

# Injection Molding Principles

R&D Center

## 1. What is injection molding?

Most engineering plastics are being manufactured by injection molding and it is important to understand both its procedures and precautions.

First, add the required colorants, stabilizers, plasticizers, and fillers to the plastic chips or pellets and put them in a hopper.

Inserted materials are melted in a heating cylinder with an appropriate temperature based on its own individual characteristics.

Then, inject the melted material into the mold by the screw.

Once the material fills the mold completely, the forwarded screw pulls back to its original position and the mold is opened to collect the shaped part.

To produce an optimal product, materials (resins), mold, injection molding machine, and relevant equipment must be well-prepared to be mutually supplementary.

## 2. Basic elements of injection molding

### (1) Mold

Mold is, in other word, a tool designed for forming material to a purposed shape.

### (2) Injection molding machine

The injection molding machine is a machine for manufacturing molding products.

### (3) Molding materials (resins)

Molding materials are a type of solid matter formulated by the links between low molecular weight monomers.

It is a high molecular weight organic compound based on organic compounds with more than 10 thousand molecular weights.

### (4) Molding condition

Molding condition is an input to configure the molding machine's condition and its process to manufacture molding products.

### 3. Injection molding machine

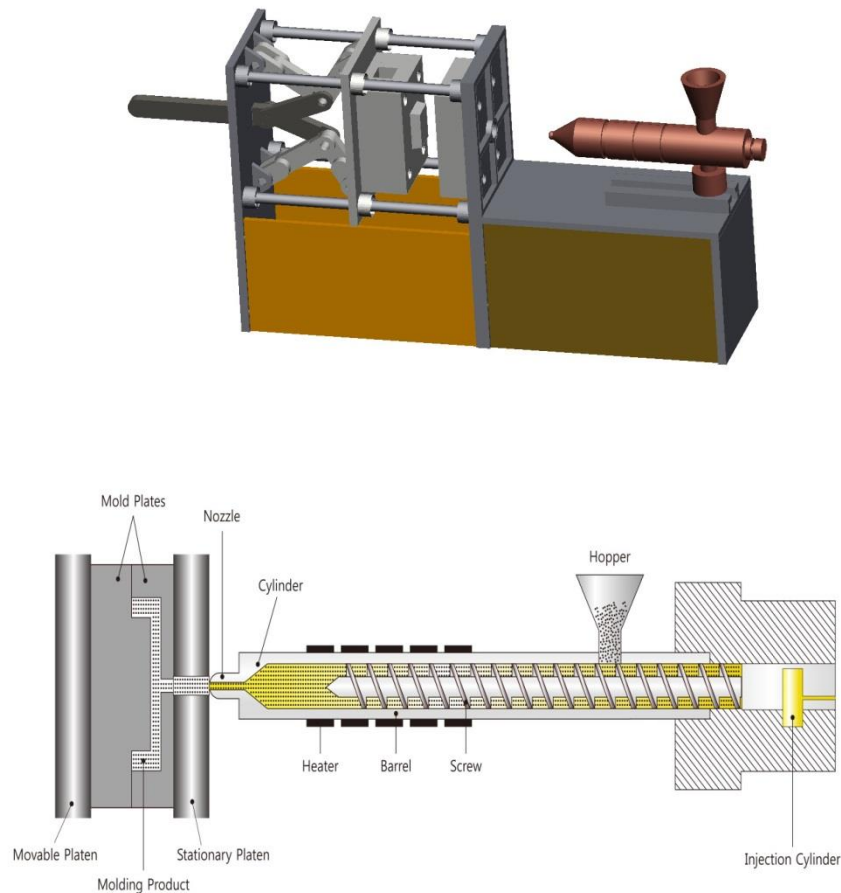


Fig. 1. Basic structure of injection molding machine

#### (1) Injection molding machine selection

To produce a fine product, using an appropriate injection molding machine is required. The decision has to be made based on the machine's capacity. The capacity of an injection machine is determined by its maximum clamping force and molding volume.

- 1) Clamping force : The maximum pressure to hold the molds shut while the melted resin is inserted into the mold.
- 2) Molding volume (in theory) : Based on GPPS (in most cases) which refers to maximum feeding volume (maximum injection volume per time).
- 3) Die-plate area : The maximum area which can project in the mold.  
Larger products can be molded if it is necessary but it is not recommended due to product safety and negative effects on the lifetime of the machine.

#### (2) Types of injection molding machines

- 1) Oil pressure type : Run by oil pressure
- 2) Electric type : Run by an electric sub-motor
- 3) Hybrid type : Combines oil pressure and electric sub-motor

(3) Classification by plasticization and injection type

- 1) Screw in-line (or in-line screw) type
- 2) Plunger type

(4) Basic structure of injection molding machine (oil pressure type)

- 1) Frame / Bed  
A base to install various equipment(mold clamp and injection instrument) and oil pressure driving parts.
- 2) Clamp part  
A part from the injection molding to open and close the mold.  
The clamp holds the molds shut when melted resin fills up the mold.  
4 types exist : Direct pressure type, toggle type, combination type, and electric type.

- ① Die Plate (Mold Plate) : Where the molds are attached.  
Divided into 2 parts : The stationary plate(fixed part for the mold) and the movable plate(moving part for the mold).
- ② Tie-Bar : Composed with 4 spindles that support the die plate while it is opening and closing.
- ③ Clamping Cylinder : Oil pressure cylinder that opens/closes the molds and generates clamping force.
- ④ Mold Thickness Control Device : Each mold has a different thickness and this device is to optimize the thickness of the molds when it is changed.
- ⑤ Ejector : A device that pushes the product to separate it from the mold.
- ⑥ Safety Door : Prevents safety accidents by automatically stopping the mold closing action while the door is open.
- ⑦ Oil Supply Device : A device that supplies the lubricant oil to slipping or friction parts.

3) Injection instrument

An instrument that plasticizes the material composed of a screw, nozzle, heater, mold, and additional equipment.

It has the most important role in the machine regarding molding condition.

Each part's name and role is as follows.

- ① Hopper  
Material for injection molding is in a shape of pellet or chip and the hopper contains it. Pellets flow from hopper to hopper neck by the barrel and screw under the force of gravity.
- ② Heating cylinder  
It has a function that melts or plasticizes the injection molding material by heat.
- ③ Nozzle  
It is attached to the mold during injection molding. Melted material is injected into the mold through the nozzle and it is the first pathway to the mold.
- ④ Injection ram cylinder  
It is the origin of injection pressure and speed. It pushes the screw forward.
- ⑤ Screw actuator device  
A device that connects the screw to the oil pressure motor or electromotor to spin the screw for realizing plasticization of material.
- ⑥ Injection units: The core part of injection molding instrument.

The backward flow prevention valve is attached on a screw head which helps melted resins not to face any backward flow (resin flows not to the molds but to the back of the screw, in other words, to the hopper).

This valve moves along a narrow gap between screw head and screw shoulder (where the screw body starts).

The valve moves back by injection pressure until the screw shoulder while the screw moves forward to the front (to the nozzle).

Conversely, the valve goes to the front during the feeding process when the screw goes back (to the hopper) and injection pressure pushes it to the front.

The important point is that the check valve prevents melted resins from backward flow by adhering to the screw shoulder during the injection process.

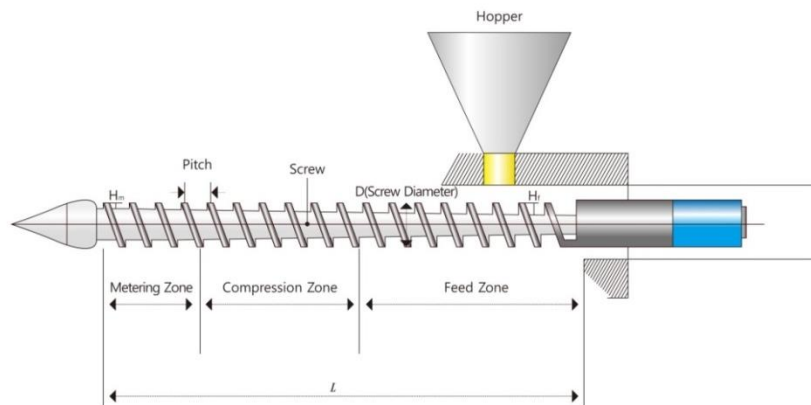


Fig. 2. Screw structure

Understanding proper L/D and pressure ratio ( $H_f:H_m$ ) with material types is important. The screw is composed of the feed section, compression section, and metering section.

① Feed section

To plasticize the plastics material, it supplies the materials into the heating cylinder (until the compression section).

The feed section starts from the initial material drop until the central section.

In this section, plastics materials are already melted and guided to the compression section.

② Compression(transition) section

Located at the middle of the screw.

Its purpose is to melt the material completely and supply it to the metering section. Plastics material is then completely fluidized in the compression section.

The screw is designed to be gradually less sharp until the tip so that the pressure can be much stronger.

③ Metering section

The metering section is the place where the plasticized(or melted) resin stays each shot; a resin is pushed forward by the injection pressure to the mold.

4) Oil pressure driving part

An injection molding machine runs by oil pressure. It is composed of a pump (a power source for generating the oil pressure), output device (cylinder and oil motor), and control device (redirection valve). The oil pressure driving part supplies power to each cylinder to perform injection molding properly.

5) Electricity control panel

Also known as a controlling board. Composed of a heating circuit (controls the temperature), controlling circuit (controls the actions of oil pressure equipment), and motor circuit (controls the power).

## 4. Mold

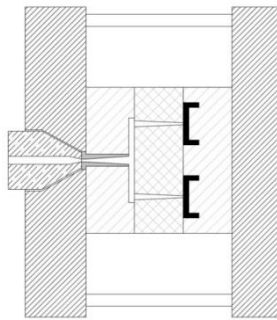
The mold for injection molding is a heat exchanger for plasticized or melted material into the shape of designed form and size.

The mold is composed of a molding plate, ejection pin, cooling line, tie-bar, movable plate, and stationary plate which supports the cavity, sprue, and runner system's components. The mold for injection molding is a combination of flat plates and molding plates made of tool steel.

The stationary plate is attached to the barrel's side of the injection molding machine and connected to the movable plate by the tie bar.

The cavity plate is, in most cases, attached to the stationary plate and supported by the injection nozzle.

The core plate is connected to the movable plate by the tie bar.



**Fig. 2. General structure of mold**

In general, the mold can be divided into a two-plate mold and a three-plate mold.

Mold		
Two-plate mold		Three-plate mold
<ul style="list-style-type: none"> <li>- Direct gate</li> <li>- Side gate</li> <li>- Submarine gate (or tunnel gate)</li> <li>- Special gate</li> </ul>	<ul style="list-style-type: none"> <li>- Slide(side) core mold</li> <li>- Screw mold</li> <li>- Other combined mold</li> </ul>	<ul style="list-style-type: none"> <li>- Pin-point gate</li> <li>- Side gate</li> </ul>

### (1) Two-plate mold

Two-plate molds are the most common type(though it has some exceptions) of mold and separated into the stationary plate and movable plate by a parting line.

It is composed of the sprue, runner, gate, and cavity. Those are usually installed together.

### (2) Three-plate mold

The mold that has a middle plate between the stationary plate and movable plate.

It is also called "a runner plate" as the runner is plasticized.

The cooling channel of a mold is a pathway of circulating heating medium(water, steam, oil, and etc.) inside of the mold.

The heating medium controls the surface temperature of the mold.

The cooling channel can be connected to other types of temperature control equipment such as a heater rod(a kind of electric heater).



## 5. Peripherals

- (1) Dryer : A dryer(hot-air circulation dryer), dehumidified dryer, vacuum dryer, nitrogen dryer, etc.
- (2) Hopper dryer : A dryer attached to the injection molding machine.
- (3) Hopper loader : Automatic material supplier which is attached to the hopper drier directly to supply material into the dryer.
- (4) Crusher : A device that cuts scrap (defective product and runner) into very small pieces for recycling.
- (5) Auto unloading device : A machine that collects the molded product from the mold.
- (6) Mold temperature controller : Automatic device to control the mold's temperature.  
Oil (water) types and chiller types are common.

## 6. Injection molding process

- (1) First, put plastics material into the hopper.  
If the resin requires pre-drying, the hopper dryer which is attached to the hopper can be used to pre-dry the resin.
- (2) Once the resin is in the hopper, it is supplied to the inside of the heating cylinder.  
Then, the screw in the heating cylinder pushes the resin to the head of the cylinder in a process called 'feeding'.  
With required injection pressure and injection speed, the melted material flows into the inside of the mold rapidly to form a product.  
After a designated time, the molds are opened automatically and a product is made.

### [Injection Molding Process]

**Mold clamping → (Nozzle forwarding) → Injection → Holding Pressure → Metering → (cooling) → Eject/Unloading of molded product → Mold clamping**

- 1) Mold clamping  
Molds are closed, and ready to start injection molding. After mold clamping, the movable plate holds the mold to prevent any movement by the pressure of melted resin.
- 2) Nozzle forwarding  
After the mold clamping is completely locked, the injection part moves forward and the nozzle contacts the sprue bushing of the mold.
- 3) Injection process  
While a screw is rectilinearly moving with high speed and pressure.
- 4) Holding pressure process  
To supplement the molding shrink while the material in the mold consolidates.  
In other words, this process helps keep the shape of the product and prevent any malfunctions (sink marks, voids, etc.) by putting additional pressure and time after the mold is filled.
- 5) Metering process(including cooling and plasticization)  
A plasticization process in which the nozzle is attached to the molds, the screw turns and melts the resins then pushes it forward ahead of the screw.  
After the product is filled in the mold by the injection and the holding pressure, the cooling process helps the product have proper shape and size.  
This process is done under certain temperatures and times.  
Plasticization is a preparation step for the next cycle in the injection part by melting the resin while the product is cooling down in the mold.

6) Eject/unloading process of molded product

This is the process to separate the product from the mold after the product is fully manufactured.

The mold is opened and the eject pin from the movable plate pushes the product.

Molds are opened and the product is retrieved as the feeding is done after the screw is stopped and the nozzle is separated from the mold, which is already open.



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