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TOOL DESIGN AND MAINTENANCE IN PLASTIC INJECTION MOULDING PROCESS

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Abstract: Injection moulding is one of the most widespread technological processes for processing plastic materials. The development of new materials and increasing demands in product exploitation obtained by injection moulding have led to the development and refinement of various injection moulding techniques. The process of producing plastic parts by injection moulding is a very simple method because injection–moulding machines have the capability to install various tools or moulds, enabling the production of different components.

Keywords: Plastic tooling design, plastic injection moulding, tool maintenance

INTRODUCTION

Plastic injection moulding is a process in which molten plastic is injected into a mould to shape the desired form. Plastic injection moulding tools are specially designed moulds that enable shaping plastic into the desired shape. These tools can be simple or complex, depending on production requirements. They consist of two halves that close to create a space for injecting plastic. Once the plastic cools and solidifies, the mould opens, and the finished product is ejected.

Tooling for plastic injection moulding is a complex process involving design, fabrication, and testing before being utilized in production. Tool design entails creating a three–dimensional mould model that will be used for shaping plastic. This model is then utilized for fabricating the mould from suitable materials, typically steel or aluminum. Following mould fabrication, testing is conducted to ensure tool functionality and quality.

The process of repairing plastic injection moulding tools involves repairs and maintenance to ensure their longevity and optimal functionality. Repairs may be necessary if damage or wear occurs to the tool during the production process. Tool maintenance involves regular cleaning, lubrication, and inspection of all components to ensure their proper functioning.

PLASTIC INJECTION MOULDING TOOL

The tool is one of the fundamental elements of the processing system directly shaping the part. A new tool is required for each new shape. After plastic injection, the part is formed and then cooled in the mould, which is why the tool must be connected to a temperature control device. After the final cooling of the part, the tool is opened, and the part is ejected using ejectors. The extraction of remaining gate system residues is performed by extractors. The tools are mounted on appropriate plates of the tool housing, one of which is connected to the movable plate of the machine, and the other to the stationary plate. Guiding of the housing plates is ensured by cylindrical guides. The housing plates can be rectangular or circular (Figure 1.).

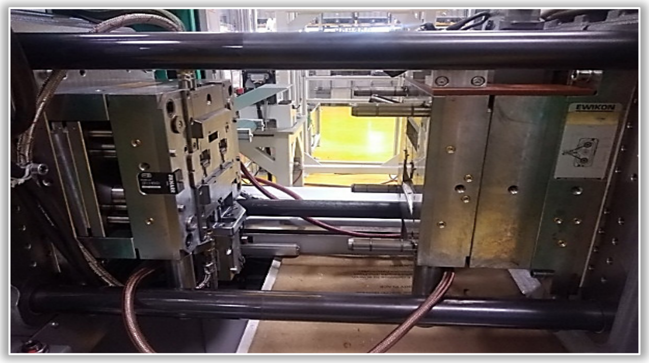


Figure 1. Plates on which the tool is mounted (secured), EWIKON machine

The total force, which depends on the projection of the cluster of parts and the material pressure, is transmitted through the plates to the closing system.

The mould cavity consists of two parts separated by a parting plane. Ejector activation is achieved automatically when the movable plate returns to the open position. The extractor profile can be shaped differently to ensure the extraction of residual material from the gate. Specialized manufacturers produce standardized parts for injection moulding tools. The basic elements of plastic injection moulding tools are shown in Figure 2.

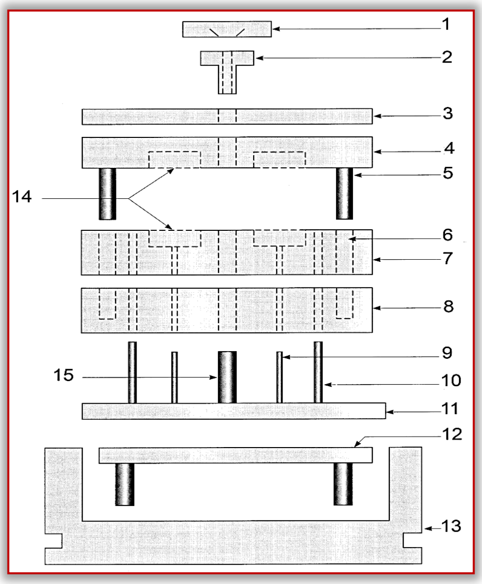


Figure 2. Elements of plastic injection moulding tool/; 1 – Nozzle centring sleeve 2 – Sprue bushing 3 – Plate 4 – Fixed mould 5 – Guide pin 6 – Guide bushing 7 –Movable mould 8 – Support plate 9 – Ejector 10 – Ejector return rod 11 – Ejector backing plate 12 – Ejector drive plate 13 – Ejector housing 14 – Mould cavity 15 – Extractor

The gating system can be cold or hot. In the first case, the gating system must be separated from the finished part after cooling. For the injection moulding of smaller pieces, it is possible to manufacture multiple parts simultaneously, fed with molten material through a branched gating system, which must be designed to ensure simultaneous filling of all cavities (Figure 3, Figure 4).

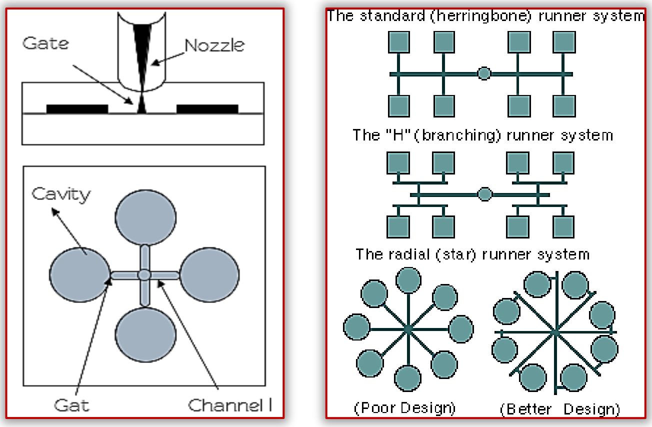
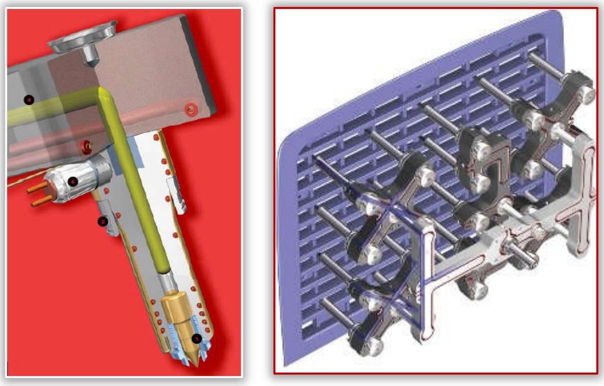


Figure 3. Elements of a cold gating system [1]: a) diagram, b) design variants.



a) b)

Figure 4. Hot gating system: a) diagram of a hot nozzle, shaping a complex grid with a hot gating system

The hot gating system is the ideal gating system that ensures seamless supply of molten polymer to the mould, without material loss, without pressure drop in the mould, and with shortened injection moulding cycles.

The cavity in the mould – the cavity, in its shape, completely corresponds to the shape of the workpiece with dimensions increased due to the cooling of the part after ejection. The number of parting planes depends on the shape, and in this sense, moulds are divided in:

- moulds with a single parting plane,
- moulds with two parting planes,
- moulds with three or more parting planes.

According to the shape of the part, moulds can be (Figure 5):

- Moulds for simple–shaped workpieces.
- Moulds for complex shapes.
- Moulds for workpieces with inserts.
- Moulds for workpieces with external threads.
- Moulds for workpieces with internal threads.

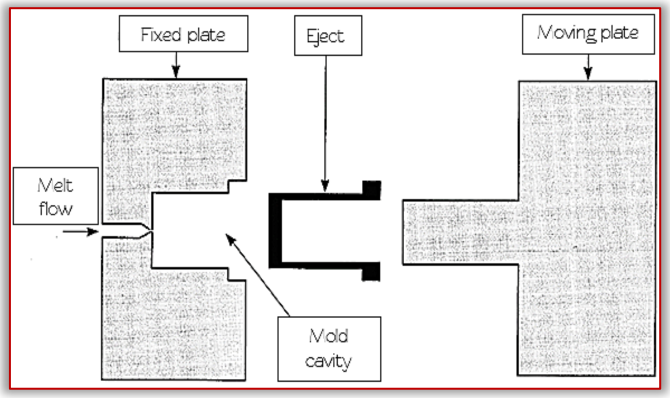


Figure 5. Types of Moulds

Weld lines (Figure 6.) are a common issue in plastic injection moulding and occur due to the meeting of molten material flows moving in opposite directions. They are especially noticeable in areas around openings and inserts made of different materials (e.g., metal inserts). Weld lines are generally undesirable, and the problem is resolved through proper tool design.

The tool design is largely determined by the level of complexity, type of material, required accuracy, production volume, and other parameters. Image 6 shows the appearance of a complex tool used for manufacturing a vacuum cleaner cover.

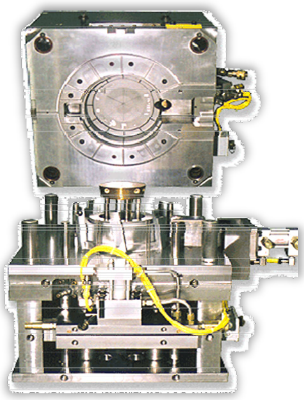


Figure 6. Plastic Injection Moulding Tool

THE ROLE OF INDIVIDUAL COMPONENTS IN PLASTIC INJECTION MOULDING TOOLS

The gating system is used to deliver the molten material from the nozzle to the mould cavity and must be designed to ensure a high–quality part. It consists of:

- Sprue (gating) channel.
- Runner channels (primary and secondary).
- Gate (entry point).

The feed (sprue) channel connects the nozzle to the runner channel. It is located in the injection sleeve, and after injection is completed, any residual material cools and is removed using ejectors. The axis of the feed channel must be aligned with the nozzle axis.

Runner channels are responsible for distributing the molten material from the sprue to the gate. The profile of the runner channel can be circular, semicircular, trapezoidal, etc. The dimensions of the runner channels are crucial.

The gate opening allows the molten material to flow from the runner channel into the mould cavity. The gate can be (a) restrictive or (b) non–restrictive.

The gate serves the following functions:

- Regulates the flow and direction of molten material.
- Facilitates the separation of the gating system from the part.
- Cools quickly and prevents backflow from the mould cavity.
- Restrictive gate channel:
- Generates frictional energy as the molten material passes through, facilitating flow.
- Reduces residual stresses in the part.
- Shortens cooling time and cycle time.

When determining the dimensions of the mould cavity, the shrinkage of the part after cooling, which is present in all types of plastic, must be considered.

Shrinkage depends on the following factors:

- Processing methods.
- Type of polymer.
- Flow conditions in the tool.
- Injection pressure.
- Temperature of additives in the material.

Table 1. Shrinkage of parts after cooling, which is present in all types of plastics

Shrinkage factor	Material type
0–0,002	Polyester(termoset) BMC, SMC
0,001–0,004	Polycarbonate, 20% fiberglass
0,002–0,008	Acrylic
0,002–0,003	PVC
0,004–0,007	ABS
0,004–0,006	Polystyrene
0,008–0,015	Nylon (6/6)
0,010–0,020	Polpropylene
0,007–0,025	LDPE
0,020–0,040	HDPE

MOULD COOLING SYSTEM

The solidification of the part in the mould occurs due to the heat being transferred from the molten material. Cooling time impacts the duration of the moulding cycle and primarily depends on the part's dimensions, injection temperature and pressure, and the type of material used. Smaller parts always cool faster than larger ones. As the injection cycles are repeated, the amount of heat in the moulds increases, and their natural cooling would slow down the production process. Therefore, moulds are cooled using forced circulation of a coolant, which is most commonly water from a water supply. Typically, both halves of the mould (the stationary and movable ones) are cooled, and appropriate water connections and flexible hoses are installed. The cooling intensity can be regulated by circulating water through cooling pipes. In addition to the mould cavities, the cores of the moulds must also be cooled. Cooling of the cores can be done using compressed air. Cooling of the tool components for cup production is shown in Figure 7.

This controller can heat up to 160 degrees and can cool the tool after heating down to 30 degrees. It is connected to a supply hose for water and a drainage hose that removes water from the tool.

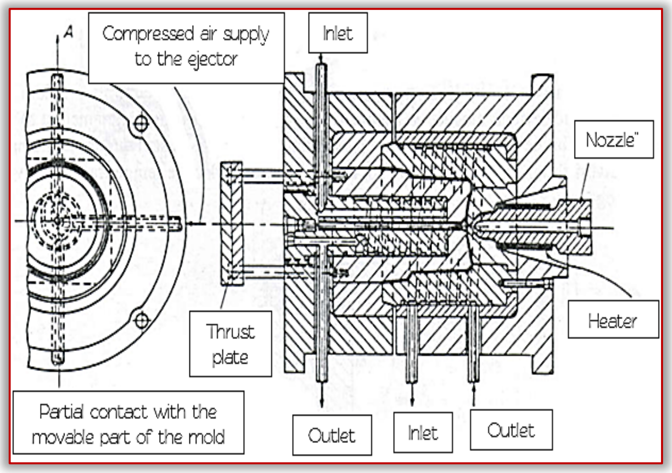


Figure 7. Cooling of the plastic injection moulding tool at GRUNER

Figure 8. Tool Heating Control

CONCLUSION

Plastic injection moulding and plastic casting, alongside the production of injection moulds, is a service that completes the entire process of plastic part manufacturing. Plastic injection moulding, or casting, is the most commonly used method in today's plastic processing. Parts produced through injection moulding under pressure can vary in complexity and surface quality.

The technological process of injection moulding consists of a series of operations that take place automatically. To begin the cycle, it is necessary to perform actions that bring the machine or injection system into a working state and initial position. These actions usually include heating the melting cylinder and hydraulic oil to operating temperature, with the initial position typically being: open mould, ejector in the retracted position, nozzle retracted, and material pre–dosed material, open mould, ejector in the retracted position, retracted nozzle, and prepared material.

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