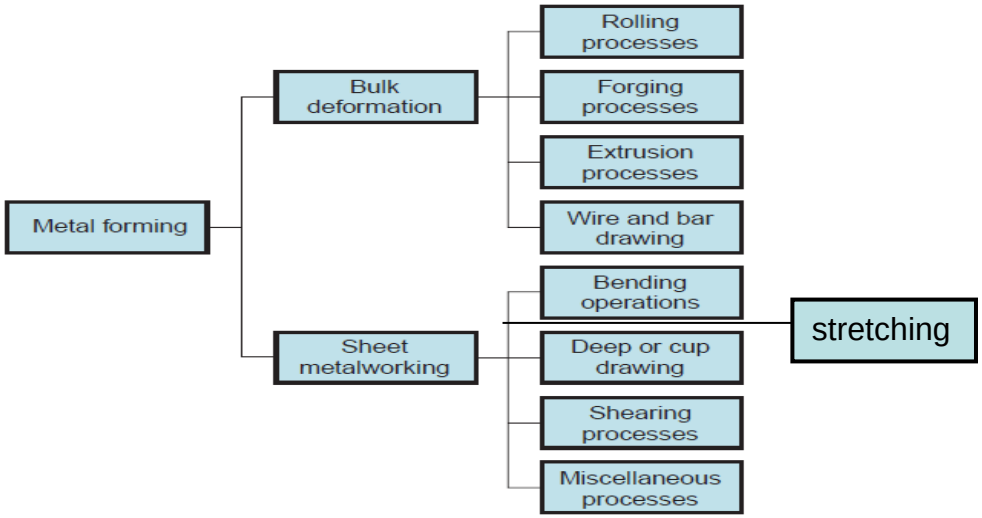
Metal forming processes

Metal forming: Large set of manufacturing processes in which the material is deformed plastically to take the shape of the die geometry. The tools used for such deformation are called die, punch etc. depending on the type of process.

Plastic deformation: Stresses beyond yield strength of the workpiece material is required.

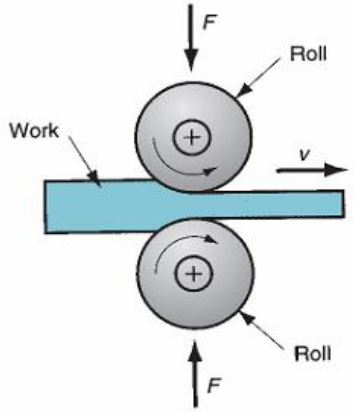
Categories: Bulk metal forming, Sheet metal forming



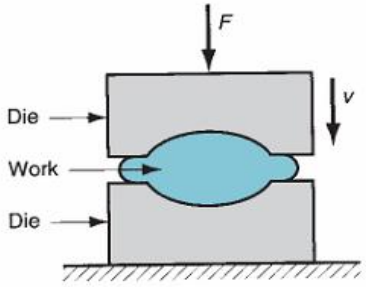
General classification of metal forming processes

M.P. Groover, *Fundamental of modern manufacturing Materials, Processes and systems*, 4ed

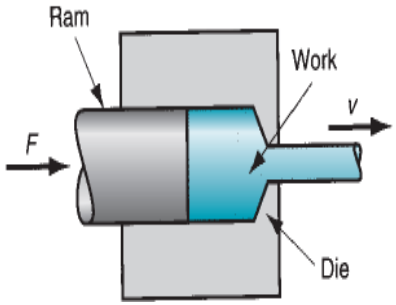
Classification of basic bulk forming processes



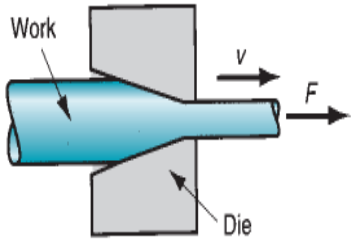
Rolling



Forging



Extrusion



Wire drawing

Bulk forming: It is a severe deformation process resulting in massive shape change. The surface area-to-volume of the work is relatively small. Mostly done in hot working conditions.

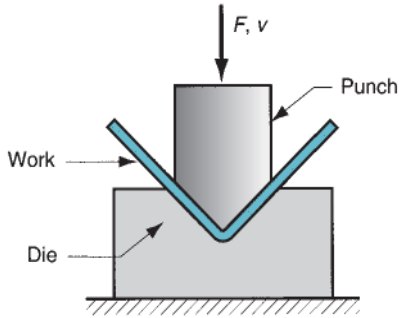
Rolling: In this process, the workpiece in the form of slab or plate is compressed between two rotating rolls in the thickness direction, so that the thickness is reduced. The rotating rolls draw the slab into the gap and compresses it. The final product is in the form of sheet.

Forging: The workpiece is compressed between two dies containing shaped contours. The die shapes are imparted into the final part.

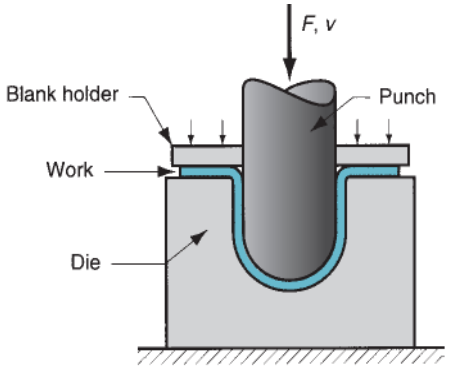
Extrusion: In this, the workpiece is compressed or pushed into the die opening to take the shape of the die hole as its cross section.

Wire or rod drawing: similar to extrusion, except that the workpiece is pulled through the die opening to take the cross-section.

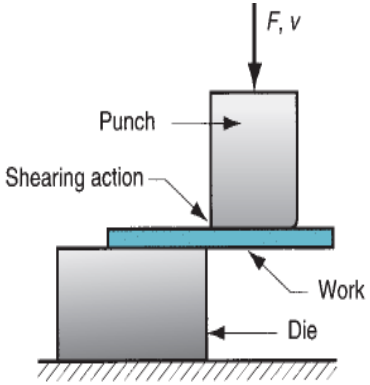
Classification of basic sheet forming processes

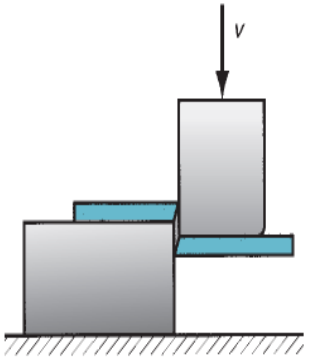


Bending



Deep drawing





shearing

Sheet forming: Sheet metal forming involves forming and cutting operations performed on metal sheets, strips, and coils. The surface area-to-volume ratio of the starting metal is relatively high. Tools include punch, die that are used to deform the sheets.

Bending: In this, the sheet material is strained by punch to give a bend shape (angle shape) usually in a straight axis.

Deep (or cup) drawing: In this operation, forming of a flat metal sheet into a hollow or concave shape like a cup, is performed by stretching the metal in some regions. A blank-holder is used to clamp the blank on the die, while the punch pushes into the sheet metal. The sheet is drawn into the die hole taking the shape of the cavity.

Shearing: This is nothing but cutting of sheets by shearing action.

Cold working, warm working, hot working

Cold working: Generally done at room temperature or slightly above RT.

Advantages compared to hot forming:
(1) closer tolerances can be achieved; (2) good surface finish; (3) because of strain hardening, higher strength and hardness is seen in part; (4) grain flow during deformation provides the opportunity for desirable directional properties; (5) since no heating of the work is involved, furnace, fuel, electricity costs are minimized, (6) Machining requirements are minimum resulting in possibility of near net shaped forming.
Disadvantages: (1) higher forces and power are required; (2) strain hardening of the work metal limit the amount of forming that can be done, (3) sometimes cold forming-annealing-cold forming cycle should be followed, (4) the work piece is not ductile enough to be cold worked.

Warm working: In this case, forming is performed at temperatures just above room temperature but below the recrystallization temperature. The working temperature is taken to be 0.3 T_m where T_m is the melting point of the workpiece.
Advantages: (1) enhanced plastic deformation properties, (2) lower forces required, (3) intricate work geometries possible, (4) annealing stages can be reduced.

Hot working: Involves deformation above recrystallization temperature, between $0.5T_m$ to $0.75T_m$.

Advantages: (1) significant plastic deformation can be given to the sample, (2) significant change in workpiece shape, (3) lower forces are required, (4) materials with premature failure can be hot formed, (5) absence of strengthening due to work hardening.
Disadvantages: (1) shorter tool life, (2) poor surface finish, (3) lower dimensional accuracy, (4) sample surface oxidation

1. Definitions and classification of Metal forming processes

1.1 Introduction:

Metal forming is a very important manufacturing operation. It enjoys industrial importance among various production operations due to its advantages such as cost effectiveness, enhanced mechanical properties, flexible operations, higher productivity, considerable material saving.

The objects and articles that we use in our daily life are man-made, engineered parts, which are obtained from some raw material through some manufacturing process. All these objects are made of a number of small components assembled into finished product. The pen that we use for writing, for example is made of several small parts, assembled together. An automobile is supposed to be an assembly of more than 15000 parts, produced through various manufacturing operations.

Manufacturing of finished parts and components from raw materials is one of the most important steps in production.

Production encompasses all types of manufacturing processes. Manufacturing refers to the conversion of raw materials into finished products employing suitable techniques. There are several methods of manufacturing such as metal casting, metal forming, metal machining, metaljoining and finishing.

Some of the modern methods of manufacturing include micro machining, nano fabrication, ultra precision manufacturing etc.

In order to fulfill the requirements of the ever-increasing demands of various types of industries, the manufacturing engineer has to choose the right type of material and the right type of equipment for manufacture so that the cost of production and the energy consumption are minimum.

The selection of suitable manufacturing process should also include concerns for environmental impacts such as air pollution, waste disposal etc.

Modern concepts such as lean manufacturing, adaptive control, agile manufacturing, group technology etc have considerable influence on cost reduction and quality improvements of products.

Computers and robots play important role in modern manufacturing techniques, today. Modeling and simulation of the process prior to mass production helps the manufacturing engineer fix up the best operating parameters and hence achieve the finished product to the utmost level of quality and cost-effectiveness.

The present course is focused on one of the important methods of manufacturing, namely, metal forming.

1.2 Metal forming – definition:

Materials are converted into finished products though different manufacturing processes. Manufacturing processes are classified into shaping [casting], forming, joining, and coating, dividing, machining and modifying material property.

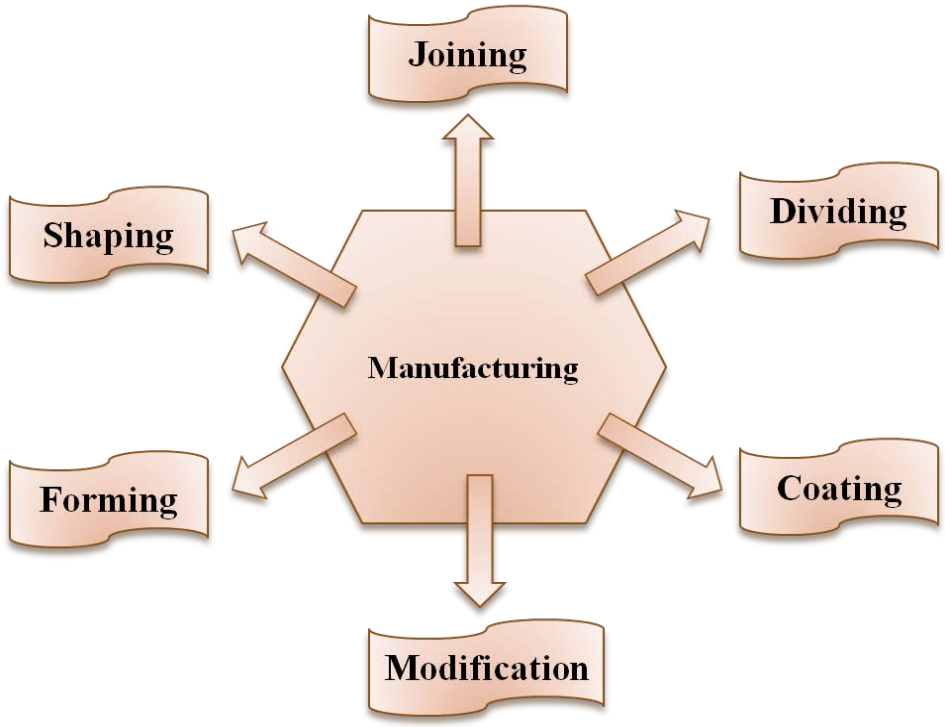


Fig.1.2.1: Various manufacturing operations on materials

Of these manufacturing processes, forming is a widely used process which finds applications in automotive, aerospace, defense and other industries.

Wrought forms of materials are produced through bulk or sheet forming operations. Cast products are made through shaping – molding and casting.

A typical automobile uses formed parts such as wheel rims, car body, valves, rolled shapes for chassis, stamped oil pan, etc.

In our daily life we use innumerable formed products e.g. cooking vessels, tooth paste containers, bicycle body, chains, tube fitting, fan blades etc.

Forming is the process of obtaining the required shape and size on the raw material by subjecting the material to plastic deformation through the application of tensile force, compressive force, bending or shear force or combinations of these forces.

1.3 Classification of forming:

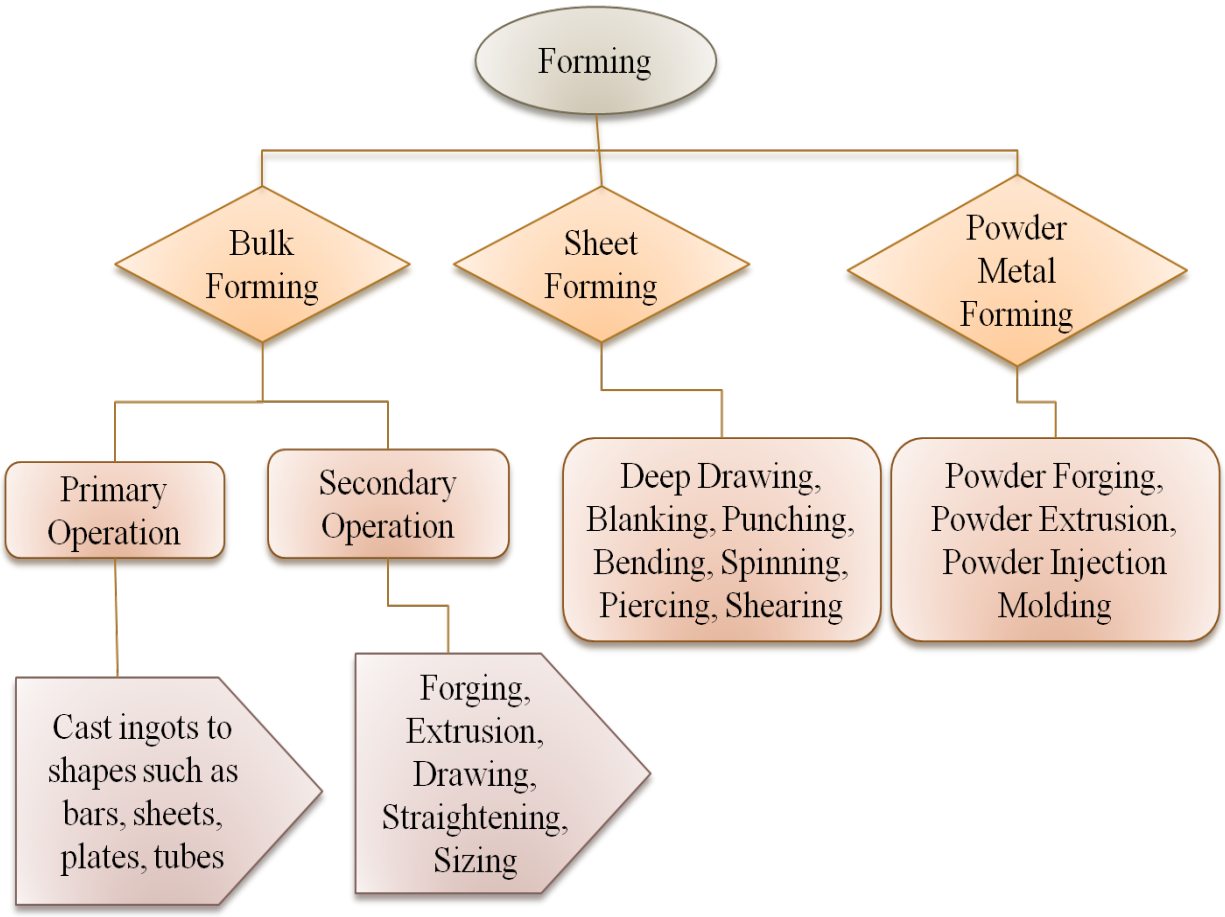


Fig. 1.3.1: Classification of metal forming processes

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 low surface area to volume ratio. Rolling, forging, extrusion and drawing are bulk forming processes. In bulk deformation processing methods, the nature of force applied may be compressive, compressive and tensile, shear or a combination of these forces.

Bulk forming is accomplished in forming presses with the help of a set of tool and die. Examples for products produced by bulk forming are: gears, bushed, valves, engine parts such as valves, connecting rods, hydraulic valves, etc.

Sheet metal forming involves application of tensile or shear forces predominantly. Working upon sheets, plates and strips mainly constitutes sheet forming. Sheet metal operations are mostly carried out in presses – hydraulic or pneumatic. A set of tools

called die and punch are used for the sheet working operations. Bending, drawing, shearing, blanking, punching are some of the sheet metal operations.

A new class of forming process called powder forming is gaining importance due to its unique capabilities. One of the important merits of powder forming is its ability to produce parts very near to final dimensions with minimum material wastage. It is called near-net-shape forming. Material compositions can be adjusted to suit the desirable mechanical properties. Formability of sintered metals is greater than conventional wrought materials. However, the challenge in powder forming continues to be the complete elimination or near-complete elimination of porosity. Porosity reduces the strength, ductility and corrosion resistance and enhances the risk of premature failure of components.

Based on the nature of deformation force applied on the material, during forming, metal forming processes are also classified into several types as shown below:

Forming by compressive stress	Tensile and compressive stresses	Forming under Tensile stress	Bending and shearing stresses
•Open Die Forging •Closed Die Forging •Rolling •Coining •Extrusion	•Deep drawing •Spinning •Stripping •Wrinkle bulging	•Stretch forming •Stretching •Expanding	•Bending •Shearing •Punching •Blanking

Forming is also classified as cold forming, hot forming or warm forming. Hot forming is the deformation carried out at temperatures above recrystallization temperatures. Typically, recrystallization temperatures for materials ranges from 0.5 Tm to 0.8 Tm, where Tm is melting temperature of material.

1.4 Brief description of forming operations

We discuss briefly the various forming operations in the following sections.

1.4.1 Bulk forming processes:

Rolling is a compressive deformation process, which is used for producing semi-finished products such as bars, sheets, plates and finished products such as angles, channels, sections.Rolling can be carried out both in hot and cold conditions.

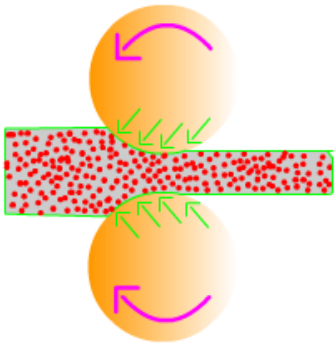
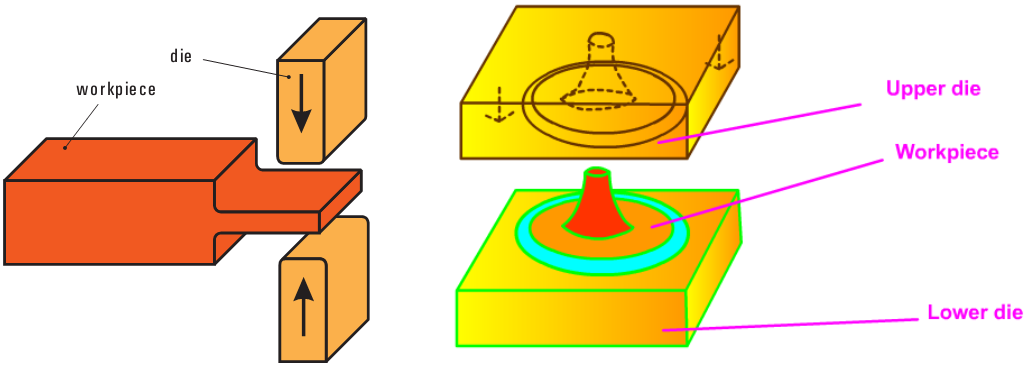


Fig.1.4.1.1:Rolling Process

Forging is a bulk forming process in which the work piece or billet is shaped into finished part by the application of compressive and tensile forces with the help of a pair of tools called die and punch. Forging can be done in open dies or closed dies. Open die forging is usually used for preliminary shaping of raw materials into a form suitable for subsequent forming or machining.



Open die forging*Closed die forming*

Fig.1.4.1.2: Forging processes

Open die forming is done using a pair of flat faced dies for operations such as drawing out, thinning, etc.

Closed die forming is performed by squeezing the raw material called billet inside the cavity formed between a pair of shaped dies. Formed products attain the shape of the die cavity. Valve parts, pump parts, small gears, connecting rods, spanners, etc are produced by closed die forming.

Coining is the process of applying compressive stress on surface of the raw material in order to impart special shapes on to the surface from the embossing punch – e.g. coins, medallions

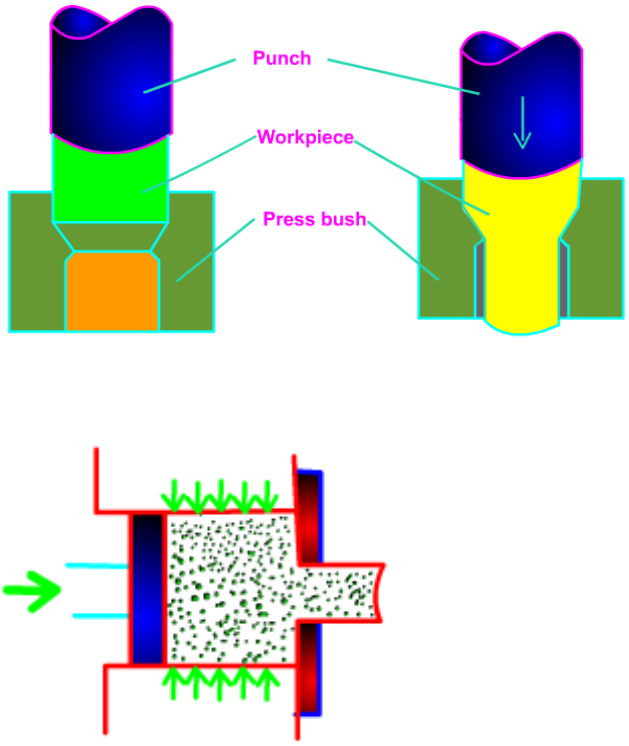


Fig.1.4.1.3:Direct extrusion process

Extrusion involves forcing the raw material through a narrow opening of constant cross-section or varying cross-section in order to reduce the diameter and increase the length. Extrusion can be done hot or cold. Extruded products include shafts, tubes, cans, cups, gears.

Basically there are two methods of extrusion, forward and backward extrusions. In forward extrusion the work and the extrusion punch move along the same direction. In backward extrusion the punch moves opposite to the direction of movement of the work piece.

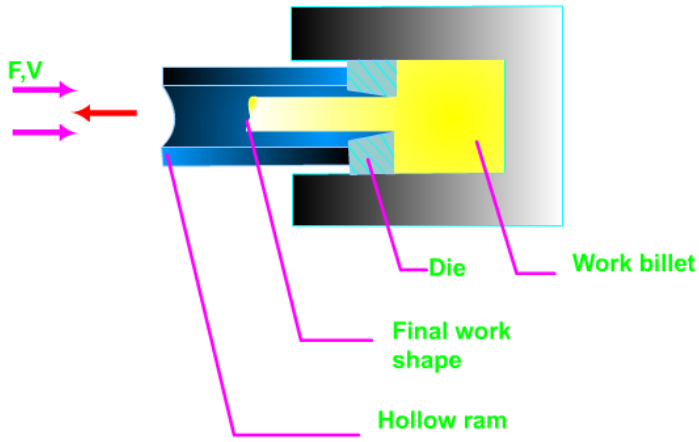


Fig.1.4.1.4:Backward extrusion or Indirect extrusion

Wire drawing process is used for producing small diameter wires from rods by reducing their diameter and stretching their length through the application of tensile force. Musical strings are produced by wire drawing process. Seamless tubes can be produced by tube drawing process.

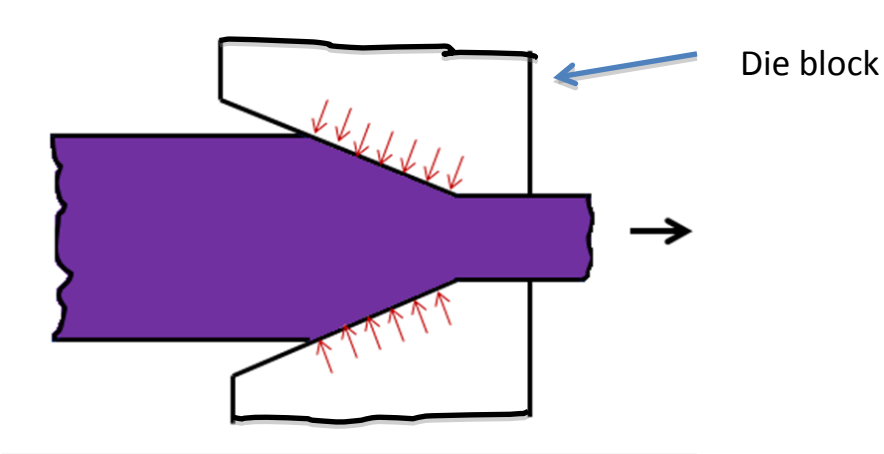


Fig.1.4.1.5:Wire Drawing

1.4. 2 Sheet metal operations:

Deep drawing is a sheet metal process the process in which a sheet metal is forced into cup of hollow shape without altering its thickness – using tensile and compressive forces. Complex shapes can be produced by deep drawing of blanks in stages – redrawing, multiple draw deep drawing etc.

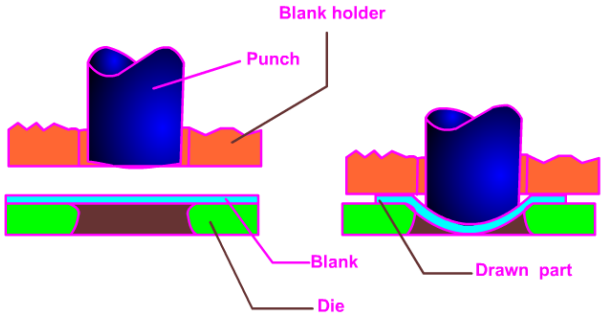


Fig.1.4.2.1:Deep drawing

Hydro mechanical deep drawing uses both punch force and hydrostatic force of a pressurized fluid for achieving the shape.

Flanges and collars are formed by flanging process.

Spinning transforms a sheet metal into a hollow shape by compressive and tensile stresses. Spinning mandrel of given shape is used against a roll head.

Embossing imparts an impression on the work piece by means of an embossing punch.

Bending of sheets includes rotary bending, swivel bending, roll bending using rotary die.

Die bending using flat die or shaped die is used for bending of sheets, or die coining of sheets.

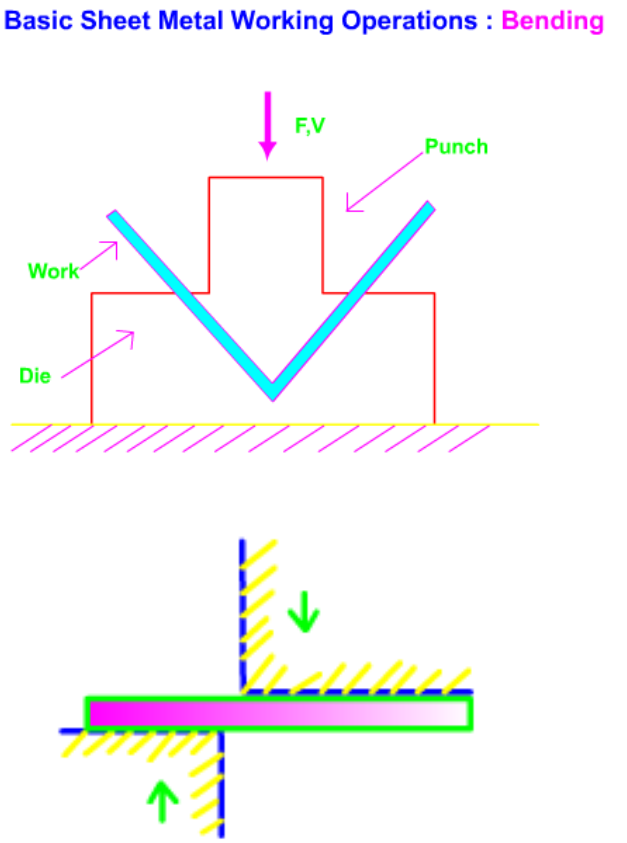


Fig.1.4.2.2:Bending and shearing