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eNOTES

PLASTIC PROCESSING

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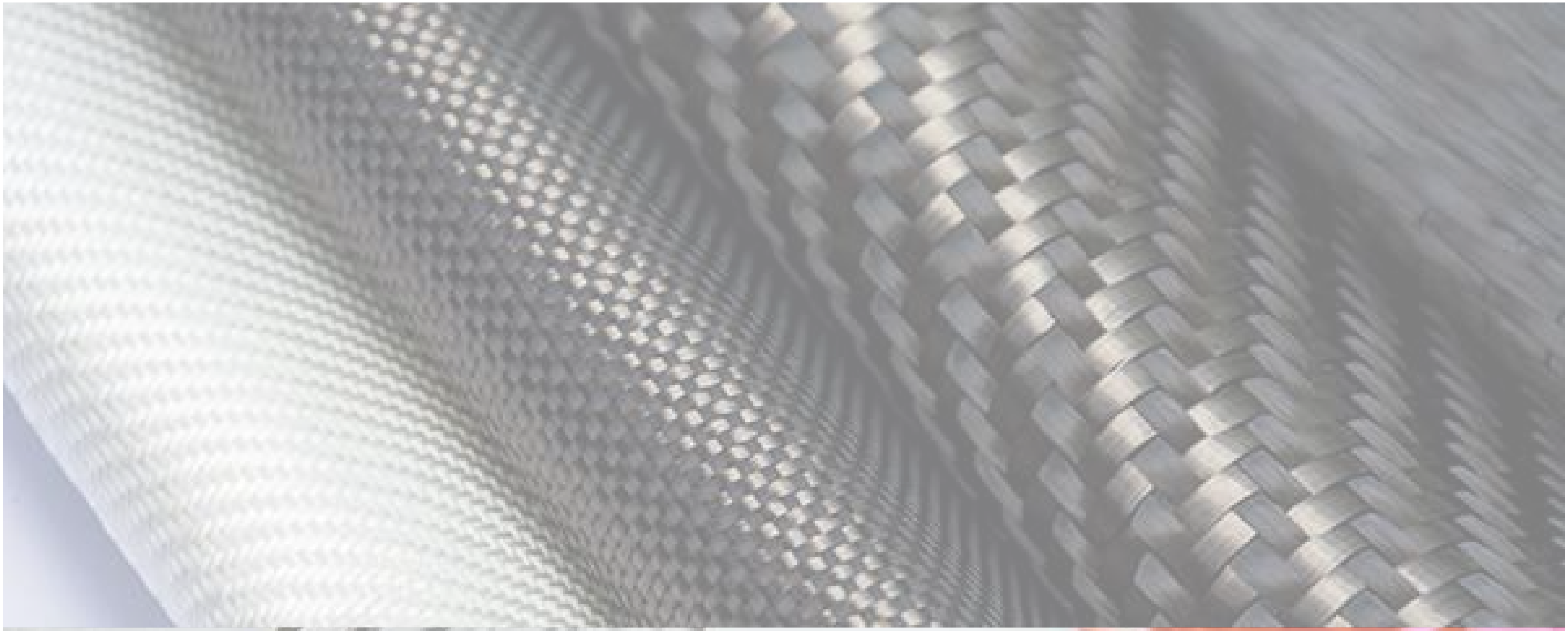

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eNotes - Plastic Processing

2021 Edition

eNotes - Plastic Processing is as
general references and readings especially to
lecturers and students of polytechnics and colleges
Malaysian community to apply best practices in
method implementation online teaching and learning.

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rujukan dan bacaan umum terutama kepada
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ABSTRACT

This eNotes - Plastic Processing offers a comprehensive guide to the fundamentals of plastic materials, including their properties, processing, design, and applications. It covers plastics materials from property formulation to final product design, integrating manufacturing processing and part design. Plastic materials characteristics, manufacturing processing, casting for plastics, applications, and the consideration of design and economics for processing plastic material are all covered in this eNotes - Plastic Processing. Plastic Materials Engineers can generate new formulations and producing those formulations. Design engineers can identify plastics materials and able to design new ideas. Manufacture Engineers on the other hand, able to apply new techniquesfor developing brand-new applications. Several types of manufacturing processessuch as transfer molding, blow molding, injection molding and extrusion process that would all benefit from this eNotes - Plastic Processing. It is a short, relevant, and instructive reference guide to plastic processing for engineers and plastics practitioners. This is also as general references and readings especially to lecturers and students of polytechnics and colleges Malaysian community to apply best practices in method implementation online teaching and learning.

Content

1.0 Introduction

This chapter describe more about plastic and composite which involve their characteristic and manufacturing processes.

The chapter ends with a description of the characteristic of the plastic and composite material based on their structure, properties and applications.

The processing of plastic involves operations that is similar to those used in the forming and shaping of metals. Unlike metals, plastic is easier to handle and shaped as plastic will melt at lower temperature and need less force and energy to process. Plastic generally can be moulded, cast, formed and machined into complex shapes (Table 1.0). Production of a wide variety of continuous or discrete products by extrusion, moulding,

Table 1.0
General characteristics of Forming and Shaping Processes for Plastics and Composite Materials

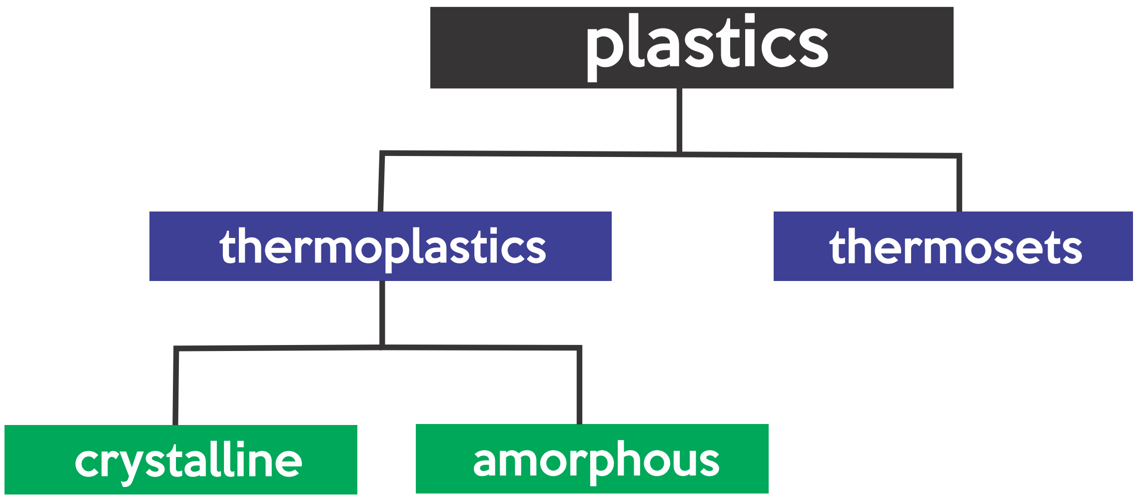
PROCESS	CHARACTERISTICS
Extrusion	Continuous, uniformly solid or hollow and complex cross section, high production rates, relatively low tooling costs and wide tolerances
Injection moulding	Complex shapes of various sizes, thin wall, high production rates, costly tooling, good dimensional accuracy.
Blow Moulding	Hollow, thin-walled parts and bottles and bottles of various sizes, high production rates, low tooling cost
Rotational Moulding	Large, hollow item (simple shape),low tooling cost, low production rates
	Shallow or deep cavities, low tooling cost, medium production rates

Compression Moulding	Parts similar to impression-die forging, expensive tooling, medium production rates.
Transfer Moulding	More complex parts than compression moulding, higher production rates, high tooling cost, Some scrap loss
Casting	Simple or intricate shapes made with rigid, low-cost mould and low production rates
Processing of	Long cycle times, expensive operation and tooling cost depends on process

Note. Adapted from Kalpakjian, S., & Schmid, S. R. (2006).
General Characteristics of Forming and Shaping Processes for Plastics and Composite Materials.
In Manufacturing Engineering and Technology (6th Edition). essay, Prentice Hall.

2.0 Plastic Processing

Plastic materials are divided into two categories, thermosets and thermoplastics. The chemical structure is used to classify the organisms. Linear molecular chains make up thermoplastics, whereas cross-linked molecular chains make up thermosetting plastics.



The words of plastics is origin from Greek words. It is known as **PLASTIKOS.**

PLASTIKOS : CAPABLE OF BEING MOULDED AND SHAPED.

Plastics are easily shaped, machined, cast, and connected into a variety of shapes. If any further surface-finishing processes are required, they are minimal. This trait gives them a significant advantage over metals. Plastics are available in a variety of types like film, sheet, plate, rods, and tubing.

Plastics are frequently delivered to production plants in the form of pellets, granules, or powders, which are melted right before being shaped. In the making of thermoset and reinforced plastic parts, liquid plastics cured into solid form are used.

Nowadays as environment awareness increasing, materials may also consist of recycled material (reground or chopped plastics) although the quality of the material is not good as the new one.

Plastics are important for a variety of reasons, both commercially and technologically:

6 REASONS WHY PLASTICS ARE IMPORTANCE

1 Plastics have a diverse set of qualities that make them ideal for a variety of technical applications when strength isn't a concern

(1) low density relative to metals and ceramics
(2) good strength-t-weigth ratios for certain polymers
(3) high corrosion resistance
(4) low electrical and thermal conductivity

2 Plastics are cost competitive with metals in terms of volumetric basis.

3. Plastics can be formed by moulding into complicated part geometries with little or no additional processing. They're well-suited to net shape processing.
4. Plastic, on a volumetric basis, take less energy and process to make than metals since the temperatures required to work with them are significantly lower.
5. Certain plastics are translucent and/or transparent, making them a viable alternative to glass in some cases.
6. Polymers (plastics) are widely used in composite materials

5 LIMITATION OF PLASTICS / POLYMERS

1. In comparison to metals and ceramics the strength of plastic is lower.
2. Service temperatures are limited to only a few hundred degrees due to the softening of TP polymers or the degradation of TS polymers and elastomers
3. When exposed to sunshine and other kinds of radiation, some polymers breakdown.
4. The viscoelastic qualities of plastics can be a significant drawback in load-bearing applications.

2.1 Differentation between Plastic Material

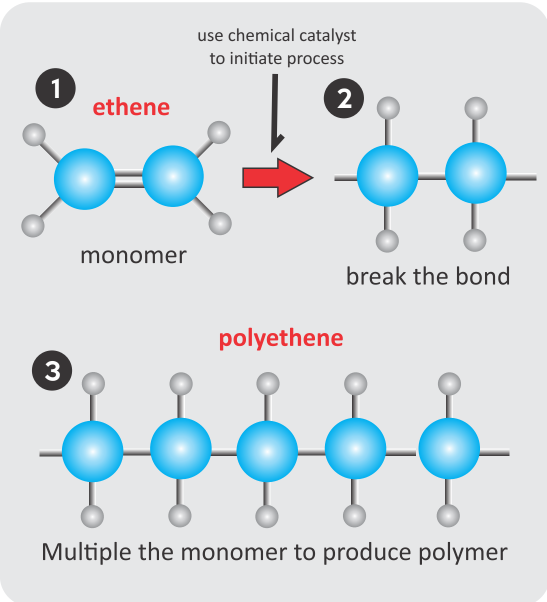
As discussed before, plastic material can be divided into two categories, which is thermoplastic and thermoset. Both of them are from two different classes of polymers which commonly differentiated based on their behavior in the presence of heat.

Table 2.0
General differentiation between thermoplastics and thermoset

THERMOPLASTICS	THERMOSETS
1 Are formed by **additional polymerisation**	1 Are formed by **condensation polymerisation**
2 Usually have a **linear structure held together by weak Van der Waals forces.**	2 They have a **3 dimensional cross-linked structure with strong covalent bonds.**

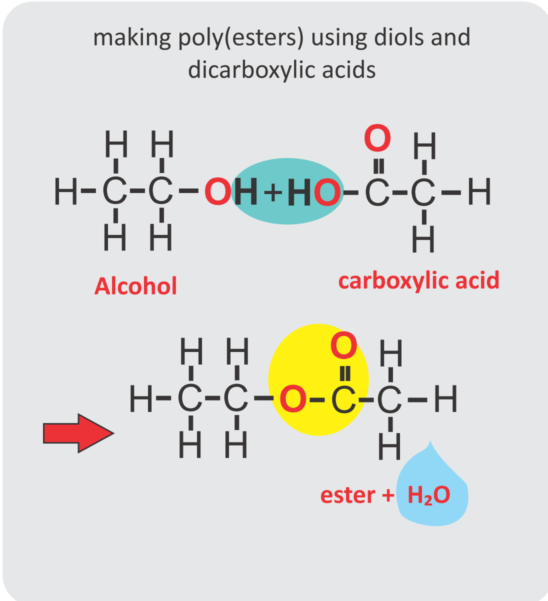
THERMOPLASTICS

1 Are formed by **additional polymerisation**



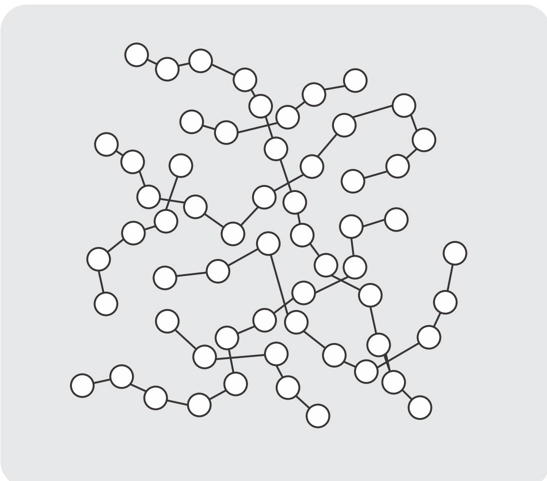
THERMOSETS

1 Are formed by **condensation polymerisation**



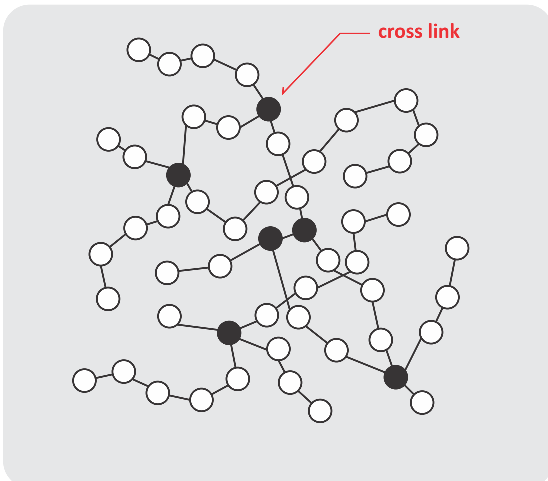
THERMOPLASTICS

2 Usually have a **linear structure held together by weak Van der Waals forces.**



THERMOSETS

2 They have a **3 dimensional cross-linked structure with strong covalent bonds.**



continue Table 2.0
General differentiation between thermoplastics and thermoset

	THERMOPLASTICS		THERMOSETS
3	When heated, it softens, and when cooled, it stiffens.	3	It does not soften when heated.
4	There are expensive	4	There are cheap
5	In organic solvents, thermoplastic is soluble.	5	In organic solvents, thermoset is insoluble.
6	Can be remoulded (recyclables)	6	Cannot be remoulded (not recyclables)
7	Reclaimed for waste	7	Cannot be reclaimed
8	Soft, weak and brittle	8	Hard, Strong and more brittle
9	Processed by injection moulding, extrusion, blow moulding, thermoforming process and rotational moulding.	9	Processed by compression moulding, reaction injection moulding.
10	Have low melting points and low tensile strength.	10	Have high melting points and tensile strength.

2.2 Manufacturing Process For Plastic Component Based On Their Characteristics

Plastics are easily shaped, machined, cast, and connected into a variety of shapes. If any further surface-finishing processes are required, they are minimal. This trait gives them a significant advantage over metals. Plastics are available in a variety of types like film, sheet, plate, rods, and tubing.

Plastics are frequently delivered to production plants in the form of pellets, granules, or powders, which are melted right before being shaped. In the making of thermoset and reinforced plastic parts, liquid plastics cured into solid form are used.

The majority of polymer shaping procedures are carried out at high temperatures, when the material is liquid or extremely plastic. The simplest straightforward scenario is thermoplastic polymers, which are also the most prevalent polymers. Thermoplastic polymers are solid at low temperatures; as the temperature rises, they typically transition into a soft rubbery material, then a thick fluid.

Nowadays as environment awareness increasing, materials may also consist of recycled material (reground or chopped plastics) although the quality of the material is not good as the new one.

In this chapter, we will learn the basic manufacturing process for plastic component based on their characteristics

Extrusion

a) Thermoplastic Processing

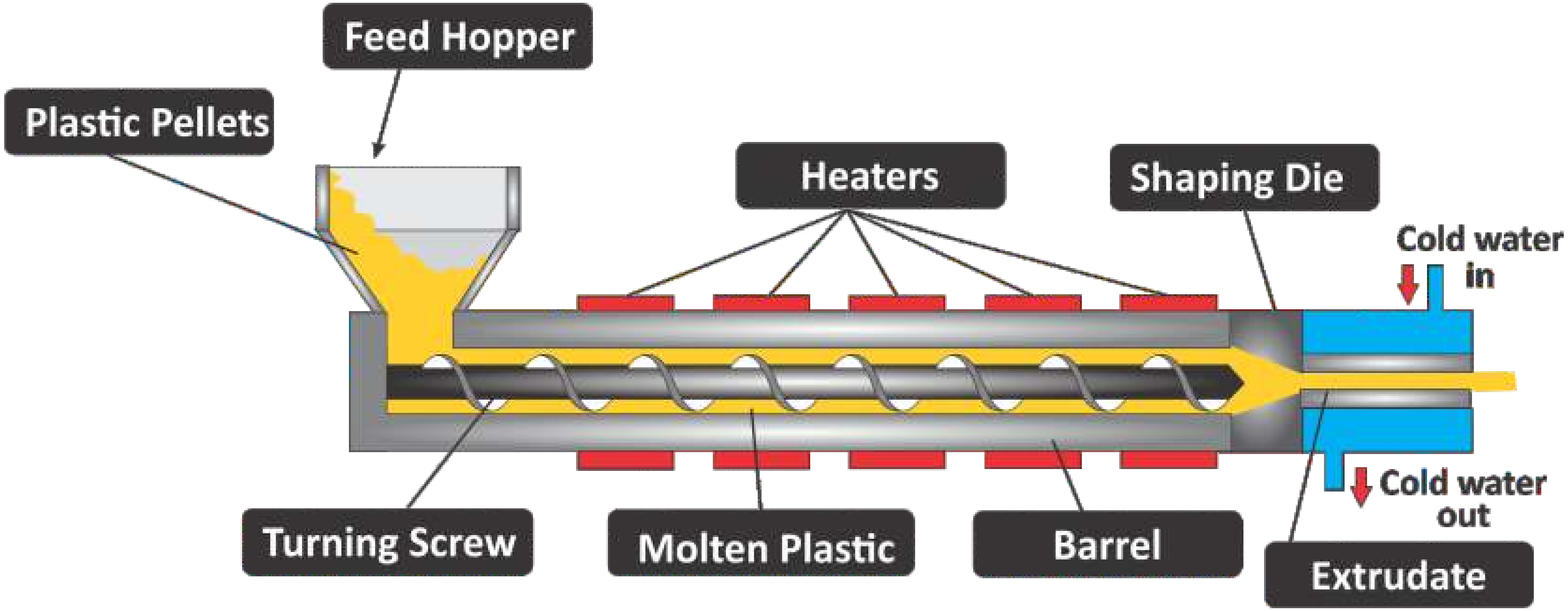
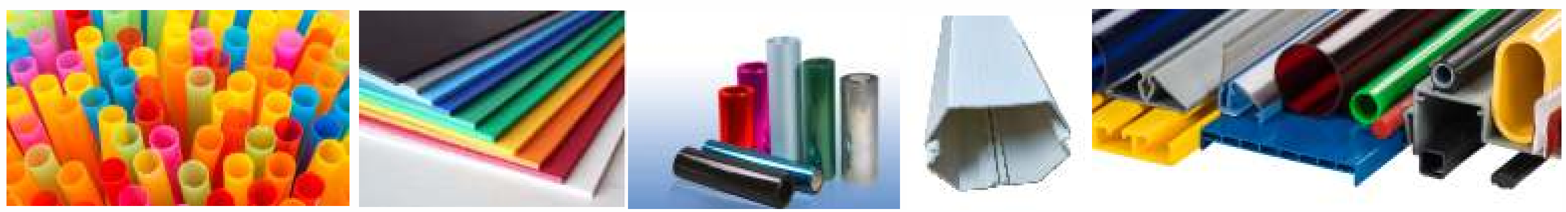


Figure 2.0 *Extrusion Machine for plastic manufacturing process*

product produce

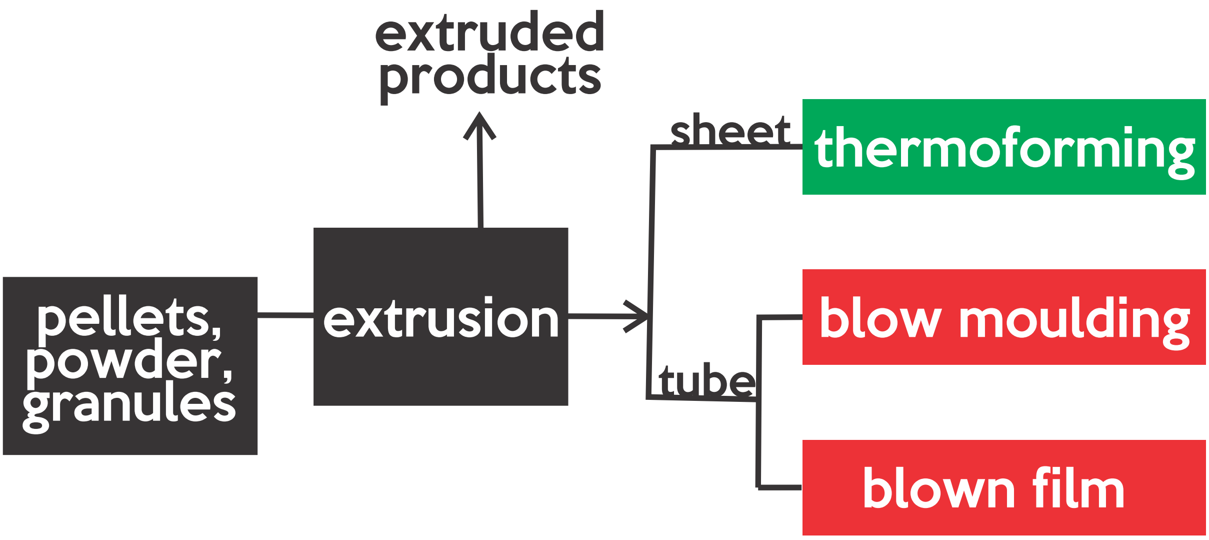


Extrusion

Characteristic

Long lengths of solid or hollow structures having a constant cross section are produced.

Outline Of Forming And Shaping Process



Common Extrusion Die Geometries

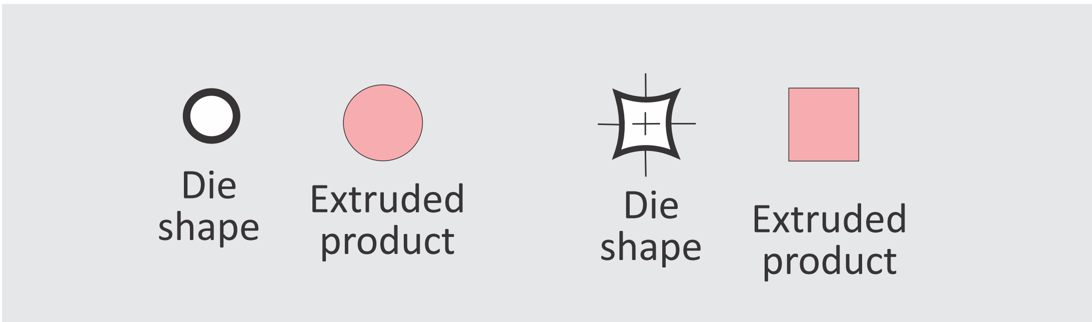


Figure 2.1 *Common extrusion die geometries*

1 The raw materials (**plastic pellets**) are put into a **feed hopper** that transports them to the extruder, which is placed at the machine's top. This means that the pellets will be fed into the extruder's barrel by gravity as shown in Figure 2.2. Any additives or colourants are added to the mix at this point in the process if they are appropriate for the end result.

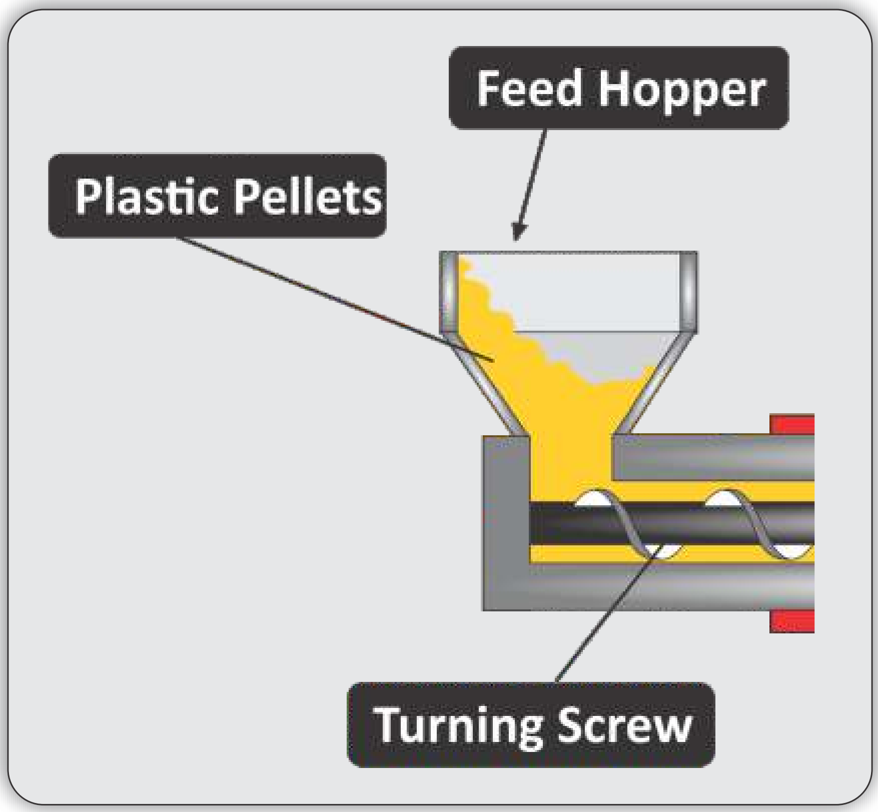


Figure 2.2 *Step 1 where the raw materials (plastic pellets) are put into a feed hopper*

2 The material enters the barrel from the hopper, where it is driven out the opposite end by the **turning screw**. The screw is located inside the barrel and revolves, pushing the material forward into the die from the front of the barrel. Heater bands (Figure 2.3) are used to heat the barrel, melting the plastic granules as they move through the screw. To melt the granules but not burn them, all plastics require the proper quantity of heat.

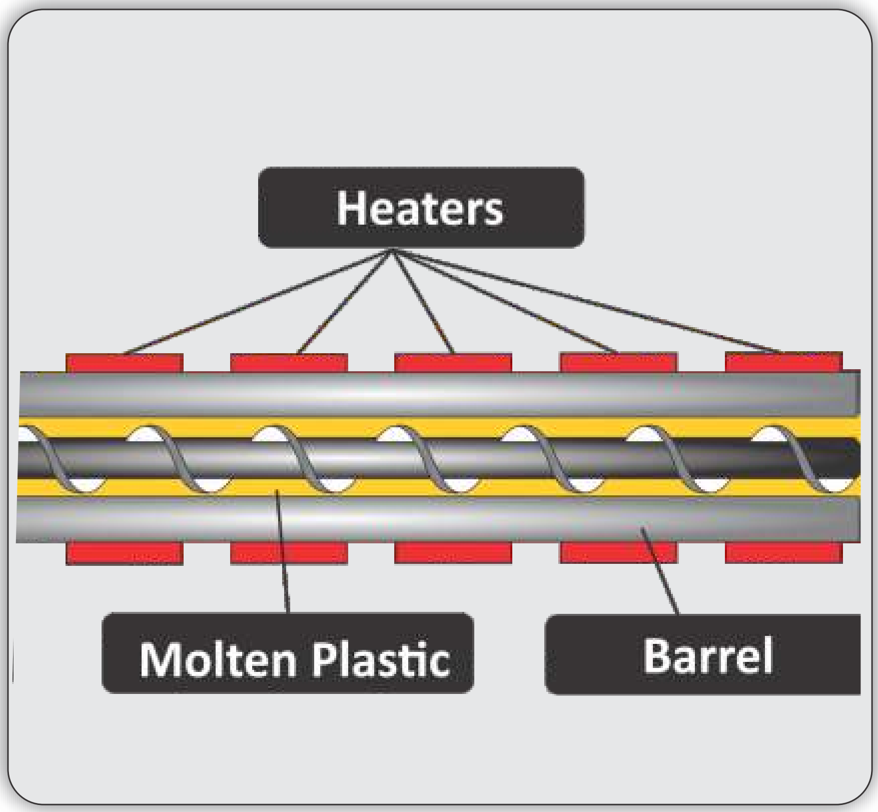


Figure 2.3 *Step 2 where heater bands are used to heat the barrel, melting the plastic granules as they move through the screw*

3 **The die is the hollowed-out shape** that the plastic will eventually take. After passing through the breaker plate, the plastic is driven into the die, which shapes it into the desired shape. This is the part of the process that requires the most attention. When creating the die, (Figure 2.4) it's important to think about how the plastics will flow through, even minor flaws might cause the final plastic product to bend. To maintain design integrity for the end product, consistency is required throughout the die flow.

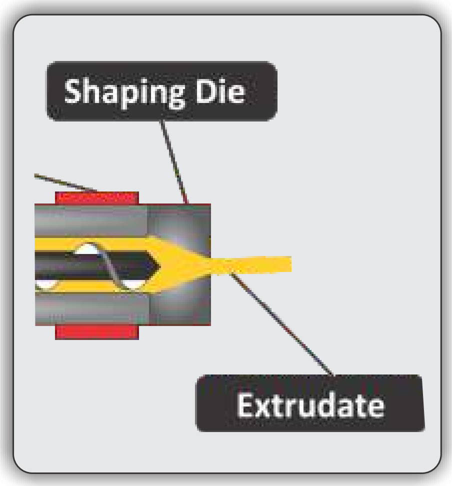


Figure 2.4 *the die will take shape as is the shaping die*

4 The plastic must cool in this shape after passing through the die in order to set in shape (Figure 2.5). Plastic cools much more slowly than other extruded materials. This necessitates a considerably more efficient cooling process because the plastic is delivered directly into water baths from the die.The calibrating equipment that supports the section while it is being cooled is located inside the water baths. This gives the portion its final shape and dimensions.

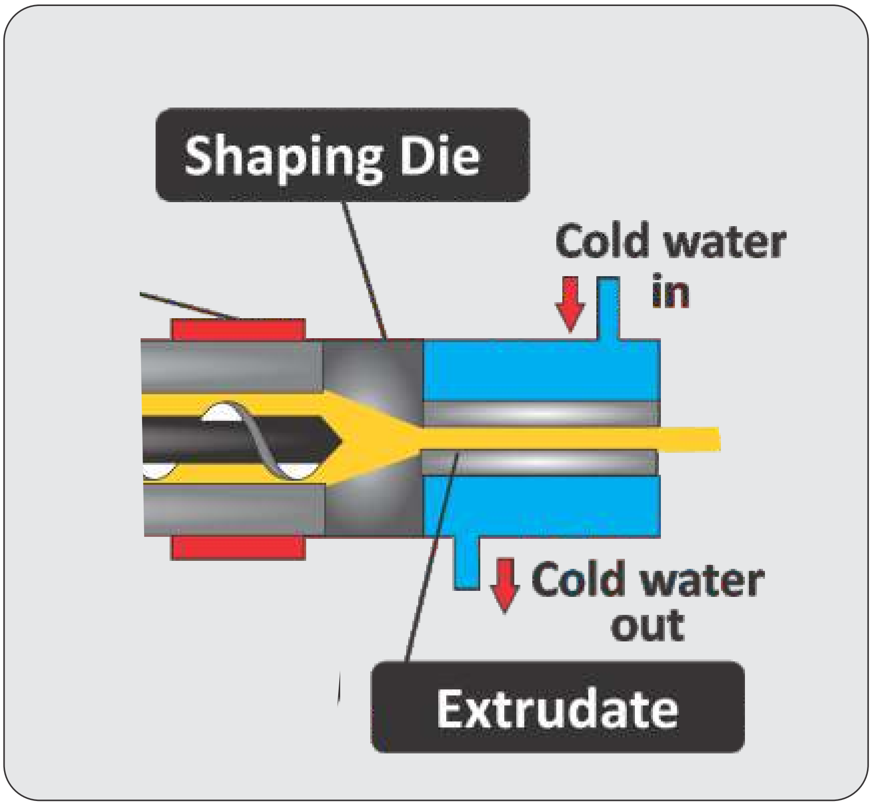


Figure 2.5 *Step 4, The plastic must cool in this shape after passing through the die in order to set in shape*

5 The haul-off is the final phase (Figure 2.6), in which the extrusion is pulled out of the calibrating equipment and into the final process. Adhesive strips, punching holes, cutting into lengths up to 5 metres, bending, drilling, printing, and coiling are just a few examples. This is just a quick rundown of the plastic extrusion process and how the finished product that you see on a daily basis is made. Depending on the type of plastic and its qualities, each method is slightly different.

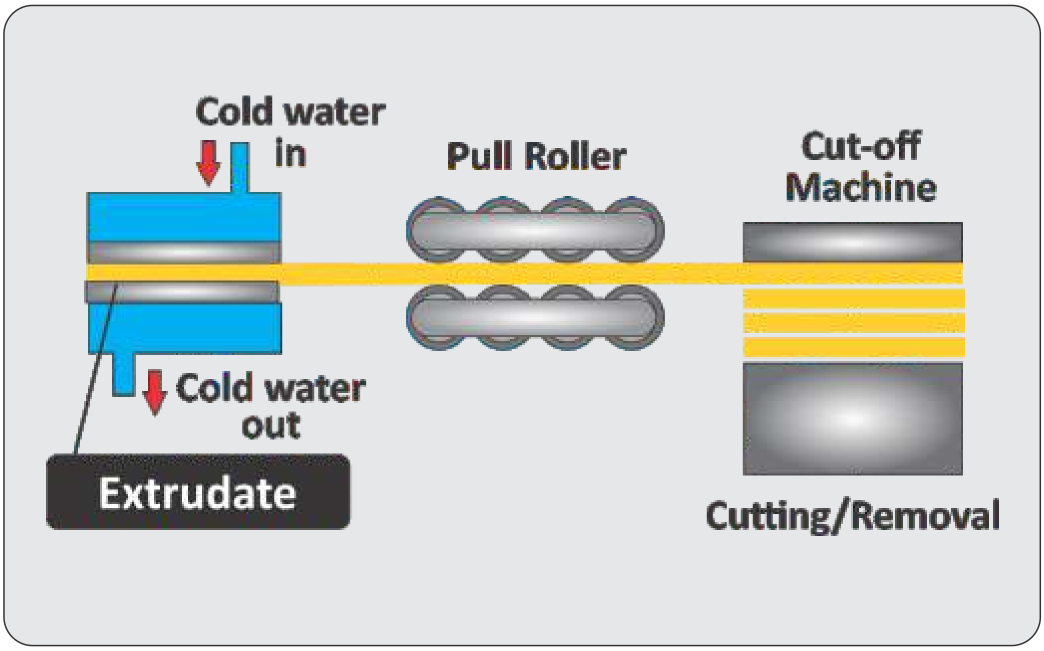
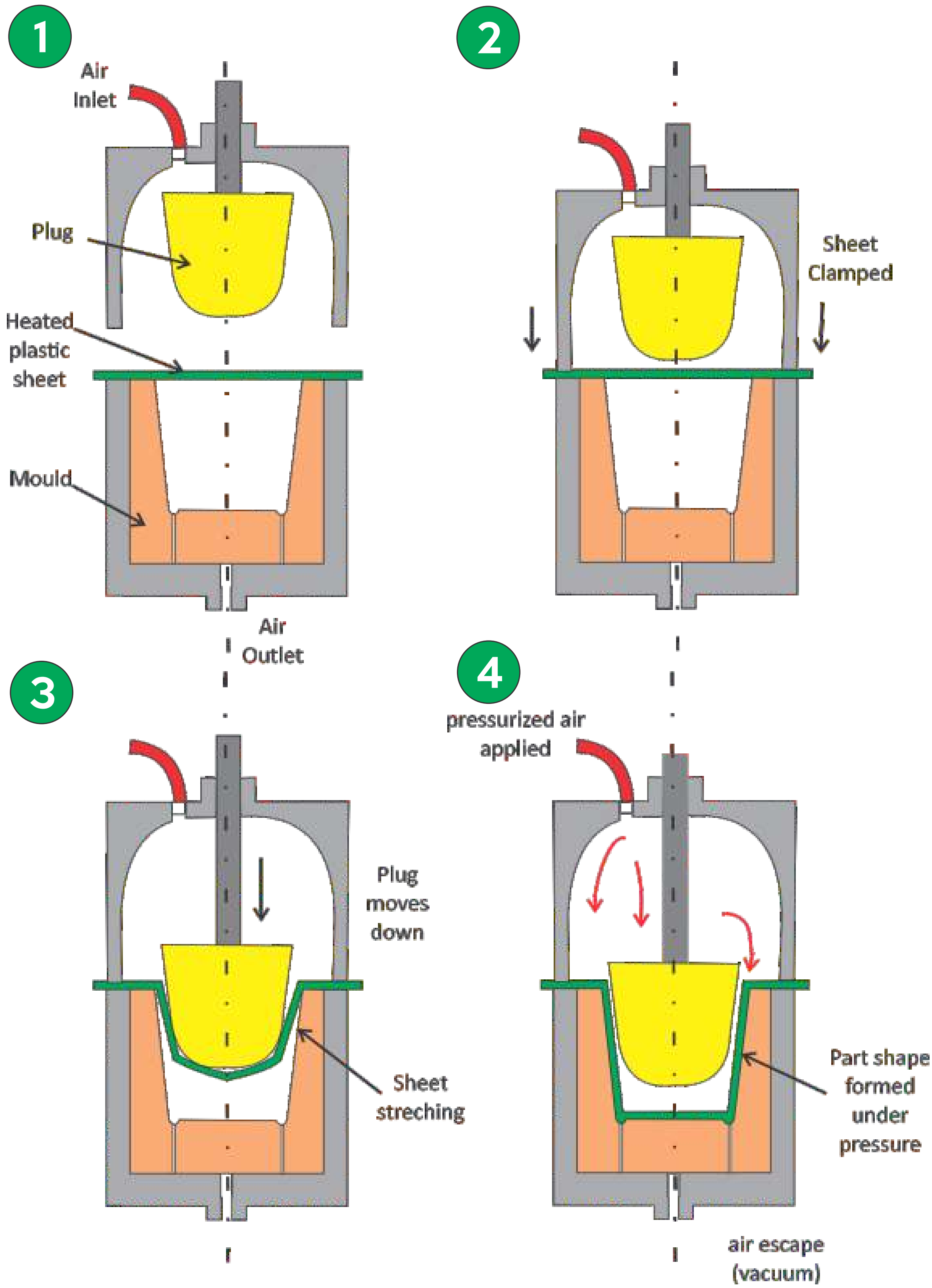


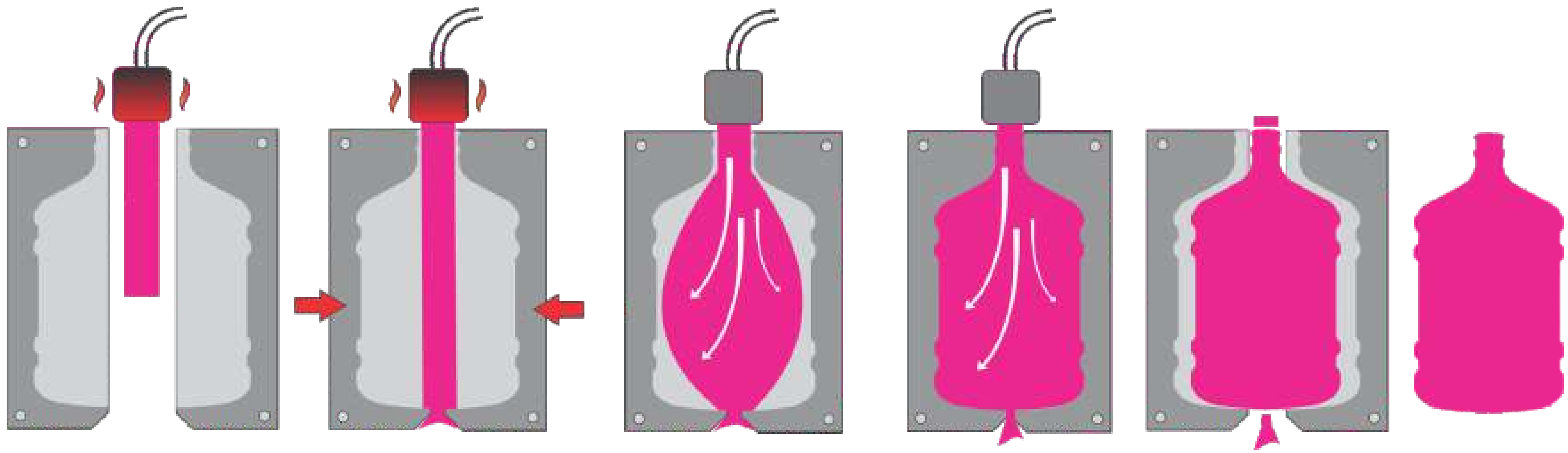
Figure 2.6 *Final step, cutting etc.*

Extended Extrusion Process (Sheet)



Blow Moulding (process)

Blow molding is a modified extrusion- and injection-molding process



Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Plastic is heated and extruded into a hollow tube (parison).	Mould is closed and parison is gripped in place.	Pressurised air is blown into the parison, inflating it.	Mould is filled with parison.	The end product is trimmed and taken out of the mould.	Ready for the next stage of production.

Example of blow moulding product

Figure 2.12 *Example of blow moulding product.*
Adapted from https://www.hdpeblowmoldingmachine.com/sale-4419107-hdpe-harpic-bottle-blowing-machine-in-4-head-extrusion-blow-molding-machine.html

Blown Film

plastic & composite

Extended Extrusion Process (Tube)

Extrusion of blown film is used to manufacture large quantities of commodity products such as supermarket and produce bags.

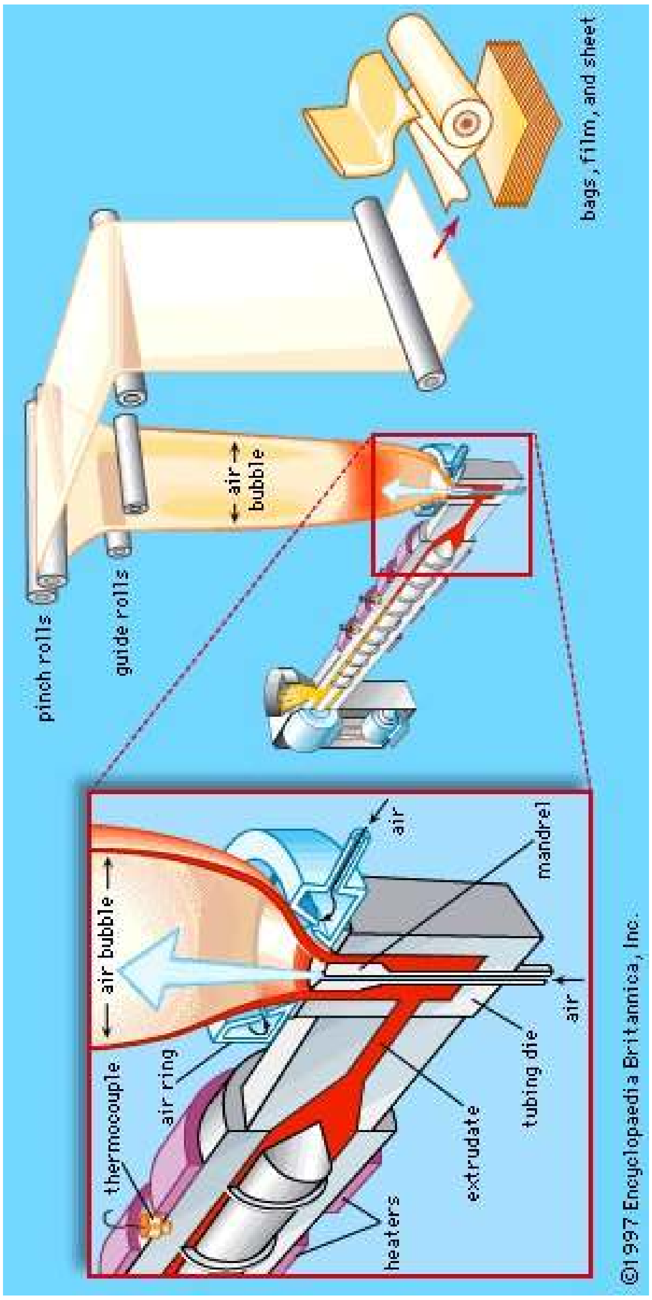


Figure 2.7 *Blown Film for plastic manufacturing process*

product produce

Injection Moulding

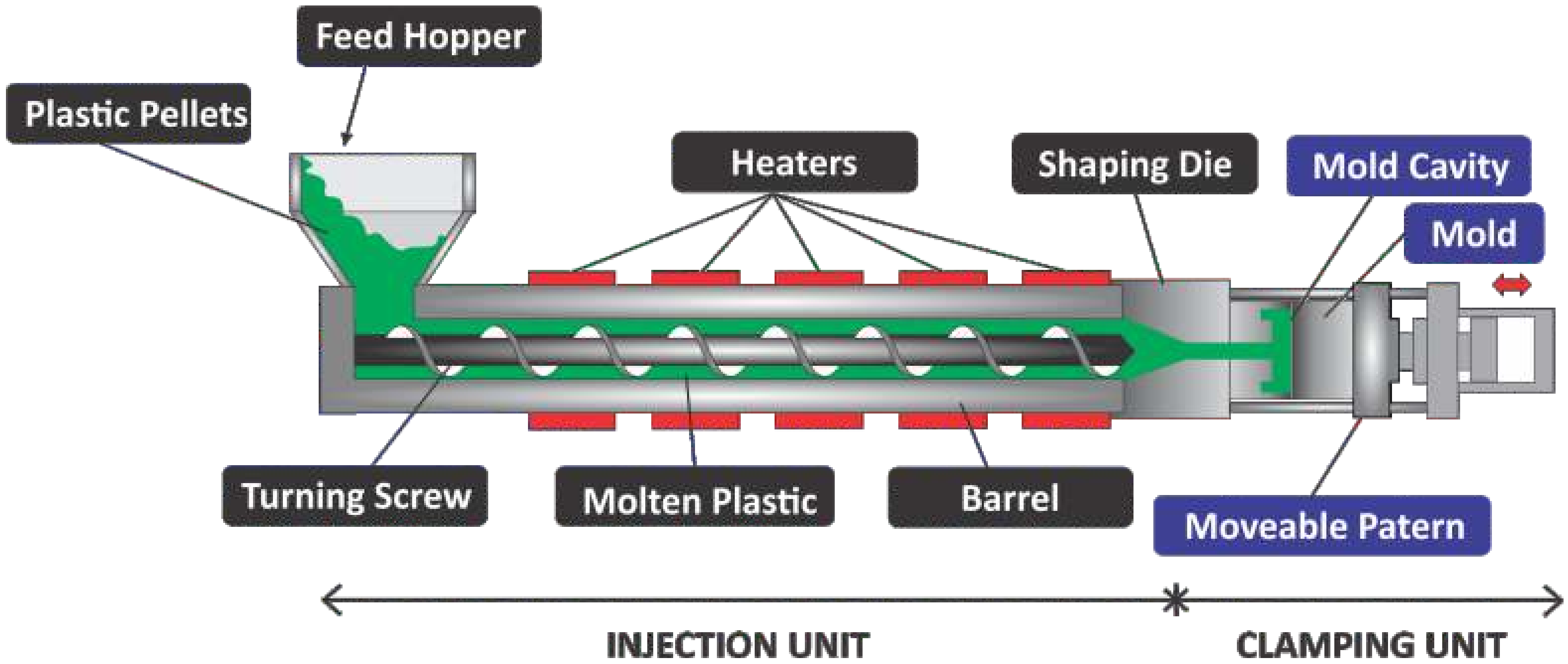


Figure 2.6 *Extrusion Machine for plastic manufacturing process*

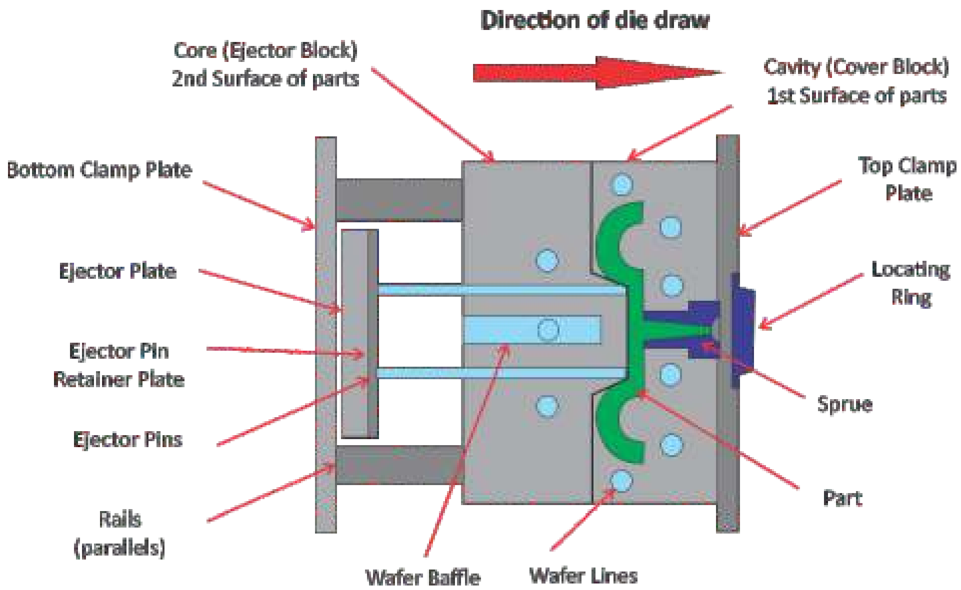
product produce

other product that produce using this process : cups, containers, housings, tool handles, knobs, toys, plumbing fixtures, telephone receivers, and electrical and communication-equipment components.

Injection Moulding

plastic & composite

Example of Mould Features for Injection Moulding



Process Capabilities

Injection moulding is a **high-volume** manufacturing technology that allows for precise dimensional control.

Although most parts weight between 100 and 600 grams, others, such as car body panels and external components can be much heavier.

Typical cycle times range from 5 to 60 seconds. However, thermosetting materials might take several minutes.

Injection moulding is a versatile technology that can create complex structures with excellent dimensional accuracy.

1 Plastic granules are fed into the barrel via a hopper and heated to a molten condition (Figure 2.7).

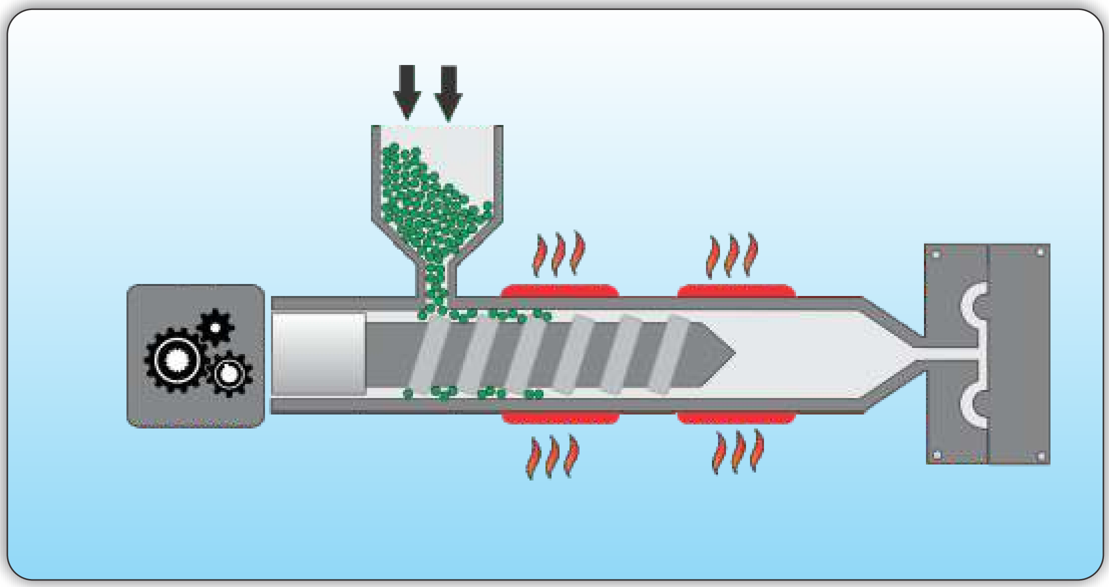


Figure 2.7 *Step 1 of extrusion process*

2 Plastic granules are fed into the barrel via a hopper and heated to a molten condition (Figure 2.7).

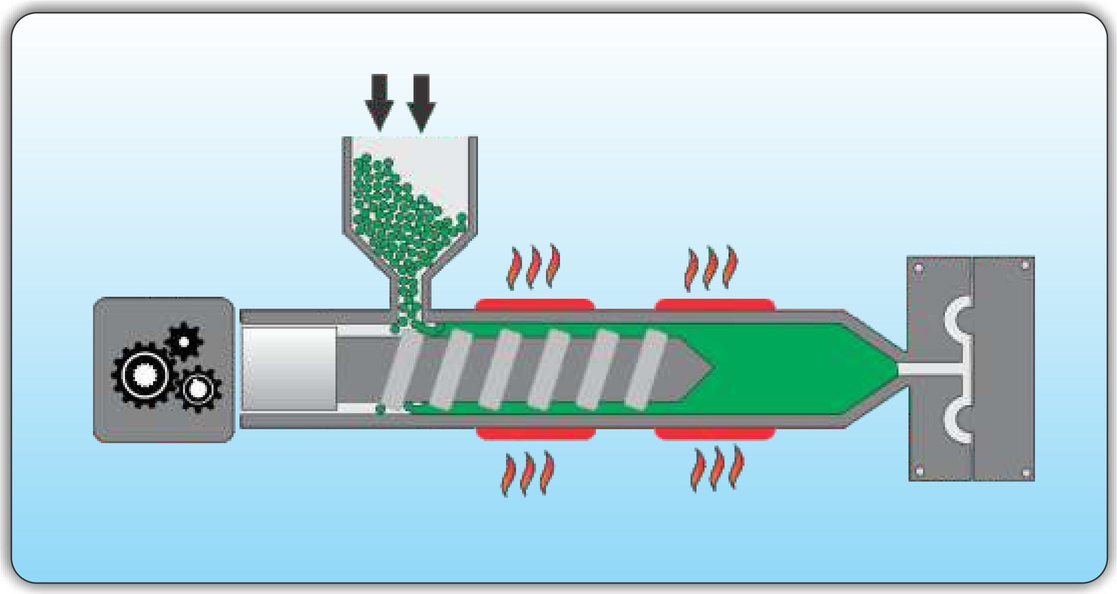


Figure 2.8 *Step 2 of extrusion process*

3 Through gates and hot runners, a screw injects molten plastic at high pressure into the mould cavity (Figure 2.9).

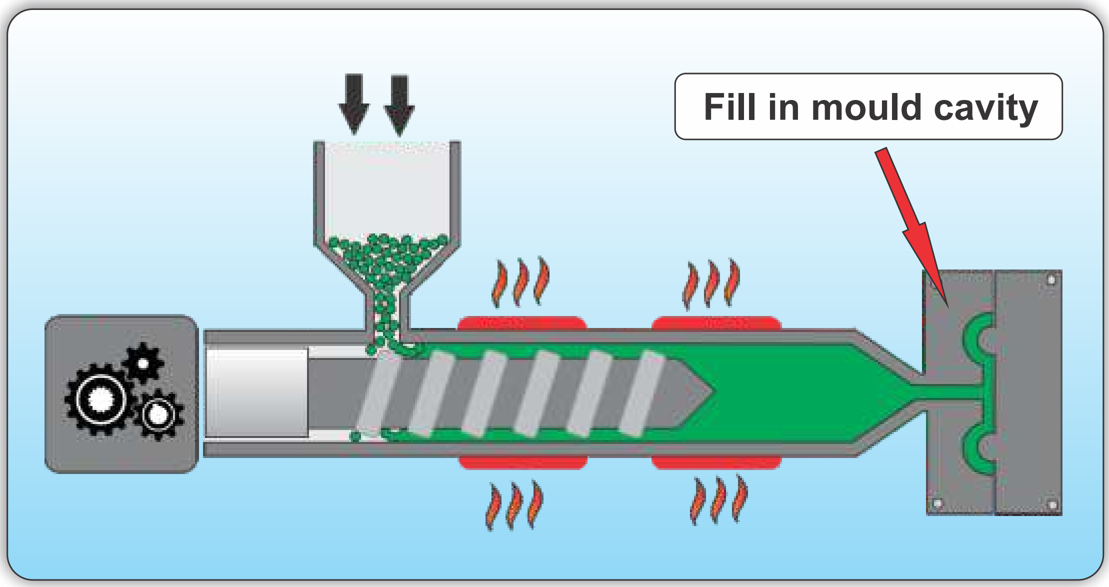


Figure 2.9 *Step 3 of extrusion process*

4 Before being evacuated from the opening mould, the plastic product is allowed to cool and harden (Figure 2.10)

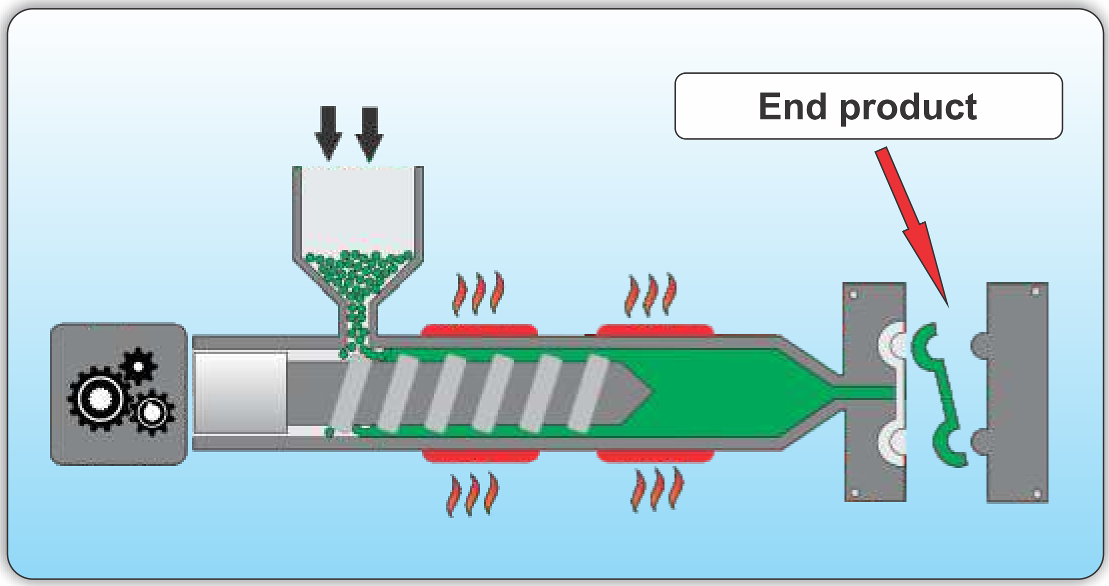


Figure 2.10 *Step 4 of extrusion process*

Example of mould

plastic & composite

Figure 2.11 *Example of mould for injection moulding process. Adapted from https://www.alibaba.com/product-detail/plastic-stool-chair-injection-mould-mold_60653523522.html and https://pin.it/3ZNkg2Z*

Compression Moulding

a) Thermoset Processing

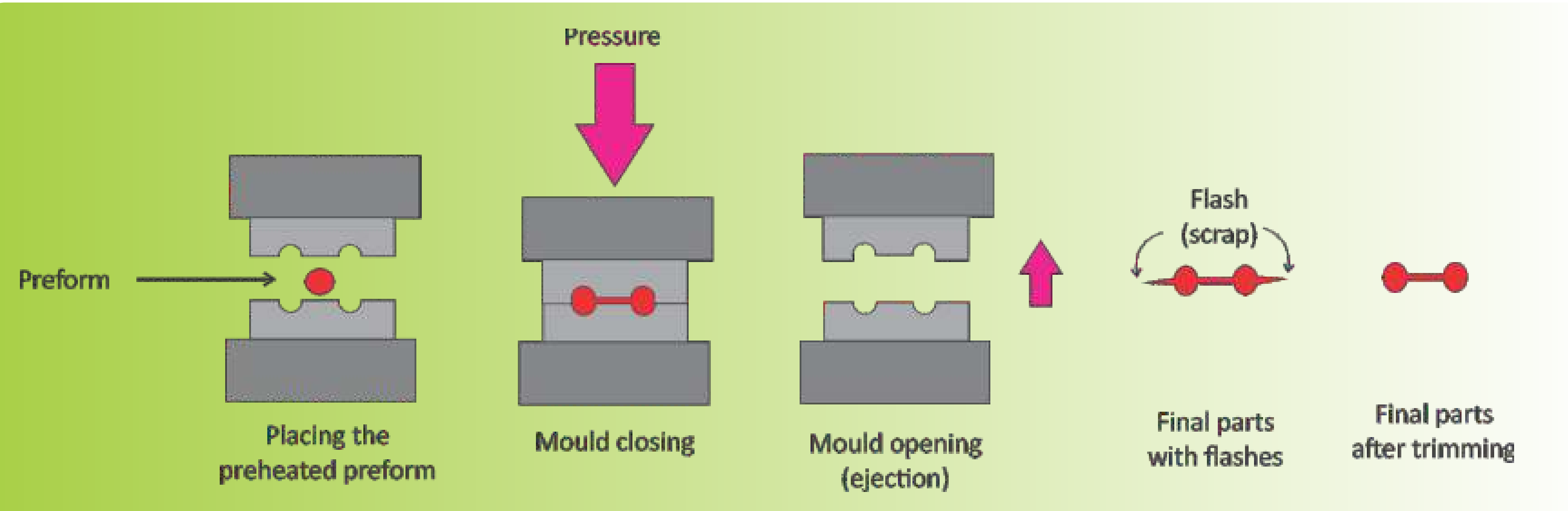


Figure 2.12 *Extrusion Machine for plastic manufacturing process*

product produce

Compression moulding (CM), one of the oldest plastic processing technologies, is frequently employed in plastic processing plants due to its advantages that are not evident in other methods. Though injection moulding is the most common method, it lacks some qualities that compression moulding can provide. With the use of high temperature and pressure, this procedure is utilised to give the plastic the desired shape.

Compression Moulding Process Requirement

1 **Preprocessing** is required for the material to be moulded in the cavity. Pre-processing steps include preheating, adding any binding agents, and reinforcing. Powders, resins, sheets, and granules are all examples of raw materials (Figure 2.13). These materials must then be treated before being placed in the cavity. To form a composite, some plastic components are combined with binding agents and reinforcements such as fibre or with other polymers. Powders must be tablated in a tablating machine in order to optimise performance and preserve the powder for a longer period of time.


Figure 2.13 *Moulding powder*


Figure 2.14 *Preform*

2 Mould with desired shaped cavity.

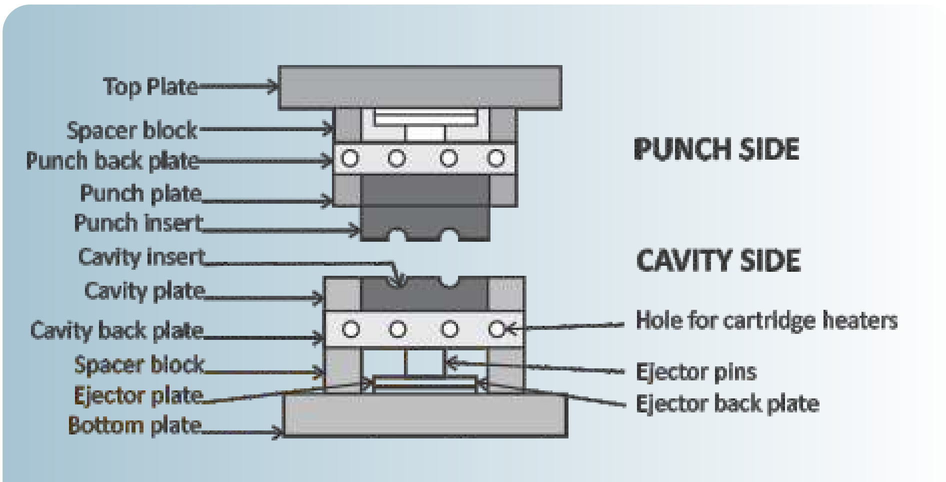


Figure 2.15 *General construction of mould.*

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3 Compression moulding machine as in Figure 2.16 which is image was being adapted from https://rubbermachineryworld.com/2015/06/02/a-step-by-step-guide-to-compression-moulding-rubber-machinery/

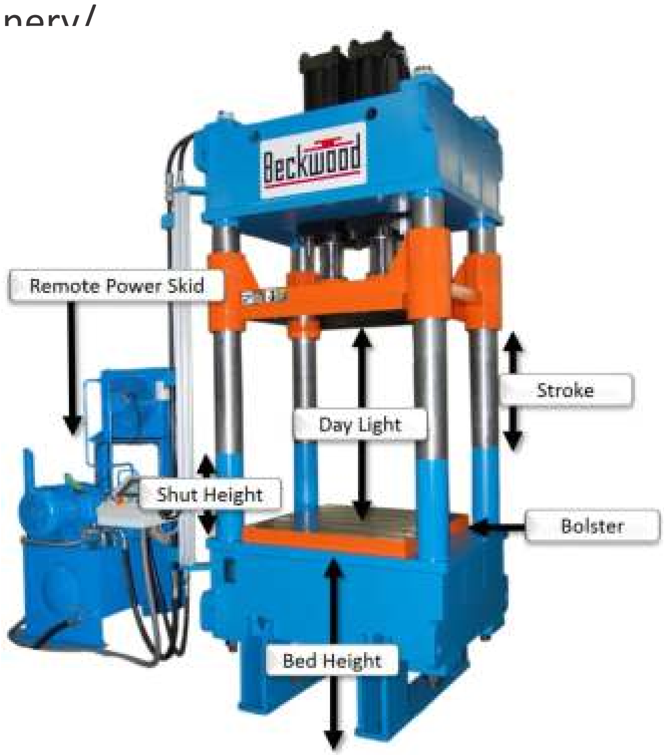


Figure 2.16 *Compression moulding machine*

1 The mould is preheated to the required temperature for the plastic raw material. The temperature of the mould is usually suggested by the raw material producer. A small convection heater is used for preheating. The prehetead plastic is then inserted into the mould cavity (Figure 2.17) before the mould halves are joined. After the mould is closed, a breathing cycle is started to eliminate any trapped air bubbles. After that, the pressure and temperature are maintained for a length of time (Figure 2.18).

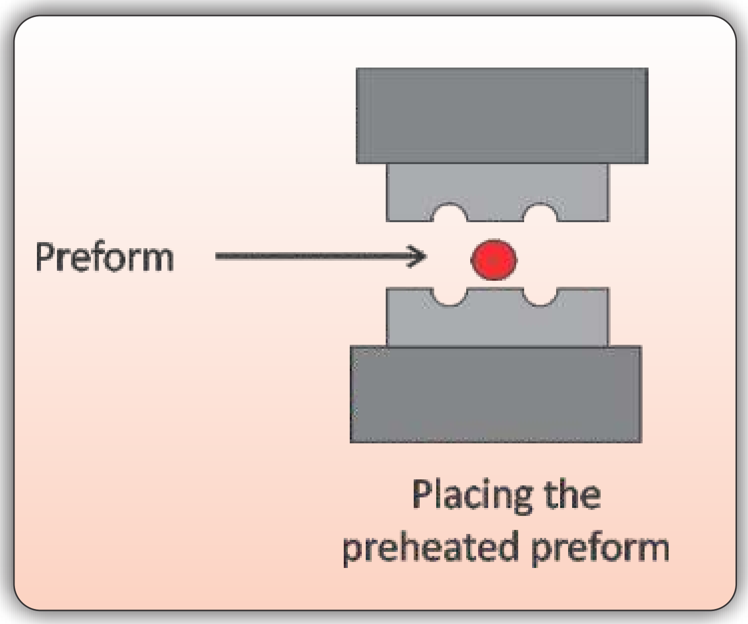


Figure 2.17 *Placing the preheated preform.*

2 Curing is a polymer chemistry and process engineering chemical process that results in the toughening or hardening of a polymer material by cross-linking polymer chains. Even though it is most closely connected with the creation of thermosetting polymers, the term curing can be applied to any process that results in a solid product from a liquid solution over a period of time.

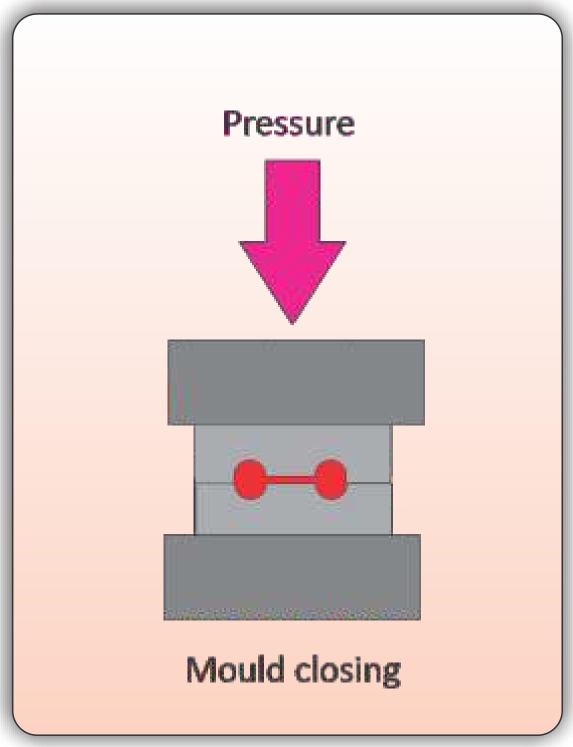


Figure 2.18 *The pressure and temperature is then held for some period of time.*

3 The part can be removed from the mould once the plastic has set (Figure 2.19). An ejection method is used to remove the part. Below the cavity and punch back plates, the mould has ejector pins and ejector plates assembled on both halves. The plates push the ejector pins out of the cavity, removing the part.

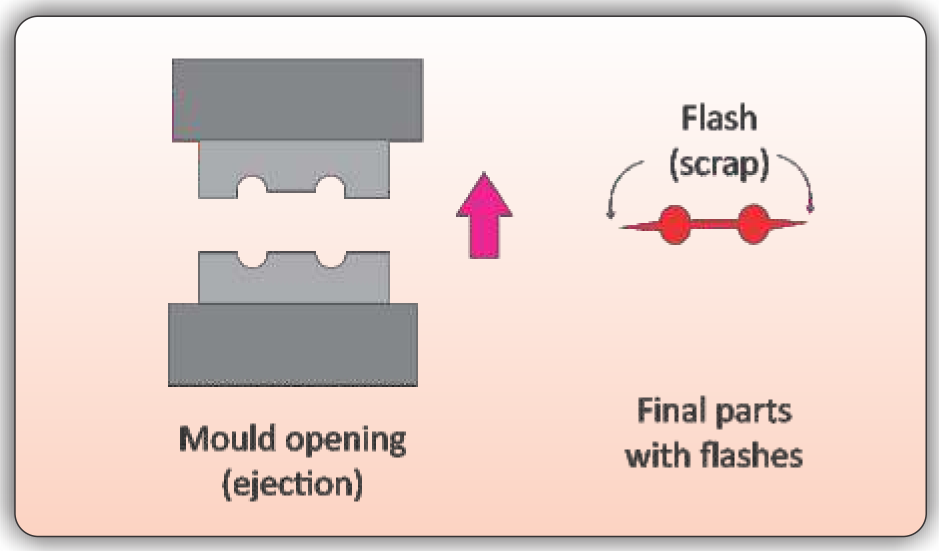


Figure 2.19 *The mould opening (ejection)*

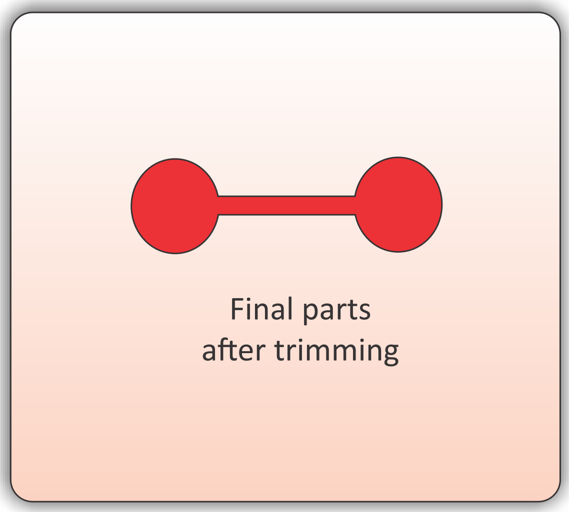


Figure 2.20 *Final parts after trimming*

4 The cycle is finished after the ejection (Figure 2.20). The mould must be cleaned before the next cycle to eliminate any debris, dust, or flash from the cavity and punch surface. Cleaning can be accomplished by wiping the surface with a cloth or by blowing compressed air on it.

c) Casting for Plastic

Casting is the process of pouring a liquid resin into a mould, filling the cavity with gravity, and allowing the polymer to cure. Thermoplastics and thermosets are both cast materials. Acrylics, polystyrene, polyamides (nylons), and vinyls are examples of the former (PVC).

Polyurethane, unsaturated polyesters, phenolics, and epoxies are examples of thermosetting polymers shaped via casting. The liquid materials that make up the thermoset are poured into a mould to cause polymerization and cross-linking. Depending on the resin system, heat and/or catalysts may be necessary. Mold pouring can only be finished if the reactions are sufficiently slow.

ADVANTAGES OF CASTING COMPARED TO INJECTION MOULDING

1. **Mold is simpler and cheaper.**
2. **Free of residual stresses**
3. **Suitable for low production products in quantities.**
4. **The clear plastic sheets can acquire a high degree of flatness and excellent optical properties thanks to the casting process.**

Basic Casting (process)

1

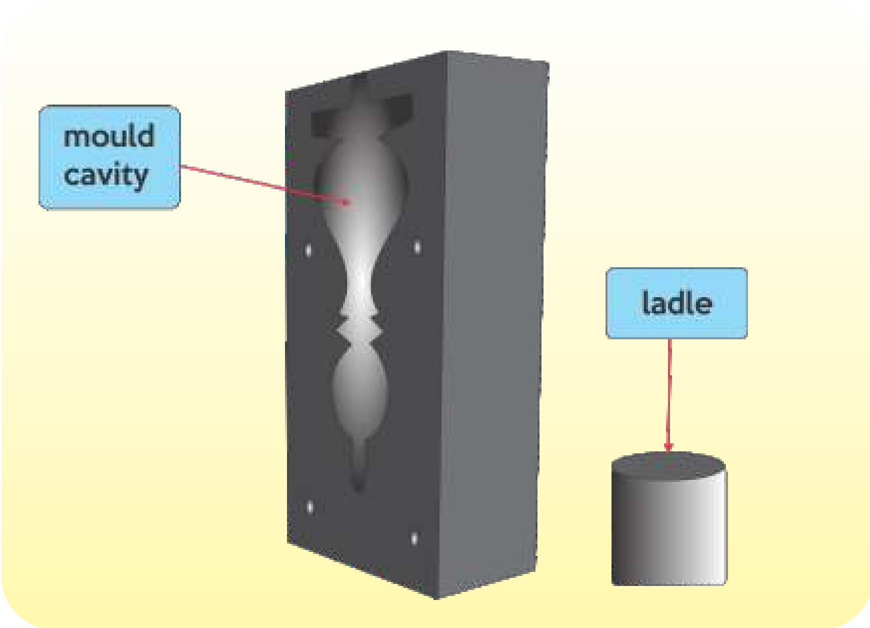


Figure 2.22 *Example of mould cavity and ladle need for basic casting*

2

In plastic casting process, the liquid plastic is poured into the mould cavity and allowed to solidify.

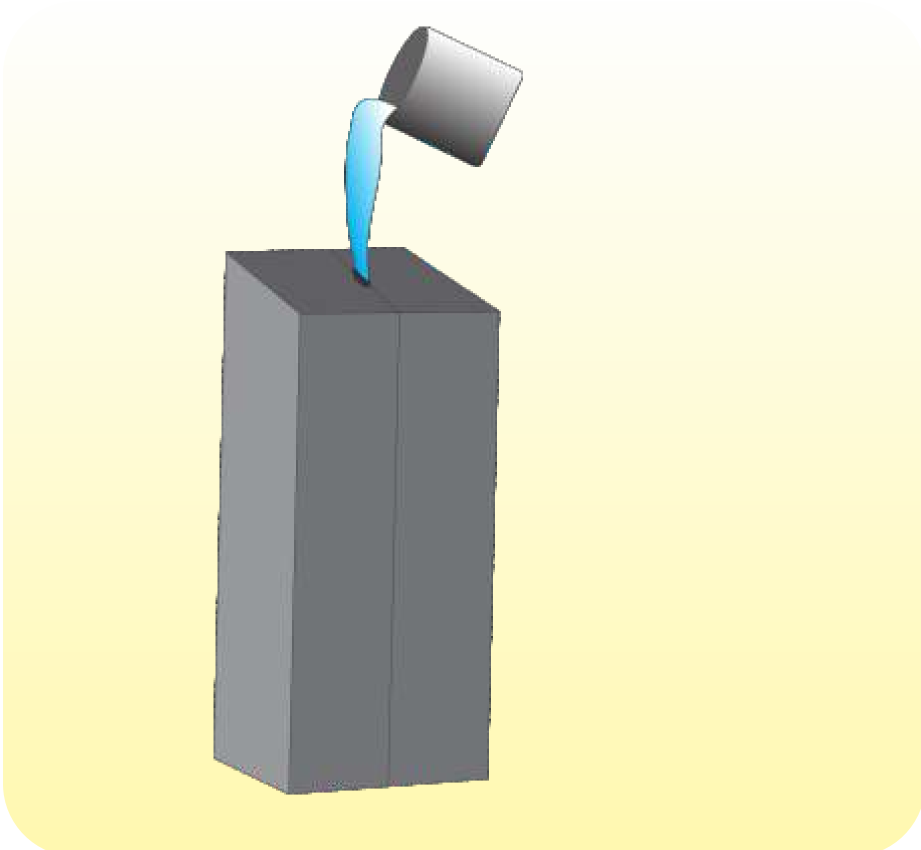


Figure 2.23 *liquid plastic being pored into mould cavity*

3 Then the solidified plastic (Figure 2.24) retains the shape of the mould cavity.

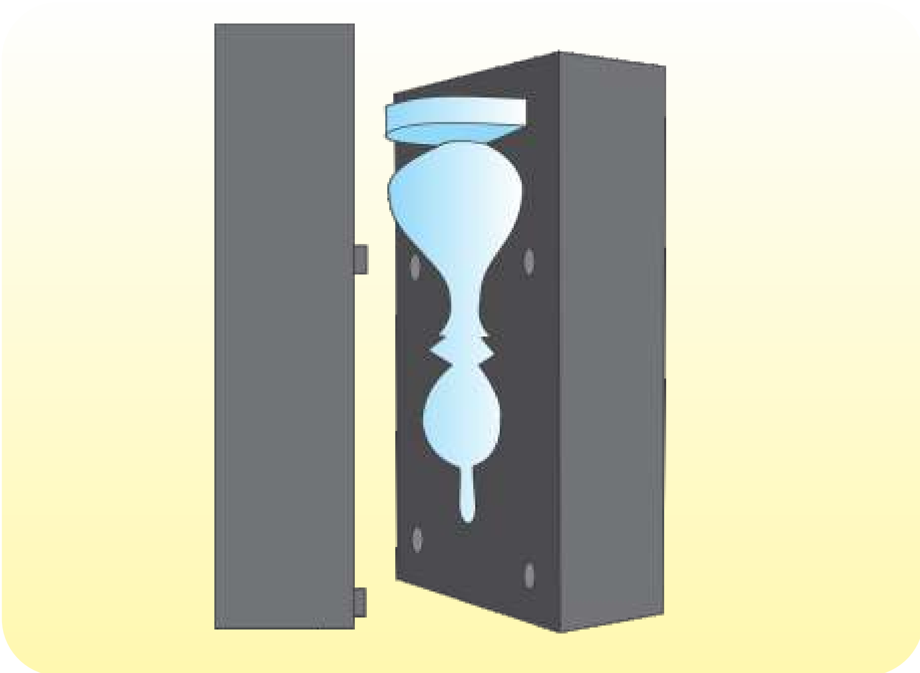


Figure 2.24 *Solidified plastic*

4 Finally the casted part (Figure 2.25) is removed from the mould cavity.

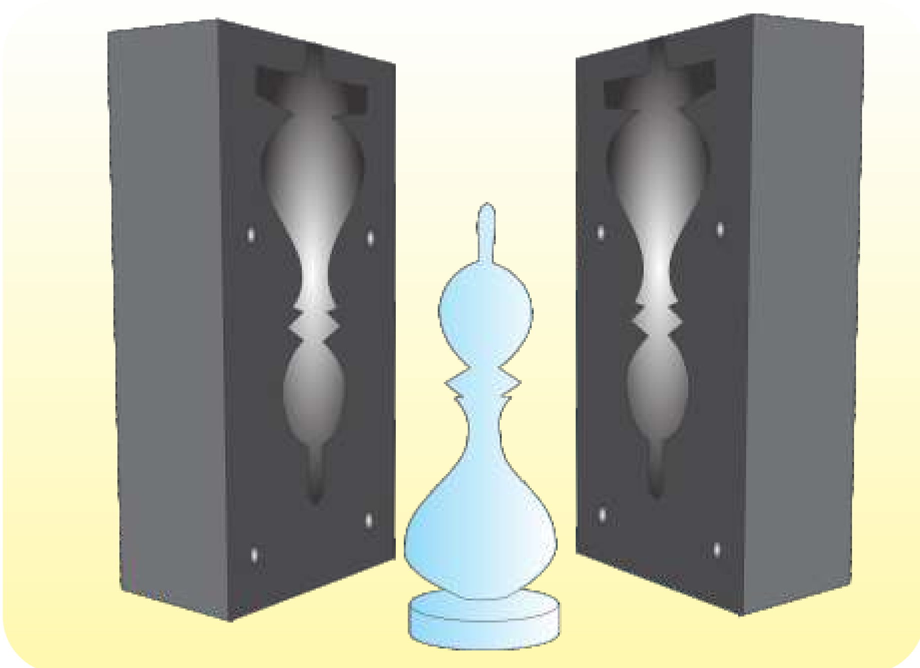


Figure 2.25 *Casted plastic*

2.3 Consideration of design and economics for processing plastic material.

Plastic forming and shaping design issues are analogous to metal casting design considerations. The selection of appropriate materials from an extensive list necessitates taking into account a variety of factors listed below :

1. **Criteria for service**
2. **Long-term consequences for attributes and behaviour (such as dimensional stability and wear)**
3. **The product's final disposal at the end of its life cycle**

GENERAL DESIGN GUIDELINES FOR THE PRODUCTION OF PLASTIC

1. **Internal and external features on complex items can be manufactured with relative ease and at high production rates. As a result, injection moulding competes effectively with powder injection moulding and die casting since all three processes are capable of manufacturing complex geometries with thin walls. When examining prospective process substitutes, keep in mind that the materials and their qualities are extremely varied, with each having its own set of features that are crucial to a certain application.**

2. Internal and external features on complex items can be manufactured with relative ease and at high production rates. As a result, injection moulding competes effectively with powder injection moulding and die casting since all three processes are capable of manufacturing complex geometries with thin walls. When examining prospective process substitutes, keep in mind that the materials and their qualities are extremely varied, with each having its own set of features that are crucial to a certain application.

3. Plastics have substantially lower stiffness and strength than metals. As a result, section sizes and forms should be chosen carefully. A high section modulus can be accomplished using design concepts found in I-beams and tubes, depending on the purpose. Simple methods like prescribing curvatures on parts can stiffen large, flat surfaces. Fiber or particle reinforcement is also effective in achieving lightweight and rigid designs.

4. The overall form and thickness of the component frequently dictate the shaping or moulding procedure to be used. Even when a certain process has been chosen, the part and die designs should be such that correct form generation, dimensional control, and surface polish will not be a problem.

5. Injection moulding, for example, has smaller dimensional tolerances than thermoforming. Controlling material flow in the mould cavities is critical in the casting of metals and alloys. The implications of molecular orientation during polymer processing, particularly in extrusion, thermoforming, and blow moulding, should also be studied. Refering Figure 2.25, it was designed to remove or reduce distortion in plastic part.

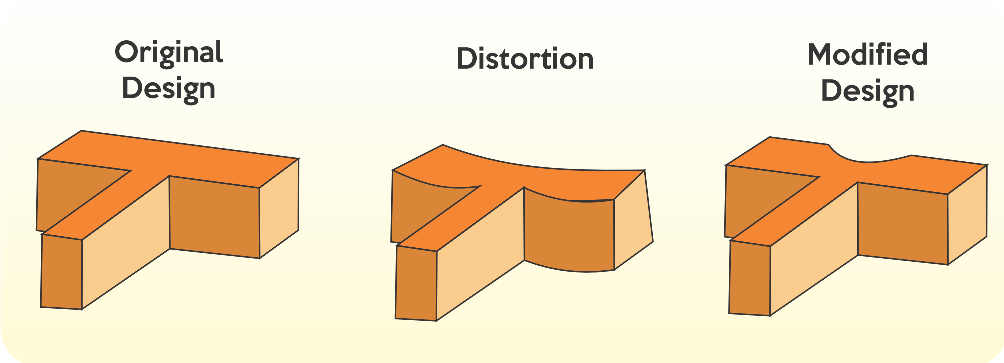


Figure 2.25 *Design improvements to remove or reduce distortion in plastic parts include:(a) proposed improvements to the design to reduce distortion.*

ECONOMICS OF PROCESSING PLASTICS

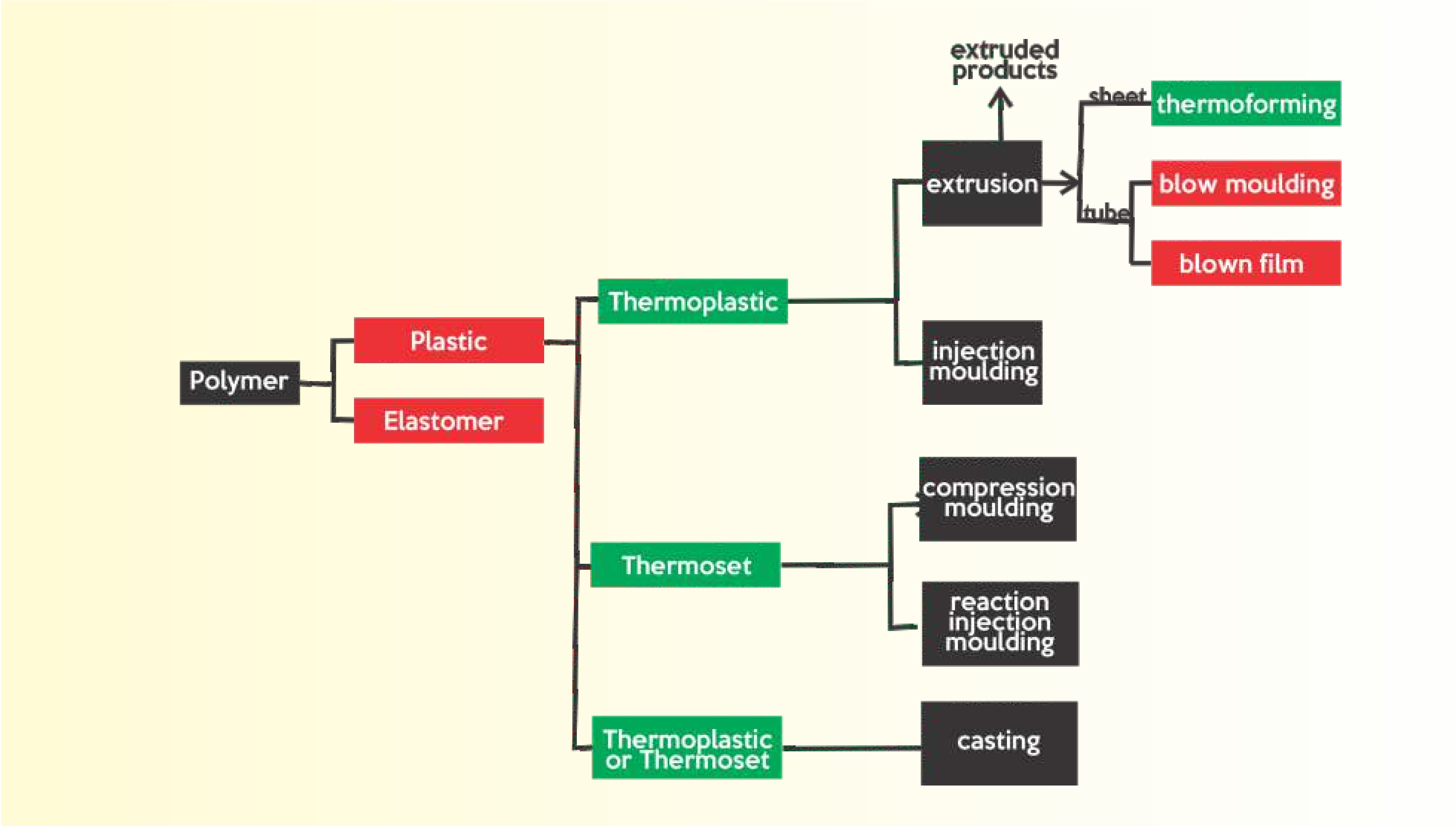
1. Design and manufacturing decisions, like all other manufacturing processes, are ultimately based on performance and cost, which includes the cost of equipment, tooling, labour, and output. The final choice of a process or a succession of processes is also influenced by the volume of production.

2. These costs are cheap because of methods like thermoforming, casting, and rotational moulding. Injection moulding machines are the most expensive, followed by compression moulding and transfer moulding machines.

3. Costs of tooling and dies are likewise significant. As with die casting, the size of the die and the optimal number of cavities in the die for producing more and more pieces in a single cycle are significant considerations in an operation like injection moulding.

4. Larger dies may be considered to accommodate a greater number of cavities (with runners to each cavity), but this would come at the penalty of increasing die cost even further. On the other hand, per machine cycle, more parts will be produced. As a result, the rate of production will grow. To optimise the whole operation and create parts at the lowest cost, a complete analysis is required to determine the overall die size, the number of cavities in the die, and the machine capacity required.

Summary of Plasticc Processing



Exercise

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1. What are the forms of raw materials for processing plastics into products?
2. How are injection-molding machines rated?
3. How is thin plastic film produced?
4. List several common products that can be made by thermoforming.
5. Describe the methods that can be used to make tubular plastic products.
6. How are plastic sheet and plastic film produced?
7. What process is used to make foam drinking cups?
8. Explain why injection moulding is capable of producing parts with complex shapes and fine detail.
9. Explain the reasons that some plastic-forming processes are more suitable for certain polymers than for others. Give examples.
10. Describe the problems involved in recycling products made from reinforced plastics.
11. Can thermosetting plastics be used in injection moulding?Explain.

References

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