**UNIT- 1 Conventional Manufacturing processes**

**Syllabus: -** Casting and moulding: Metal casting processes and equipment, Heat transfer and solidification,

shrinkage, riser design, casting defects and residual stresses .Introduction to bulk and sheet metal

forming, plastic deformation and yield criteria; fundamentals of hot and cold working processes; load

estimation for bulk forming (forging, rolling, extrusion, drawing) and sheet forming (shearing, deep

drawing, bending) principles of powder metallurgy.

**Conventional manufacturing**

Conventional manufacturing processes consist of coating the conducting lead grid with a paste formed from a mixture of lead and lead oxide powder, additives and appropriate amounts of acid and water to produce the required density, followed by reduction of the sulphated mix to a porous lead mass.

**Metal casting processes**

Casting is one of the oldest manufacturing processes. It is the first step in making most of the products.

Steps: - Making mould cavity - Material is first liquefied by properly heating it in a suitable furnace. - Liquid is poured into a prepared mould cavity - allowed to solidify - product is taken out of the mould cavity, trimmed and made to shape We should concentrate on the following for successful casting operation:

(i) Preparation of moulds of patterns

(ii)Melting and pouring of the liquefied metal

(iii)Solidification and further cooling to room temperature

(iv) Defects and inspection

Advantages

Molten material can flow into very small sections so that intricate shapes can be made by this process. As a result, many other operations, such as machining, forging, and welding, can be minimized.

• Possible to cast practically any material: ferrous or non-ferrous.

• The necessary tools required for casting moulds are very simple and inexpensive. As a result, for production of a small lot, it is the ideal process.

• There are certain parts (like turbine blades) made from metals and alloys that can only be processed this way. Turbine blades: Fully casting + last machining.

• Size and weight of the product is not a limitation for the casting process.

Limitations

Dimensional accuracy and surface finish of the castings made by sand casting processes are a limitation to this technique.

• Many new casting processes have been developed which can take into consideration the aspects of dimensional accuracy and surface finish. Some of these processes are die casting process, investment casting process, vacuum-sealed moulding process, and shell moulding process.

• Metal casting is a labour intensive process

• Automation: a question

Flask: A metal or wood frame, without fixed top or bottom, in which the mould is formed. Depending upon the position of the flask in the moulding structure, it is referred to by various names such as drag – lower moulding flask, cope – upper moulding flask, cheek – intermediate moulding flask used in three piece moulding. Pattern: It is the replica of the final object to be made. The mould cavity is made with the help of pattern. Parting line: This is the dividing line between the two moulding flasks that makes up the mould. Moulding sand: Sand, which binds strongly without losing its permeability to air or gases. It is a mixture of silica sand, clay, and moisture in appropriate proportions. Facing sand: The small amount of carbonaceous material sprinkled on the inner surface of the mould cavity to give a better surface finish to the castings. Core: A separate part of the mould, made of sand and generally baked, which is used to create openings and various shaped cavities in the castings. Pouring basin: A small funnel shaped cavity at the top of the mould into which the molten metal is poured. Sprue: The passage through which the molten metal, from the pouring basin, reaches the mould cavity. In many cases it controls the flow of metal into the mould. Runner: The channel through which the molten metal is carried from the sprue to the gate. Gate: A channel through which the molten metal enters the mould cavity. Chaplets: Chaplets are used to support the cores inside the mould cavity to take care of its own weight and overcome the metallostatic force. Riser: A column of molten metal placed in the mould to feed the castings as it shrinks and solidifies. Also known as “feed head”.

The six basic steps in making sand castings are,

1. Pattern making,
2. (ii) Core making,
3. (iii) Moulding,
4. (iv) Melting and pouring,
5. (v) Cleaning Pattern making –

Pattern

: Replica of the part to be cast and is used to prepare the mould cavity. It is the physical model of the casting used to make the mould. Made of either wood or metal. -The mould is made by packing some readily formed aggregate material, such as moulding sand, surrounding the pattern. When the pattern is withdrawn, its imprint provides the mould cavity. This cavity is filled with metal to become the casting. - If the casting is to be hollow, additional patterns called ‘cores’, are used to form these cavities. Core making Cores are placed into a mould cavity to form the interior surfaces of castings. Thus the void space is filled with molten metal and eventually becomes the casting. Moulding Moulding is nothing but the mould preparation activities for receiving molten metal. Moulding usually involves:

1. preparing the consolidated sand mould around a pattern held within a supporting metal frame,
2. removing the pattern to leave the mould cavity with cores. Mould cavity is the primary cavity. The mould cavity contains the liquid metal and it acts as a negative of the desired product.
3. The mould also contains secondary cavities for pouring and channelling the liquid material in to the primary cavity and will act a reservoir, if required. Melting and Pouring
4. The preparation of molten metal for casting is referred to simply as melting. The molten metal is transferred to the pouring area where the moulds are filled.
5. Cleaning Cleaning involves removal of sand, scale, and excess metal from the casting. Burned-on sand and scale are removed to improved the surface appearance of the casting. Excess metal, in the form of fins, wires, parting line fins, and gates, is removed. Inspection of the casting for defects and general quality is performed.

Pattern The pattern and the part to be made are not same. They differ in the following aspects. 1.A pattern is always made larger than the final part to be made. The excess dimension is known as Pattern allowance.

Pattern allowance =>

shrinkage allowance,

machining allowance

Shrinkage allowance: will take care of contractions of a casting which occurs as the metal cools to room temperature.

Liquid Shrinkage: Reduction in volume when the metal changes from liquid state to solid state. Riser which feed the liquid metal to the casting is provided in the mould to compensate for this.

Solid Shrinkage: Reduction in volume caused when metal looses temperature in solid state. Shrinkage allowance is provided on the patterns to account for this. Shrink rule is used to compensate solid shrinkage depending on the material contraction rate.

. The shrinkage allowance depends on the coefficient of thermal expansion of the material (α). A simple relation indicates that higher the value of α, more is the shrinkage allowance.] 3. For a dimension ‘l’, shrinkage allowance is αl (θf –θ0 ). Here θf is the freezing temperature and θ0 is the room temperature.

4. Machining allowance: will take care of the extra material that will be removed to obtain a finished product. In this the rough surface in the cast product will be removed. The machining allowance depends on the size of the casting, material properties, material distortion, finishing accuracy and machining method.

5. Draft allowance: All the surfaces parallel to the direction in which the pattern will be removed are tapered slightly inward to facilitate safe removal of the pattern. This is called ‘draft allowance’. General usage:

6. Core and core print: - Cores are used to make holes, recesses etc. in castings - So where coring is required, provision should be made to support the core inside the mould cavity. Core prints are used to serve this purpose. The core print is an added projection on the pattern and it forms a seat in the mould on which the sand core rests during pouring of the mould. - The core print must be of adequate size and shape so that it can support the weight of the core during the casting operation.

7. Distortion allowance (camber) - Vertical edges will be curved or distorted - This is prevented by shaped pattern converge slightly (inward) so that the casting after distortion will have its sides vertical - The distortion in casting may occur due to internal stresses. These internal stresses are caused on account of unequal cooling of different sections of the casting and hindered contraction. Prevention: - providing sufficient machining allowance to cover the distortion affect - Providing suitable allowance on the pattern, called camber or distortion allowance (inverse reflection)

8. The tapped hole and slot will not be sand cast. They will be made by machining operations. 9. The pattern shown is made in two halves which are located by dowel pins. This is called ‘split pattern’. 10. Pattern material: wood => light, easily workable, minimum tendency for checking and warping

Pattern materials

Patterns for sand castings are subjected to considerable wear and tear due to ramming action that is required and the abrasive action of the sand • Should be impervious to moisture because of changing surroundings

• Made of: wood, metal, plastics, plaster and synthetic materials

• Woods => white pine, sugar pine; The wood should be straight grain, light, easy to work, little tendency to develop crack and warp.

• More durable: Mahogany

• For large castings: metal such as cast iron or aluminium

• When metal pattern are cast from the wooden master pattern, double shrinkage must be provided on the wooden master pattern

• Assume metal pattern is made of aluminium and castings are made of CI, the shrinkage allowance for the wooden master pattern is: 5/32 inch per foot for Al+ 1/8 inch per foot CI = 9/32 inch per foot

Core and core print

Where a core does not extend entirely through the casting, it should be fixed/balanced properly as shown. Too long cores can not be balanced properly. A pattern with a hanging core print is shown for making a piston. The core in the mold acts as a cover for mold cavity and hence cope is not needed. A method for molding two pistons at a time having one balanced core

Using chaplets –

Chaplets are used to support a core and are placed between a core and the mold wall. - As the mold is filled with molten metal, the chaplet prevents the core to float and move upwards dislocating from its position. - The part of chaplet in mold will be fused into the casting. - chaplets not fused properly will create mechanical weakness and mold wall leak. - They are generally made heavier rather than lighter, such that they seldom unite with the surrounding metal. - Tin or copper plated chaplets are used for ferrous castings to avoid rusting

Core making •

Generally Cores are used for making interior surfaces of hollow castings and now-a-days it is used for making exterior surfaces and for other purposes.

• Green sand cores contain ordinary molding sand and dry sand core contains hardened or baked sand.

• Core mix contains clay free silica sand. This is suitably mixed with binders, water and other ingredients to produce a core mix.

• Synthetic core binders have some unusual properties like shorter baking times and excellent collapsibilities which reduces the defect castings.

• Urea formaldehyde binders burn out faster and collapse at lower temperature as compared to phenol formaldehyde binders. Thus urea formaldehyde binders are suitable for use at lower temperature metals like Al, Mg, thin sections of brass, bronze.

• Phenol formaldehyde binders are employed for thick sections of CI, steel castings R.Ganesh Narayanan, IITG Core characteristics Good dry sand cores should have the following characteristics:

1. Good dry strength and hardness after baking

2. Sufficient green strength to retain the shape before baking

3. Refractoriness

4. Surface smoothness

5. Permeability

6. Lowest possible amount of gas created during the pouring of casting Core dryers

• cores must be supported properly in the green state, before they are baked, hardened

. • Curved surfaces of the cores will be flattened if placed on the flat core plates

• Cores should be prevented from sagging and breaking

• Flat surfaces are required for supporting the cores. These are called ‘Core dryers’. They are designed to support the cores.

Melting of metals Gases in metals:

The gases in metal is important in deciding the defect free castings. In metal castings, gases may be mechanically trapped, generated due to variation in their solubility at different temperatures and phases, generated because of chemical reaction. Gases generally present are: hydrogen, nitrogen Hydrogen: Based on the solubility of hydrogen, metals are divided as Endothermic (metals like Al, Mg, Cu, Fe, Ni), Exothermic (like Ti, Zr) The solubility of hydrogen in various metals are shown in figure. Here solubility S is the volume of H2 gas absorbed by 100 g. of metal. The solubility of hydrogen in solid and liquid phases (pressure = 1 atm) at solidus temperature is given in table. Metal Liquid solubility (cc/kg) Solid solubility (cc/kg) Fe 270 70 Mg 260 180 Cu 55 20 s− = ])θ E /(k[Al 7 0.4 S Cexp ES : heat of solution of one mol of hydrogen; sign determines endothermic or exothermic

Pouring, Gating design

A good gating design should ensure proper distribution of molten metal without excessive temperature loss, turbulence, gas entrapping and slags. If the molten metal is poured very slowly, since time taken to fill the mould cavity will become longer, solidification will start even before the mould is completely filled. This can be restricted by using super heated metal, but in this case solubility will be a problem. If the molten metal is poured very faster, it can erode the mould cavity. So gating design is important and it depends on the metal and molten metal composition. For example, aluminium can get oxidized easily. Gating design is classified mainly into two (modified: three) types: Vertical gating, bottom gating, horizontal gating

Vertical gating:

the liquid metal is poured vertically, directly to fill the mould with atmospheric pressure at the base end. Bottom gating: molten metal is poured from top, but filled from bottom to top. This minimizes oxidation and splashing while pouring. Horizontal gating is a modification of bottom gating, in which some horizontal portions are added for good distribution of molten metal and to avoid turbulence

. The energy balance between point 1 and 3 gives, / 2 2 3 gh v t ght= v3 2= Here v3 can be referred as velocity at the sprue base or say gate, vg Continuity equation: Volumetric flow rate, Q = A1v1 = A3v3 Above two equations say that sprue should be tapered.

Pouring basin:

This reduces the eroding force of the liquid metal poured from furnace. This also maintains a constant pouring head. Experience shows that pouring basin depth of 2.5 times the sprue entrance diameter is enough for smooth metal flow. Radius of 25R (mm) is good for smooth entrance of sprue.

Riser design

The riser can be designed as per Chvorinov’s rule mentioned earlier. The following example will illustrate the same. A cylindrical riser must be designed for a sand-casting mold. The casting itself is a steel rectangular plate with dimensions 7.5 cm x12.5 cm x 2.0 cm. Previous observations have indicated that the solidification time for this casting is 1.6 min. The cylinder for the riser will have a diameter-to-height ratio as 1.0. Determine the dimensions of the riser so that its solidification time is 2.0 min. V/A ratio = (7.5 x 1

Sheet Metal Forming Processes

When making sheet metals, however, companies often use one or more of the following forming processes.

1. Curling:- Curling is a sheet metal forming process that’s used to smooth out the otherwise sharp & rugged edges of sheet metal.
2. Bending:- Another common sheet metal forming process is bending. Companies typically perform bending on sheets of metal using either a brake press or a similar machine press.
3. Ironing:-Sheet metal may as well be ironed to achieve a uniform thickness. Most aluminium can, for instance, is made of ironed aluminium.
4. Laser Cutting:- Laser cutting has become an increasingly common sheet metal forming process in recent years. With laser cutting, sheet metals are exposed to a high-powered laser that burns holes in the metal.
5. Hydro forming:- A lesser-known sheet metal forming process is hydro forming. Like deep drawing, hydro forming involves stretching blanks over a die.
6. Punching:-Finally, punching is a sheet metal forming process that involves the use of a punch & dies set to create holes in sheet metal. Sheets metal is placed between the punch & die.

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Sheet Metal Forming

Sheet metal forming is a process where pieces of sheet metal are modified to their geometry rather than removing any materials. The applied process generates a force that stresses the material to deform. This in turn gives the possibility to bend ouch stretch the sheet to a variety of complex shapes.

Forming Metal

Metal forming is a fabrication process that creates structural parts and components out of metal sheets or tubing. A basic metal forming process will bend or deform a metal work piece to a desired geometric shape.

Metal Forming Techniques

Typically, metal forming processes can be classified into two broad groups. One is bulk-forming and the other is sheet metal forming. Bulk deformation refers to the use of raw materials for forming which have a low surface area to volume ratio. Rolling, forging, extrusion, and drawing are bulk forming processes.

Metal Forming

Metal forming is a process where materials are subjected to plastic deformation to obtain the required size, shape, and/or change the physical and chemical properties. Metal forming is divided into two groups, bulk-forming, and sheet forming.

Forming Process

Forming is a mechanical process used in manufacturing industries wherein materials (mostly metals) undergo plastic deformations and acquire required shapes and sizes by application of suitable stresses such as compression, shear, and tensi Forming, also known as “metal forming,” includes a wide range of manufacturing processes in which metal is deformed into a required shape by the application of suitable stresses. To make the metal plastically deformed, forces must be applied that are greater than the yield strength of the metals.

Forming

general, “forming” refers to the act of shaping or creating something. It involves the transformation of a material or substance into a desired shape, structure, or form. For example, in manufacturing, forming may involve processes like casting, forging, molding, or bending, where raw materials are manipulated to obtain specific shapes or products.

In the context of psychology and group dynamics, “forming” is one of the stages in the development of a team or group. It is the initial stage where individuals come together, establish their roles and relationships, and begin to form a cohesive unit. This stage is characterized by orientation, getting to know one another, and setting the foundation for future interactions.

In the context of the Tuckman’s stages of group development model, “forming” is the first stage, followed by storming, norming, and performing. This model describes the natural progression and challenges that groups typically experience as they develop and work towards achieving their goals.

“Forming” can also refer to the process of creating or filling out a form, such as a document or application. It involves providing information, answering questions, and completing the necessary fields or sections.

Forming Process in Sheet Metal

Sheet metal forming includes treatments such as bending, spinning, drawing, or stretching implemented by dies or punching tools. Forming is mostly performed on a press and parts are formed between two dies. Metal Forming Process Metal forming is a primary manufacturing process that includes drawing, forging, rolling, and bending. Ultrasonic metal forming is the application of ultrasonic vibrations to these processes to enhance performance through increased production speeds, less tool wear, reduced forming forces, and better surface finish.The forming process refers to a set of manufacturing techniques used to shape materials into specific geometries or forms. It involves the transformation of raw materials into desired shapes or structures by applying mechanical forces, heat, or a combination of both. The forming process is commonly used in various industries, including manufacturing, construction, automotive, aerospace, and more.

Forming Manufacturing Process

* rolling, where the material passes through a pair of rolls,
* extrusion, where machine push the material through an orifice,
* die forming, where a press stamps the material around or onto a die,
* forging, where localized compressive forces shape the material.

Types of Forming Process

There are four types of forming processes: forging, rolling, extruding, and drawing. I like to refer to these as pounding, rolling, pushing, and pulling. Hopefully, by the end of this section, you will understand why I use those terms. Blacksmiths have been hammering (pounding) metals into shape for some time.

Following Is an Example of Metal Forming Process

Some popular metal forming processes are forging, rolling, wire drawing, extrusion, deep drawing, and bending.

Types of Metal Forming Process

There are several types of metal forming processes, each with its own unique characteristics and applications. Here are some common types of metal forming processes:

* Rolling: Rolling is a process that involves passing a metal through a set of rollers to reduce its thickness or change its shape. It is commonly used to produce sheets, plates, and foils.
* Extrusion: Extrusion is a process where a metal is forced through a die to create a continuous profile with a fixed cross-section. This process is commonly used to produce long, cylindrical shapes such as rods, tubes, and structural components.
* Forging: Forging involves shaping a metal by applying compressive forces using hammers, presses, or dies. This process can be done either through hot forging (heating the metal) or cold forging (forming at room temperature). Forging is used to produce strong and durable components like gears, crankshafts, and connecting rods.
* Stamping: Stamping is a process where a flat sheet of metal is formed into a specific shape or contour using a press and a die. It is commonly used in mass production to create parts such as car body panels, appliance casings, and metal furniture.
* Drawing: Drawing is a metal forming process where a flat sheet or wire is pulled through a die to reduce its cross-section while increasing its length. It is commonly used to produce wires, tubes, and seamless pipes.
* Bending: Bending involves deforming a metal sheet or bar to form angles or curves. It is often used to create components such as brackets, frames, and enclosures.
* Deep Drawing: Deep drawing is a specialized form of sheet metal forming where a flat sheet is drawn into a three-dimensional shape, such as a cup or container, using a die and a punch.

Example of Metal Forming Process

Some of the more common processes are bending, stretching, deep drawing, and roll forming. Bending is a flexible metal forming process, bending utilizes a brake press or similar type of press machine. The metal sheet is formed by placing it over a die block that punch-presses the material.

Forming Manufacturing

Forming is a mechanical process used in manufacturing industries wherein materials (mostly metals) undergo plastic deformations and acquire required shapes and sizes by application of suitable stresses such as compression, shear and tension.

Forming in Manufacturing Process

In metalworking, forming is the fashioning of metal parts and objects through mechanical deformation; the work piece is reshaped without adding or removing material, and its mass remains unchanged.

Metal Working Processes

* Forging. Forging is a common practice for intricate metalwork.
* Casting. Whereas forging metal is something that’s done by hand, casting is the process of pouring molten metal into a mould.
* Drawing.
* Forming.
* Machining.
* Extrusion.
* Cutting.
* Punching.

Metal Manufacturing Processes

Metal manufacturing processes encompass a wide range of techniques used to produce metal components, structures, or products. Here are some common metal manufacturing processes:

* Casting: Casting involves pouring molten metal into a mold and allowing it to solidify to obtain a desired shape. It is used to produce complex shapes or parts with intricate details. Casting processes include sand casting, investment casting, die casting, and continuous casting.
* Machining: Machining is a subtractive manufacturing process that involves removing material from a metal workpiece using cutting tools. Common machining processes include milling, turning, drilling, grinding, and threading. These processes are used to achieve precise dimensions, surface finishes, and complex shapes.
* Forming: Forming processes reshape metal materials without removing material. This includes techniques such as rolling, extrusion, forging, stamping, bending, and deep drawing, which were discussed in the previous response.
* Welding: Welding joins metal parts together by melting and fusing them. It is commonly used in structural fabrication, construction, and automotive industries. Welding processes include arc welding, gas welding, resistance welding, and laser welding.
* Powder Metallurgy: Powder metallurgy involves compacting fine metal powders into a desired shape and then sintering them to bond the particles. It is used to produce complex shapes, porous structures, and components with specific properties. Powder metallurgy processes include powder compaction, sintering, and post-processing operations.
* Additive Manufacturing (3D Printing): Additive manufacturing processes build metal objects layer by layer using computer-controlled systems. Metal 3D printing enables the production of intricate geometries, customization, and reduced material waste. Common metal additive manufacturing techniques include selective laser melting (SLM), electron beam melting (EBM), and binder jetting.
* Heat Treatment: Heat treatment processes involve subjecting metal parts to controlled heating and cooling cycles to alter their properties. This includes processes like annealing, quenching, tempering, and case hardening. Heat treatment enhances metal strength, hardness, toughness, and ductility.

## Introduction

“Hot working and cold working” are to be done for the process of “metal formation”. Through the “mechanical deformation process” “metal formation” of objects and parts is to take place. “Hot working” has to be carried out in general at the temperature above “recrystallization temperature”. But carried out below the “Melting point” of metal. Whereas “cold working process” has to be carried out below the “recrystallization temperature”.

### “Cold working”

“Cold working” is a process executed for the “metal formation process”. According to its name, this metal formation has to be executed below “recrystallization temperature”.  At room temperature hot working is to be done. In this case, expected recovery of metal cannot be gained. This process contrasts with the “hot working” process as it disfigures the gained structure and is unable to provide satisfaction in decreasing size. Unlike “hot working”, in “cold working process”, much more pressure needs to be applied. If metal is more ductile or flexible, then the process has to be done through a “cold working process”. “Cold working processes” cause “strain hardening”, “grain deformation”, and “crystal structure”. “Cold working process” is to be done for reducing flexibility of metal.

### Cold working processes

“Cold working process” is also known as “cold rolling process”. In the cold working process, at first, the material is heated and then the “plastic deformation process” is applied. After the “cold working process” is done, the grains are stretched in materials that’s why this process is carried out below the temperature of “recrystallization”. During the “cold working process” takes place, residual stresses started developing in the metal. For example, during the bending operation of metal, the upper portion of the bent part goes through tension, and the lower part experiences compression. Therefore, the upper portion experiences “tensile stress” and the lower portion experiences “compressive stress”. After load removal, in such a case, the metal will remain in the same structure as it was but residual stresses started developing in the bending part. The upper part of the metal goes through residual compression and the lower part experiences residual tension. In the case of “cold working process,” this residual stress takes place in material. Due to the “higher deformation process” taking place in this case stress needed for deformation is comparatively high. In the “plastic deformation process”, the force has to be applied in high proportion. As this process is carried out below “recrystallization temperature”, more forces are required. “Cold working processes” lead to distortion of grains. After executing the “cold working process”, the grains are elongated. It means distortion of grains takes place. In “cold working process”, metal gets work hardened. Hardening is a “metallurgical metalworking process” used for increasing the hardness of a metal. That means after “cold working process” an increase of metal size can be observed after hardening. Because of this process ultimate “tensile strength” and “fatigue strength” increases but “corrosion resistance” decreases. Sothis process is done under “recrystallization temperature” then the grains get distorted and elongated and due to which these properties increase. But due to this distortion, the chance of getting more corrosion increases after a “cold working process” is applied.

### During cold working process

During “cold working processes” impact strength and elongation of the material reduces. “Impact strength” is defined as the significant energy that a material can resist until it applies on it.“Impact strength” can be measured by “Charpy test configuration” and “Izod test configuration”. Due to the cold working process, worked parts carry a better surface finish. There is less chance of oxidation and scaling as the whole process is carried out below “recrystallization temperature”. In “cold working process”, “superior dimensional accuracy” can be obtained. Close dimensions; corrosion can be obtained through this process. This process is applicable where “work hardening”needs to be performed. It means whenever hardness of the material needs to be increased, “cold working process” is under consideration.

### “Hot working”

“Hot working” is performed above the temperature of “recrystallization”. Yet this process is said to be accomplished above  “melting point” for recovery and deformation both can be achieved at the same time. After applying heat to the “metal-plastic deformation “the structure of the metal changes at the end. During this development, no residual stress takes place. Due to increased deformation takes place in this process the temperature used; the stress needed for deformation is less. In this case, very less force is required to be applied to metal. Then the metal gets plastically deformed. Due to “hot working process: metal grains are refined which results in properties of metal.

#### Conclusion

The conclusion is drawn based on the fact that both processes are used for metal formation. For “hot working processes”, large deformations can be repeated continuously because the metal remains flexible and soft. After a hot working process, the hardness of material cannot be controlled. Hardness is generally lower in cold working processes and the needed energy for deformation is high. Cold working process can help in achieving ideal metal qualities.

# Types Of Rolling Process In Manufacturing

Rolling is the most important and widely used metal forming process because of its lower cost and higher productivity. The rolling process is best defined as the shaping of metals into semi-finished or finished forms by passing between rollers rotating in opposite direction. Just like any other metal forming process, rolling works in the same way. The deformation takes place when a compressive force is applied by a set of rolls on ingot or any other product like billets, blooms, sheets, slabs, plates, strips, etc. This deformation decreases the cross-section area of the metal and converts it into the required shape. The main purpose of rolling is to decrease the thickness of the metal. Steel, magnesium, aluminium, copper, and their alloys are the materials commonly rolled. As a result of the friction between the rolls and the metal surface, the metal is subjected to high compressive stresses. High production rate, grain structure, and surface-finish are obtained, which makes it a most suitable metal forming process for large length cross-section work pieces like plates and sheets of steel and aluminium for other works and structure. However, the high set up cost of the [rolling machine](https://plantautomation-technology.com/pat/rolling-machine) makes it an alternative process.

The rolling process is done both hot and cold, which is accomplished in rolling mills. A rolling mill is a complex machine having two or more supporting rollers, working rollers, drive motor, roll stands, working rollers, coupling gear, flywheel, etc. According to the requirement of the process and technical issues, these rolling machines are available in different shapes and sizes. Each [rolling mill](https://plantautomation-technology.com/pat/rolling-mill) consists of a minimum of two rolls. As per the process requirement, these numbers can extend even. Depending upon the shape of the rolled product, the rollers may be grooved or plain. The shape of the metal changes gradually during the period in which it's in contact with the two rollers. Compared to forging, rolling is a more economical method of deformation when metal is required in long lengths of uniform cross-section. The hot rolling process occurs with the initial breakdown of ingots into billets and blooms. This is followed by further hot rolling into the sheet, plate, bar, rod, rail, and pipe. It's done at the above recrystallization temperature and used for large deformations. Hot rolling gives residual stresses free product, but due to scale formation, it gives poor dimension accuracy and surface finish. A major role in the industry is played by the cold-rolling of metals by providing sheet, strip, foil with high mechanical strength, good surface finish, along with dimension accuracy. The cold rolling which is done to get the final product is done at below recrystallization temperature. We shall discuss here the types of rolling process and its applications in the manufacturing industry.

**Types of Rolling**

The types of the rolling process can be classified into the following ways-

* Thread/Gear Rolling
* Shape Rolling
* Ring Rolling
* Tube Piercing
* Transverse Rolling/Roll Forging
* Skew Rolling
* Roll Bending
* Flat Rolling
* Controlled Rolling

**A) Thread/Gear Rolling**

The thread/[gear rolling](https://plantautomation-technology.com/pat/gear-rolling) is a cold-forming type of rolling process used to cut gear or threads on a cylindrical blank. In this process, the threaded dies are fitted on cylindrical rollers of the rolling machine. The cylindrical blank presses the threaded roller and roll against the faces, which displace the material and form threads on the cylindrical blank. The thread-rolling process has the benefit of generating threads with high strength (due to cold working), without any material loss (scrap) and good surface finish. The thread/gear rolling is used for the production of screws, bolts, etc. in mass quantities.

**B) Shape Rolling/Structural Shape Rolling/Profile Rolling**

The shape rolling is used to cut different shapes on the metal work piece. It does not involve any significant change in thickness. It’s a special type of cold rolling that is suitable for producing moulded sections such as irregular shaped channels and trim. It's used to roll construction shapes such as I-beams, L-beams, and U channels, rails for railroad tracks, and round and square bars and rods, etc. The applications of shape rolling are -

* Construction materials
* Ceiling panel
* Metal furniture
* Household appliances
* Partition beam
* Steel pipe
* Automotive parts
* Roofing panels
* Door and window frames and other metal products

**C) Ring Rolling**

Ring rolling is a type of hot rolling that increases the diameter of a ring. Two rollers i.e. main and idler are arranged and rotated in the same direction to each other in this process. Due to the rotation of the roller, the ring rotates and the rollers then start moving close to each other, with a decrease in ring thickness and hence this results in an increase in its diameter. To maintain the height of the ring, a pair of edge rollers are used, which does not allow metal flow in the direction of height. This process gives material finish and high accuracy. Common applications of ring rolling include -

* Large bearings
* Turbines
* Airplanes
* Railway tyres
* Gears
* Rockets
* Pipes
* Pressure vessels

**D) Tube Piercing**

[Tube piercing](https://plantautomation-technology.com/pat/tube-piercing)is another rolling process in which you can find a stationary mandrel at the canter of tube and cavity form, due to tensile stress in a cylindrical rod when subjected to external compressive stress. Two rolls are rotated in the opposite direction in this process which compresses the tube and feeds it against mandrel which creates a hollow cavity in it. This process is used to make seamless hollow tubes of a thick wall.

**E) Transverse Rolling/**[Roll Forging](https://plantautomation-technology.com/pat/roll-forging)

Also called cross rolling, which is used to produce table knives, leaf springs, tapered shafts, and hand tools. In this process, both rollers rotate in the same direction and the heated bar is cut to length and is fed transversely between rolls. Usually, circular wedge rolls are used in the transverse rolling.

**F) Skew Rolling**

This is a process similar to roll forging. Typically used for making ball bearings. In this process, round wire or bar is fed directly into specially designed rollers which continuously form spherical balls by rolling action. Used for the mass production of small size spherical balls.

**G) Roll Bending**

In [**roll bending**](https://plantautomation-technology.com/pat/roll-bending), a cylindrical shaped product is produced from plate or steel metals. The rolls change shape during rolling because of the forces acting on them, which tends to bend the elasticity of the rolls during rolling. If the elastic modulus of the roll material is high, then the roll deflection would be smaller. Compared to its edges, the rolled strip tends to be thicker at the centre. We can avoid this problem by grinding the rolls in such a way that their diameter at the canter is slightly larger than at their edges.

**H) Flat Rolling**

This is the most basic form of rolling in which the starting and end material both have a rectangular cross-section. The material is fed in between two rollers that rotate in opposite directions. The two rollers in flat rolling are called working rolls. The gap between the two rolls is less than the thickness of the starting material, which causes the deformity of it. The material, which is pushed through due to the friction at the interface between the material and the rolls, even elongates due to the decrease in material thickness. However, the friction between the rolls limits the amount of deformation possible in a single pass. The rolls just slip over the material and do not draw it in if the change in thickness is too great.

**I) Controlled Rolling**

It’s a type of thermo-mechanical processing which combines heat treating and controlled deformation. The work piece is brought above the recrystallization temperature with the help of heat, which performs the heat treatments to avoid any subsequent heat treating. Controlling the nature, size, and distribution of various transformation products; production of a fine grain structure; controlling the toughness; inducing precipitation hardening are some of the types of heat treatments included. The entire process must be closely monitored and controlled, to achieve this. The deformation levels, cool-down conditions, starting material composition and structure, the temperature at various stages are the common variables in controlled rolling. Better mechanical properties and energy savings are the benefits of controlled rolling.

Extrusion

Extrusion is a process to create a specific shaped object by pushing a material through a die. The die is a little disk with an opening of a specific size and shape. When the material is put under pressure through the die, it will create a desired shape. Often the die is made of steel. A simple example of extrusion is the toys used when playing with play dough. The items that play dough is pushed through, in order to create a specific shape, is the die; and the process is called extrusion. In order for the die to create the desired shape, the material needs to be pushed through with force. Sometimes pressure is utilized as well.

Many foods found on grocery store shelves are made using extrusion, including:

* Most cereals, such as Cheerios
* Puffed snack foods, such as Cheetos
* Pasta, such as macaroni or penne

Extrusion is also used to make many parts such as:

* Pipes
* Window frames
* Shower stalls
* Windshield wipers
* Plastic bags

There are many different types of extrusion. The major categories are based on the main type of materials used: metal, plastic, and food. Each of these categories have sub-categories.

Plastic Extrusion Types

The different types of plastic extrusion can create very different final products. These types include:

## Extrusion Process

Extrusion occurs by first preparing the material to be extruded. This may mean preparing dough, melting metal or plastic, or simply preparing a hopper of the material, such as pouring in plastic pieces. Then the material goes through the extruder. The exact parts of the extruder differ based on the type of extruder, but generally the parts consist of:

* Container for the material
* A ram or punch to push the material through
* The die to create the final shape

Metal drawing is a manufacturing process that forms metal work stock by reducing its cross section. This is accomplished by forcing the work through a mold, (die), of smaller cross sectional area than the work. This process is very similar to metal extrusion, the difference being in the application of force. In extrusion the work is pushed through the die opening, where in drawing it is pulled through. The basic concept of metal drawing is illustrated in the following figure. Many of the same manufacturing factors of metal extrusion are also present in metal drawing. Similar to extrusion, the die angle, amount of area reduction and geometry of cross sections are all essential considerations. Friction and its effects on metal flow should be controlled. There is a fundamental difference between metal extrusion and metal drawing practice, based on the fundamental difference between the two processes. Metal extrusion can provide tremendous reductions in cross sectional area by pushing the material through the mold. In metal drawing the amount of cross sectional reduction is much more limited, by the fact that the metal is pulled through. As in extrusion, the greater the reduction in cross sectional area the greater the force required to form the work. When the force needed to pull a work piece through a mold exceeds the yield strength of the work, it will begin to yield. Yielding of the work in this manner is not desirable in metal drawing manufacture.

In theory the highest possible amount of area reduction, based on preventing yielding of the work, is usually about 63%. In industrial manufacturing practice, area reductions generally range from 15% to 45%. In order to obtain greater reductions in cross sectional area, the work may be drawn through two or more drawing die in series. Metal drawing often involves round profiles. The term draft is used to denote the reduction in diameter of drawn round cross sections. In addition to the specific cross sectional reduction, the work material and the speed at which the product is drawn are also critical operational factors when manufacturing by metal drawing.

## Metal Drawing Process

The metal drawing process in manufacturing industry is usually performed cold. Cold working will impart the drawn product with accurate tolerances, favorable grain structure, improved material properties and good surface finish. Preparation of the work, prior to drawing, is an important part of the operation. The work is sometimes annealed first, to recover the material from existing stresses. Next the work surfaces are cleaned. Common industrial practice for cleaning metal stock includes shot blasting or submersion in some, (typically acidic), solution. The work is then washed to remove any solution, it may also be dried at a low temperature. After the cleaning phase the stock may be conditioned, this can involve the application of a variety of different chemical solutions to the surface of the work. Specific chemicals used depend on the manufacturing situation and the work material. The main reason for these conditioning agents is to help the work surface hold the lubrication necessary for the process.

Once prepared, the work piece is pointed at one end, allowing that end to be inserted through the die. This end is then mechanically gripped so that the rest of the work can be pulled through. At certain points in the process, the drawn product may require straightening. Straightening rolls can be employed as part of the manufacturing process. Metal drawing can be either a discrete or continuous operation and can be very economically efficient for certain applications. In commercial industry, this process provides stock material for machining operations and for the manufacture of such items as fences, coat hangers, nails, screws and bolts. Metal wire drawing plays a huge roll in the manufacturing industry in the production of cable and electrical wire.

**Drawing Dies**

Metal drawing dies, in manufacturing industry, are usually made of cemented carbides or tool steels. Mandrels for tube drawing are often made of similar materials as the die. Occasionally diamond die are employed to form extremely thin wire. As the work transverses the mold it passes through different sections. The die's first section is a bell curved opening. This area does not contact the work, but helps filter lubricant into the mold and allows for adequate entry of the work into the mold without damage from die edges. Next, the forming of the work occurs in the approach section.

The approach angles down the cross sectional area, connecting with the next section, the bearing surface. Bearing surface, also known as land, holds the precise geometric cross section for a length of the draw. This acts as a sizing operation, ensuring tight tolerances. The last section is the exit zone, this is a steeply angled section similar to the entry zone. Exit zones are used to protect drawn work from the edges of the die.

## Defects In Metal Drawing

Defects that occur in metal drawing manufacture are similar to those that occur while manufacturing by extrusion. Controlling metal flow is essential in preventing defects.

Mold characteristics and friction play a critical roll in the process.  
  
Internal Cracking: Internal breakage may occur in drawn products, particularly along the centerline.

This is due to improper metal flow creating high internal stresses. Causes may be high die angles or low friction.  
  
Surface Defect: A wide variety of surface defects can be observed in metal drawing manufacture. Seams, scratches and cracks are all possible defects on the surface of drawn product. Excessive force on the surface of the work during the drawing operation, (such as from friction), can be the cause of breakage. Also, many metal drawing operations form at very high speeds, sufficiently designed entry and exit zones need to be provided in order to avoid damage to the work material from the die. For more detailed information on internal breakage and surface defects see [extrusion defects](https://thelibraryofmanufacturing.com/extrusion.html).

# Introduction to Powder Metallurgy

What is powder metallurgy? Powder metallurgy is a metal-forming process performed by heating compacted metal powders to just below their melting points. Although the process has existed for more than 100 years, over the past quarter century it has become widely recognized as a superior way of producing high-quality parts for a variety of important applications. This success is due to the advantages the process offers over other metal forming technologies such as forging and metal casting, advantages in material utilization, shape complexity, near-net-shape dimensional control, among others. These, in turn, contribute to sustainability, making powder metallurgy a recognized green technology.

The images in Figure 1 include a complex planetary carrier for a four-wheel drive torque transfer system, a helical gear and blades of stainless steel used in laparoscopic surgical scissors, a manifold weighing over 6.5 tons used on an offshore oil platform, and a steel connecting rod used in V-8 engines. All of these components were made using powder metallurgy.

## Powder Metallurgy Technologies

In reality, powder metallurgy comprises several different technologies for fabricating semi-dense and fully dense components. The [conventional powder metallurgy process](https://www.mpif.org/IntrotoPM/Processes/ConventionalPowderMetallurgy.aspx)**,** referred to as press-and-sinter, was used to produce the planetary carrier shown here. The surgical scissor parts were formed through the [metal injection moulding](https://www.mpif.org/IntrotoPM/Processes/MetalInjectionMolding.aspx) (MIM) process, the manifold was manufactured through hot [is static pressing](https://www.mpif.org/IntrotoPM/Processes/IsostaticPressing.aspx) (HIP), while the connecting rod was produced using powder forging (PF). Meanwhile, new to the scene, [metal additive manufacturing](https://www.mpif.org/IntrotoPM/Processes/MetalAdditiveManufacturing.aspx) (AM) is gaining popularity.

Using many of these PM processing techniques, as well as other processes such as spray forming, roll compaction, rapid solidification, and others, components are also produced today from particulate materials other than metal powders. Today's advanced materials are seldom made of metals and metallic alloys alone, often incorporating ceramics, ceramic fibbers, and intermetallic compounds. These include:

* cermets
* intermetallic compounds
* metal matrix composites
* nanostructured materials
* high-speed steels

Powder metallurgy is an integral part of our lives.

**Definition of Casting Defects :**It is an unwanted irregularities that appear in the casting during metal casting process. There is various reason or sources which is responsible for the defects in the cast metal. Here in this blog we will discuss all the major types of casting defects. Some of the defects produced may be neglected or tolerated and some are not acceptable, it must be eliminated for better functioning of the parts.

**Types**

**1. Gas Porosity:**Blowholes, open holes, pinholes  
**2. Shrinkage defects:** shrinkage cavity  
**3. Mould material defects:** Cut and washes, swell, drops, metal penetration, rat tail  
**4. Pouring metal defects:** Cold shut, misrun, slag inclusion  
**5. Metallurgical defects:** Hot tears, hot spot.

**1. Shift or Mismatch:**The defect caused due to misalignment of upper and lower part of the casting and misplacement of the core at parting line.

**Cause:**   
**(1)** Improper alignment of upper and lower part during mould preparation.  
**(2)** Misalignment of flask (a flask is type of tool which is used to contain a mould in metal casting. it may be square, round, rectangular or of any convenient shape.)

**Remedies**

**(i)** Proper alignment of the pattern or die part, moulding boxes.  
**(ii)** Correct mountings of pattern on pattern plates.  
**(iii)**Check the alignment of flask.

**2. Swell:**   
It is the enlargement of the mould cavity because of the molten metal pressure, which results in localised or overall enlargement of the casting.

**Causes**   
**(i)**  Defective or improper ramming of the mould.

**Remedies**   
**(i)** The sand should be rammed properly and evenly.

**3. Blowholes:**  
When gases entrapped on the surface of the casting due to solidifying metal, a rounded or oval cavity is formed called as blowholes. These defects are always present in the cope part of the mould.

**Causes :**  
**(i)** Excessive moisture in the sand.  
**(ii)** Low Permeability of the sand.  
**(iii)** Sand grains are too fine.  
**(iv)** Too hard rammed sand.  
**(v)**Insufficient venting is provided.

**Remedies :**  
**(i)** the moisture content in the sand must be controlled and kept at desired level.  
**(ii)** High permeability sand should be used.  
**(iii)** Sand of appropriate grain size should be used.  
**(iv)** Sufficient ramming should be done.  
**(v)** Adequate venting facility should be provided.

**4. Drop:**  
Drop defect occurs when there is cracking on the upper surface of the sand and sand pieces fall into the molten metal.

**Causes :**  
**(i)** Soft ramming and low strength of sand.  
**(ii)** Insufficient fluxing of molten metal. Fluxing means addition of a substance in molten metal to remove impurities. After fluxing the impurities from the molten metal can be easily removed.  
**(iii)** Insufficient reinforcement of sand projections in the cope.

**Remedies :**  
**(i)** Sand of high strength should be used with proper ramming (neither too hard nor soft).  
**(ii)** There should be proper fluxing of molten metal, so the impurities present in molten metal is removed easily before pouring it into the mould.  
**(iii)** Sufficient reinforcement of the sand projections in the cope.

**5. Metal Penetration**  
these casting defects appear as an uneven and rough surface of the casting. When the size of sand grains is large, the molten fuses into the sand and solidifies giving us metal penetration defect.

**Causes :**  
**(i)** It is caused due to low strength, large grain size, high permeability and soft ramming of sand. Because of this the molten metal penetrates in the moulding sand and we get rough or uneven casting surface.

**Remedies :**  
**(ii)** this defect can be eliminated by using high strength, small grain size, low permeability and soft ramming of sand.

**6. Pinholes:**  
They are very small holes of about 2 mm in size which appears on the surface of the casting. This defect happens because of the dissolution of the hydrogen gases in the molten metal. When the molten metal is poured in the mould cavity and as it starts to solidify, the solubility of the hydrogen gas decreases and it starts escaping out the molten metal leaves behind small number of holes called as pinholes.

**Causes :**  
**(i)** Use of high moisture content sand.  
**(ii)** Absorption of hydrogen or carbon monoxide gas by molten metal.  
**(iii)** Pouring of steel from wet ladles or not sufficiently gasified.

**Remedies :**  
**(i)** By reducing the moisture content of the moulding sand.  
**(ii)** Good fluxing and melting practices should be used.  
**(iii)** Increasing permeability of the sand.  
**(iv)** By doing rapid rate of solidification.

**7. Shrinkage Cavity**  
The formation of cavity in the casting due to volumetric contraction is called as shrinkage cavity.

**Causes :**  
**(i)** Uneven or uncontrolled solidification of molten metal.  
**(ii)** Pouring temperature is too high.

**Remedies :**  
**(i)**this defect can be removed by applying principle of directional solidification in mold design.  
**(ii)** Wise use of chills (a chill is an object which is used to promote solidification in a specific portion of a metal casting) and padding.

**8. Cold Shut**  
It is a type of surface defects and a line on the surface can be seen. When the molten metal enters into the mould from two gates and when these two streams of molten metal meet at a junction with low temperatures than they do not fuse with each other and solidifies creating a cold shut (appear as line on the casting). It looks like a crack with round edge.

**Causes:**  
**(i)** Poor gating system  
**(ii)** Low melting temperature  
**(iii)** Lack of fluidity

**Remedies:**  
**(i)** Improved gating system.  
**(ii)** Proper pouring temperature.

**9. Misrun**  
When the molten metal solidifies before completely filling the mold cavity and leaves a space in the mould called as misrun.

**Causes:**  
**(i)** Low fluidity of the molten metal.  
**(ii)** Low temperature of the molten metal which decreases its fluidity.  
**(iii)** Too thin section and improper gating system.

**Remedies**   
**(i)** Increasing the pouring temperature of the molten metal increases the fluidity.  
**(ii)**Proper gating system   
**(iii)** Too thin section is avoided.

**10. Slag Inclusion**  
this defect is caused when the molten metal containing slag particles is poured in the mold cavity and it gets solidifies.

**Causes :**  
**(i)** the presence of slag in the molten metal

**Remedies :**  
**(i)** Remove slag particles from the molten metal before pouring it into the mold cavity.

**11. Hot Tears or Hot Cracks**  
when the metal is hot it is weak and the residual stress (tensile) in the material cause the casting fails as the molten metal cools down. The failure of casting in this case is looks like cracks and called as hot tears or hot cracking.

**Causes :**  
**(i)** Improper mould design.

**Remedies:**  
**(i)**Proper mould design can easily eliminate these types of casting defects.  
**(ii)**Elimination of residual stress from the material of the casting.

**12. Hot Spot or Hard Spot:**  
Hot spot defects occur when an area on the casting cools more rapidly than the surrounding materials. Hot spot are areas on the casting which is harder than the surrounding area. It is also called as hard spot.

**Causes :**  
**(i)** The rapid cooling an area of the casting than the surrounding materials causes this defect.

**Remedies :**  
**(i)** This defect can be avoided by using proper cooling practice.  
**(ii)** By changing the chemical composition of the metal.

**13. Sand Holes**  
It is the holes created on the external surface or inside the casting. It occurs when loose sand washes into the mould cavity and fuses into the interior of the casting or rapid pouring of the molten metal.

**Causes:**  
**(i)** Loose ramming of the sand.  
**(ii)** Rapid pouring of the molten metal into the mould results in wash away of sand from the mould and a hole is created.  
**(iii)** Improper cleaning of the mould cavity.

**Remedies:**  
**(i)** Proper ramming of the sand.  
**(ii)** Molten metal should be poured carefully in the mould.  
**(iii)** Proper cleaning of the molten cavity eliminates sand holes.

**14. Dirt**  
the embedding of particles of dust and sand in the casting surface, results in dirt defect.

**Causes:**  
**(i)** Cursing of mould due to improper handling and Sand wash (A sloping surface of sand that spread out by stream of molten metal).  
**(ii)** Presence of slag particles in the molten metal.

**Remedies:**  
**(i)** Proper handling of the mould to avoid crushing.  
**(ii)** Sufficient fluxing should be done to remove slag impurities from molten metal.

**15. Honeycombing or Sponginess**  
It is an external defect in which there is a number of small cavities in close proximity present in the metal casting.

**Causes:**  
**(i)** It is caused due to dirt and scurf held mechanically in the suspension of the molten metal.  
**(ii)** Due to imperfect skimming in the ladle.

**Remedies:**  
**(i)** Prevent the entry of dirt and scurf in the molten metal.  
**(ii)** Prevent sand wash.  
**(iii)** Remove slag materials from the molten metal by proper skimming in the ladle.

**16. War page:**  
It is an accidental and unwanted deformation in the casting that happens during or after solidification. Due to this defect, the dimension of the final product changes.

**Causes:**  
**(i)** Due to different rates of solidification of different sections. This induces stresses in adjoining walls and result in war page.  
**(ii)** Large and flat sections or intersecting section such as ribs are more prone to these casting defects.

**Remedies**   
**(i)** It can be prevented by producing large areas with wavy, corrugated construction, or add sufficient rib-like shape, to provide equal cooling rates in all areas.  
**(ii)** Proper casting designs can reduce these defects more efficiently.

**17. Fins**  
A thin projection of metal, not considered as a part of casting is called as fins or fin. It is usually occurs at the parting of the mould or core section.

**Causes:**  
**(i)** Incorrect assembling of mould and cores.  
**(ii)** Insufficient weight of the mould or improper clamping of the flask may produce the fins.

**Remedies:**  
**(i)** Correct assembly of the mould and cores.  
**(ii)** There should be sufficient weight on the top part of the mould so that the two parts fit together tightly.

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