3.1 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.

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

3.2 Metal Forming

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

Forming is the process of obtaining the required shape and size from 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.

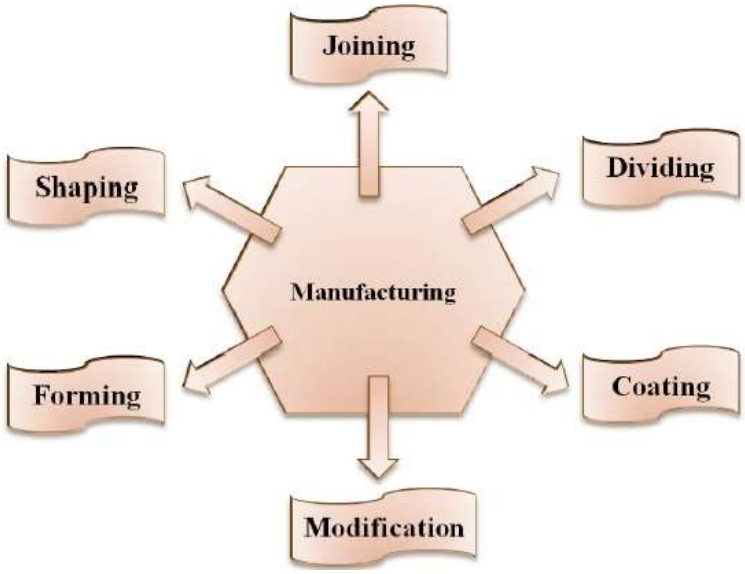

Figure 3.1: Various manufacturing operations on materials

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.

3.3 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 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 of 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. Press could either be 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.

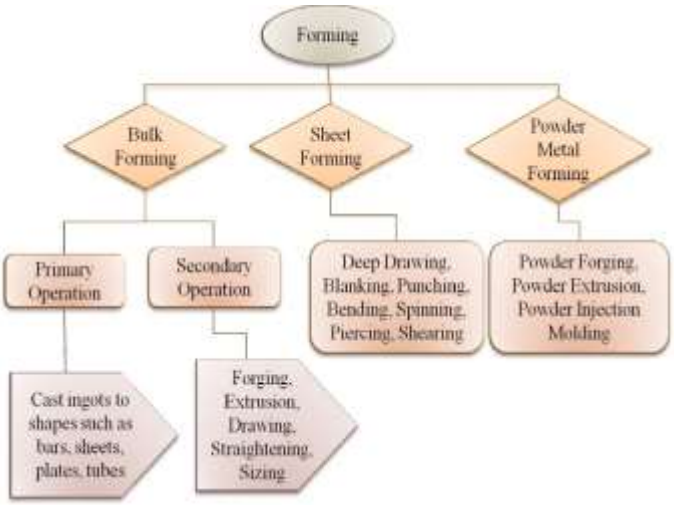

Figure 3.2: Classification of metal forming processes

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:

i. Cold forming
ii. Hot forming or warm forming.

Hot forming is the deformation carried out at temperatures above recrystallization temperatures. Typically, recrystallization temperatures for materials ranges from $0.5T_m$ to $0.8T_m$, where T_m is melting temperature of material.

3.4 Description of Forming Operations

3.4.1 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.

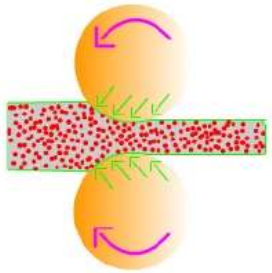

Figure 3.3: Rolling Process

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.

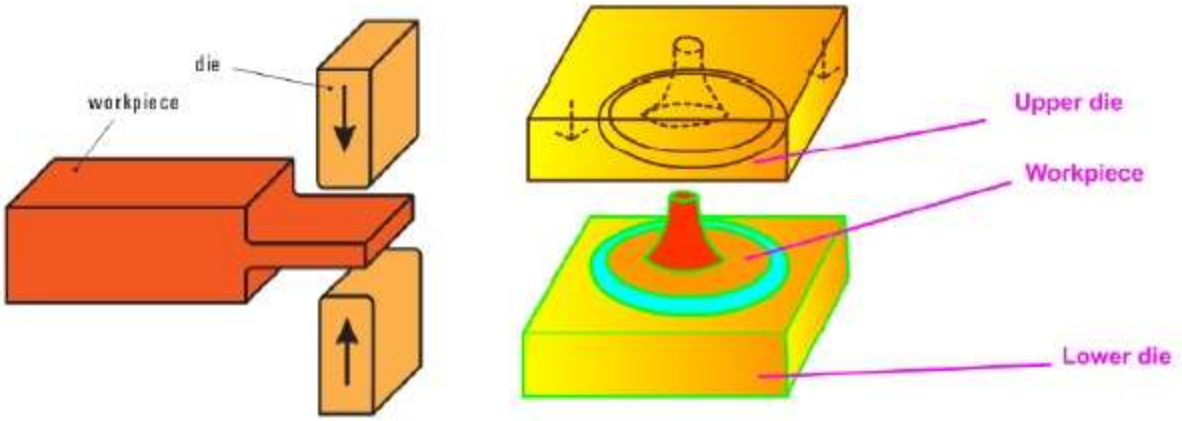

Figure 3.4: Forging processes

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

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.

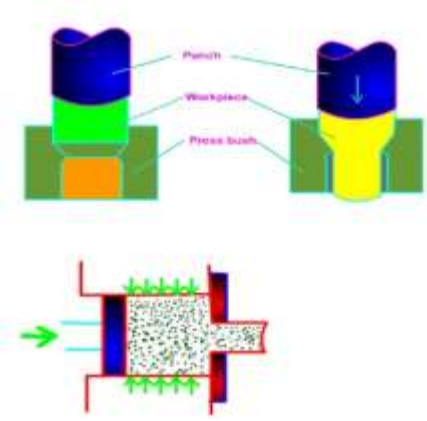

Figure 3.5: Direct extrusion process

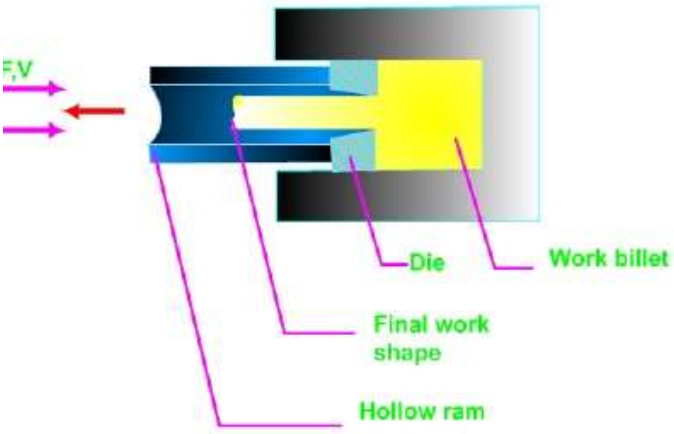

Figure 3.6: Backward extrusion or Indirect extrusion

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.

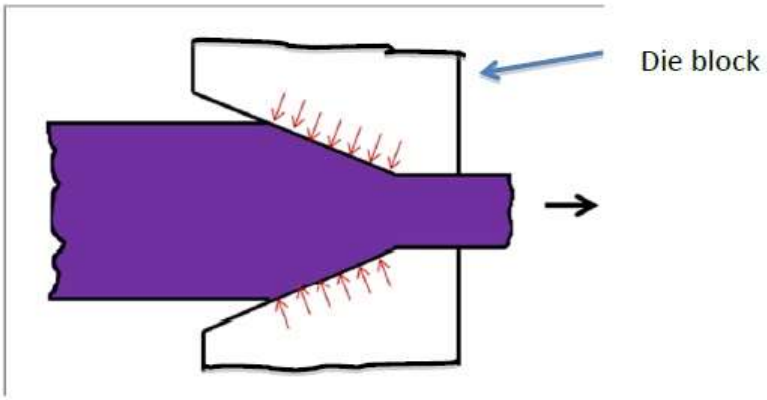

Figure 3.7: Wire Drawing

3.4.2 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.

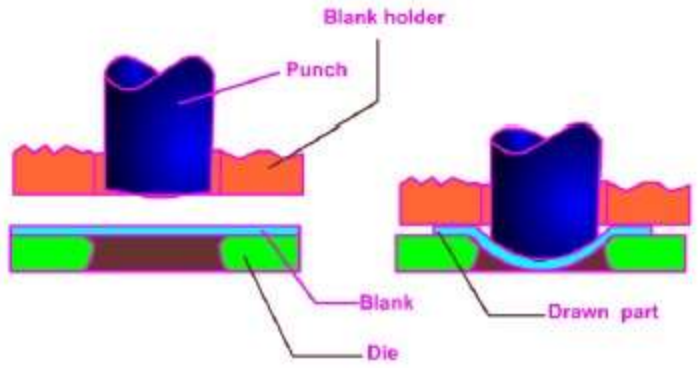

Figure 3.8: Deep drawing

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.

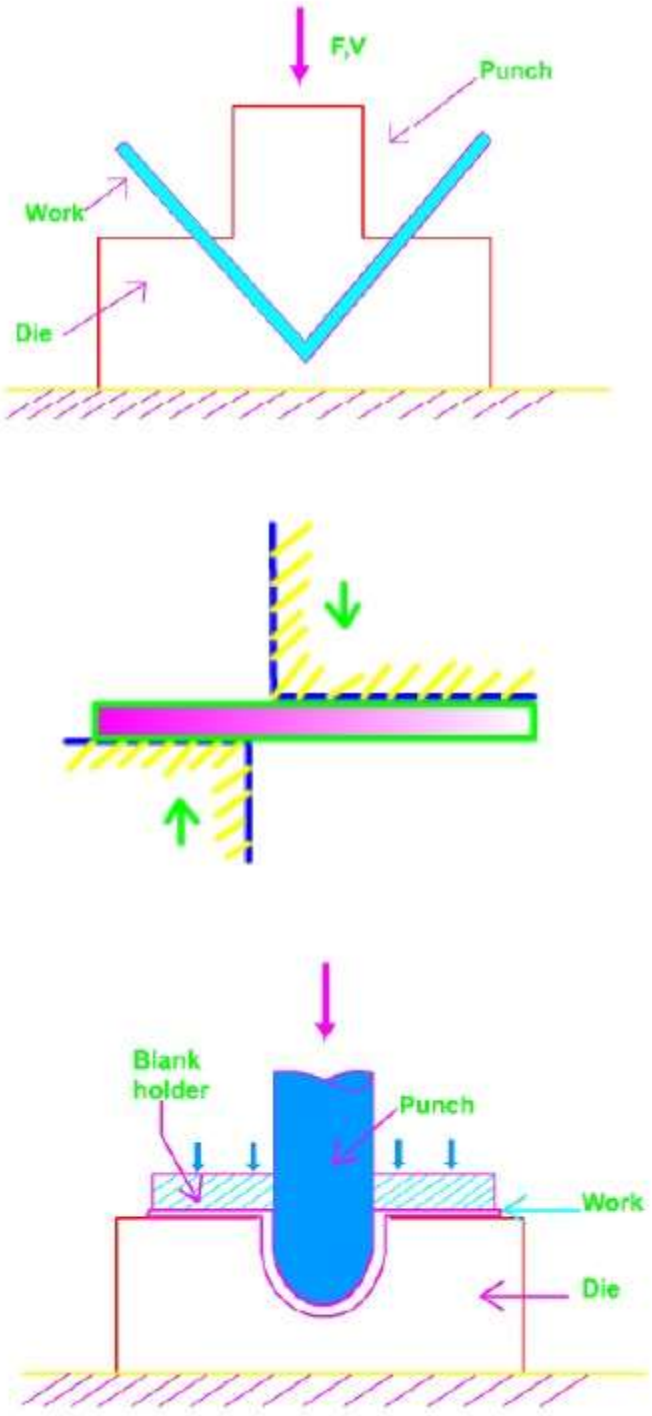

Figure 3.9: Bending and shearing