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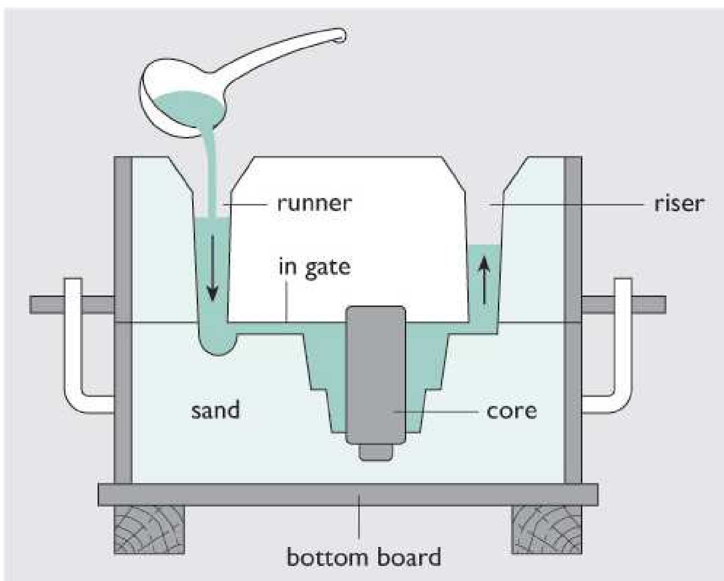
Task 1

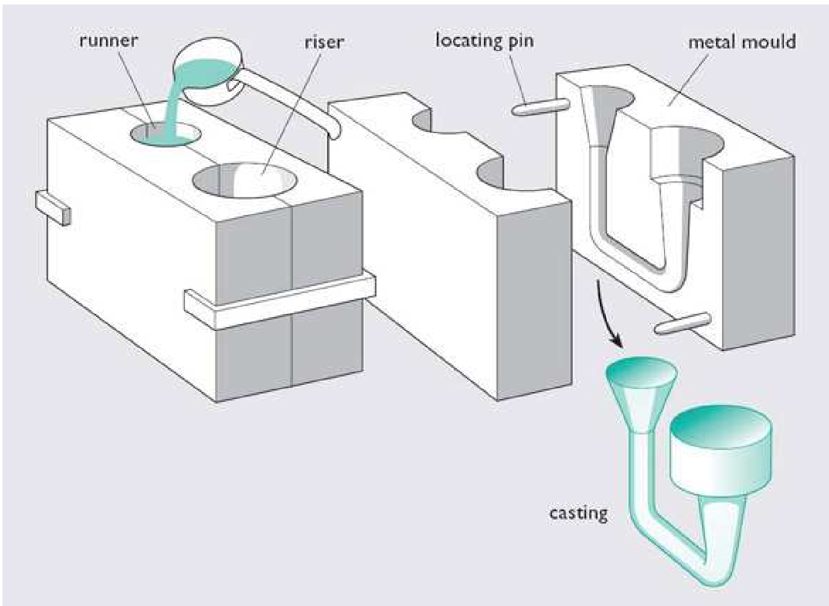
Cast metal components can be manufactured using a variety of techniques including sand casting, investment casting, and die casting. From your research describe each of these processes and state why each particular method is used.

Sand casting

In the sand casting process, a pattern is made in the shape of the desired part. The pattern is typically made of wood, plastic, or metal. A single piece solid pattern is used for simple designs. Patterns that are more complex are made in two parts, called split patterns. The upper part of a split pattern is called a cope, while the bottom section is called a drag. Where the cope and drag separate, it is known as the parting line. Both solid and split patterns can have cores inserted to complete the final part shape.



The pattern is housed in a box called the flask, and then packed with sand. A binder helps harden the sand into a semi-permanent shape. Once the sand mould is cured, the pattern is removed. This leaves a hollow space in the sand in the shape of the desired part. The pattern is made larger than the cast to allow for shrinkage during cooling. Sand cores can then be inserted in the mould to create holes and improve the casting's overall shape. Simple patterns are usually open on top, allowing molten metal to be poured into them. Two-piece moulds are clamped together. Molten metal is poured into a pouring cup where it will then travel down a sprue and into the gating system. Vent holes are created to allow hot gases to escape during the pour. Ideally, the pouring temperature of the molten metal is a few hundred degrees higher than the melting point, assuring good fluidity. The temperature difference also prevents premature cooling and resulting voids and porosity. After the metal cools, the sand mould is removed and the metal part is ready for additional operations, such as cut-off and grinding.



The sand casting process is often far less expensive than other techniques, and is often one of the fastest methods available. One piece products of a complex shape, can be made at moderate cost, in large quantities. The process can cope with making large heavy objects, or small parts. There is also little material wastage through out the process, as feeders and risers can be re-melted.

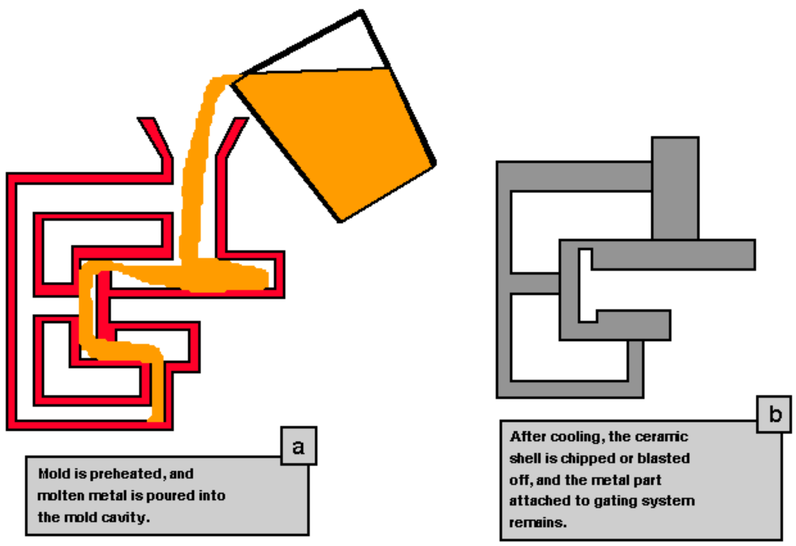
Investment casting

Investment casting is a process in which temporary patterns are made in low melting point wax. This wax is coated in ceramic, which when hardened, and the wax melted out, becomes the final mould into which the molten metal is poured.

The process is generally used for small castings, but has produced complete aircraft door frames, steel castings of up to 300 kg and aluminum castings of up to 30 kg. It is generally more expensive per unit than die casting or sand casting but with lower equipment cost. It can produce complicated shapes that would be difficult or impossible with die casting, yet like that process, it requires little surface finishing and only minor machining.

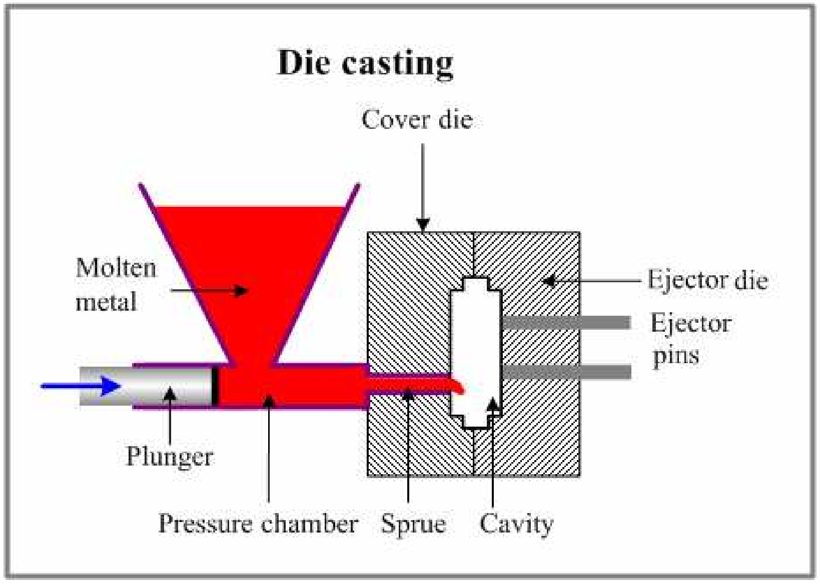
Because the pattern is a one-piece wax structure, no pattern removal is necessary. The surface finish is so good on the finished product, that in the majority of cases, no machining is necessary. It can also produce multiple components in one cast.

A pattern of the component to be cast is produced by injection-molding special waxes into a metal die. Pre-formed ceramic cores can be included in the wax pattern as it is molded, which can create intricate hollows within the finished casting. As many as several hundred patterns may be assembled into a tree around a wax runner system (riser & sprue). Once a tree has been assembled, a pour cup is attached.



<u>Die casting</u>

Die casting is the process of forcing molten metal under high pressure into mold cavities. Most die castings are made from nonferrous metals, specifically zinc, copper, aluminum, magnesium, lead, and tin based alloys, but ferrous metal die castings are possible. The die casting method is especially suited for applications where large quantities of small to medium sized parts are needed with good detail, a fine surface quality and dimensional consistency.



This level of versatility has placed die castings among the highest volume products made in the metalworking industry. In recent years, injection-molded plastic parts have replaced some die castings because they are cheaper and lighter. Plastic parts are a practical alternative if hardness is not required and little strength is needed.

Die casting is very accurate, making castings to remarkably close tolerances of up to 0.025mm. This eliminates the need for machining after production. Because of the high molding pressure used in die casting, sections as thin as 1mm can be created. The surface finish is very smooth, due to the highly polished surfaces of the die, and this, in may cases eliminates the need for surface finishing treatments.

Advantages

- Excellent dimensional accuracy (dependent on casting material, but typically 0.1 mm for the first 2.5 cm (0.005 in. for the first inch) and 0.02 mm for th each additional centimeter (0.002 in. for each additional inch).
- Smooth cast surfaces (1—2.5 µm (40—100 µin.) rms).
- Thinner walls can be cast as compared to sand and permanent mold casting (approximately 0.75 mm (0.030 in.).
- Inserts can be cast-in (such as threaded inserts, heating elements, and high strength bearing surfaces).
- Reduces or eliminates secondary machining operations.
- Rapid production rates.
- Casting tensile strength as high as 415 MPa (60 ksi).

Disadvantages

- Casting weight must be between 30 grams (1 oz) and 10 kg (20 lb).
- Casting must be smaller than 600 mm (24 in.).
- High initial cost.
- Limited to high-fluidity metals.
- A certain amount of porosity is common.
- Thickest section should be less than 13 mm (0.5 in.).
- A large production volume is needed to make this an economical alternative to other processes.

Task 2

Ceramics are now being used in a wide variety of engineering fields. What are the common methods used in manufacture of ceramic based components and give examples of where ceramic components may be used.

Ceramic Engineering is the technology of manufacturing and usage of ceramic materials. Many engineering applications benefit from ceramics characteristics as a material. The characteristics of ceramics have gathered attention from engineers across the world, in many different fields e.g. Electrical Engineering, Materials Engineering, Chemical Engineering, Mechanical Engineering. Highly regarded for being resistant to heat, ceramics can be used for many demanding tasks that other materials like Metal cannot.

Traditional ceramic raw materials include clay minerals such as kaolinite, more recent materials include aluminum oxide, more commonly known as alumina. The modern ceramic materials, which are classified as advanced ceramics, include silicon carbide and tungsten carbide. Both are valued for their abrasion resistance, and hence find use in applications such as the wear plates of crushing equipment in mining operations. Advanced ceramics are also used in the medicine, electrical and electronics industries.

Ceramic Engineers are found in a wide variety of manufacturing, research and educational fields. These include mining, aerospace, medicine, refinery, food industry, chemical industry, packaging science, electronics, industrial electricity, and transmission electricity.

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The ceramic process generally follows this flow.

Milling→ Batching→ Mixing→ Forming→ Drying→ Firing→ Assembly→

Milling is the process by which materials are reduced from a larger size to a smaller size.

Batching is the process of weighing the oxides according to recipes, and preparing them for mixing and drying.

Mixing occurs after batching and involves a variety of equipment such as dry mixing ribbons, Mueller mixers, and pug mills. Wet mixing generally involves the same equipment.

Forming is making the mixed material into shapes, ranging from toilet bowls to spark plug insulators.

Drying is removing the water or binder from the formed material.

Firing is where the dried parts pass through a controlled heating process, and the oxides are chemically changed to cause sintering and bonding.

Assembly This process is for parts that require additional subassembly parts.

Below I have given the common methods used in manufacture of ceramic based components, so now I will give examples of where ceramic components may be used:

Aerospace

Engines, shielding a hot running airplane engine from damaging other components.

Biomedical

Artificial bone e.g. Dentistry applications, teeth.

Electronics and Electrical Industry

Capacitors

Optical/Photonic

Optical fibers e.g. Glass fibers for super fast data transmission.

Isostatic pressing

Isostatic pressing is a manufacturing process used to reduce the porosity of metals and influence the density of many ceramic materials. This improves the mechanical properties, workability and ceramic density. The process subjects a component to both elevated temperature and isostatic gas pressure in a high pressure containment vessel. The pressurizing gas most widely used is argon. An inert gas is used, so that the material does not chemically react. The chamber is heated, causing the pressure inside the vessel to increase. Many systems use associated gas pumping to achieve necessary pressure level. Pressure is applied to the material from all directions.

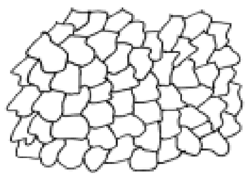
Extrusion

Extrusion is a process used to create objects of a fixed cross-sectional profile. A material is pushed or drawn through a die of the desired cross-section. The two main advantages of this process over other manufacturing processes is its ability to create very complex cross-sections and work materials that are brittle, because the material only encounters compressive and shear stresses. It also forms finished parts with an excellent surface finish.
Extrusion may be continuous (theoretically producing indefinitely long material) or semi-continuous (producing many pieces). The extrusion process can be done with the material hot or cold.
Commonly extruded materials include metals, polymers, ceramics, and foodstuffs.

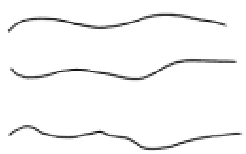
Task 3

Describe the moulding techniques used for both thermosetting and thermoplastics.

A thermoplastic is a plastic that melts to a liquid when heated and freezes to a brittle, very glassy state when cooled. The difference between thermoplastics and thermosetting plastics is that thermoplastics become soft, remold able and weldable when heat is added. Thermosetting plastics however, when heated, will chemically decompose, so they can not be welded or remolded. On the other hand, once a thermosetting is cured it tends to be stronger than a thermoplastic.



Thermosets are hard and have a very tight-meshed, branched molecular structure. Curing proceeds during shaping, after which it is no longer possible to shape the material by heating. Further shaping may then only be performed by machining. They are used, for example, to make light switches.

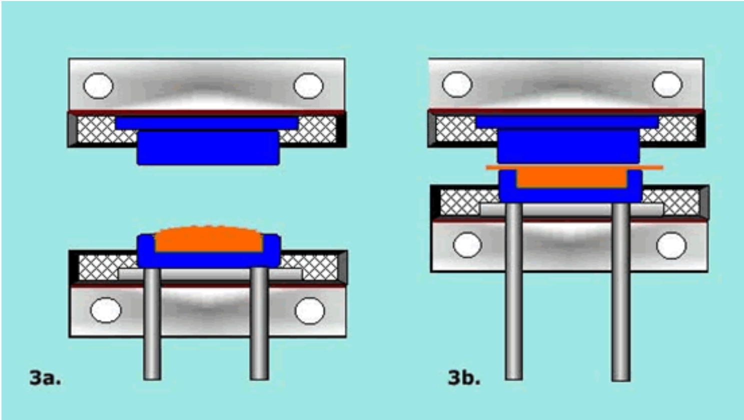


Thermoplastics have a linear or branched molecular structure which determines their strength and thermal behaviour; they are flexible at ordinary temperatures. At approx. 120 - 180°C, thermoplastics become a liquid mass. The service temperature range for thermoplastics is considerably lower than that for thermosets. The thermoplastics polyethylene (PE), polyvinyl chloride (PVC) and polystyrene (PS) are used, for example, in packaging applications.

Below is an example of a moulding technique for each type of plastic:

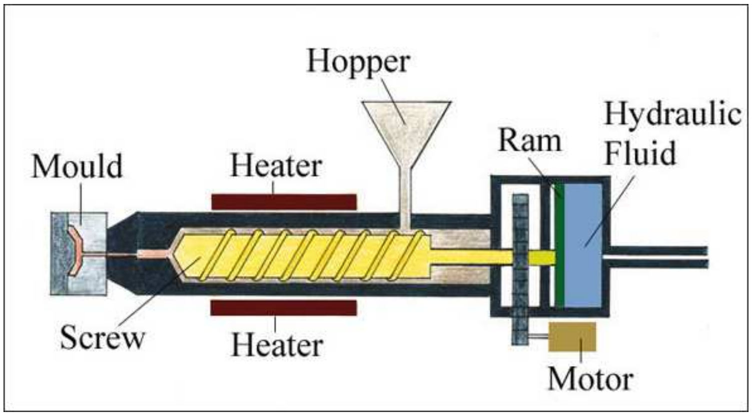
Compression moulding (thermosetting plastics)

In Compression molding the plastic raw material, in either a granular generally preheated, is first placed in an open, heated mold cavity. The mold is closed with a top force or plug member, pressure is applied to force the material into contact with all mold areas, and heat and pressure are maintained until the molding material has cured.



Injection moulding (thermoplastics)

Molten plastic is injected at high pressure into a mold, which is the inverse of the product's shape. After a product is designed, usually by an industrial designer or an engineer, molds are made by a from metal, usually either steel or aluminum, and precision-machined to form the features of the desired part.
It produces such small products as bottle tops; sink plugs, children's toys, containers, model kits, disposable razors and parts of cameras. It is also used to manufacture larger items such as dustbins, and milk crates.



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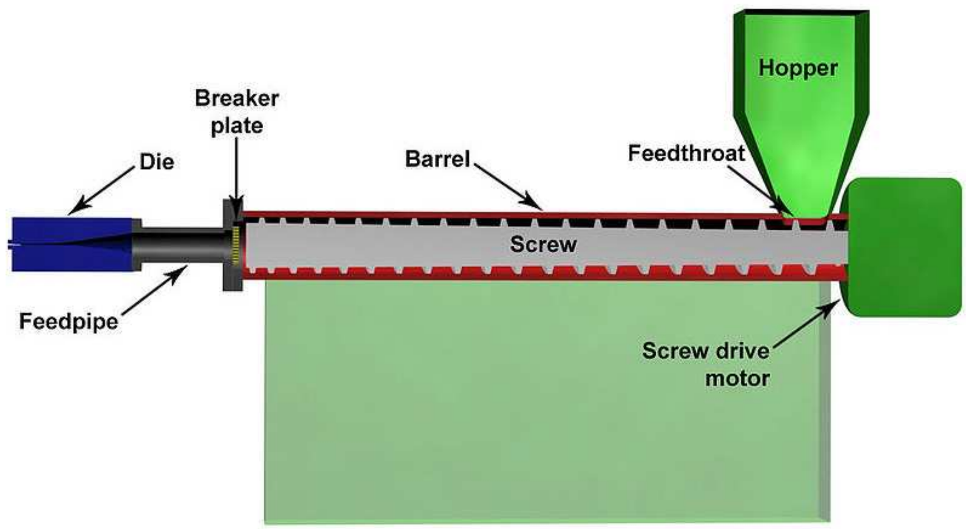
Plastics extrusion

Plastic extrusion is a high volume manufacturing process in which raw plastic material is melted and formed into a continuous profile. Extrusion produces items such as pipe/tubing, weather stripping, window frames, adhesive tape and wire insulation.



In the extrusion of plastics, raw thermoplastic material in the form of small beads (often called resin in the industry) is gravity fed from a top mounted hopper into the barrel of the extruder. Additives such as colorants and UV inhibitors (in either liquid or pellet form) are often used and can be mixed into the resin prior to arriving at the hopper.

The material enters through the feed throat (an opening near the rear of the barrel) and comes into contact with the screw. The rotating screw (normally turning at up to 120 rpm) forces the plastic beads forward into the barrel which is heated to the desired melt temperature of the molten plastic (which can range from 200 °C/400 °F to 275 °C/530 °F depending on the polymer). In most processes, a heating profile is set for the barrel in which three or more independent PID controlled heater zones gradually increase the temperature of the barrel from the rear (where the plastic enters) to the front. This allows the plastic beads to melt gradually as they are pushed through the barrel and lowers the risk of overheating which may cause degradation in the polymer.

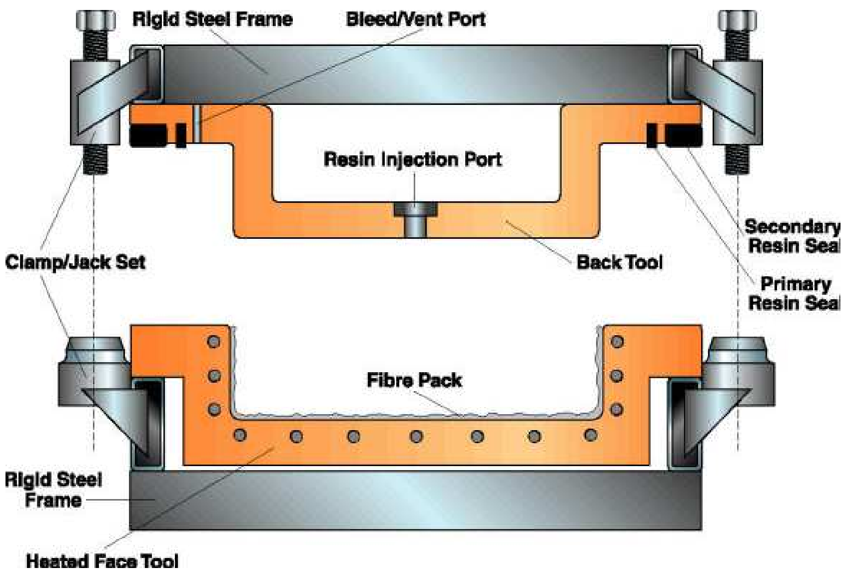
Extra heat is contributed by the intense pressure and friction taking place inside the barrel. In fact, if an extrusion line is running a certain material fast enough, the heaters can be shut off and the melt tempe rature maintained by pressure and friction alone inside the barrel. In most extruders, cooling fans are present to keep the temperature below a set value if too much heat is generated. If forced air cooling proves insufficient then cast-in heater jackets are employed, and they generally use a closed loop of distilled water in heat exchange with tower or city water.

Transfer moulding

Transfer molding, like compression molding, is a process where the amount of molding material, usually a thermoset plastic is measured and inserted before the molding takes place. The molding material is preheated and loaded into a chamber known as the pot. A plunger is then used to force the material from the pot through channels known as a sprue and runner system into the mold cavities. The mold remains closed as the material is inserted and is opened to release the part from the sprue and runner. The mold walls are heated to a te mperature above the melting point of the mold material; this allows a faster flow of material through the cavities.

This is an automated operation that combines compression -, molding, and transfer-molding processes. This combination has the good surface finish, dimensional stability, and mechanical properties obtained in compression molding and the high-automation capability and low cost of injection molding and transfer molding. Transfer Molding is having a "piston and cylinder"-like device built into the mold so that the rubber is squirted into the cavity through small holes. A piece of uncured rubber is placed into a portion of the transfer mold called the "pot." The mold is cl osed and under hydraulic pressure the rubber or plastic is forced through a small hole into the cavity. The mold is held closed while the plastic or rubber cures. The plunger is raised up and the material may be removed and thrown away. The transfer mold is opened and the part can be removed. The flash and the gate may need to be trimmed.

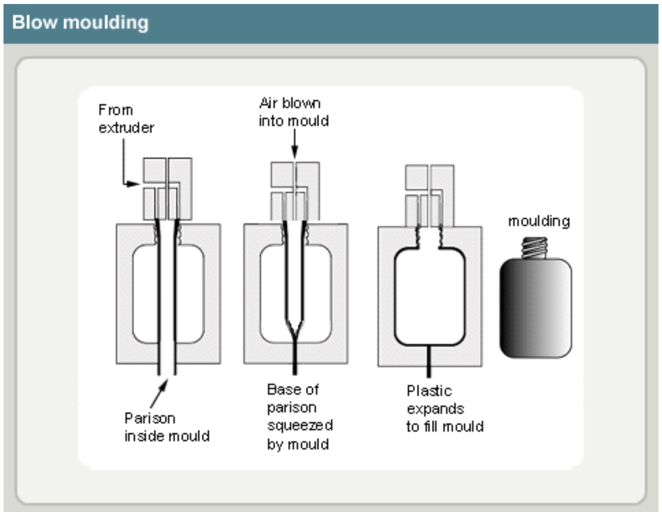
Transfer molding provides product consistency. Transfer molding has short cycle times. Transfer molding is suited for rubber to metal bonding. The molds in both compression and transfer molding remain closed until the curing reaction within the material is complete. Ejector pins are usually incorporated into the design of the molding tool and are used to push the part from the mold once it has hardened. These types of molding are ideal for high production runs as they have short pro duction cycles. Transfer molding, unlike compression molding uses a closed mold, so smaller tolerances and more intricate parts can be achieved. The fixed cost of the tooling in transfer molding is greater than in compression molding and as both methods produce waste material, whether it be flash or the material remaining in the sprue and runners, transf er molding is the more expensive process.



Blow moulding

Blow molding, also known as blow forming, is a manufacturing process by which hollow plastic parts are formed. In general, there are three main types of blow molding: extrusion blow molding, injection blow molding, and stretch blow molding. The blow molding process begins with melting down the plastic and forming it into a preform. The preform is a tube-like piece of plastic with a hole in one end in which compressed air can pass through.

The preform is then clamped into a mold and air is pumped into it. The air pressure then pushes the plastic out to match the mold. Once the plastic has cooled and hardened the mold opens up and the part is ejected.



Task 4

In tasks 1, 2 and 3 you examined in detail a number of moulding techniques used in industry. In order to achieve the merit criteria it is necessary to compare and contrast the processes involved. In order to do this you should look at a number of components, identify the process used to produce them, and state why this process is deemed a more suitable method of production than others described.

Sand casting

Sand casting is the most common method used to make the engine block of a vehicle. It is used due to the large size and weight of the block, and also because it is the most money efficient. The downside to this process however, is the fact that additional finishing is needed e.g. plating. Out of the 3 different casting methods, sand casting has the worst surface finish.

Investment casting

Investment casting has the highest degree of accuracy out of the 3 methods, and offers high production rates, particularly for small or highly complex components, and extremely good surface finish. It is most commonly used for making aerospace equipment, such as turbine blades, because its accuracy can be as good as 0.125mm. The downside however is the high costs, and the fact that the process normally requires numerous operations to complete.

Die casting

Die casting, is another very accurate moulding method, that forces molten metal under high pressure into mold cavities. This process is also expensive, due to the high costs of designing the dies. The benefit is that operational costs are rather low, because of the high level of automation, and small number of production steps. This process is best suited for mass production of components, as simple as kitchen sinks, to more complex ones, such as connector housing.

Injection moulding

The physical properties are easy to change, and the production cycles are automated and last only seconds. With good precision, extra machining can be avoided. Although there are a number of advantages to this process, the moulds are very expensive to create, and only thermoplastics can be used. Flash removal is also necessary to remove the component, without marking it.

Compression moulding

The advantage of compression molding is its ability to mold large, fairly detailed parts. It is one of the lowest cost molding methods compared with other methods such as transfer molding and injection molding. It also wastes relatively little material, giving it an advantage when working with expensive compounds. However, compression molding often provides poor product consistency and difficulty in controlling flashing, and it is not suitable for some types of parts. Compression molding produces fewer knit lines and less fiber-length degradation than injection molding. Compression-molding is also suitable for ultra-large basic shape production in sizes beyond the capacity of extrusion techniques.