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Design and Analysis of Mini Injection Moulding Machine for Recycling of Plastic Wastes

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ABSTRACT: The project deals about the injection moulding machine. The main principle is to compress the plastic material in a barrel and the compressing motion is developed by rotating the rack and pinion arrangement. The plastic material is heated by the heater surrounding the barrel. Then it is converted into molten state. The molten plastic is injected through the nozzle in barrel to the die by the compressing force. After completing this process, we will get the product from the die. Commercial products like bushes, couplings, switches etc., can be produced

Keywords: Injection, Moulding,Mechanism, Machine, Plastics, Industries,

1 Introduction

The polymer material are converted into plastics and used as tubes, sheets, foams, rods, adhesives, etc., The theological properties, softening, tempering, stability, the size and shape are important in describing the method. These methods are different kinds of plastics. Broadly speaking the method may be discussed under the following headings,

- MOULDING PROCESS
- FOAMING PROCESS

Moulding process:

In this process the plastics are fabricated under the effect pressure and heat and both thermoplastics and thermosetting plastics may be starting materials.

Injection moulding:

Thermoplastics are produced by this method. In this the material is softened by heating and the hot softened plastic is forced under high pressure into the mold, when it is set by cooling and the mold is ejected.

Foaming process:

This involves the blowing of a volatile organic liquid, which is entrapped into a polymer network resulting in the formation of foamed plastics. Foamed polystyrenes are produced in this process.

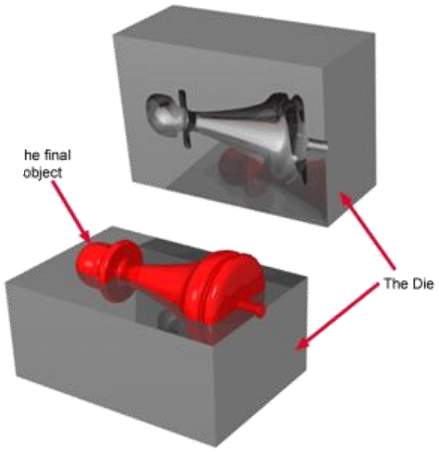
Moulding process:

Moulding or moulding (see spelling differences) is the process of manufacturing by shaping liquid or pliable raw material using a rigid frame called a mold or matrix.[1] This itself may have been made using a pattern or model of the final object.

A mold or mould is a hollowed-out block that is filled with a liquid or pliable material such as plastic, glass, metal, or ceramic raw material.[2] The liquid hardens or sets inside the mold, adopting its shape. A mold is the counterpart to a cast.

Types of Plastic Moulding

- Rotational Moulding
- Injection Moulding
- Blow Moulding
- Compression Moulding
- Extrusion Moulding
- Thermoforming



Injection moulding:

Injection moulding is a manufacturing process for producing parts by injecting molten material into a mould. Injection moulding can be performed with a host of materials mainly including metals, (for which the process is called die-casting), glasses, elastomers, confections and most commonly thermoplastic and thermosetting polymer s. Material for the part is fed into a heated barrel, mixed (Using a helical shaped screw), and injected (Forced) into a mould cavity, where it cools and hardens to the configuration of the cavity.[1]:240 After a product is designed, usually by an industrial designer or an engineer, moulds are made by a mould-maker (or toolmaker) from metal, usually either steel or aluminium, and precision-machined to form the features of the desired part. Injection moulding is widely used for manufacturing a variety of parts, from the smallest components to entire body panels of cars. Advances in 3D printing technology, using photopolymers which do not melt during the injection moulding of some lower temperature thermoplastics.

Types of injection Moulding machines

Hydraulic. Hydraulic presses have historically been the only option available to molders until Nissei Plastic Industrial Co., LTD introduced the first all-electric injection Moulding machine in 1983.

- Mechanical injection Moulding machine
- Electrical injection Moulding machine
- machine

Mechanical injection moulding:

Mechanical type machines use the toggle system for building up tonnage on the clamp side of the machine. Tonnage is required on all machines so that the clamp side of the machine does not open (i.e. tool half mounted on the platen) due to the injection pressure. If the tool half opens up it will create flash in the plastic product.

Injection units:

Consists of three main components:

- Screw motor drive
- Reciprocating screw and barrel
- Heaters, Thermocouple, Ring plunger

Working principle

The injection-moulding process is best suited for producing articles made of thermoplastic materials. Here, the equipment cost is relatively high but the main attraction is the amenability of the injection-moulding process to a high production rate. In

injection Moulding, a definite quantity of molten thermoplastic material is injected under pressure into a relatively cold mold where it solidifies to the shape of the mould.

The injection – moulding machine is shown in the process consists of feeding the compounded plastic material as granules, pellets or powder through the hopper at definite time intervals into the hot horizontal cylinder where it gets softened. Pressure is applied through a hydraulically driven piston to push the molten material through a cylinder into a mould fitted at the end of the cylinder. While moving through the hot zone of the cylinder, a device called torpedo helps spread the plastic material uniformly around the inside wall of the hot cylinder sand thus ensures uniform heat distribution. The molten plastic material from the cylinder is then injected through a nozzle material from the cylinder is then injected through a nozzle into the mould cavity.

The mould used, in its simplest form, is a two-part system. One is a movable part and the other stationary. The stationary part is fixed to the end of the cylinder while the movable part can be opened or locked on to the stationary part. By using a mechanical locking device, the mould is proper held in position as the molten plastic material is injected under a pressure as high as 1500kg/cm. The locking device has to be very skillfully designed in order to withstand high operating pressures. Further more, a proper flow of the molten material to the interior regions of the mold is achieved by preheating the mould to an appropriate temperature. Usually, this temperature is slightly lower than the softening temperature of the plastic material under going moulding.

After the mould is filled with the molten material under pressure, then it is cooled by cold water circulation and then opened so as to eject the molded article. The whole cycle could be repeated several time either manually of in an automated mode.

Major components

- RACK AND PINION
- VICE
- HANDLE
- HEATER
- FRAME
- SHAFT
- BEARING
- METAL STRIP
- MOULD DESIGN

Rack and pinion

Rack and pinion animations rack and pinion is a type of linear actuator that comprises a pair of gears which convert rotational motion into linear motion. The circular pinion engages teeth on a linear "gear" bar–the rack. Rotational motion applied to the pinion will cause the rack to move to the side, up to the limit of its travel. For example, in a rack railway, the rotation of a pinion mounted on a locomotive or a rail car engages a rack between the rails and pulls a train along a steep slope.

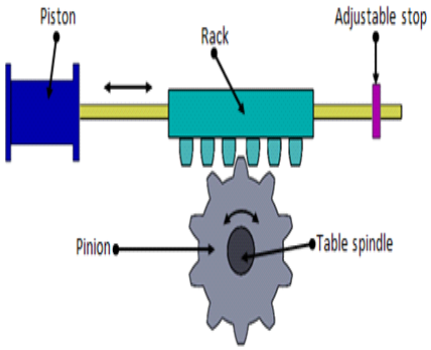


Fig.3 Rack and Pinion gear

- A rack is a gear whose pitch diameter is infinite, resulting in a straight line pitch circle.
- Involute of a very large base circle approaches a straight line.
- Used to convert rotary motion to straight line motion.
- Used in machine tools.

Specifications

Material	: cast-iron
Outside diameter	: 76mm
Circular pitch	: 4.9mm
Tooth depth	: 3.385mm
Module	: 1.7mm
Pressure angle	: 21
Pitch circle diameter	: 77mm
Addendum	: 1.5mm
Dedendum	: 1.875mm
Circular tooth Thickness	: 2.365mm
Fillet radius	: 0.46mm
Clearance	: 0.385mm

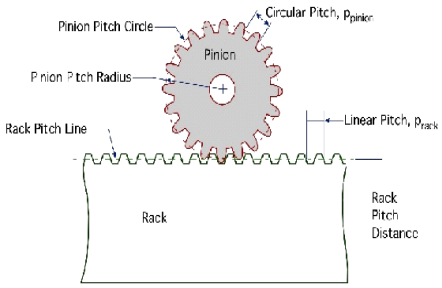


Fig.4 Rack and Pinion gear

A rack and pinion is a type of linear actuator that comprises a pair of gears which convert rotational motion into linear motion. A circular gear called "the pinion" engages teeth on a linear "gear" bar called "the rack"; rotational motion applied to the pinion causes the rack to move, thereby translating the rotational motion of the pinion into the linear motion of the rack.

Fig .5 Rack and Pinion gear in cast iron

For example, in a rack railway, the rotation of a pinion mounted on a locomotive or a rail car engages a rack between the rails and forces a train up a steep slope. For every pair of conjugate involute profile, there is a basic rack. This basic rack is the profile of the conjugate gear of infinite pitch radius. (I.e. a toothed straight edge.) A generating rack is a rack outline used to indicate tooth details and dimensions for the design of a generating tool, such as a hob or a gear shaper cutter.

Pinion

Pinion With high precision and load-bearing capacity as well as smooth running properties, the pinions from WMH Herion are extremely reliable power transmitters even during continuous operation.

Rack

Rack Precision-ground racks from WMH Herion allow the rotary movement of the pinion to be transformed exactly into a linear movement.

When we say "on request" we mean: everything is possible. You benefit from the flexibility of two specialist companies with development skills and a range of components that is quite unique in the world. We do everything in our power to ensure you get just the rack and pinion drive you require. From customising through more minor application-specific

adaptation of our range components through adaptation of design sizes to the development of tailor-made solutions. Working with you, we design the optimum and most economic customised solution which is in no way inferior to our tried-and trusted series products in terms of either quality or efficiency.

In practice, keyway connections have proved themselves economical and are convincing thanks to their simple fitting/removal. In addition, the precise and central seat of the hub is an advantage.

Vice

Vices are used as holding device on machines like lathes, milling machine, drilling machine etc. and also by tool makers for holding jobs. Design wise three types of vices are very common in use namely plain vice, swivel vice and tool makers vice which is commonly known as bench vice

Fig.6 vice

Without qualification, "vise" usually refers to a bench vise with flat, parallel jaws, attached to a workbench. There are two main types: a woodworking vise and engineer's vise. The woodworker's bench vise main characteristic is its integration into the bench. An engineer's bench vise is usually clamped or bolted onto the top of the bench. The handle is usually adjustable so that it can be tightened in small places.

Hand lever

- Material: Mild Steel

Fig.7 Hand lever

Plastic heater

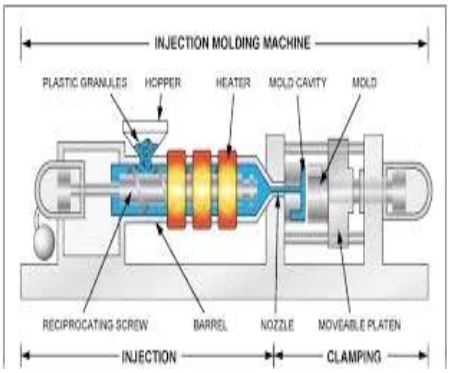


Fig.8 Plastic heater

Electric heating is a process in which electrical energy is converted to heat energy. Common applications include space heating, cooking, water heating and industrial processes. An electric heater is an electrical device that converts an electric current into heat. The heating element inside every electric heater is an electrical resistor, and works on the principle of Joule heating: an electric current passing through a resistor will convert that electrical energy into heat energy. Most modern electric heating devices use nichrome wire as the active element; the heating element, depicted on the right, uses nichrome wire supported by ceramic insulators. A warning that these can go to very high temperatures and create excruciating burns.

Alternatively, a heat pump uses an electric motor to drive a refrigeration cycle, that draws heat energy from a source such as the ground or outside air and directs that heat into the space to be warmed. Some systems can be reversed so that the interior space is cooled and the warm air is discharged outside or into the ground.

Electric radiant heating uses heating elements that reach a high temperature. The element is usually packaged inside a glass envelope resembling a light bulb and with a reflector to direct the energy output away from the body of the heater. The element emits infrared radiation that travels through air or space until it hits an absorbing surface, where it is partially converted to heat and partially reflected. This heat directly warms people and objects in the room, rather than warming the air. This style of heater is particularly useful in areas through which unheated air flows. They are also ideal for basements and garages where spot heating is desired. More generally, they are an excellent choice for task-specific heating. Radiant heaters operate silently and present the greatest potential danger of ignition of nearby furnishings due to the focused intensity of their output and lack of overheat protection. In the United Kingdom, these appliances are sometimes called electric fires, because they were originally used to replace open fires.

The active medium of the heater depicted in this section is a coil of nichrome resistance wire inside a fused silica tube, open to the atmosphere at the ends, although models exist where the fused silica is sealed at the ends and the resistance alloy is not nichrome.

Metal frame

The metal frame is generally made of mild steel bars for machining, suitable for lightly stressed components including studs, bolts, gears and shafts. It can be case-hardened to improve wear resistance. They are available in bright rounds, squares and flats, and hot rolled rounds

Fig.9 Metal frame

Suitable machining allowances should therefore be added when ordering. It does not contain any additions for enhancing mechanical or machining properties. Bright drawn mild steel is an improved quality material, free of scale, and has been cold worked (drawn or rolled) to size. It is produced to close dimensional tolerances. Straightness and flatness are better than black steel. It is more suitable for repetition precision machining. Bright drawn steel has more consistent hardness, and increased tensile strength. Bright steel can also be obtained in precision turned or ground form if desired.

Ball bearing

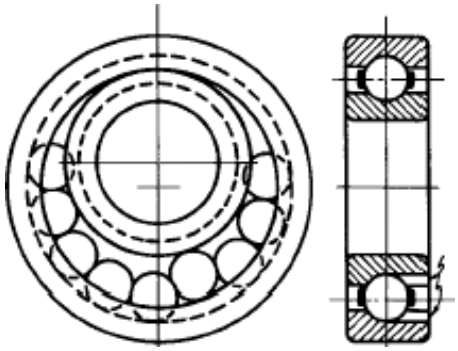
A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races.

The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads. It achieves this by using at least three races to contain the balls and transmit the loads through the balls. In most applications, one race is stationary and the other is attached to the rotating assembly (e.g., a hub or shaft). As one of the bearing races rotates it causes the balls to rotate as well. Because the balls are rolling they have a much lower coefficient of friction than if two flat surfaces were sliding against each other.

Ball bearings tend to have lower load capacity for their size than other kinds of rolling-element bearings due to the smaller contact area between the

balls and races. However, they can tolerate some misalignment of the inner and outer races.

Specifications & Design of ball bearing:



INNER DIA :12mm

OUTER DIA : 37mm

Angular contact

An angular contact ball bearing uses axially asymmetric races. An axial load passes in a straight line through the bearing, whereas a radial load takes an oblique path that acts to separate the races axially. So the angle of contact on the inner race is the same as that on the outer race. Angular contact bearings better support combined loads (loading in both the radial and axial directions) and the contact angle of the bearing should be matched to the relative proportions of each. The larger the contact angle (typically in the range 10 to 45 degrees), the higher the axial load supported, but the lower the radial load. In high speed applications, such as turbines,

Jet engines, and dentistry equipment, the centrifugal forces generated by the balls changes the contact angle at the inner and outer race. Ceramics such as silicon nitride are now regularly used in such applications due to their low density (40% of steel). These materials significantly reduce centrifugal force and function well in high temperature environments. They also tend to wear in a similar way to bearing steel—rather than cracking or shattering like glass or porcelain. Most bicycles use angular-contact bearings in the headsets because the forces on these bearings are in both the radial and axial direction.

Axial

An axial or thrust ball bearing uses side-by-side races. An axial load is transmitted directly through the bearing, while a radial load is poorly supported and tends to separate the races,so that a larger radial load is likely to damage the bearing.

Deep-groove

In a deep-groove radial bearing, the race dimensions are close to the dimensions of the balls that run in it. Deep-groove bearings support higher loads than a shallower groove. Like angular contact bearings, deep-groove bearings support both radial and axial loads, but without a choice of contact angle to allow choice of relative proportion of these load capacities.

Preloaded pairs

The above basic types of bearings are typically applied in a method of preloaded pairs, where two individual bearings are rigidly fastened along a rotating shaft to face each other. This improves the axial runout by taking up (preloading) the necessary slight clearance between the bearing balls and races. Pairing also provides an advantage of evenly distributing the loads, nearly doubling the total load capacity compared to a single bearing. Angular contact bearings are almost always used in opposing pairs: the asymmetric design of each bearing supports axial loads in only one direction, so an

opposed pair is required if the application demands support both directions. The preloading force must be designed and assembled carefully, because it deducts from the axial force capacity of the bearings, and can damage bearings if applied excessively. The pairing mechanism may simply face the bearings together directly, or separate them with a shim, bushing, or shaft feature.

Applications

In general, ball bearings are used in most applications that involve moving parts. Some of these applications have specific features and requirements:

Hard drive bearings used to be highly spherical, and were said to be the best spherical manufactured shapes, but this is no longer true, and more and more are being replaced with

- fluid bearings.
- German ball bearing factories were often a target of allied
- aerial bombings during World War II; such was the importance of the ball bearing to the German war industry.
- In horology, the company
- Jean Lassale designed a watch movement that used ball bearings to reduce the thickness of the movement. Using 0.20 mm balls, the Calibre 1200 was only 1.2 mm thick, which still is the thinnest mechanical watch movement.
- Aerospace bearings are used in many applications on commercial, private and military aircraft including pulleys, gearboxes
- jet engine shafts. Materials include M50 tool steel (AMS6491), Carbon chrome steel (AMS6444), the corrosion resistant AMS5930, 440C stainless steel,
- silicon nitride (ceramic) and
- titanium carbide-coated 440C.
- skateboard wheel contains two bearings, which are subject to both axial and radial time-varying loads. Most commonly bearing 608-2Z is used (a deep groove ball bearing from series 60 with 8 mm bore diameter)

Mold design

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

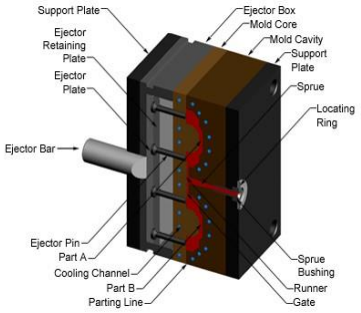


Fig.11 mould

Manufacturing process

Manufacturing processes are the steps through which raw materials are transformed into a final product. The manufacturing process begins with the creation of the materials from which the design is

made. These materials are then modified through manufacturing processes to become the required part. Manufacturing processes can include treating (such as heat treating or coating), machining, or reshaping the material. The manufacturing process also includes tests and checks for quality assurance during or after the manufacturing, and planning the production process prior to manufacturing.

Process cycle

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

- CLAMPING
- INJECTION
- COOLING
- EJECTION

Diagram Of Injection Moulding Machine:

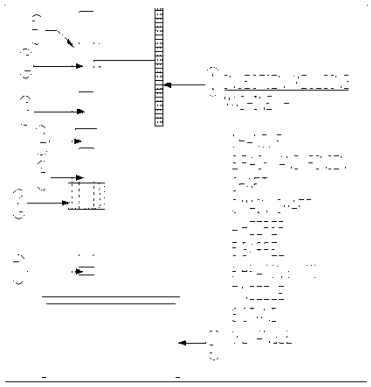


Fig 12 injection mloulding machine

Clamping :

Prior to the injection of the material into the mold, the two halves of the mold must first be securely closed by the clamping unit. Each half of the mold is attached to the injection Moulding machine and one half is allowed to slide. The hydraulically powered clamping unit pushes the mold halves together and exerts sufficient force to keep the mold securely closed while the material is injected. The time required to close and clamp the mold is dependent upon the machine - larger machines (those with greater clamping forces) will require more time. This time can be estimated from the dry cycle time of the machine.

Injection :

The raw plastic material, usually in the form of pellets, is fed into the injection Moulding machine, and advanced towards the mold by the injection unit. During this process, the material is melted by heat and pressure. The molten plastic is then injected into the mold very quickly and the buildup of pressure packs and holds the material. The amount of material that is injected is referred to as the shot. The injection time is difficult to calculate accurately due to the complex and changing flow of the molten plastic into the mold. However, the injection time can be estimated by the shot volume, injection pressure, and injection power.

cooling :

The molten plastic that is inside the mold begins to cool as soon as it makes contact with the interior mold surfaces. As the plastic cools, it will solidify into the shape of the desired part. However, during cooling some shrinkage of the part may occur. The packing of material in the injection stage allows additional material to flow into the mold and reduce the amount of visible shrinkage. The mold can not be opened until the required cooling time has elapsed. The cooling time can be estimated from several thermodynamic properties of the plastic and the maximum wall thickness of the part.

Ejection :

After sufficient time has passed, the cooled part may be ejected from the mold by the ejection system, which is attached to the rear half of the mold. When the mold is opened, a mechanism is used to push the part out of the mold. Force must be applied to eject the part because during cooling the part shrinks and adheres to the mold. In order to facilitate the ejection of the part, a mold release agent can be sprayed onto the surfaces of the mold cavity prior to injection of the material. The time that is required to open the

mold and eject the part can be estimated from the dry cycle time of the machine and should include time for the part to fall free of the mold. Once the part is ejected, the mold can be clamped shut for the next shot to be injected.

Recycled plastics, the environment and improved profits

An environmentally responsible business plan is becoming an increasingly vital component of any effective long-term strategy. This is not merely due to the growing number of environmental laws businesses must comply with, but also due to the fact that the public expects that the business world will do its part in preserving the environment. Fortunately, plastic Moulding is a technology that can combine productivity, cost-effectiveness and an environmentally responsible production process in one package.

Environmental benefits of recycled plastic in injection moulding

Plastic is a durable and flexible material that can be used for a wide range of purposes while also being easy to recycle. Instead of being disposed of in landfills, plastic containers and components can be economically recycled and later used for plastic injection Moulding and other industrial processes.

In addition to helping to preserve landfill space, recycling plastic also reduces the amount of plastic that must be produced from scratch, which further reduces the environmental impact of a business that uses recycled plastic. This includes reducing ground pollution, as well as the amount of greenhouse gas emissions stemming from the production of new plastic. Most importantly, these benefits come without any loss in quality. Recycled plastic can be of any color or type required by the end user, whether they need a flexible plastic part or a unit that requires a high degree of tensile strength. Plastic mold building allows recycled plastic to be reshaped as needed. When combined with the fast production time found in the plastic Moulding process, this makes it an ideal choice for rapid prototyping or large-scale production alike.

Closed industrial process

Another advantage of applying recycling to the plastic injection Moulding process is that it becomes easy to create a closed industrial materials process, where used parts are recycled and provide the material needed for new plastic components. A company can thus not only provide excellent parts for its customers, but also assist them in recycling their older components.

Not only is this process environmentally responsible, but it can reduce the company's material expenses. This is especially true given the fact that the price of new plastic can often be impacted by unexpected changes in petrochemical prices. Finally, the company can pass those savings back to its customers, helping to create a loyal customer base.

The public benefits of plastic recycling

Any company that is using recycled plastic in its industrial process can benefit from the public's perception that the business is working to protect the environment. Not only does this benefit the company's reputation, it can actually improve sales among individuals and organizations that see environmental responsibility as a high priority.

Ultimately, making use of recycled plastic in plastic Moulding and other industrial processes is a beneficial decision at every level. Not only does this reduce the cost of production while protecting the environment, but it can also improve the company's reputation. For this reason, wise businesses are likely to see the use of recycled plastic as the shape of things to come.

Advantages &applications:

Advantages

- The daily using components can be easily made.
- The cost of the project is very less.
- High electricity consumption.
- Textile products can be produced.

- Less skilled labour is enough.
- Different shape of the components can be made according to the die what are used.

Disadvantages

- High Manual Force is required
- Heating coil consumes high current

Applications

- Injection moulding is used to create many things such as wire spools, packaging, bottle caps, automotive parts and components, toys, pocket comb.

- some musical instruments (and parts of them), one-piece chairs and small tables, storage containers, mechanical parts (including gears), and most other plastic products available today.

- Injection moulding is the most common modern method of manufacturing plastic parts; it is ideal for producing high volumes of the same object.

Conclusion:

Injection Moulding is the one of the most important of various types of plastic products can be manufactured.Now all electrical components are made up of nylon polymer is very costly and time consuming to produce the components. So that here we are used PP having low cost and reinforcement with the glass fibre will reduces the thermal conductivity and increases the hardness and strength. Cost and processing of the component is also easy and takes a less time to produce the components.Heater is attached to the plastic injection moulding machine only so that the other separate heating equipment is not necessary it reduces the cost of the machine and requires a less space for machine.Due to low cost, this project will be designed and manufactured and this project can be used for small scale.

References:

- P.K. Bharti and M.I. Khan, "Recent methods for optimization of plastic injection Moulding process –A retrospective and literature review," International Journal of Engineering Science and Technology, Vol. 2, No.09, 2010, pp.04540-4554.
- Radhwan Hussin, RozaimiMohdSaad, RazaidiHussin and MohdSyedi Imran MohdDawi, "An Optimization of Plastic Injection Moulding Parameters Using Taguchi Optimization Method," Asian Transactions on Engineering, Vol. 2, Issue 5, pp.75-80.
- M. Kemal Karasu, Mehmet Cakmakci, Merve B. Cakiroglu, ElifAyva and Neslihan Demirel-Ortabas."Improvement of change over times via Taguchi empowered SMED/case study on injection Moulding production," Measurement, Vol. 47, 2014, pp. 741-748.
- B. Sha, S. Dimov, C. Griffiths and M. Packianather, "Investigation of micro-injection moulding: Factors affecting the replication quality," Journal of Materials Processing Technology, vol. 183, 2007, pp. 284–0296.
- Dr.A. RiazAhamed, Dr.A.K. ShaikDawood, R.Karthikeyan "Designing and optimizing the parameters which affect the Moulding process using Design of Experiment" International Journal of Research in Mechanical Engineering Volume 1,Issue 2, October-December, 2013 pp.116-122.
- D.Papageorgiou,C.Medrea,N.Kyriakou. "Failure analysis of H13 working die used in plastic injection Moulding" in Engineering failure analysis, volume 35, December 2103, pages 355-359.
- Y.P. Tidke, A.V.Dhote, Dr.C.R.Patil; "Study and Optimization of Process Parameters in Plastic

Injection Moulding-AReview", international journal for research in applied science and engineering technology Vol. 20Issue IV, April 2014.

- Zhang, S., Dubay, R., & Charest, M. (2015). A principal component analysis model-based predictive controller for controlling part warpage in plastic injection Moulding. Expert Systems with Applications, 42(6), 2919-2927
- Chen, C. P., Chuang, M. T., Hsiao, Y. H., Yang, Y. K., & Tsai, C. H. (2009). Simulation and experimental study in determining injection Moulding process parameters for thin-shell plastic parts via design of experiments analysis. Expert Systems with Applications, 36(7), 10752-10759.
- M. Packianather, F. Chan, C. Griffiths, S. Dimov and D. T. Pham,"Optimisation of Micro Injection Moulding Process through Design of Experiments," Procedia CIRP Conference on Intelligent Computation in Manufacturing Engineering, 2013, pp. 300-305.