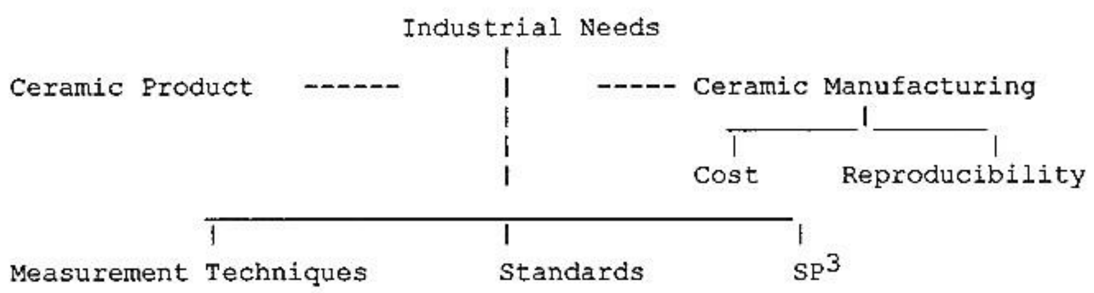
UNIT III MANUFACTURING PROCESSING AND ECONOMIC ANALYSIS

Interaction of Materials Selection, Design, and Manufacturing Processes - Production Processes and Equipment for Metals - Metal Forming, Shaping, and Casting - Plastic Parts Processing - Composites Fabrication Processes - Advanced Ceramics Processing – surface treatment - Resource -The Price and Availability of Materials.

Advanced Ceramics Processing

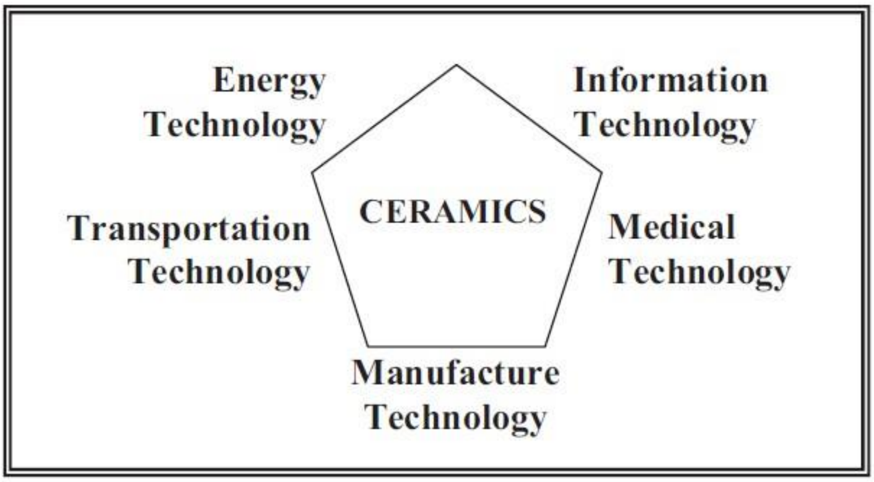
An alternative way to view ceramic processing is in terms of industrials needs. Suppose there is a need, that can be satisfied by a ceramic product. The role of processing weighs more heavily on the manufacturing side. Because issues of cost and reproducibility balance the function of the product, the eventual implementation of the ceramic product may hinge on whether or not the product can be made in a practical way.



Industrial issues relevant to ceramics.

When it comes to advanced ceramics, we can assume that there is value added in the product that justifies advanced processing. If there is no value added, then we might as well follow the methods developed thousands of years ago for pottery. It would be foolish to suggest that we are abandoning pottery and whitewares or that we ever will. To the contrary, whitewares constitute a major part of the ceramic industry, and there are continuing improvements in their manufacture, with respect to increasing their environmental friendliness, recycling, performance, and economics.

Ceramics are a class of materials broadly defined as “inorganic, nonmetallic solids” and are commonly electrical and thermal insulators, brittle and composed of more than one element. Here the term will be restricted to polycrystalline, inorganic, non-metallic materials that acquire their mechanical strength through firing or sintering process



Technology areas which benefit from advanced ceramics

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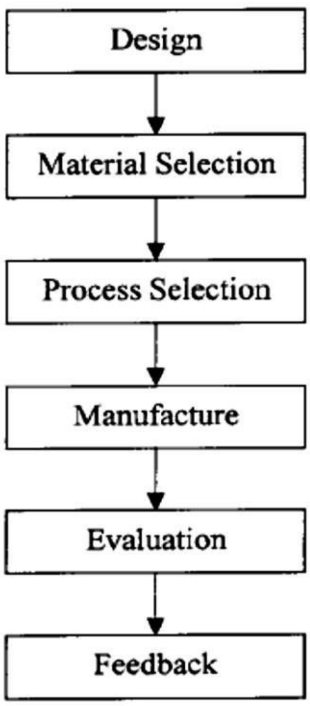
Interaction of Materials Selection, Design, and Manufacturing Processes

- Manufacturing operations are targeted toward the production of products or components that will adequately perform their intended task. Implicit in this statement is the generation of parts with the required geometrical shape and precision.
- Further, these parts must be made from selected materials, with internal structures and companion properties that have been optimized for the specific service environment that the product must withstand.
- The *ideal product* is one that is' 'just good enough.'' Anything better will usually incur added cost through higher-grade materials, enhanced processing, or improved properties that may not be necessary. Anything worse, and we may encounter product failure, dissatisfied customers, and possible unemployment



Typical sequence of manufacturing activity.

Interaction of Materials Selection, Design, and Manufacturing Processes

Various Approaches

There are several possible approaches that may be taken in the manufacture of products or components. One of the simplest is the case history approach. By accessing what has been done in the past (or done by a competitor), we can learn from that experience, use it as a starting base, and either duplicate or modify the details of that solution. A basic assumption of this approach is that similar requirements can be met with similar solutions.

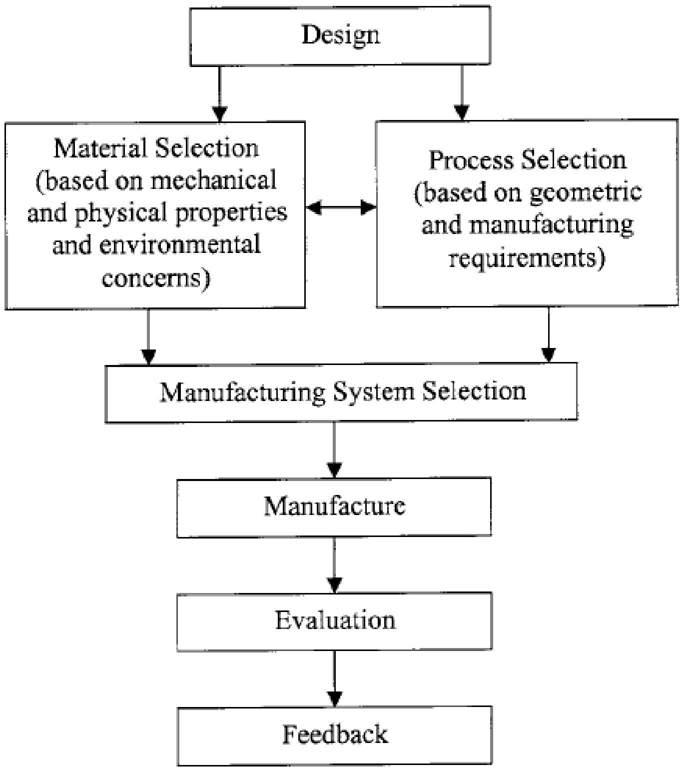
Design

The first step in any manufacturing problem is to define the needs of the product, i.e., to describe the ‘‘target’’ in complete detail. The word *design* is often used to describe this process and entails the specification of geometric requirements, property requirements, and manufacturing requirements for each component of the assembly. It is the responsibility of the designer to identify the specific properties or characteristics that will be necessary for each part to adequately perform its intended function.

Material Selection

A wide spectrum of engineering materials is currently available, each with its own unique set of strengths and limitations. It is possible that one material will emerge as the obvious choice for meeting the design requirements. More likely, there will be multiple candidates that will each meet the requirements to varying degrees.

Selection now becomes a matter of preference with the final choice reflecting the relative merits of the entire manufacturing systems (material and complete method of fabrication). It may also be possible that no existing material is capable of meeting the stated requirements, or the materials that are feasible are eliminated because of features such as high cost, limited availability, environmental concerns, or the need for recyclability. In these cases, alternatives must be made possible through redesign, compromise of requirements, or the development of new engineering materials.



Modified sequence of manufacturing activity showing parallel selection of material and process.

Selection of Fabrication Process

Our objective is to produce parts with the right shape and companion properties that will enable successful performance of the intended function. We must now consider the various ways of producing the desired shape and evaluate each with regard to its compatibility with the candidate materials.

Completing the system: secondary processing

It is rare for a single manufacturing process to produce a part with both the desired shape and the desired properties. One process may produce the desired

- dimensional precision in a single operation, while another less expensive alternative might require some secondary machining. Grinding or polishing may be necessary to produce surfaces with the desired surface finish. These secondary processes must be incorporated into each of the candidate manufacturing systems. Moreover, because these secondary processes incur the added expenses of handling, positioning, fixturing, and associated tooling, it is not uncommon for them to be among the most expensive stages of the system.

- We began with well-defined needs and objectives and proceeded to identify candidate manufacturing systems, each of which begins with a starting material and includes everything that must be done to convert it into the desired final product. Every one of the options involves a series of highly interrelated decisions.

- Performance and property needs restrict candidate materials. Various materials limit the fabrication possibilities. The fabrication method, in turn, affects the material properties. Processes designed to modify certain properties may simultaneously alter other properties.
- The design and manufacture of a successful product is an iterative and evolving process. Costs change, prototype or customer assessment may reveal unexpected weaknesses or the possibility of improvements, and manufacturing problems may be encountered. A change in material may well require a change in manufacturing process, and conversely improvements in processing may warrant a reevaluation of material. It is vitally important to maintain an understanding of the various system interactions to assure that any change or corrective action will not adversely affect other aspects of the system.

Number of factors common to both the material and process selection decisions:

- The number of components to be made;
- The component size
- The component weight
- The precision required;
- The surface finish and appearance required.

Materials Selection Process

1. Identify product design requirements
2. Identify product element design requirements
3. Identify potential materials
4. Evaluate materials
5. Determine whether any of the materials meet the selection criteria
6. Select materials

Factors to be considered for selection of materials for design

- Availability: Material should be available easily in the market.
- Cost: the material should be available at cheaper rate.

Manufacturing Consideration: the manufacturing play a vital role in selection of material and the material should suitable for required manufacturing process

- Physical properties: like colour, density etc
- Mechanical properties: such as strength, ductility, Malleability etc.
- Corrosion resistance: it should be corrosion resistant.

Factors affecting selection of manufacturing process

- Material selection including and considering all the environmental and recycling aspects
- Selection of processing methods such as metal casting, metal forming, sheet metal working, powder metallurgy, machining, joining, finishing etc.
- Shape and appearance of the final product
- Dimensional tolerance and surface finish aspects of the final product
- Economics of tooling
- Design requirements
- Functional requirements of the product
- Production quantity required
- Safety and environmental concerns
- Cost

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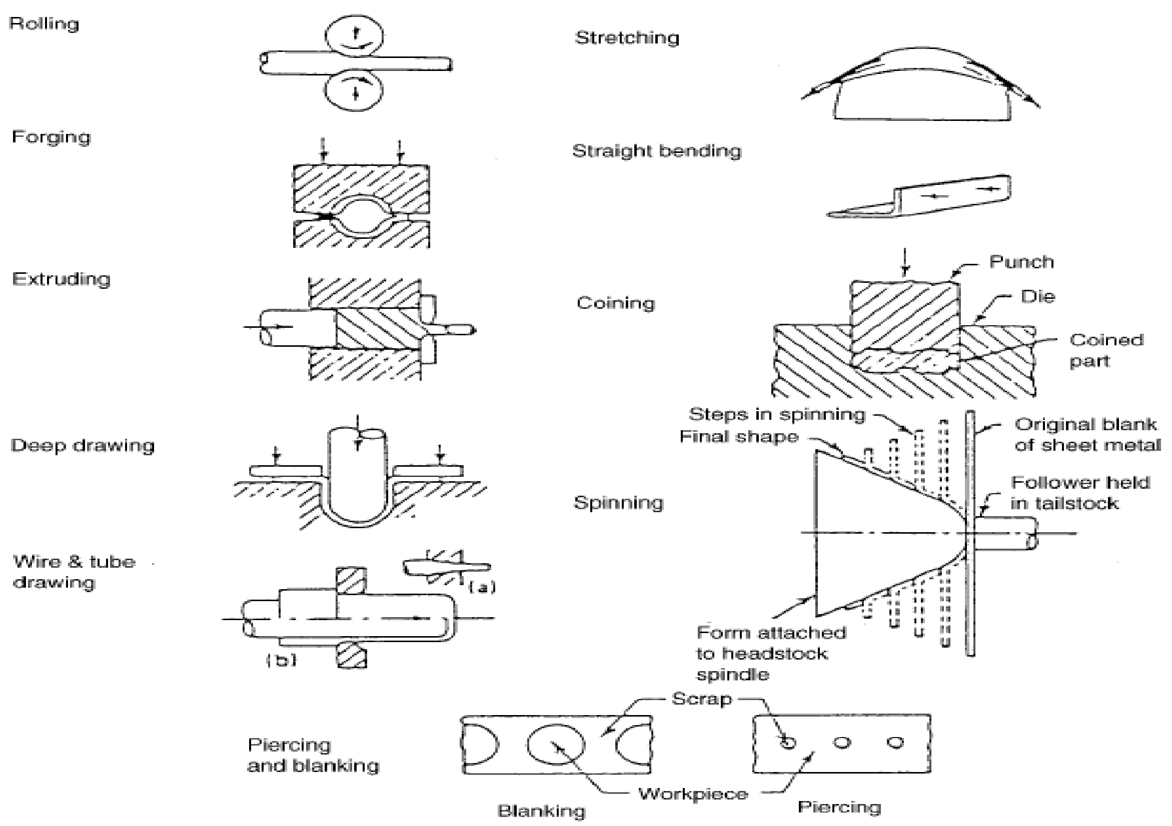
Metal Forming, Shaping, & Casting

- Metal-forming processes use a remarkable property of metals—their ability to flow plastically in the solid state without concurrent deterioration of properties.
- Metal-forming processes are classified into two categories:

  1. Hot-working processes
  2. Cold working processes.



Metal-forming processes.

Hot working is defined as the plastic deformation of metals above their recrystallization temperature. Here it is important to note that the crystallization temperature varies greatly with different materials. Lead and tin are hot worked at room temperature, while steels require temperatures of 2000F (1100C). Hot working does not necessarily indicate high absolute temperatures.

Classification of Hot-Working Processes

The most obvious reason for the popularity of hot working is that it provides an attractive means of forming a desired shape. Some of the hot-working processes that are of major importance in modern manufacturing are

1. Rolling

2. Forging

3. Extrusion and upsetting

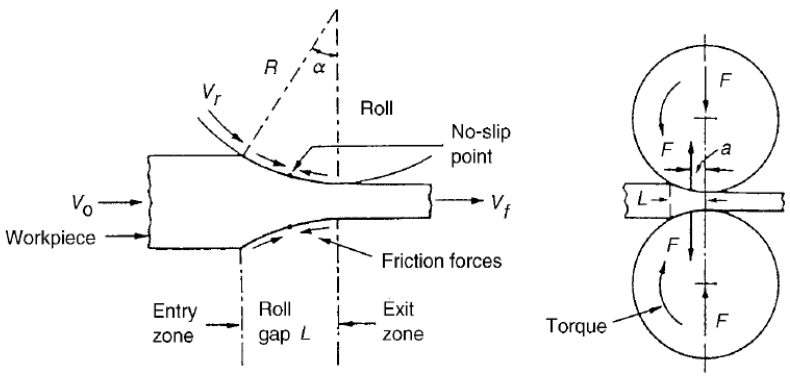
4. Drawing

5. Spinning

6. Pipe welding

7. Piercing

Hot rolling consists of passing heated metal between two rolls that revolve in opposite directions, the space between the rolls being somewhat less than the thickness of the entering metal. Many finished parts, such as hot-rolled structural shapes, are completed entirely by hot rolling. More often, however, hot-rolled products, such as sheets, plates, bars, and strips, serve as input material for other processes, such as cold forming or machining.

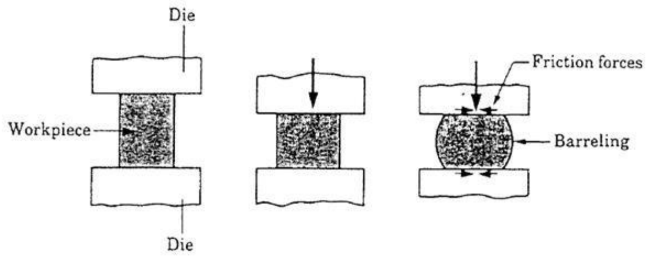


Hot rolling.

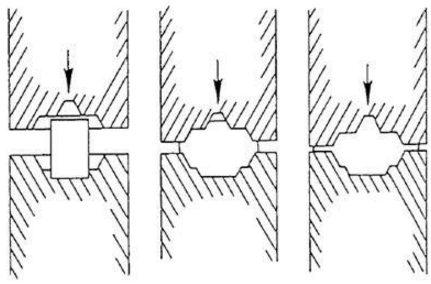
Forging

Forging is the plastic working of metal by means of localized compressive forces exerted by manual or power hammers, presses, or special forging machines. Various types of forging have been developed to provide great flexibility, making it economically possible to forge a single piece or to mass produce thousands of identical parts.

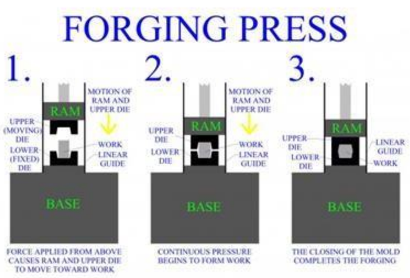
1. Open-die hammer
2. Impression-die drop forging
3. Press forging
4. Upset forging
5. Roll forging
6. Swaging

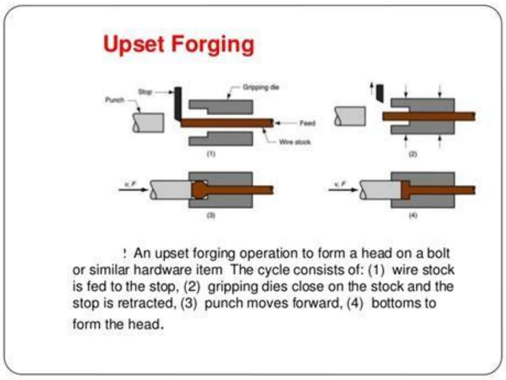


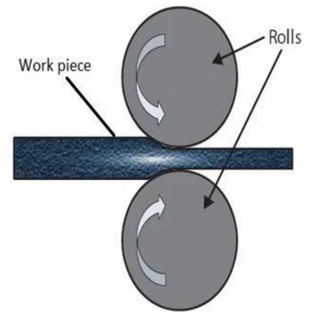
Open-die hammer forging.



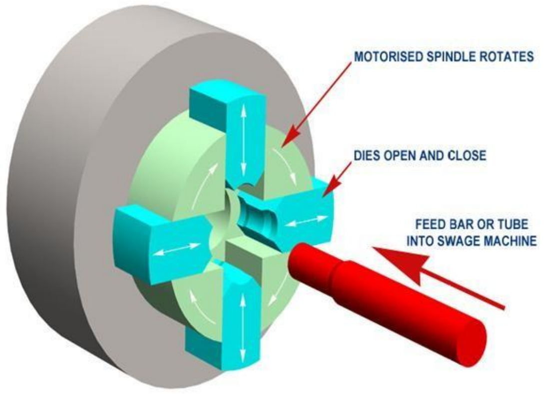
Impression-die drop forging.







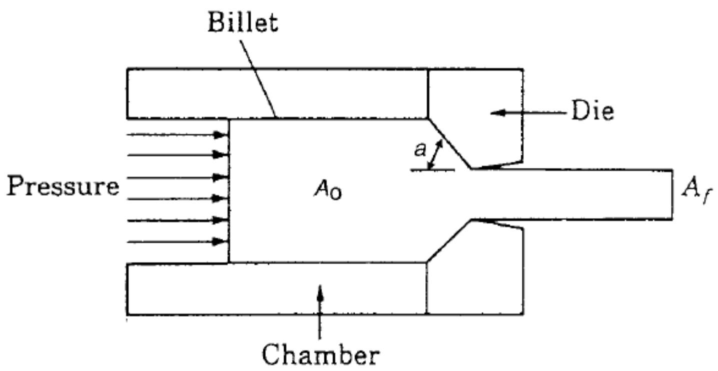
ROLL FORGING



Swaging

Extrusion

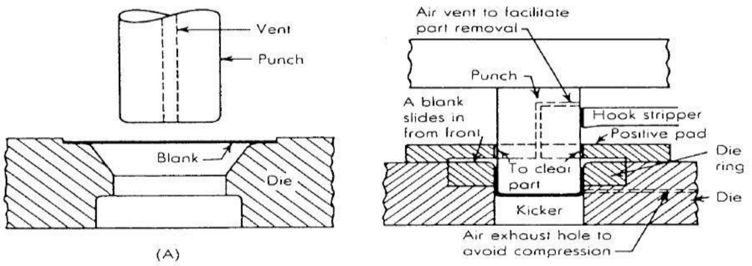
In the extrusion process metal is compressively forced to flow through a suitably shaped die to form a product with reduced cross section. Although it may be performed either hot or cold, hot extrusion is employed for many metals to reduce the forces required, to eliminate cold-working effects, and to reduce directional properties.



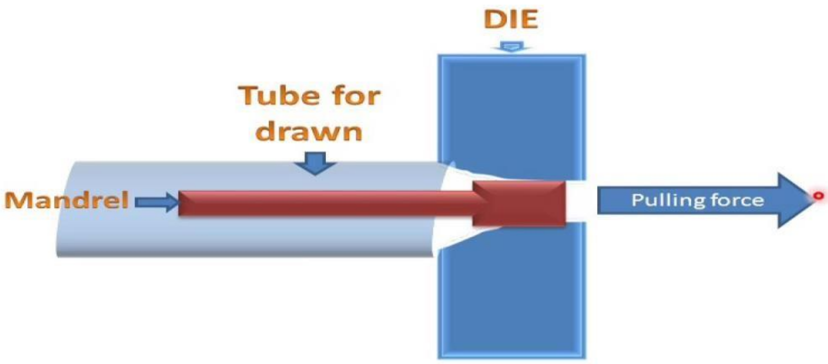
Extrusion process.

Drawing

Drawing is a process for forming sheet metal between an edge-opposing punch and a die (draw ring) to produce a cup, cone, box, or shell-like part. The work metal is bent over and wrapped around the punch nose.

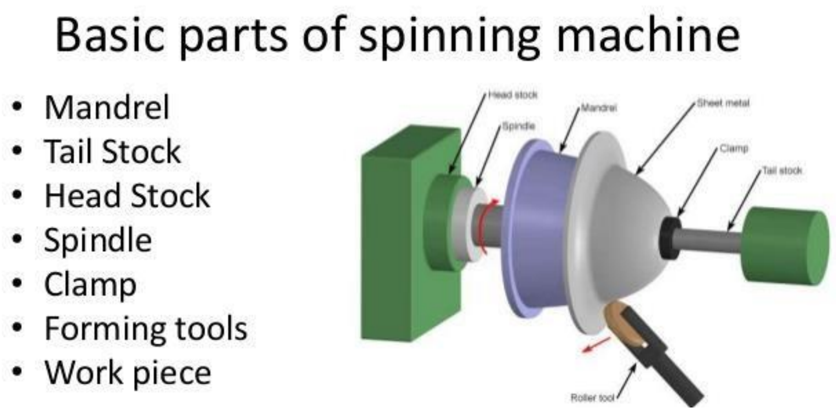


Drawing process.



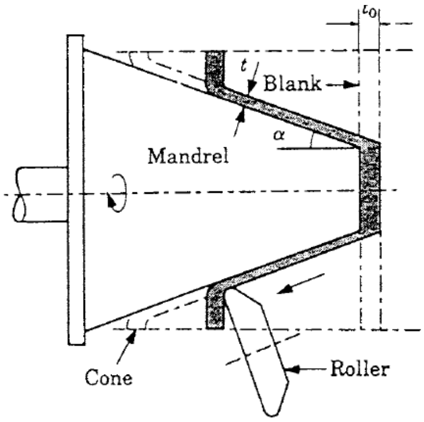
Spinning

- Spinning is a method of forming sheet metal or tubing into seamless hollow cylinders, cones, hemispheres, or other circular shapes by a combination of rotation and force. On the basis of techniques used, applications, and results obtainable, the method may be divided into two categories: *manual spinning* (with or without mechanical assistance to increase the force) and *power spinning*.



Pipe Welding

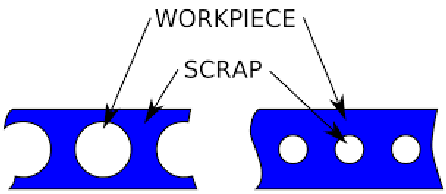
Large quantities of small-diameter steel pipe are produced by two processes that involve hot forming of metal strip and welding of its edges through utilization of the heat contained in the metal



Setup and dimensional relations for one-operation power spinning of a cone.

Piercing

Thick-walled and seamless tubing is made by the piercing process. A heated, round billet, with its leading end center-punched, is pushed longitudinally between two large, convex-tapered rolls that revolve in the same direction, their axes being inclined at opposite angles of about 6 from the axis of the billet. The clearance between the rolls is somewhat less than the diameter of the billet. As the billet is caught by the rolls and rotated, their inclination causes the billet to be drawn forward into them.



COLD-WORKING PROCESSES

- Cold working is the plastic deformation of metals below the recrystallization temperature. In most cases of manufacturing, such cold forming is done at room temperature. In some cases, however, the working may be done at elevated temperatures that will provide increased ductility and reduced strength, but will be below the recrystallization temperature. When compared to hot working, cold-working processes have certain distinct advantages:

- No heating required, Better surface finish obtained, Superior dimension control
- Better reproducibility and interchangeability of parts, Improved strength properties, Directional properties can be imparted, Contamination problems minimized

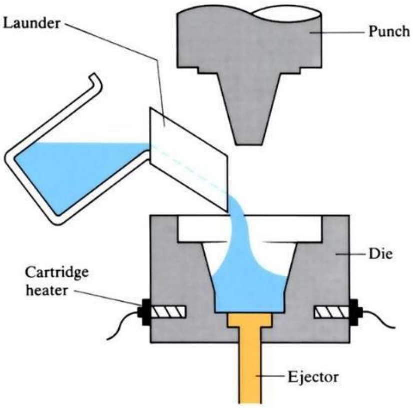
Classification of Cold-Working Operations

The major cold-working operations can be classified basically under the headings of squeezing, bending, shearing, and drawing, as follows:

Squeezing	*Bending*	*Shearing*	*Drawing*
Rolling	Angle	Shearing	Bar and tube drawing
Swaging	Roll	Slitting	Wire drawing
Cold forging	Roll forming	Blanking	Spinning
Sizing	Drawing	Piercing	Embossing
Extrusion	Seaming	Lancing	Stretch forming
Riveting	Flanging	Perforating	Shell drawing
Staking	Straightening	Notching	Ironing
Coining		Nibbling	High-energy rate forming
Peening		Shaving	
Burnishing		Trimming	
Die hobbing		Cutoff	
Thread rolling		Dinking	

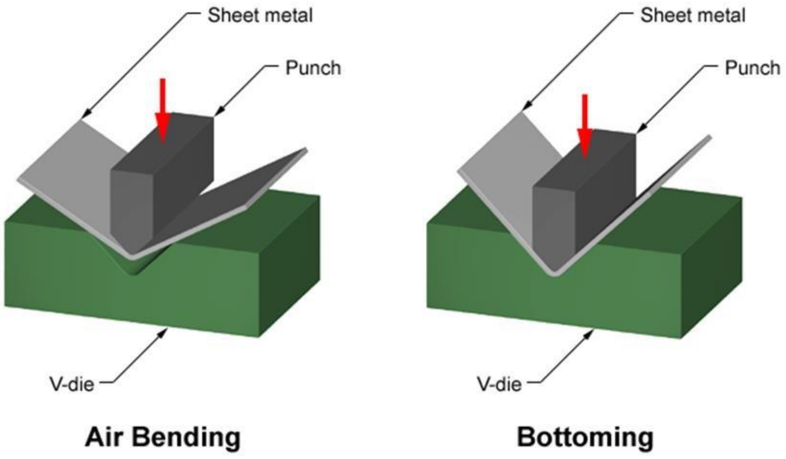
Squeezing Processes

Most of the cold-working squeezing processes have identical hot-working counterparts or are extensions of them. The primary reasons for deforming cold rather than hot are to obtain better dimensional accuracy and surface finish. In many cases, the equipment is basically the same, except that it must be more powerful.



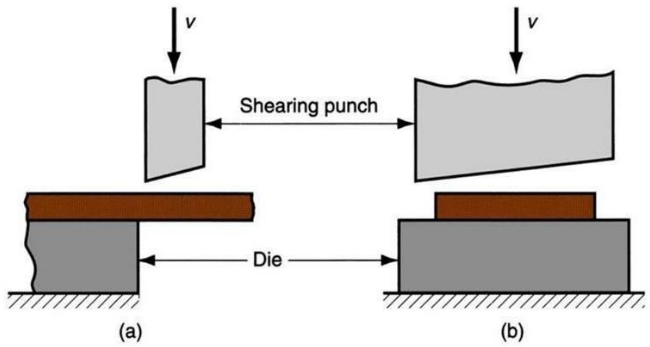
Bending

Bending is the uniform straining of material, usually flat sheet or strip metal, around a straight axis that lies in the neutral plane and normal to the lengthwise direction of the sheet or strip. Metal flow takes place within the plastic range of the metal, so that the bend retains a permanent set after removal of the applied stress. The inner surface of the bend is in compression; the outer surface is in tension.



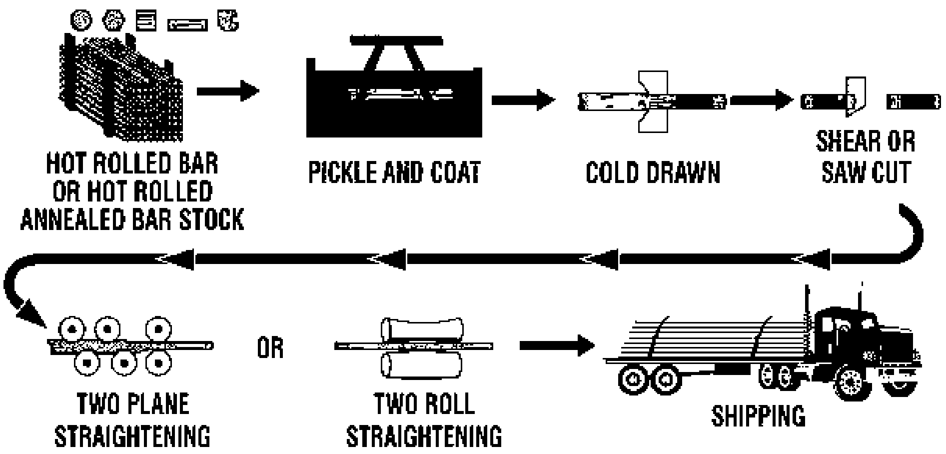
Shearing

Shearing is the mechanical cutting of materials in sheet or plate form without the formation of chips or use of burning or melting. When the two cutting blades are straight, the process is called *shearing*. Other processes, in which the shearing blades are in the form of curved edges or punches and dies, are called by other names, such as *blanking*, *piercing*, *notching*, *shaving*, and *trimming*



Drawing

Cold drawing is a term that can refer to two somewhat different operations. If the stock is in the form of sheet metal, cold drawing is the forming of parts wherein plastic flow occurs over a curved axis. This is one of the most important of all cold-working operations because a wide range of parts, from small caps to large automobile body tops and fenders, can be drawn in a few seconds each. Cold drawing is similar to hot drawing, but the higher deformation forces, thinner metal, limited ductility, and closer dimensional tolerance create some distinctive problems.



METAL CASTING AND MOLDING PROCESSES

Casting provides a versatility and flexibility that have maintained casting position as a primary production method for machine elements. Casting processes are divided according to the specific type of molding method used in casting, as follows:

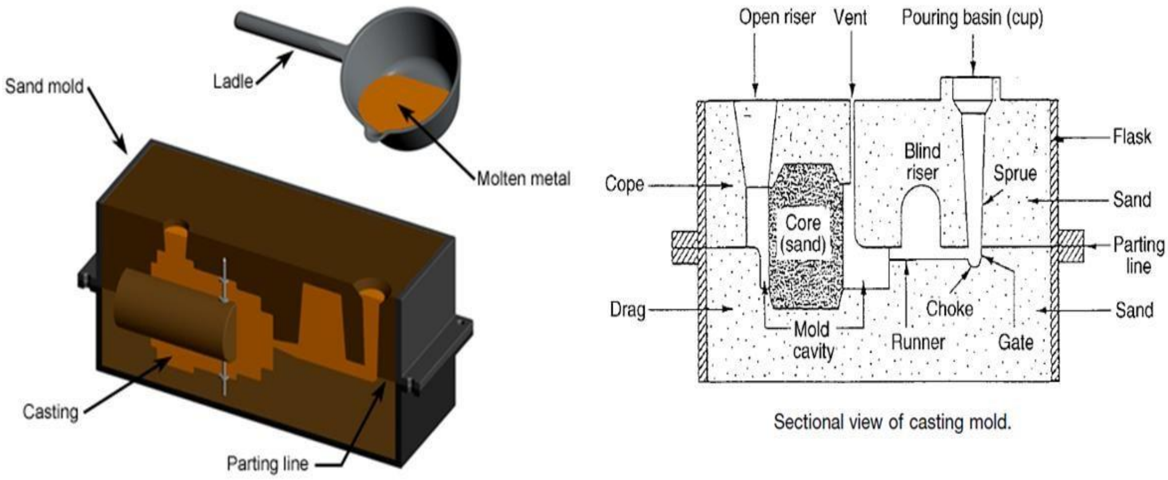
1. Sand
2. Centrifugal
3. Permanent
4. Die

5. Plaster-mold

6. Investment

Sand Casting

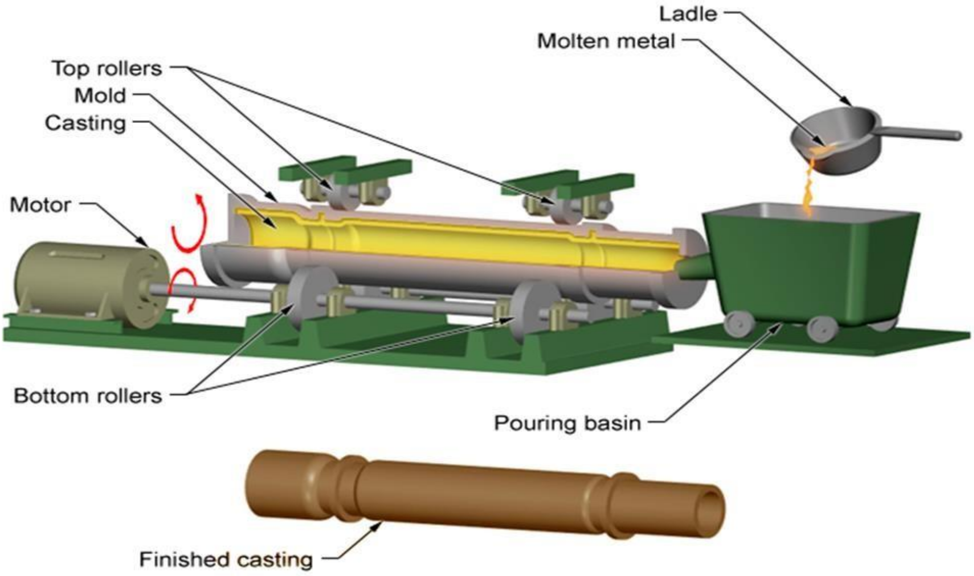
Sand casting consists basically of pouring molten metal into appropriate cavities formed in a sand mold . The sand may be natural, synthetic, or an artificially blended material.



Sectional view of casting mold.

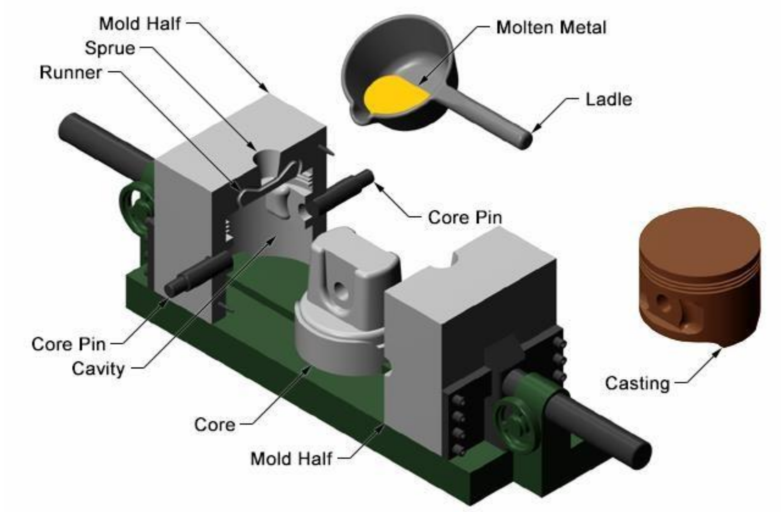
Centrifugal Casting

Centrifugal casting consists of having a sand, metal, or ceramic mold that is rotated at high speeds. When the molten metal is poured into the mold, it is thrown against the mold wall, where it remains until it cools and solidifies. The process is increasingly being used for such products as cast-iron pipes, cylinder liners, gun barrels, pressure vessels, brake drums, gears, and flywheels. The metals used include almost all castable alloys. Most dental tooth caps are made by a combined lost-wax process and centrifugal casting



Permanent-Mold Casting

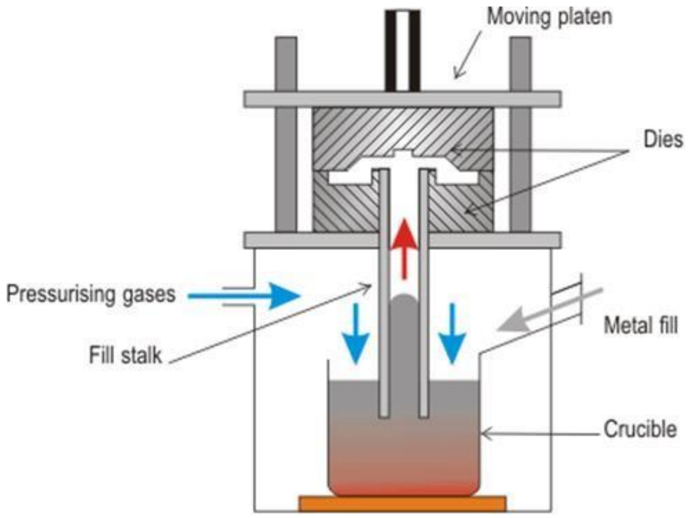
As demand for quality castings in production quantities increased, the attractive possibilities of metal molds brought about the development of the permanent mold process. Although not as flexible regarding design as sand casting, metal mold casting made possible the continuous production of quantities of casting from a single mold as compared to batch production of individual sand molds



Die Casting

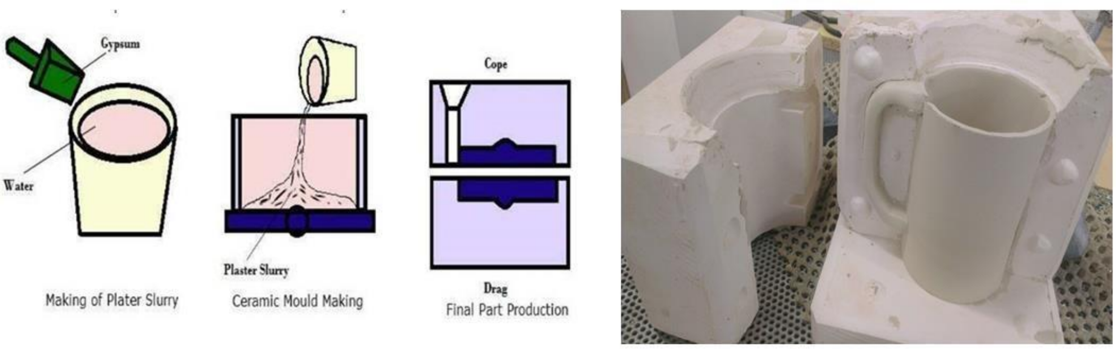
- Die casting may be classified as a permanent-mold casting system; however, it differs from the process just described in that the molten metal is forced into the mold or die under high pressure.

- There are two main types of machines used: the hot-chamber and the cold chamber types.



Plaster-mold casting

- In general, the various methods of plaster-mold casting are similar. The plaster, also known as *gypsum* or *calcium sulfate*, is mixed dry with other elements, such as talc, sand, asbestos, and sodium silicate. To this mix is added a controlled amount of water to provide the desired permeability in the mold. The slurry that results is heated and delivered through a hose to the flasks, all surfaces of which have been sprayed with a parting compound. The plaster slurry readily fills in and around the most minute details in the highly polished brass patterns. Following filling, the molds are subjected to a short period of vibration and the slurry sets in 5–10 min.



Plaster Mould Casting

Investment Casting

- **Investment Casting** Casting processes in which the pattern is used only once are variously referred to as lost-wax or precision-casting processes. They involve making a pattern of the desired form out of wax or plastic (usually polystyrene).

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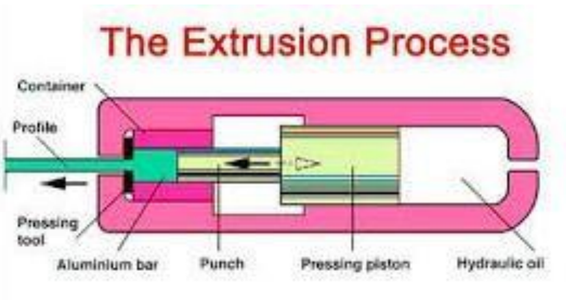
Plastic Parts Processing

1. Techniques involving the continuous manufacture of a product with a uniform cross section, such as extrusion, extrusion covering, film blowing, and calendaring
2. Techniques involving the shaping of a deformable polymer preform against a mold surface, including sheet thermoforming and blow molding;
3. Techniques involving the gradual buildup of a polymer layer against a mold surface, such as coating and rotational molding; and
4. Techniques involving the filling of a mold cavity, including casting, compression molding, transfer molding, injection molding, and reaction injection molding.

Extrusion

The extrusion process consists of continuously shaping a fluid polymer through the orifice of a die and subsequently solidifying it into a product. The feed material, usually a thermoplastic in powder or pellet form, is heated to a fluid state and forced through the die using a screw extruder. The extruded product is solidified by cooling after it exits the die.

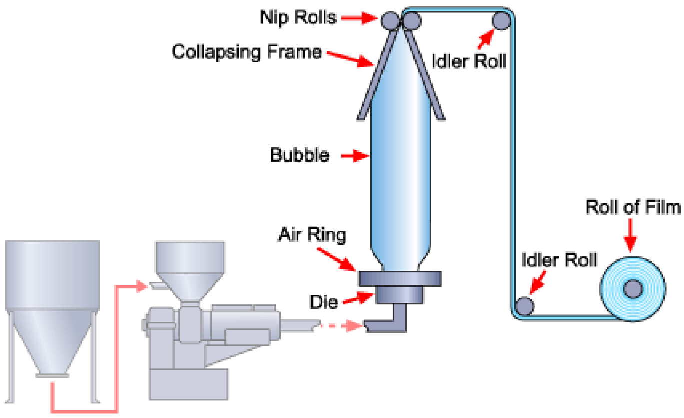


Extrusion Covering

The expression ‘‘extrusion covering’’ is used here to describe a process that completely surrounds a continuous substrate with a cover of polymeric material. Its most common use is for the formation of an insulating layer or a protective jacket on power or communication electrical wires and cables.

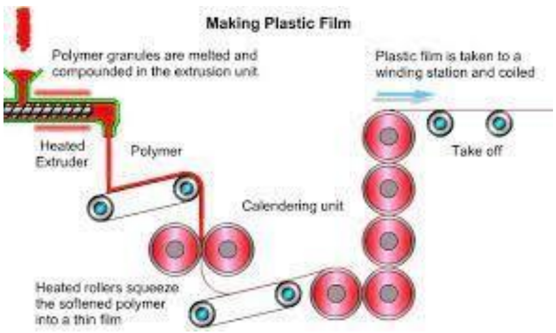
Film Blowing

The film-blowing process basically consists of extruding a tube of molten thermoplastic and continuously inflating it to several times its initial diameter, to form a thin tubular product that can be used directly or slit to form a flat film.



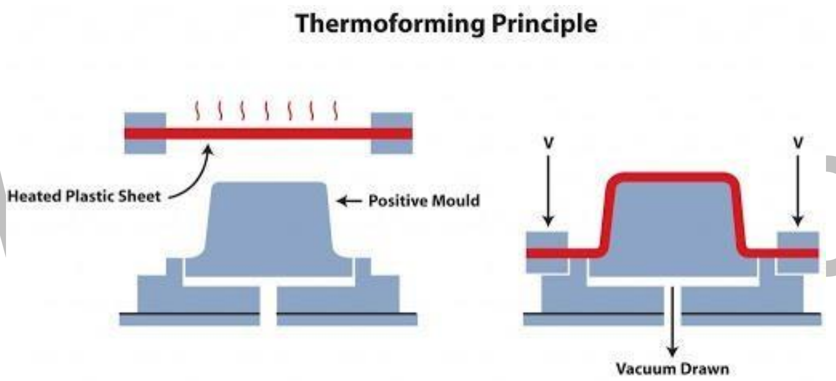
Calendering

The calendering processes is used for the fast production of flat films or sheets of plastics or rubbers. Calendaring is a specialty process for high-volume, high quality plastic film and sheet, mainly used for PVC as well as for certain other modified thermoplastics. The melted polymer is subject to heat and pressure in an extruder and formed into sheet or film by calendaring rolls.



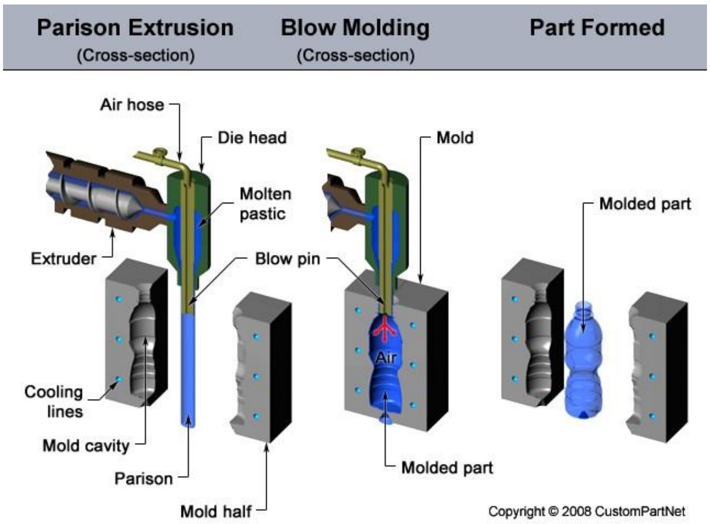
Sheet Thermoforming

Sheet thermoforming, or simply thermoforming, involves the heating of a flat thermoplastic sheet to a softened state. Thermoforming describes the process of heating a thermoplastic sheet to its softening point, stretching it over or into a single-sided mold, and holding it in place while it cools and solidifies into the desired shape. The thermoplastic sheet is clamped into a holding device and heated by an oven using either convection or radiant heat until it is softened. The sheet is then held horizontally over a mold and pressed into or stretched over the mold using vacuum pressure, air pressure, or mechanical force. The softened sheet conforms to the shape of the mold and is held in place until it cools. The excess material is then trimmed away and the formed part is released. Excess material can be reground, mixed with unused plastic, and reformed into thermoplastic sheets.



Blow Molding

The basic principle of the blow-molding process is to inflate a softened thermoplastic hollow preform against the cooled surface of a closed mold, where the material solidifies into a hollow product. Blow molding is a molding process used in the manufacturing industry to create hollow objects made of plastic. Like other molding processes, it involves the use of heated, liquid material that’s forced into a mold cavity under pressure. Blow molding is a special type of molding process, however, that leverages the properties of traditional glassblowing.

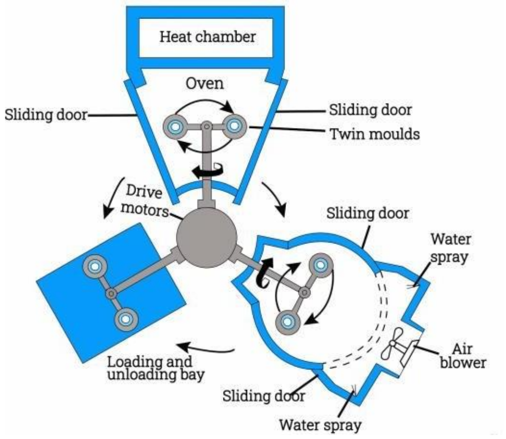


Coating

Coating may be defined as the formation (application) of a layer (coat) of polymer on a substrate; ‘‘planar coating,’’ is used for flat film and sheet substrates and ‘‘contour coating,’’ for general three-dimensional objects. Plastic coating is the application of liquid polymers or plastic on the surface of a work piece by dipping or immersion. The result is a thick plastic finish for protective and decorative purposes. This gives the material additional resistance against scratches, wear, corrosion, and external elements. This makes the metal piece more durable, and obtain a longer service life. It also offers convenience and protection to the end-user by providing surfaces for gripping and insulation.

Rotational Molding

The process of rotational molding suitable powdery thermoplastic material charge is introduced in the open mold. The mold is then closed and mounted on a holding device, which permits its double, biaxial, rotation around two perpendicular axes to produce a tumbling action.

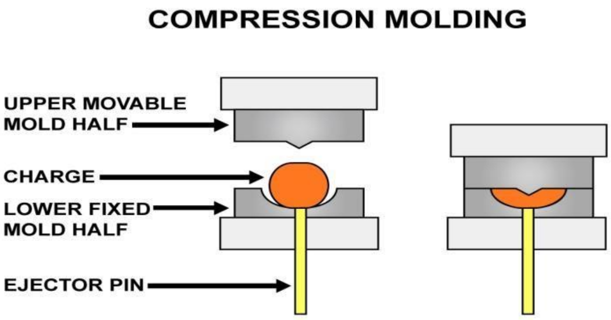


Casting

Casting corresponds to the pouring or casting of the liquid resin system into a mold (gravity or atmospheric pressure casting. In some cases, the chemical reaction that is taking place during a casting process converts a low-molecular-weight monomer into a high-molecular-weight thermoplastic.

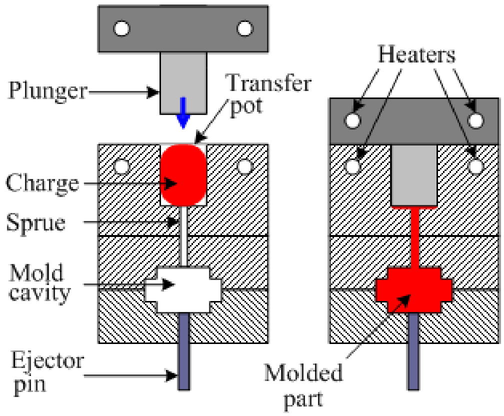
Compression Molding

The compression-molding process is used almost exclusively for temperature activated thermosetting polymers. Compression molding basically involves the pressing of a deformable material between the two halves of a heated mold, and its transformation into a solid product under the effect of the elevated mold temperature



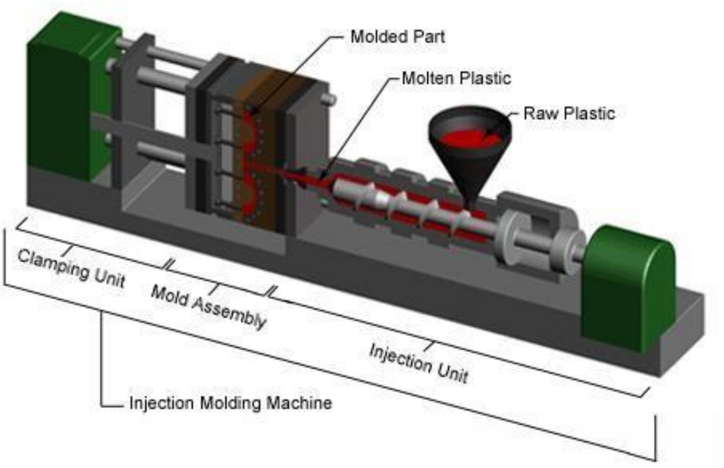
Transfer Molding

In transfer molding, a softened temperature-activated thermoset, or a vulcanizable rubber, is transferred through a narrow gate into the closed cavity of a heated mold, where it cures to a solid state.



Injection Molding

The injection-molding process involves the rapid pressure filling of a shape specific mold cavity with a fluid material, followed by the solidification of the material into a product. The process is used for thermoplastics, thermosetting resins, and rubbers.

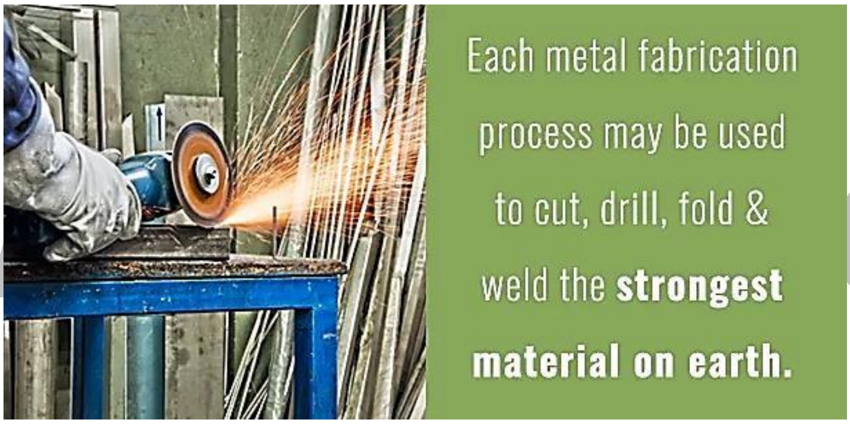


UNIT III MANUFACTURING PROCESSING AND ECONOMIC ANALYSIS

Interaction of Materials Selection, Design, and Manufacturing Processes - Production Processes and Equipment for Metals - Metal Forming, Shaping, and Casting - Plastic Parts Processing - Composites Fabrication Processes - Advanced Ceramics Processing – surface treatment - Resource -The Price and Availability of Materials.

Production Processes and Equipment for Metals

Metal fabrication is the process of turning raw metals into pre-made shapes for assembly use. For example, the panels that comprise the frame of an automobile are made through custom metal fabrication processes, which are usually performed at a fabrication facility and then sent to an auto assembly plant



Cutting:

Perhaps the most commonly used metal fabrication processes involve cutting, where sheets of metal are split into halves, thirds or smaller sections. In a lot of applications, the metal being cut is freshly made, and has yet to be shaped into anything in particular. In other applications, pre-shaped metals like bars and measured panels are submitted for cutting. Cuts are performed on a range of machinery, from lasers and plasma torches to more elaborate, high-tech pieces of machinery.

Folding:

One of the more complicated processes of metal fabrication involves folding, where a metal surface is manipulated to shape at a certain angle. With certain folding applications, the intent is to make the metal surface fold at a 90-degree angle, or something else that's either more or less blunt. However, folding may only be performed in facilities that are equipped with specific, high-tech equipment due to the complexity of the whole process. In many cases where a fold is needed, the joining of two metal panels at select angles would be the more practical alternative.

Welding.:

Along with cutting, welding is one of the most popular metal fabrication processes among crafts enthusiasts. The process of welding involves the joining of two separate metal parts. The parts used in a welding application could be sheets, panels, bars or shapes — as long as the parts are made of metal, it really doesn't matter. Welding is achievable through numerous methods and tool types. Often, a weld is achieved through the application of heat along the points where the two pieces are meant to be joined. A lot of metalworkers first pursue the area of metal fabrication with welding projects in mind.

Machining.:

When a machine is used to remove portions from a piece of metal, the process is known as machining. Typically, the process is performed on a lathe, which will rotate the metal against tools that trim corners and edges to cut the piece down to a desired shape or measurement. In other machining applications, a hole or set of holes will be formed directly through the metal surface. As such, the metal drill could be classified as a machining tool.

Punching:

When holes are formed in a piece of metal, the process involved consists of punching, where metal is placed under a die and submitted to a punch-through by a drill. For the punch to be the correct size, the circumference of the drill must slot correctly through the die. Punching falls into one of two sub categories based on the intention of a given application. In most cases, the intent is to punch holes into a panel of metal for the purpose of fastening latches or other foreign parts. In other applications — alternately known as blanking — the area with the hole is specifically extracted from the larger panel to form a smaller bit part.

Shearing:

For sheets of metal that require long cuts, the process is known as shearing. In some cases, the sheet is fed horizontally through a metal-cutting machine. In other applications, a cutting tool is applied vertically against the length of a flat metal sheet. A third method involves placing the metal over the edge of an open cutter and lowering the blade, much like the paper cutters found at copy facilities. Shearing is often applied to trim down the edge of a metal sheet, but the process may be done anywhere along the metal.

Stamping:

Punching is not the only metal fabrication process to utilize a die. In some applications, however, the intention is not to form a hole, but to raise a certain portion of a metal sheet, without penetrating. For applications like these, the process of stamping is used to form certain shapes, letters or images within a metal sheet or panel. In effect, metal stamping is similar to relief carving in wood or marble. A primary example of metal stamping is seen on coins, where words, currency amounts and the faces of presidents are stamped from each surface side on pennies, nickels, dimes and quarters.

Casting.:

One of the oldest types of metal fabrication involves casting, where molten metal is poured into a mold and is left to solidify into a specific form. As one of the most flexible methods of metal fabrication, casting is ideal for a wide range of complex shape-making. In some cases, casting provides a solution to fabrication problems that would otherwise take several other methods to solve, such as with assembly parts that would need folding, shearing, and stamping. The most common metals employed in this application include steel, iron, gold, copper, silver, and magnesium.

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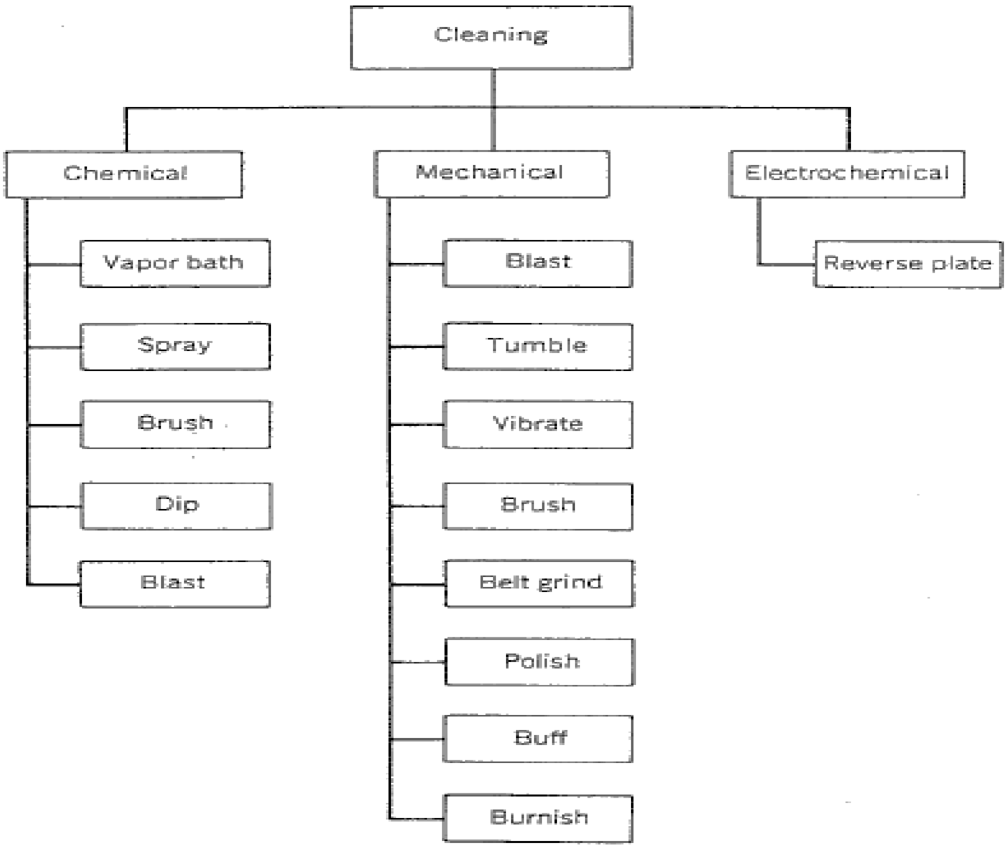
surface treatment

- Products that have been completed to their proper shape and size frequently require some type of surface finishing to enable them to satisfactorily fulfill their function. In some cases, it is necessary to improve the physical properties of the surface material for resistance to penetration or abrasion. Surface finishing may sometimes become an intermediate step in processing. For instance, cleaning and polishing are usually essential before any kind of plating process. Another important need for surface finishing is for corrosion protection in a variety of environments.

SURFACE TREATMENT

Cleaning methods.



- The type of protection provided will depend largely on the anticipated exposure, with due consideration to the material being protected and the economic factors involved. Satisfying the above objectives necessitates the use of many surface-finishing methods that involve chemical change of the surface; mechanical work affecting surface properties, cleaning by a variety of methods, and the application of protective coatings organic and metallic.