The main characteristics of aluminum in the construction of molds are due to their reduced weight, high thermal conduction, good chemical stability and easy machining. However, the application of aluminum is limited by its low strength. As a consequence of its low resistance aluminum alloys are used that give more resistance for example: AlCuNi, AlCuMg and AlMgSi, are the hardest alloys.

Aluminum and its alloys are often used in the construction of molds for fast delivery to the consumer, for example in the manufacture of plastic bottles, to reduce costs and above all in prototype molds. In the latter case, it is an agile and reliable means of verifying the development of new products without risk taking initiation of the construction of definitive molds, especially in the case that it is necessary to make modifications in the mold that in some extreme cases may suppose to have Than to make a new mold.

As already mentioned, an important factor in the manufacture of molds is knowing how to select the material for a good performance and performance. For that reason you have to analyze what function each piece of mold will have and what properties you have to demand so that it can fulfill its function in the best way.

### **2.11 Properties we must have.**

The performance of the mold material depends on the wear resistance, compressive strength, corrosion, thermal conductivity and toughness. These are characteristics that must be taken into account when designing and manufacturing a blow mold. This information must be correctly analyzed depending on the environment and type of work performed by the mold. This has to be taken into account. Because this ensures a correct function and the most important thing is to ensure the quality and integrity of the blow mold.

## **2.12. Wear resistance.**

The level of wear resistance required will depend on the type of resins Used, the filling agent, the quantity of additives, production series, tolerances, etc. The Wear resistance of steels and alloys can be Treatment or surface coating nitriding type, chrome, etc. These types of Surface treatments should preferably be applied after the mold has Been properly finished since further machining could be difficult.

### **2.12.1. Resistance to compression.**

The required compressive strength is determined by the Molding, injection and closing pressure as well as finishing tolerances. During The molding operation the compression forces are concentrated in the partition line of the tool. Local tempering, for example flame quenching, may bring about an increase Of the compressive strength.

### **2.12.2. Resistance to corrosion.**

The surfaces of the mold should not deteriorate during production if they To manufacture parts with a high and constant level of manufacture and with a uniform quality. The Corrosion, with the consequent risk of loss of efficiency in production can

Different ways.

- Certain plastic types cause corrosion during production. An example of it Is the hydrochloric acid produced by PVC.
- The cooling medium can also be corrosive. This would result in the loss Of cooling efficiency or in a total obstruction of the cooling channels.
- Production in a humid or corrosive atmosphere or a prolonged Storage can cause surface damage due to condensation of the water, and Subsequently oxide in the cavities with the consequent loss of surface finish of the product.

### **2.12.3. Thermal conductivity.**

The level of production of a mold depends mainly on the capacity of the mold in Transferring the heat from the molded plastic to the cooling agent. In a high steel Alloy the coefficient of thermal conductivity is reduced to some extent compared With a low alloy steel. Although the research carried out clearly indicates that it is The plastic of the molding which dominates the heat flow in the mold due to its low Thermal conductivity compared to steel. When mold materials with good corrosion resistance are required in Combination with a very high thermal conductivity we can supply qualities with Copper alloy.

### **2.12.4. Tenacity.**

The appearance and development of cracks is one of the worst problems that can occur to a mold. Complicated figures, small radii, sharp corners, thin walls and severe section changes are currently common denominators. Tenacity is therefore one of the most important properties that a mold material must possess. The fracture strength of a material is a measure of its ability to withstand the propagation of cracks that appear due to the creation of stresses by subjecting the mold to different types of fatigue. In practice, these stress initiations occur due to surface effects from machining operations, incipient fatigue cracks, inclusions or defective structure due to inadequate heat treatment. Using techniques such as vacuum degassing, special refining processes and slag electrofining, the toughness of the material increases. This good tenacity is evident not only on the surface but also on the core of the material.

### **2.13. Choice of material.**

Once exposed the most important aspects to take into account in the correct choice of material for the manufacture of the mold, proceed to your choice. The piece to be produced will be made of polypropylene, ideal for injection molds, due to its very good flowability, in addition the piece will not require optimum tolerances. Therefore the only aspect to take into account on the wear of the material will be production, since it will be medium-high.

The material for the mold, will not need a great resistance to the compression, since the machine injectora will have a small closing force, about a fifty tons of force. Since six water cooling channels are in the mold, the material Need a high resistance to corrosion.

The tenacity that will have to have the material will be, medium high. This tenacity will not be due, for the most part, to complicated piece geometries or section changes, but to fatigue caused by repetitions in short intervals of the injection cycle. This is because it is a high production and a high process speed. As mentioned above, these are quite high productions and speeds, therefore the most influential aspect in the choice of material is the thermal conductivity, combined with good resistance to corrosion. It has therefore been decided to manufacture it with a copper alloy.

Since copper-zinc (brass), and copper-tin (bronze) alloys have a very low tensile strength, between 50 and 60 kp / mm<sup>2</sup> and their main use is in blow molding or vacuum molding, Discarded. The copper-beryllium-cobalt alloy remains the material for the construction of the mold.

Another part to be designed for the mold is the centering ring, due to different problems of space in the mold, has not opted for the option of choosing a standard centering ring, since its dimensions could create problems in the arrangement of others elements. Therefore we will proceed to the choice of an ideal steel for the case. The other components that form the mold can be acquired normalized from their respective manufacturers, such as the air valves, the hot runner nozzle, and the different Allen screws.

## **2.14 Used materials.**

### **2.14.1 ALUMINUM 5083.**

#### **FREQUENT USES**

Components of shaped and / or welded plates, mechanical parts, plastic industry, automotive industry (cars, commercial vehicles), naval industry, aeronautical industry, outdoor installations, pressure vessels welded non-exposed to the flames, cryogenic, towers TV, equipment Transport, shielding plates. Applications requiring weldability, moderate mechanical strength and good corrosion resistance.

#### **CHEMICAL COMPOSITION ON% :**

Table 2.4 CHEMICAL ELEMENTS

%	SILICO N	IRO N	COPPE R	MANGANES E	MAGNESIU M	CHROM E	ZIN C	TITANIU M	OTHER S	ALUMINU M
<b>MIN</b>				.40	4.00	0.05				
<b>MAX</b>	0.40	0.40	0.10	0.10	4.90	0.25	0.25	0.15	0.15	Rest

PHYSICAL PROPERTIES:

Table 2.5 PROPERTIES

<b>Density [gr/cm<sup>3</sup>]</b>	2.66	<b>Expansivity (0 at 100 °C) [°C<sup>-1</sup> x 10<sup>6</sup>]</b>	23.9
<b>Melting Range [°C]</b>	580 – 640	<b>Thermal conductivity (0 at 100 °C) [W/m °C]</b>	Temper 0/H32: 120
<b>Modulus of Elasticity [MPa]</b>	71000	<b>Resistivity at 20 °C [μΩcm]</b>	Temper 0/H32: 6.0
<b>Poisson Coefficient</b>	0.33	<b>Specific heat (0 at 100 °C)</b>	945

TECHNOLOGICAL PROPERTIES:

Table 2.6 PROPERTIES And QUALIFICATIONS

Process	Classification	Process	Classification
<b>Weldability:</b>		<u>Machinability (Temper</u>	
<b>Beam Electron</b>		<u>H116/H32):</u>	
<b>Inert Gas (TIG or</b>	A	Chip cutting	C
<b>MIG)</b>	A	Brightness of sup.	A
<b>By resistance</b>	A	Mechanized	
<b>Brazing</b>	D		
<b>Deep Inlay:</b>		<u>Resistance to corrosion:</u>	
<b>Annealing</b>		Atmospheric agents	A
<b>Half dead</b>	B	Marine environment	A
<b>Hard</b>	C		

<b>Reputed:</b>		<u>Anodized:</u>	
<b>Temper 0</b>	C	Protection	A
		Sparkly	C
		Hard	A

**MECHANICAL PROPERTIES**

Brinell Hardness: 90

**2.14.2 Steel SISA 8620.**

**CHARACTERISTICS.**

Nickel-chromium-molybdenum grade steel for cementing. It offers very good surface hardness and great toughness to the core. The cementing process is applied to increase the carbon content in the surface so that with a suitable heat treatment, the surface is substantially harder than the core.

Table 2.7 CHEMICAL COMPOSITION

CHEMICAL COMPOSITION -% AVERAGE					
CARBON	MANGANESE	SILICON	nickel	chrome	molybdenum
0.20	0.80	0.25	0.60	0.50	0.20

**TYPICAL APPLICATIONS.**

- Crankshafts
- Pinions
- Gears
- Gears for
- Reducers
- Endless Screws
- Bolts
- Pistons

- Arrows

Table 2.8 PHYSICAL PROPERTIES

PHYSICAL PROPERTIES		
Modulus of Elasticity	30 psi x 10 <sup>6</sup>	(207 GPa)
Specific Gravity		(7.84)
Density	7840 kg/m <sup>3</sup>	(0.283 lb/in <sup>3</sup> )

## HEAT TREATMENT

### Wrought

1050-850 ° C (1920-1560 ° F) Do not forge below 825 ° C (1520 ° F), slow cooling in oven or heat insulation material.

### Anneal

Heat to 870 ° C (1600 ° F), maintain 2 hours, slow cooling from 30 ° C (50 ° F) per hour to 650 ° C (1200 ° F), allow to cool in the oven or in air

Quenched at room temperature. Hardness in Annealed State Approx. BHN 143/163.

### Relief of Efforts

Annealed Parts: Heat to 1100-1300 ° F (595-740 ° C), keep for 2 hours, allow to cool in still air.

Tempered parts: Heat to 30-55 ° C (50-100 ° F) below the original tempering temperature, keep for 2 hours, allow to cool in still air. Straightening: Recommended to do between 205-425 ° C (400-800 ° F)

## CEMENTED - Carburized

In box or in salts at the desired depth at 880-925 ° C (1615-1700 ° F). Cooling in oil or the environment. Revenge immediately.

### To revenge

For 1 hour minimum at 150-260 ° C (300-500 ° F).

The cementitious process is applied to increase the carbon content in the surface so that through a suitable heat treatment, the cemented surface becomes substantially harder than the core. The combined process of carburizing and quenching by heat treatment is generally known as "cemented." The heat treatment process is

selected for each particular application, according to the required properties on both the surface and the core. Although there are many heat treatments for cementing steels, the following treatments are some of the typically used.

## 2.15 Activities carried out with conventional machinery.

### 2.15.1 Radial bore

Drilling of plastic blow mold backing plates to make 7/16 "(11.1 mm) and 1/4" (6.35 mm) NPT chute guides. Total 7 pieces drill holes right side and 7 pieces drill left side.

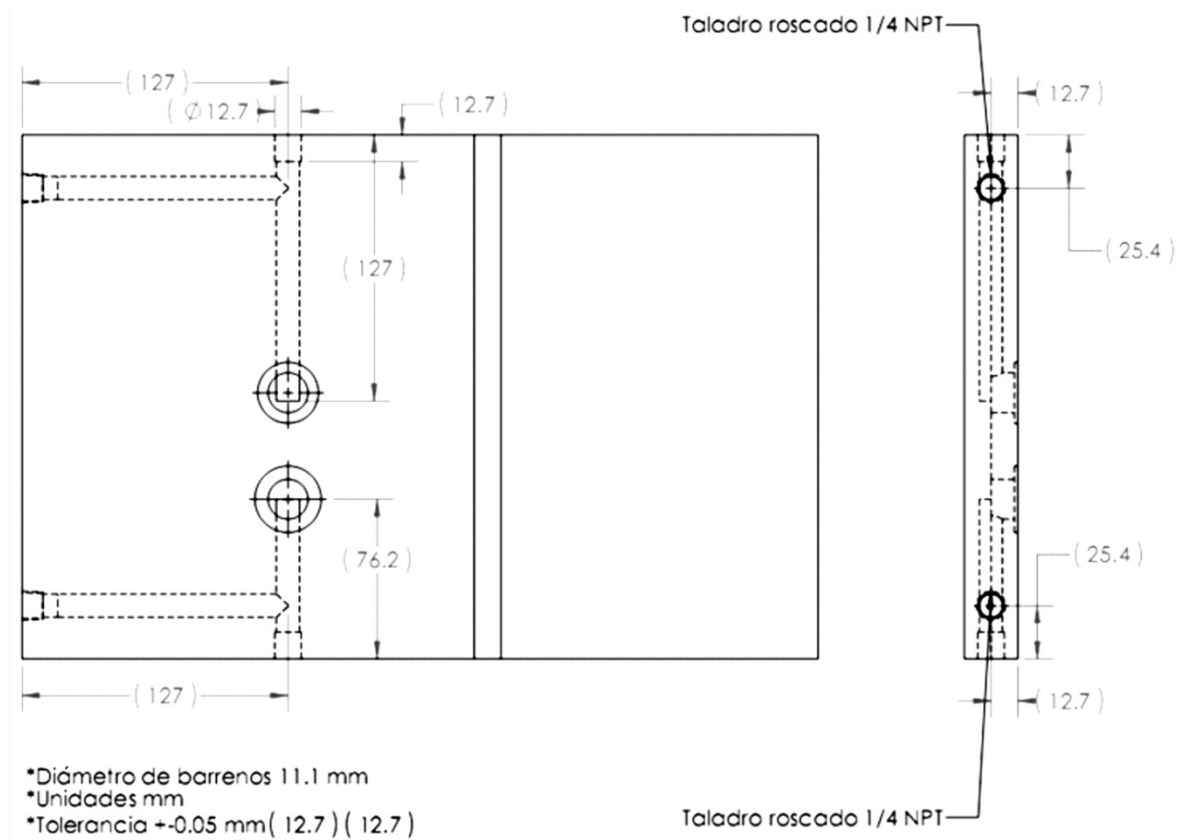


Figure 2.13 Plaque Barren Plan

Table 2.9 Applications of duralumin

NPT tube nozzle	
Diameter of connection	Drill Diameter
1/8	8.33 mm
1/4	11.11 mm
3/8	13.89 mm

The process that is carried out to use the radial drill is as follows:

- Fix the material to the radial drill bed and check that the material is perpendicular to the axis of the spindle.
- Trace the corresponding measures in each hole, in this case as several plates with the same measure of holes will be used a stop to avoid moving the drill spindle with each plate in this way will save time in the machining.
- Center drill each drill that is made must be tapped with this drill bit.
- Selection of drills for the measurement of well-sharp and right-hand drill holes, at least two sizes of drill bit should be chosen for drill depth and one drill bit, the short drill bit serves as a guide to a minimum depth, otherwise this is done there is the possibility that a long drill will suffer some deformation and the hole will deviate from its destination.
- In the process of drilling no matter what the first drill bit to trace, manual work requires a lot of practice and always be aware that the drill bit does not lose edge, you can use coolant or air.
- The 6.35 mm (1/4 ") NPT spigot should enter approximately 18 mm deep.



Figura 2.14 Radial Drill Bench

In Fig. 2.14 A plate attached to the drill bed is shown, when a material is drilled, either in a CNC machine or conventional machinery, the drill force must be taken into account on the material, since without a support in the lower part this in some occasions is displaced and therefore the depth of boring varies.

### 2.15.2 Lathe

Roughing of different parts, elaboration of aluminum stoppers to seal cooling chambers of the different blow molds.

The plugs for the backing plates are made as follows:

- In the plane of Figure 5.1 The measures 12.7 x 12.7 mm is where the plug will be housed, in practice when drilling with a drill the drill tends to be +0.1 mm larger than the diameter of the drill bit that to make the plugs you must take a plate already drilled to take the measure that will be given to the plug and give the necessary tightening so that there is no risk of leakage in the cooling.

- The measure that will be given to the cap will be 0.02 mm of tightening this is determined after the diameter of the box for the cap has been measured, will be manufactured in aluminum current with a height of 12 mm
- This procedure is used in the manufacture of plugs for various molds.

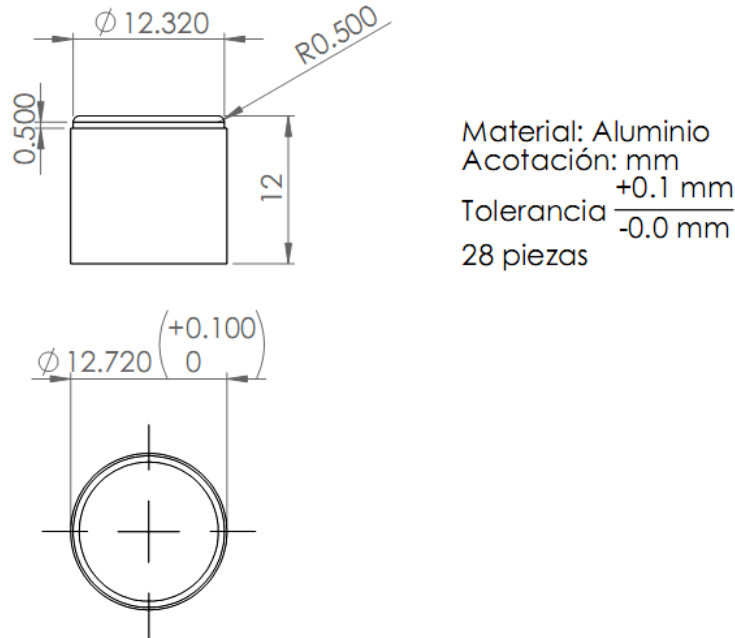
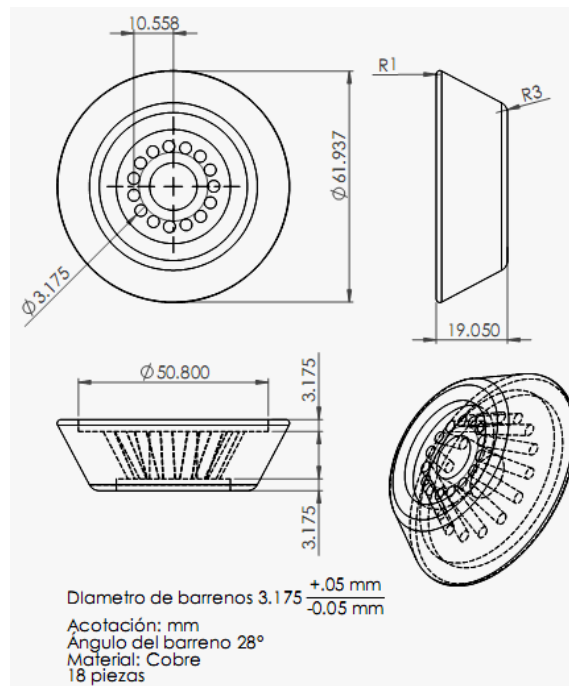


Figure 2.15 Drawing of the cap

In the previous figure you can see the plane of a plug, however when performing these jobs that are not so precise, it is not necessary to draw a plane, the operator must perform this work completely from taking the measurement until the capping, this to avoid that a plug is a measure smaller than allowed and this does not reach the required tightening to avoid leakage.

### 2.15.3 Milling machine

Boring nozzle blowing according to the drawing shown below in figure 5.4 This process is almost equal to that of the radial drill, the FNK 2 milling machine allows the drilling of various materials and parts the advantage of using this machine is that by its smaller size the works that are made are in less time and with a greater precision, as disadvantage it can be mentioned that the pieces must be of small volume and with a weight not more than 200 kg.



. Figure 2.16 Blowing nozzle.

Focusing specifically on the drilling of the nozzle shown in the previous drawing we can see that the holes have an inclination of  $28^\circ$  with respect to the external wall of the material, to start with the process we must have the right tools, in this process alone the drill of 3.175 mm diameter will be used, it will not be used drill centers not because it is not necessary to use it but the material to be machined is copper and is a very soft material to be penetrated by the drill bit.

The piece carries 15 uniformly distributed boreholes to make the distribution should use a divider head that will lean on the table of the milling cutter must be aligned with respect to the X and Y axes, in case the 28 degree angle can be solved 2 different ways one is to move the milling spindle to  $28^\circ$  or to give the  $28^\circ$  to the spindle if it allows. Once all this is ready you can start the work of Barrenado.

For the thinning of materials for CNC machining is only to give them an approximate measure or simply squaring it prevents CNC machines from taking the time to do these processes. This is done mainly when the new or recently cut material is coarse and does not allow a correct alignment or fastening in the machines.



Figure 2.18 AISI H13 Raw 12 "x 3".

In the previous figure we observe a raw material for the CNC machining first the section of the hearth should be cut into smaller pieces leaving about 2.5 mm for each side to be covered. That is to say if in a plane it indicates to us a piece of 90 x 60 x 60 mm the material to be obtained or to cut must be obtained of 95 x 65 x 65 mm or of a superior measurement in each face.

### 2.16 Activities carried out with the CNC machinery

The operation of the Haas CNC machines is very simple the control boards are identical the only variation that exists between the lathe and the machining centers is that the lathe only moves on the X and Z axes and in the center of machining are used X, Y and Z.

The following figure shows the board of the VF-20 and with this a brief description of the operation of the CNC of the company will be made.

In Figure 2.19 it can be seen that the board was distributed in areas with the letters A, B and C and other numbered parts this is to know the location of the menus.

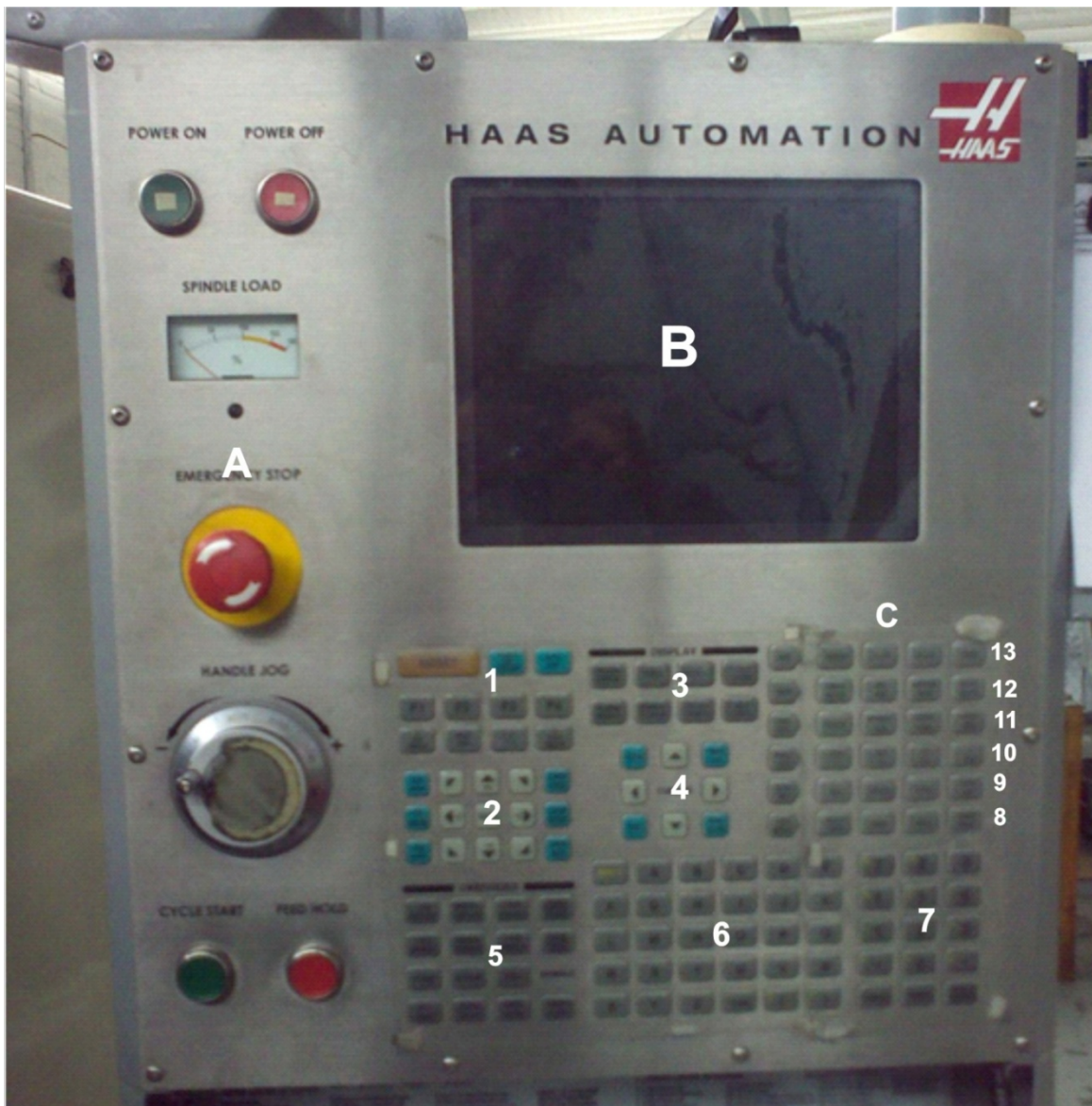


Figure 2.19 VF-20 CNC lathe board

- Zone A: Top, in this zone are the switches on, off and emergency stop, the bottom is located the knob for manual use and the start and stop switches of a program.
- Zone B: Display.
- Zone C: Main operating menu of the machine
- 1: In this part the keys are reset, power up, keys F1 to F4, tool offset measure and part zero set.
- 2: X, -X, Y, -Y, Z, and -Z axis selection keys. and jog lok.
- 3: Keys for menus of general settings.
- 4: On-screen scroll keys.
- 5: Keys for control of the Spindle
- 6: Alphabetical keyboard
- 7: Number keypad

### **2.16.1 Process of energizing the machines**

- CNC machines are connected to an air network inside the workshop. Therefore, only the flow valve must be checked before starting the machine. This is for both the CNC lathe and the machining centers. machine does not have the open air supply will mark the low air pressure alarm.
- Once this is verified, the machines can be switched on with the Power on switch (green top panel button)
- Since the machine has switched on and entered your system, we will dial 2 alarms, emergency stop and servos off, these alarms are removed by removing the emergency stop and pressing the reset key on the dashboard.
- Deactivate code 51 of the general settings to work with the door open this same code works on the VF-20 as well as on the VF-1 and VF-2 in the machining center VM-3 this code works with a mechanism which is removed manually. Since these steps were followed, the power up key is pressed to activate the servomotors and the machine can interpret the distance of its movements.

### **2.16.2 Receiving and executing programs on CNC machines**

In Hass CNC machines it is simple, they all have the same menu for receiving programs the keys are located according to the previous figure in the line marked with the number 8.

- List program: Open programs saved in memory either usb or local disk
- Select program: select a program
- Erase program: Deletes a selected program

Once the program has been received it is proceeded to edit it, assign Z-axis verification tool numbers etc. The editing is done with the keys located on the line marked with the number 13.

The execution of a program is done with caution to avoid hitting the machine destroy the tool or that the operator suffers an injury, this is always when the first piece is made, to execute a program with caution use the keys of the area marked with the letter A and number 5.

With the menu marked 5, cutting speed, speed control and fast machine movements can be reduced by 5, 25, 50 percent, up to 100 percent, all of which are independent of each other.

### 2.16.3 Turning Off the Machine

- To turn the machine off, the lathe must be in Home position and in the case of machining centers there should be no tool placed on the spindle.
- Activate emergency stop
- Power off switch
- Close the air valve

### 2.17 Lathe VF-20

- To place a piece on the winch, the jaws must be adjusted to fit the material, the jaws run on a toothed base with which they are fastened to the chuck, depending on the diameter of the material the jaws must be adjusted and tightly screwed to the base .
- The jaws open and close hydraulically with a foot pedal located at the bottom of the winch.
- The material once subject should be checked for alignment with the dial gauge should not have variation greater than 0.05 mm. For verification of the material the meter is placed in a fixed part of the machine and with rotating movements of the chuck can verify the centering of the piece.
- To establish the point Z0, a thinning is made on the front side of the material. As shown in figure 5.9 once this is done, the tool must rub against the final point of roughing and thus assign to the machine part zero set in the respective menu.
- Check Z path in the program and Z0 has enough distance for the tool path if this is not done, there is a risk that the carousel will hit the chuck.
- Run programs until the part has the desired dimensions.

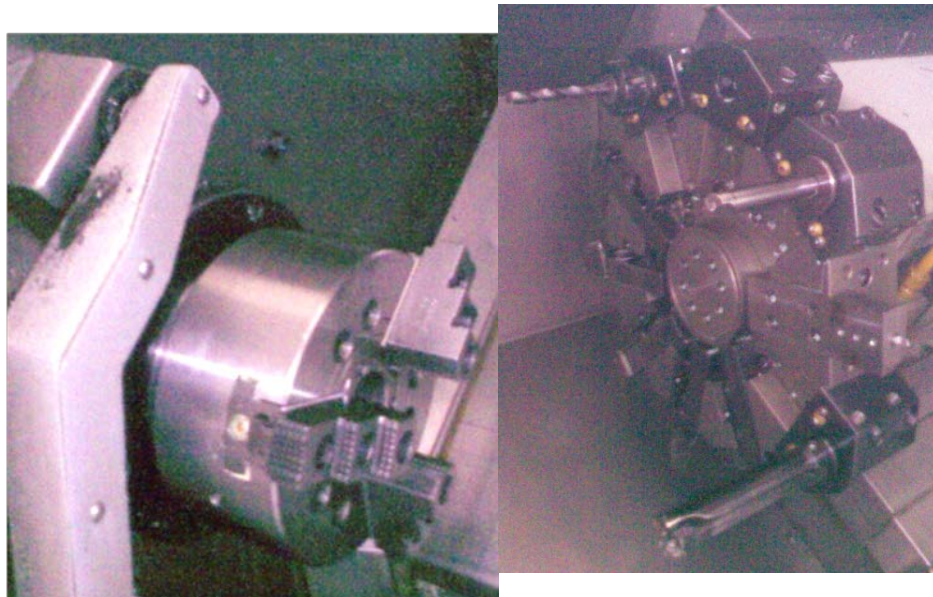


Figure 2.20 y 2.21 Respectively chuck and carousel tool carriers.

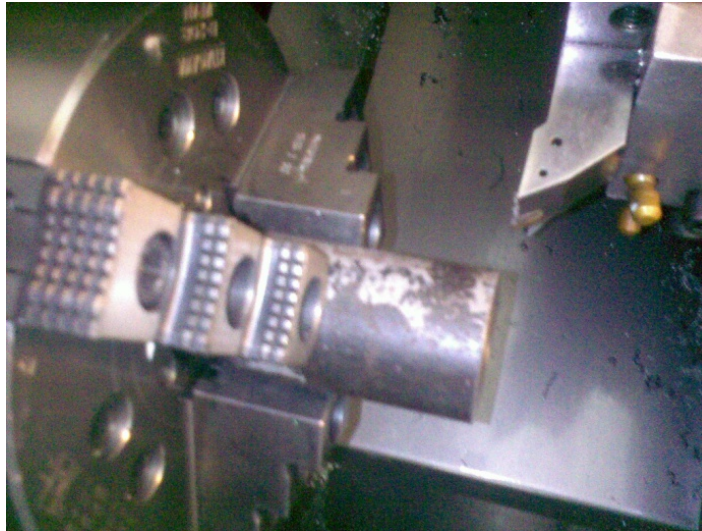


Figure 2.22 Material set for part zero set.

### 2.18 Machining Centers VF-1, VF-2 and VM-3

Operation of the machines, placement of the part to running machining programs. For the operation of the machining centers the workpiece must be positioned and aligned with respect to the X, Y, and Z axes with a variation of not more than 0.05 mm. The figure below shows a cover meter used to check the alignment of the part, at the top and side.

Steps for alignment verification:

- Insert the dial indicator on the spindle base.
- Touch with the tip of the indicated on one of the faces to check either X, Y or Z.
- In case of X check the tip of the indicator should rub against a lateral side of the material position the cover at a point 0 and make uniform movements from X to -X on the piece the displacement of the needle will indicate that the right is the piece.
- For Y the previous operation is performed but on a face perpendicular to the X axis.
- For the Z axis it is verified on the surface and the faceplate must be moved on the X and Y axes.
- Once this is done you can continue the process of the parts to be machined.



Figure 2.23 Dial indicator

To establish the zero piece can be used probing tools as shown in figure 2.23 this tool has a light indicator that when the internal circuit is closed this is illuminated this tool has a height of 50.8 mm and once the circuit of the tool the height is subtracted in the distance Z. since it was compensated we establish Z0 with the key part zero set.



Figure 2.24 Probe for the Z axis

To set X and Y uses a different probe this tool also has a light indicator that when it rubs with the material closes the circuit, has a diameter of 5.08 mm and depending on where you want to locate the X0 or Y0 will make the compensation If you want to place in the middle of the material, the probe should touch the 2 parallel faces of the material and divide the distance traveled between 2. Once the probe was located in the correct position, set X0 and Y0 with the part zero set key.



Figure 2.25 Probe for X and Y axes.

## 2.19 Arming of Blow Molds

Once all parts of a mold have been finished they are assembled as follows and as shown in the figure.



Figure 2.26 y 2.27 Mold body and bottom

To assemble these two parts orings are inserted into the coolant guides to prevent leakage and ensure an excellent blowing process. When these two parts are joined, they must match perfectly on their front faces as shown in Figure 2.29.



Figure 2.28 y 2.29 Orings and bottom of mold

In Figure 2.29 the bottom is seen in conjunction with the mold body the bottom has a copper-beryllium alloy insert this helps the mold temperature in that part to be uniform and the blown material has a better grip towards the walls , you can also see that in the bottom is the part that has hub and air outlets in the body. Hence the other half of the mold will have integrated the bolt which will serve in the mold coupling. The set of parts that continue to be assembled in the mold are the crown, crown insert and its cutter.



Figure 2.30 y 2.31 Mold Body Top

In the previous figures the upper part of the mold is observed, this is the opposite of the bushing carrier, to assemble the upper part, follow the previous steps. An appropriate measuring ring is inserted and the parts are assembled in the same way as with the bottom, the side surface of the cavity being well-encased.

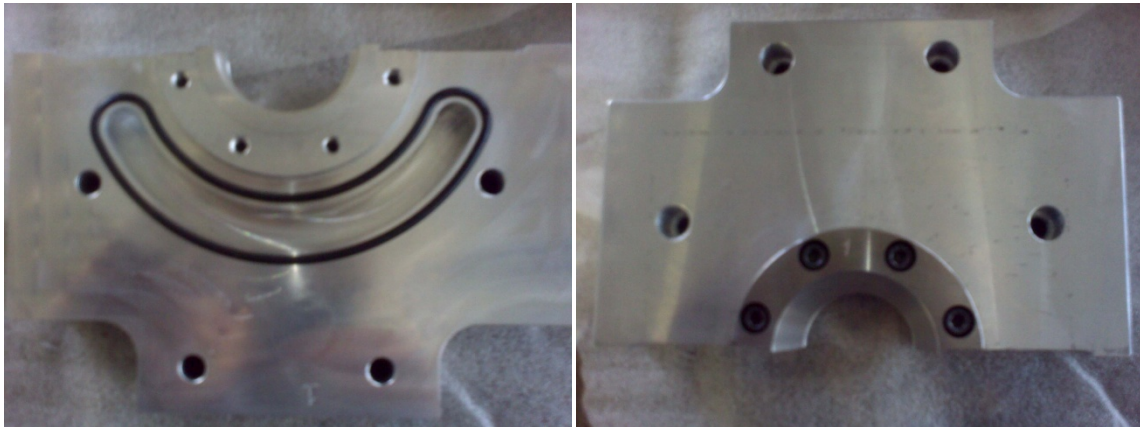


Figure 2.32 y 2.33 Crown and crown insert.

The crown insert carries the bottle cutter on the top. This cutter has as main function the cutting of the plastic hose that comes down from the blowing nozzle and helps to avoid with this cut the deformation of the bottle.

### 2.19.1 Some of the data to be checked in the operation of the mold are:

Regarding the physical state:

- Machining
- Countermeasures (adjustments and tolerances)
- Finishing the Surface

As for mold work:

- Leaks
- Weight of blown bottle
- Volume
- Maximum pressure that resists the bottle
- Bottle height
- Bottle imperfections

## 2.20 Maintenance at VF-2

The VF.2 machine presented an alarm indicating that the carousel was not in the correct position to receive the tool.

The procedure followed to correct the fault was as follows:

- General cleaning of the machine.
- Disassembly of parts containing main mechanisms associated with the tool carrier carousel.
- With a multimeter, input and output voltages of each sensor were verified.
- Once the fault was found, the sensor was removed and a new one was fitted.

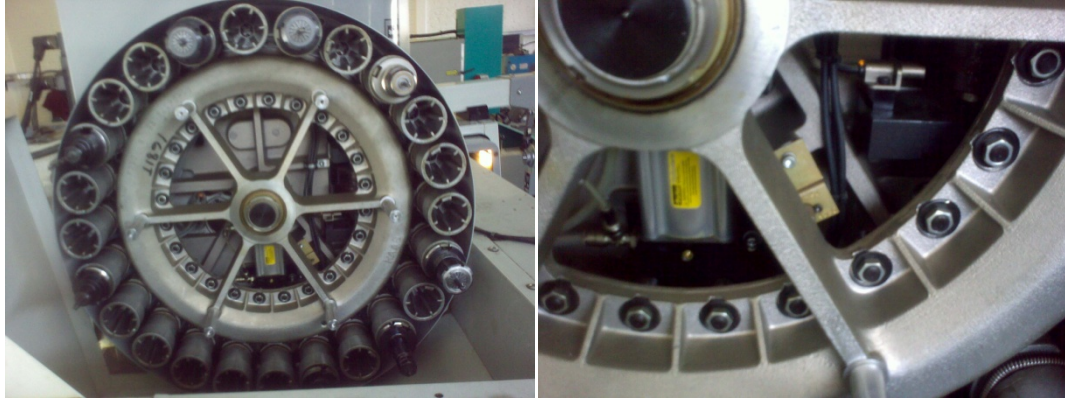


Figure 2.34 y 2.35 VF-2 Tool Carousel



Figure 2.36 Sensor positioning tool

# **CHAPTER THREE**

## **BUDGET FOR THE DESIGN AND MANUFACTURE OF A BLOW MOLD IN MEXICO AND WHAT IS THE SITUATION OF MANUFACTURING IN MEXICO**

### **3.1 Overview of the mold sector in Mexico.**

According to Alfredo Aguilar, technical manager of the project in Mexico, for US \$ 1.6 billion For this sector, which does not take advantage of the lack of national capacity. "Between 5% and 10% of the demand for molds, dies and tools, is handled by domestic companies, the rest is mainly imported from the United States, Canada, China, Japan, Germany, Spain and Portugal," he said.

He said that the number of Mexican companies in the sector is between 1,000 and 1,500, approximate number because there are no accurate data. The National Statistical Directory of Inegi Economic Units (Denue), indicates that there are 544 manufacturers of forged and die-cut metal products; 678 manufacturers of coatings and metal finishes, and almost ten thousand manufacturers of metal parts and screws.

In Mexico, the main industries that require molds, dies and tools are aeronautics, automotive and household appliances, while the processes that demand molds, dies and tools are metal smelting; Injection, extrusion and thermoforming of polymers; Cutting of metal foil; Hidroformado of metal; Extrusion of metals and metal forging.

### **3.2 Current situation in Mexico.**

#### **3.2.1 Real demand of the plastic sector**

The domestic plastics market has grown vigorously - 8.6% per year on average between 2003 and 2008. In 2010, a total of 4.85 million tons of plastic was consumed in Mexico (ie world consumption ratio of 228 million tons), Which represent 48 kg / inhabitant. With this Consumption, Mexico occupies the 12th place in the world. The National Association of Plastic Industries AC - ANIPAC, which has been looking for 48 years

to look after the interests of the plastic industry, has defined the following model that in a generic way describes the actors involved in the plastic chain. This model aligns with the national conditions in which the country is located with the main objective of achieving competitiveness and profitability of the sector. The industrial chain of plastic presents a serious imbalance in its trade balance. 53% of the volume of resins consumed are imported, more than 80% of the machinery and tooling comes from abroad. The maquiladora industry is supplied marginally by domestic companies. [10] (Conde, 2012)

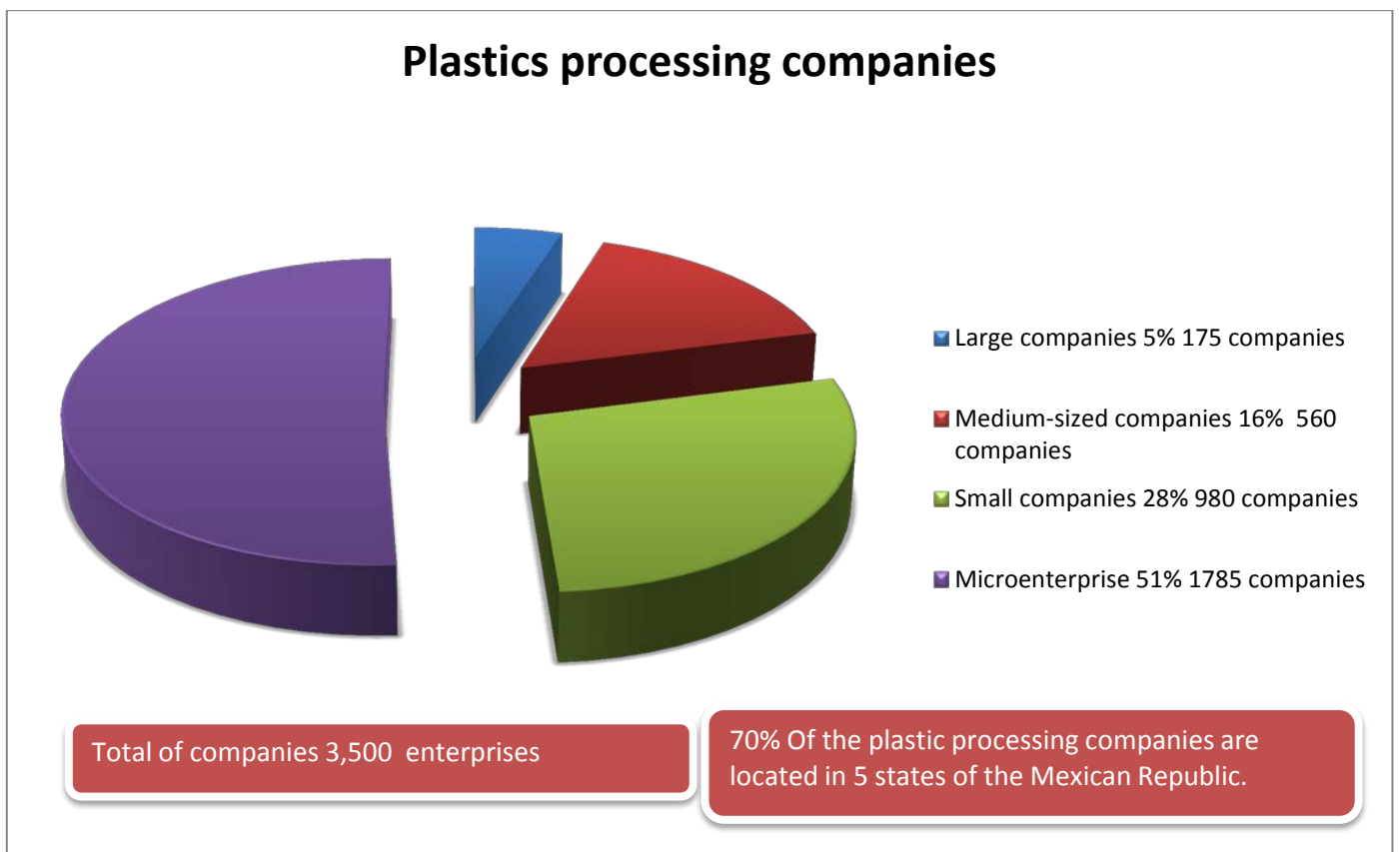


Figure 3.1 processing companies. [10] (Conde, 2012)

Table 3.1 plastic transformers. [27](Plastic industry. <http://www.beta.inegi.org.mx/>)

States with greater number of plastic transformers.	
State	Number of companies
Federal district	800
State of Mexico	650
Jalisco	420
New Leon	320
Guanajuato	280

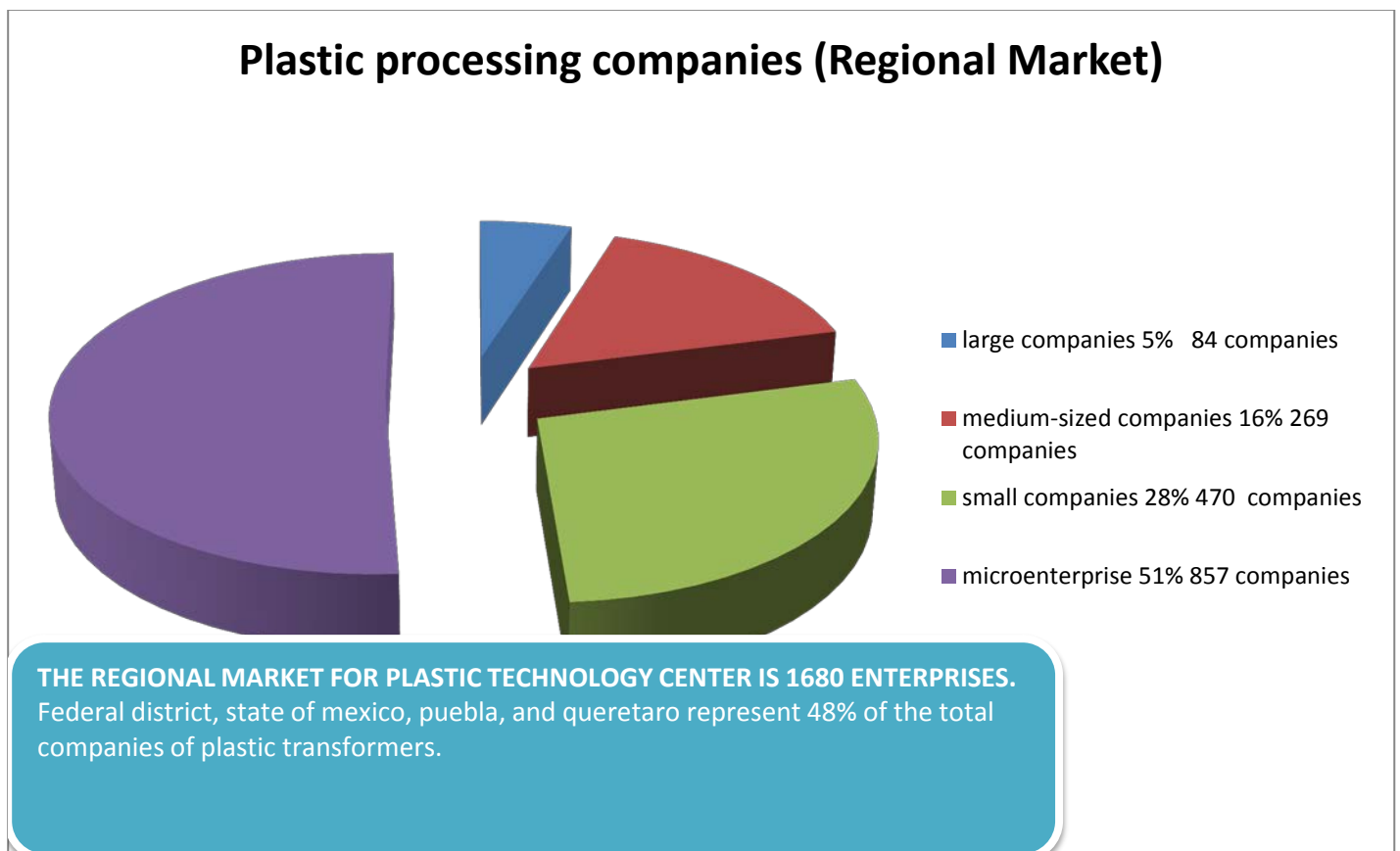


Figure 3.2 regional market. [10] (Conde, 2012)

### Regional market of plastic transformers

State	Number of companies
Federal district	800
State of Mexico	650
Puebla	130
Queretaro	100

Table 3.2 Regional plastic transformers. [27](Plastic industry. <http://www.beta.inegi.org.mx/>)

84% of the companies in the plastic / rubber sector are micro and small, of which a good proportion are family businesses. 38% are not incorporated as commercial companies (they are natural persons), 71% of the value added of the transformation of plastics is concentrated in 9% of the companies. Studies have shown that the average of a mold manufacturing operation is only 15% in value-added activities, 85% of the remaining time can be classified into bank work, adjustment, machine cleaning, assembly and commissioning. work,

Re-working molds on floor waiting to be processed, transit parts inside the workshop.

The following points list the characteristics of the plastic transformation companies in Mexico:

- Most products are "half-made"
- Most products are not standardized
- Quality is heterogeneous and inconsistent
- Lack of knowledge of materials and properties
- Processes are inefficient
- Equipment of different brands
- About 50 percent of manufacturing companies have equipment with more than 10 years of life, which makes them more frequent preventive and corrective maintenance, increasing their operating costs.

- Shortage of research and development laboratories in the plastic theme.
- Lack of technical service to the user
- Disinformation of current and potential markets
- Markets are more or less attended to
- Unstable markets and customers
- Few companies plan their overall management
- Low plastics culture at all levels

Among the internal factors of companies that encourage or inhibit the competitiveness of the plastic chain are: Commercial and logistical capabilities, production capacities and innovation, technological capabilities and sustainable development, work environment, financial capacities, economic resources of support, organizational capacity and competitive environment.

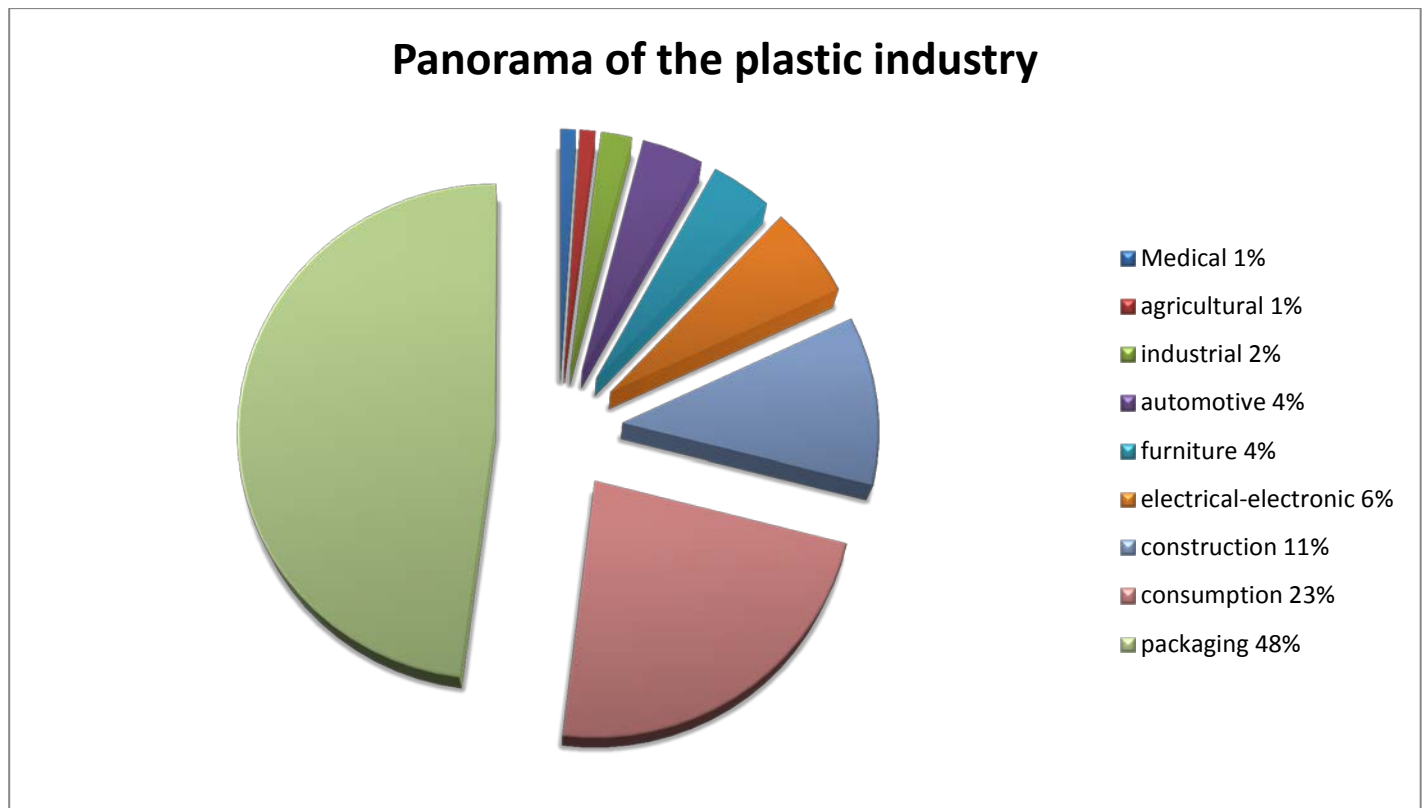


Figure 3.3 Panorama of the plastic industry. [10] (Conde, 2012)

Table 3.3 Plastic stage. [27](Plastic industry. <http://www.beta.inegi.org.mx/>)

<b>Injection 57% 1960 companies</b>
<b>Extrusion 23% 770 companies</b>
<b>Blowing 11.5% 385 companies</b>
<b>Rotomoulding 1.6% 55 companies</b>
<b>Other 6.9% 330 companies</b>

During 2008 there was a growth of 3%, highlighting the technical plastics and the process of blowing with investments. The future of this market lies in the automotive/auto parts industry, agricultural and Packaging /packaging. There are other latent markets where plastics are not used despite their great potential. Market demand is growing faster than domestic production, while plastics converters saw their domestic market share decline from 87% to less than 80% in the same period.

The main drivers of demand for plastics are specified below:

- The substitution and combination of traditional materials with plastics
- The consumption of the export manufacturing industry
- Construction applications
- Application in agricultural applications and for irrigation.

### 3.3 Design and manufacture of molds and tooling in Mexico.

With the penetration of the maquiladoras in Mexico to serve the markets of North America, represents a significant demand for molds and tools. Next figure shows the behavior of molds and tooling by transformation processes.

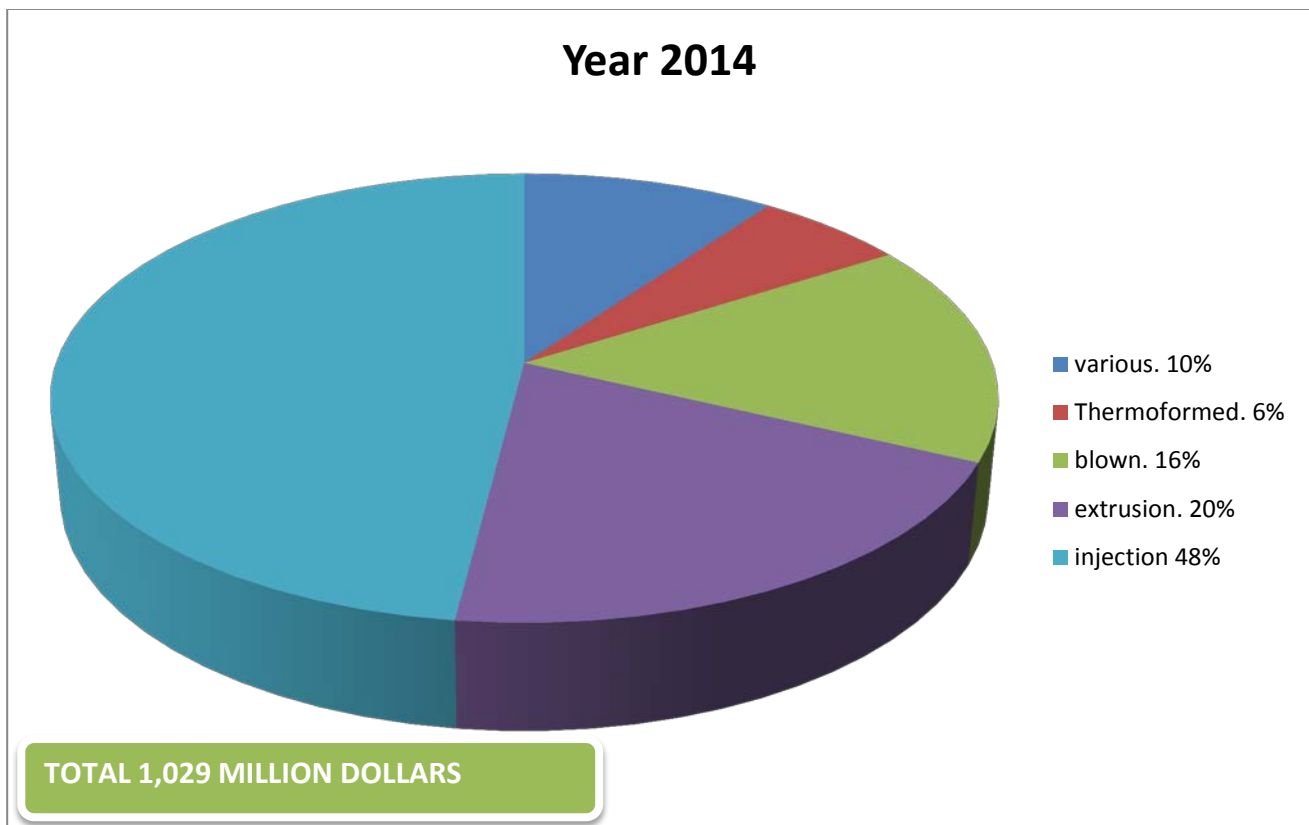


Figure 3.4 Tooling behavior by process. [27](Plastic industry. <http://www.beta.inegi.org.mx/>)

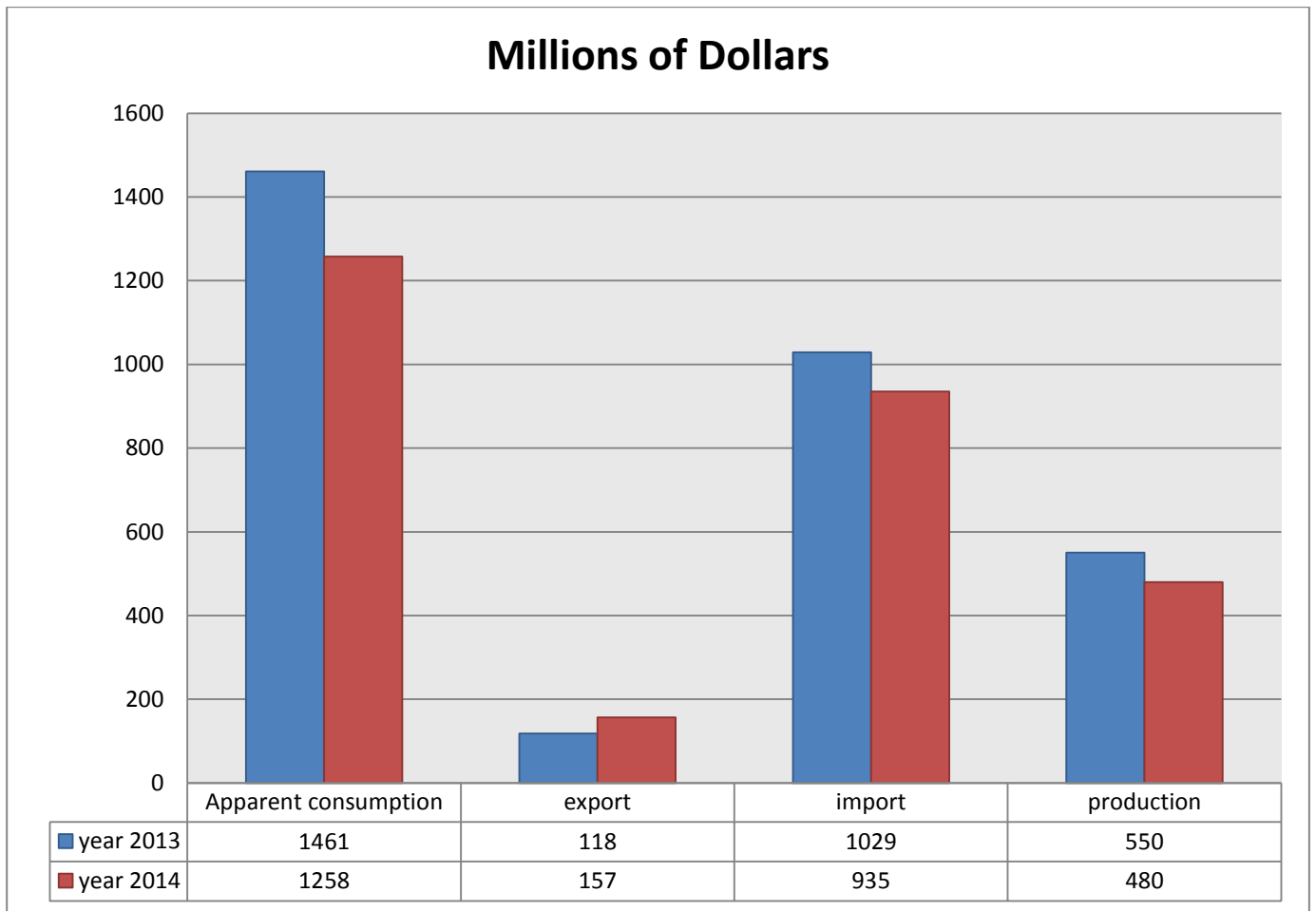


Figure 3.5 Mold and tooling market.

Mexico has an important place in the design and manufacture of molds and tools for the transformation of plastics. According to recent statistics, the production of domestic molds represents 79% of domestic consumption while the export is equivalent to 21% of production of molds and tools made in Mexico. It is appreciated that the trade balance that more than 70% of molds and tooling apparent consumption are imported from China, Portugal or Spain. As shown in Figure 14, the mold import rate grew 500% during 2009 to 2014 while the mold export trend in Mexico fell.

### 3.4. Current situation of vocational training for design and manufacturing.

Lack of Training is one of the main problems that industrialists have expressed in different forums in the plastic industry, with an impact of 35% .1 Transformers commented that this problem means that they do not reach the quality levels that now Demands the market and that its international competition is increasingly aggressive. The suppliers of raw materials and machinery consider that this problem limits the growth and development of products of companies, besides that motivates the lack of investment. Based on a survey more than 70% of 251 responses indicate a high priority of training in companies.

The needs in the plastic training industry vary in terms of levels and competencies.

Table 3.4 needs of training

Technicians.	Higher Technicians.	engineer	Postgraduate
<ul style="list-style-type: none"> <li>• Operators of machinery               <ul style="list-style-type: none"> <li>➤ Injectors</li> <li>➤ Extruders</li> </ul> </li> <li>• Processors equipment               <ul style="list-style-type: none"> <li>➤ CNC</li> <li>➤ EDM</li> </ul> </li> <li>•Technicians for Maintenance of Molds and dice</li> </ul>	<ul style="list-style-type: none"> <li>• CAD Technicians</li> <li>• CAM technicians</li> <li>• Technical Prototypes Rapid</li> <li>• Technicians for Maintenance of Molds and dice</li> </ul>	<ul style="list-style-type: none"> <li>• Engineers process</li> <li>• CAD Engineers</li> <li>• Designers of Parts</li> <li>• CAE Engineers</li> <li>• Engineers Fast prototypes</li> <li>• Designers of Molds and dice</li> <li>Engineers CAM</li> </ul>	<ul style="list-style-type: none"> <li>• Researchers</li> </ul>

### 3.5. Innovation and Technological Development in Mexico.

Plastic industrialists in the raw materials and processing sector believe that technological innovation, quality and raw material costs will continue to be key determinants of competitiveness for the next five years. The following chart shows an overview of the plastic sector in Mexico:

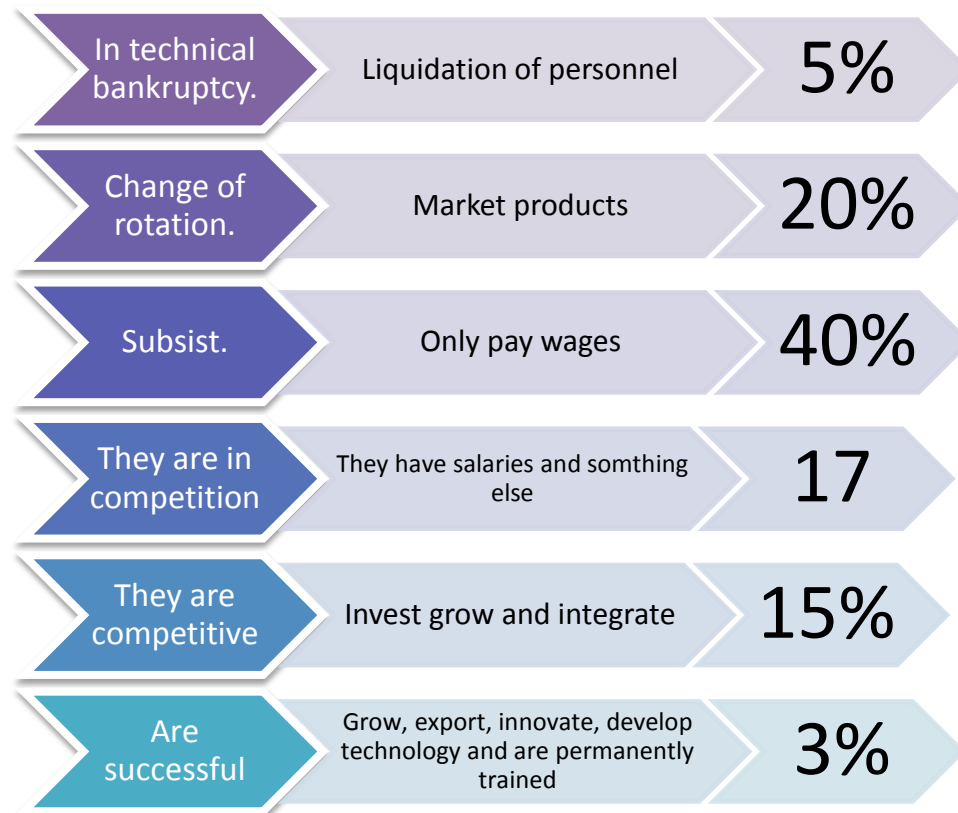


Figure 3.6 Situation of the Plastic Companies in Mexico. June 2014

The key to companies that are successful and make up 3% of the total, is the orientation they have had since their inception to development, innovation and training. Investment in research and development of new products is an opportunity to improve competitiveness. Forty percent of Respondents responded that it does not use financial resources for the research and development of new products.

### 3.6 Future of tooling manufacturing in Mexico.

The future for the sector is brightly promising and continues to grow as indicated in the table in which a growth of 5 times in volume of 5 times in the period from 20010 to 2014 can be observed.

Table 3.5 Analysis and recommendations

Year	Export (millions of dollars)	Import (millions of dollars)
<b>2013</b>	8.3	160.3
<b>2014</b>	25.2	838.7

#### 5.1 SWOT Analysis

The following material was extracted from the document: "Updating of the strategic study to increase the competitiveness and sustainable development of the plastic production chain in Mexico".

The points that were analyzed were:

A) Production and Innovation

- Research, development and product design
- Availability of trained human resources

B) Business culture and working environment

C) Financing and support

Table 3.6 Production and innovation

STRENGTHS	WEAKNESSES
<ul style="list-style-type: none"> <li>- <b>Financial sustainability and sustained development of the chain despite positive and / or negative external fluctuations.</b></li> <li>- <b>Productive chain formed mostly by micro, small and medium enterprises, which makes an area of opportunity for the development and application of strategies that promote competitive change.</b></li> <li>- <b>The contributions of large and medium-sized enterprises to the economic activity of the industry is decisive in terms of employment, value of production and generation of added value.</b></li> <li>- <b>Sector that tends to use modern machinery.</b></li> <li>- <b>Use of fairs and exhibitions for the update in production, as well as the relationship with suppliers.</b></li> <li>- <b>The willingness of the entrepreneurs of the link to join forces to promote the competitive development of the chain</b></li> </ul>	<ul style="list-style-type: none"> <li>- The raw material as a determining factor in the competitiveness of the sector.</li> <li>- It is not visualized to generate an added value from the innovation and development of new products.</li> <li>- Little importance to standardization and quality certifications to compete in the market; As well as in the registration of marks and patents.</li> <li>- Ineffective communication between what the market demands and the research and development of new products.</li> <li>- Low link with research and development centers, related to the chain.</li> </ul>
THREATS	OPPORTUNITIES
<ul style="list-style-type: none"> <li>- <b>Increase in the price of the raw material, which makes the manufacturing sector less competitive.</b></li> <li>- <b>Incipient basic petrochemicals, in favor of the needs of the plastic production chain</b></li> <li>- <b>Entry of foreign competitors with competitive products via cost.</b></li> <li>- <b>The productive chain of plastic can be excluded if parallel coordination with the strategic lines of the competitive agendas of the strategic sectors of the national manufacturing industry is not achieved.</b></li> <li>- <b>Poor infrastructure and transport development to support</b></li> </ul>	<ul style="list-style-type: none"> <li>- Plastic industry flexible and adaptable to the macroeconomic circumstances of the country.</li> <li>- Expansion of the Asian and American market in the development and innovation of new products.</li> <li>- Opportunity to focus the development of the plastic production chain to specialized markets and niches, to cover specific needs through products with high added value.</li> <li>- Expanding markets and new markets for plastics such as health and medicine, agriculture, automotive, recycled, among others.</li> <li>- Tendency of Mexican entrepreneurs to promote the</li> </ul>

<b>The competitiveness of the chain.</b>	innovation of their companies, including their production processes.
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Research, Development and Product Design:

Table 3.7 Production and innovation

<b>Discipline</b>	<b>Capacity</b>	<b>Research, Development and Product Design</b>
<b>Innovation</b>	Types of Innovation	<ul style="list-style-type: none"> <li>• The great variety of innovation activities in the plastics industry can be surprising.</li> <li>• Innovation activities in this industry cover the three categories of innovation (radical, incremental and process) and are found in virtually all industrial segments, since plastic is a material that offers endless opportunities for innovation.</li> <li>• Radical innovation processes in plastic / polymer resins and production technologies can lead to the development of new industries. Unfortunately, the State of Mexico has lost any competitive advantage it has achieved in the past in this activity. Currently, most of the resins consumed by companies in the State of Mexico are imported.</li> <li>• Incremental innovation in raw materials, production technologies and plastic product lines is ubiquitous and can represent an important value creation.</li> <li>• Innovations in production processes in this industry may represent the economic viability of many products, particularly those highly generic.</li> <li>• Plastic product design activities are also an important area of innovation, however, it often requires a high level of specialized technical expertise in plastics and at the moment the State of Mexico lacks these capabilities.</li> </ul>
		<b>Plastic Sheet, Sheet and Plastic Manufacturing</b>
		<ul style="list-style-type: none"> <li>• Innovation activities in this segment are often very focused on process improvement.</li> <li>• Given the high level of cost competitiveness in this segment, only companies with significant production scales can finance personnel specializing in innovation activities.</li> </ul>

	<ul style="list-style-type: none"> <li>• However, many companies in the State of Mexico have the necessary scale for such investments and carry out innovation activities on an ongoing basis. These activities are usually of an incremental type and generate an important added value for the company.</li> </ul>
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Plastic Sheet, Sheet and Plastic Manufacturing:

Table 3.8 Plastic Sheet

Discipline	Capacity	Plastic Sheet, Sheet and Plastic Manufacturing
<p><b>Innovation</b></p>	<p>Types of Innovation</p>	<ul style="list-style-type: none"> <li>• Innovation capabilities are a key competitive attribute for specialized plastics companies.</li> <li>• The high level of competitiveness of this segment forces many companies to incorporate continuous innovation as a fundamental aspect of their operating procedures.</li> <li>• The large and medium-sized specialized plastics companies operating in the State of Mexico have remarkable capacity for incremental innovation.</li> <li>• However, the existing gaps in the area of R &amp; D (capacities and financing), and engineering and technical capabilities with a focus on plastics in the State of Mexico, limit the scope of innovation activities carried out in most Of the state's plastic companies.</li> </ul>

Business Culture and Work Environment:

Table 3.9 Business Culture

STRENGTHS	WEAKNESSES
<ul style="list-style-type: none"> <li>- <b>Constant development of small industry, despite external fluctuations.</b></li> <li>- <b>Willingness to undertake changes in the face of market competition.</b></li> <li>- <b>Human factor as an important element in following the strategic lines of a competitive agenda.</b></li> <li>- <b>There are operational plans.</b></li> <li>- <b>Search for internal reforms in each of the links of the productive chain.</b></li> </ul>	<ul style="list-style-type: none"> <li>- The business culture is focused on the permanence and survival of the business.</li> <li>- Deficiencies in business development, in terms of business management, marketing, financing, human capital development.</li> <li>- Little investment in human resource training.</li> <li>- Ignorance of public or private training programs, technical advice and financing.</li> <li>- Lack of long-term vision; Planning only operational, not strategic.</li> </ul>
THREATS	OPPORTUNITIES
<ul style="list-style-type: none"> <li>- <b>Changes and global trends in new ways of doing business and how to manage them.</b></li> <li>- <b>Potential growth of plastic competitors with appropriate business strategies.</b></li> <li>- <b>The labor force offered by the market tends to</b></li> </ul>	<ul style="list-style-type: none"> <li>- Attitude of the entrepreneur to advance in an integral vision of the business and to give greater importance to the personnel as an elementary factor.</li> <li>- Opportunity to advance in socially responsible companies, applying environmental policies that translate into sustainability of the chain, and</li> </ul>

<p><b>be inoperative and costly.</b></p> <p><b>- Increase in staff turnover.</b></p> <p><b>- Trend of environmental conservation and sustainability in developed economies.</b></p>	<p>therefore in sustained business growth.</p> <p>- Trends in the country of the development of an entrepreneurial culture, that is promoter of quality, continuous improvement and learning.</p>
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Financing and Support:

Table 3.10 Financing and Support

<b>STRENGTHS</b>	<b>WEAKNESSES</b>
<p><b>- Good financial management with few sources of financing.</b></p> <p><b>- Positive attitude towards the search for new sources of financing.</b></p>	<p>- The financing comes, for the most part, from suppliers.</p> <p>- The financing obtained goes to the purchase of raw material, being scarce for projects of innovation and development of products.</p> <p>- Ignorance of public or private training programs, technical advice and financing.</p>
<b>THREATS</b>	<b>OPPORTUNITIES</b>
<p><b>- The supplier, as the main source of financing, does not allow an extensive application of capital to productive and development projects technological.</b></p> <p><b>- Perception of a complex access to funding sources.</b></p> <p><b>- Government programs do not cooperate with the chain, investments are lacking in the development of the same.</b></p>	<p>- To be promoters of sources of financing through schemes like "seed capital" for the detone of technological innovation projects.</p> <p>- Assistance to forums, fairs and exhibitions of financing.</p> <p>- Use of the SME Fund.</p> <p>- Development of sources of financing in support of SMEs by the federal government.</p> <p>- There is a trend towards a decrease in interest rates on commercial credit for micro, small and medium-sized enterprises; As well as the increase of the terms for the credits.</p>

- Institutes and academies with new business incubator programs.
- Support and investment policies for research projects by public and private institutions.

### **3.7 Budget.**

The budget is made on an approximate basis, taking into account the Molding, machining, assembly of both the mold and the machine, etc. All this will Perform a calculation of the mold manufacturing cost. Due to the large number of processes involved, it is complex to set a price exact. The reason for the lack of precision are errors in the calculation of machining hours, Which are estimated, the contingencies that may arise during operations and modify The production times and consequently the final cost. To make the budget is divided into different parts:

- Mold design
- Materials
- Machining

#### **3.7.1 Design.**

#### **3.7.2 Mold design.**

The first phase of the budget indicates the study hours of the project, design In CAD and plans made. The total number of hours devoted to the study and design of the mold is 60 Hours with a cost of 750 MXN / h. Total: 45,000.00 MXN. The cost of design is variable, because this cost is taken as a reasonably high price for the payment per hour of engineering work, this means that the price for the engineering fee may decline depending on the agreement between the company And the engineer who will design the blow mold.

### **3.7.3 Materials and components.**

The price of each part of the mold in terms of materials and Standard parts or purchased from a manufacturer for later modification.

- Fixed plate / core (MOLDMAX HH): 6,500.00 MXN
- Mobile plate / cavity (MOLDMAX HH): 6000.00 MXN
- Centering ring (Steel 1.1730 gross 100x500x10): 650.00 MXN
- Air valves: 3x 1600.00 MNX
- Runner nozzle: 16,500.00 MXN
- Screw M12x120: 8x 50.00 MXN
- Screw M4x20: 4x 20.00 MXN€

Total: 31 750 MXN

### **3.7.4 Machining.**

Raw materials of the same size as possible are purchased from the Part or from a manufacturer of mold components and then modify them, with the Aim of reducing machining costs.

Within the machining costs, only the total costs per hour are presented, because these costs are provided by a company dedicated to the manufacture. this means. Will look for a company that can manufacture the mold at the best price.

This means that companies will not have to invest in technology to manufacture their molds. Which is the biggest advantage that they can obtain, since all their budget can be used completely for the operation of the company.

- Cavity milling: 7 hours
- Core milling: 7 hours
- Milling of plates and rings: 3 hours
- Grinding of cylindrical elements: 5 hours

- Flat element grinding: 3 hours
- Hole drilling: 2 hours

Total hours: 27 hours

Unit price per process: 800 MXN / h

Total: 21, 600.00 MXN

**TOTAL COST: 98,350.00 MXN**

### 3.8 Comparison of prices.

For the comparison of prices it uses information of 2 companies one located in the United States and the second one located in Spain.

These 2 companies were taken, due to the geographic location of Mexico. For this we made a quote for a blow mold, which will generate a plastic bottle with a volume of 1 liter.

The estimated prices may vary due to the different taxes that can be applied to the importation of these molds, also due to the complexity of the mold, specific characteristics, materials used for the manufacture, and so on.

In this case, do not take into account the different import taxes, which in this case would be import costs for Europe, and import costs for the United States.

Table 3.11 Cost comparison

	Mexico	United States	Spain
<b>COST:</b>	<b>98,350.00</b>	11,000.00 Dollars = 204,841.71	12,000.00 Euros = 250,033.51
<b>Approximately.</b>	<b>MXN.</b>	MXN. Approximately.	MXN. Approximately.

The reason for the price comparison between the United States and Spain. Is due to the geographic location of these two countries, since being located in different latitudes of the world, the costs of importation and costs of logistics will be different, which will change the final cost of each mold manufactured within the manufactured industry of each Parents, we just have to remember that these costs can be variable.

## CONCLUSION

The design proposal of a blow mold presented in this work includes drawings of the blocks of aluminum that will serve to manufacture the mold. The objective of this thesis work was fulfilled, as it presents a design that will be an option more for the small and medium companies that need to compare a mold of blowing. This work will benefit the client to stop importing this type of technology and save capital, having an option that is within your budget.

For the design of the blow mold it was based on a proposed methodology, that methodology is fusion of several approaches because in the plastic that will be used for the manufacture of the bottles can have different effects on the material of the mold.

Mexico being a manufacturing country has the capacity and need to manufacture blow molds. The training is a step that Mexican companies need to be able to manufacture blow molds since having the capacity to manufacture these molds, will give a competitive advantage to small and medium companies, these companies are in a constant search for Position in a Market and gain an advantage over their competitors, in order to achieve this it is necessary that they obtain the best tools within reach of their budget.

In this project we explored an option directed to this type of companies which need to innovate in their products to obtain a competitive advantage over their rivals and to be able to survive in a globalized world, the power of innovations generate a world of possibilities for the new companies .

This project is focused in the area of the manufacture of plastic bottles, which can be manufactured by means of two forms of manufacture:

- Injection-blow molding consists of obtaining a preform of the polymer to be processed, similar to a test tube, which is subsequently heated and inserted into the mold which houses the desired geometry, sometimes a stretching of The preform injected, then air is injected, which achieves the expansion of the material and the final shape of the piece and finally proceed to its extraction. In many cases it is necessary to modify the thickness of the preform, either to get a piece with different thicknesses or to

achieve a uniform thickness throughout the piece, because in the blowing phase not all parts of the materials are deformed equally. The advantage of using preforms is that they can be injected and stored, producing different colors and sizes, which can be done in places other than where the blowing will take place. The preforms are stable and can be blown at high speed according to the required demand.

- Extrusion-blown molding Blown extrusion molding is a blowing process in which the preform is a tubular sleeve, formed by extrusion, called a parison, which closes at the bottom in a hermetic manner due to the clamping exerted by the Parts of the mold when closed, is subsequently blown, allowed to cool and the part is ejected.

These two forms of manufacture of plastic bottles, allows us to use the same type of mold, which does not help to maintain an innovation. Since no matter what type of manufacture is used for the manufacture of plastic bottles, the same mold can be used.

This indicates that companies that have a very limited capital can acquire a tool which provides them with a form of innovation in their products, since they can count on a plastic bottle that has the aesthetic characteristics they want and specific characteristics necessary for their products .

And the most important feature of this project is that the company that needs a blow mold will have its own design created for their needs, but without having to invest in machinery since Mexico has the technology and experience necessary to be able to manufacture this type of projects , This characteristic is fundamental for small and medium companies since they do not need to invest in tools for the manufacture of their blow mold, because mexico counts on workshops specialized in the manufacture of high quality and technology. Another important point concerning the total price of the blow mold, is visualized with the idea of delivering a design generated with computer-aided design in combination with computer-aided engineering allows us to obtain thanks to computer-aided manufacturing, everything necessary to To make a blow mold at low cost, since small and medium enterprises may be able to design their own molds, and this will make the cost of producing a blow mold less.

Since to be able to generate their own designs, they will only need to look for a specialized workshop, and therefore the cost will be lower, since the cost of design will be absorbed by the own company since the design can be elaborated by its group of engineers.

This work of thesis aims to demonstrate that the manufacture of a blow mold at low cost is possible, using CAD, CAE and CAM tools, these tools provide us with an unprecedented level of design and manufacturing, as they allow us to perform Designs that years ago were very difficult and expensive to do.

The advancement of technology gives us a competitive advantage never before seen, which is demonstrated in the present work of thesis.

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