4.10 Special forming processes

Generally, forming process is done by pressing the form tool over the blank to obtain the required shape. The form tool is actuated by hydraulic cylinder using hydraulic fluid. In the case of mating die method, sheet metal is placed over the lower die and its ends are fixed on movable grippers. Then, the upper die is moved towards the blank. If the female or upper die is actuated by any other means except hydraulic fluid contained in the cylinder in forming process called special forming process. Example: Explosive forming metal spinning, hydro forming etc.

Types of special forming process

There are various types special forming process as follows:

1. Hydroforming
2. Rubber pad forming
3. Metal spinning
4. Explosive forming
5. Magnetic pulse forming
6. Peen forming
7. Super plastic forming

4.10.1 Hydro forming process

Hydroforming is a drawing process. It is forming process is carried out in two ways, they are

1. Hydro mechanical forming, and
2. Electro hydraulic forming

1. Hydro Mechanical Forming

In this type of forming process, the punch is connected to the lower die called male die. The required shape of inner configuration is made on the punch. A rubber diaphragm or seal is used for making perfect sealing between male and female die. This seal is placed across the bottom of the pressure forming chamber. The pressure-forming chamber is filled with a hydraulic fluid. Then, the blank is correctly positioned over the male die or lower die. Now, the pressure forming chamber called dome is lowered over the blank in such a way that the dome is made to just contact with the blank.

After this, hydraulic pressure is applied over the blank. Simultaneously, the punch is pushed into the blank. The pressure applied by the hydraulic fluid is increased continuously. Due to this, the blank metal flows around the punch to form the required shape. The inverted shape of the punch is made on the blank. (Convex shape of the punch is made as concave shape on the blank and vice versa). After forming the required shape, the chamber pressure is released. Then the chamber is raised form the blank. Finally, the blank is stripped out from the punch. In this case, the required shape of the blank is obtained only by drawing rather than by bending. And also, the blank metal is displaced due to plastic flow instead of stretching.

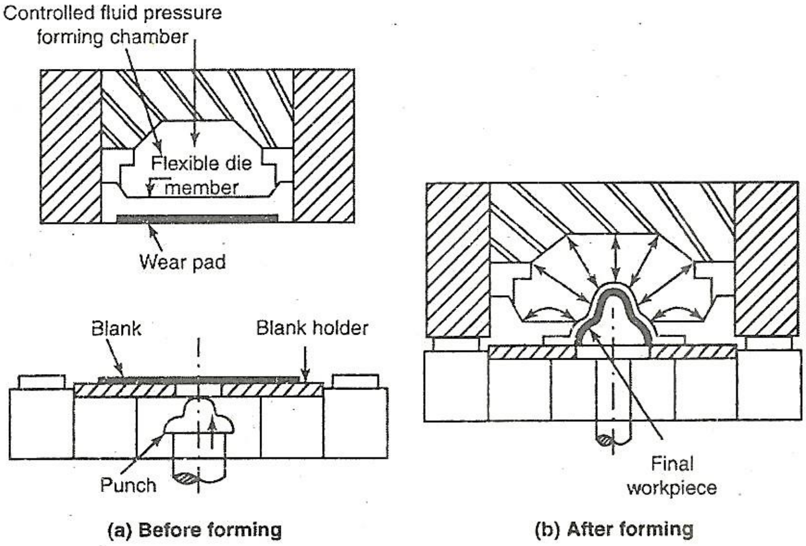


Figure 4.34 Hydro Mechanical Forming

Advantages:

1. Thinning of metal, spot stresses and spring back are drastically reduced or completely eliminated.
2. It is used for mass production because work performed per operation is high.
3. Tool changing can be done rapidly.
4. Complicated contours can also be made.
5. Sharp corners are also possible.
6. All type of sheet metals can be handled.
7. Due to uniform flow metal between punch and pressure chamber, the mechanical and physical properties are improved.
8. Tolerance of 0.005mm/mm are possible practically.

2. Electrohydraulic Forming Process

The working principle of metal forming process is same as that of hydro mechanical forming process. But, the applied pressure over the blank differs because the pressure inside the pressure forming chamber is produced by electrical means. The arrangement of this electro hydraulic forming system is shown figure 4.35.

When the supply is given to electrical circuit, a high energy is discharged through a bank of capacitor to the hydraulic fluid contained the chamber. The discharged energy in the chamber is in the form of shock waves and pressure. This mechanical energy is used for metal forming operations in the same manner as mentioned in hydro mechanical forming operations.

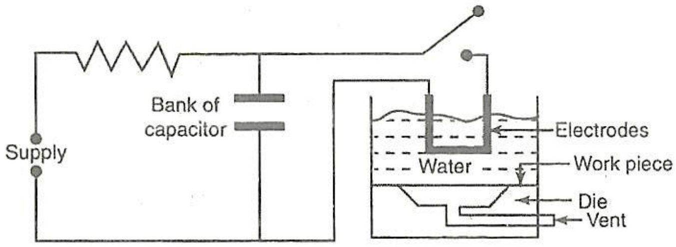


Figure 4.35 Electrohydraulic Forming Process

Advantages:

1. The pressure inside the chamber is high due to combined shock wave and fluid pressure.
2. Time required per operation is low when compared to hydro mechanical forming operations.

Disadvantages

1. Energy losses occur between electrical components to hydraulic fluid.
2. Due to shock waves drag force and lift force is created and finally it results stagnation pressure in the fluid.
3. Stagnation properties refer to the properties at zero velocity.

4.10.2 Explosive forming

Explosive forming makes use of the pressure wave generated by an explosion in a fluid, for applying the pressure against the wall of the die. The explosives are used in the form of rod, sheet, granules, stick, liquid, etc. According to the placement of the explosive (charge) the operations are divided in two categories:

1. Standoff operation 2. Contact operation

1. Standoff operation:

In this type of operation, the charge is located some distance away from the workpiece and energy is transmitted through a fluid medium like water. Operating pressure for the workpiece is between several thousand to several hundred thousand kg/cm^2. Process time or working time is measured in milliseconds, whereas metal removal velocity is measured in m/sec. This method is used to form and size the parts.

2. Contact operation:

In this type of operation, the explosive or charge is in direct contact with the workpiece and the explosive energy acts directly on the metal. By using this method, welding, hardening, compacting powdered metals and controlled cutting are performed.

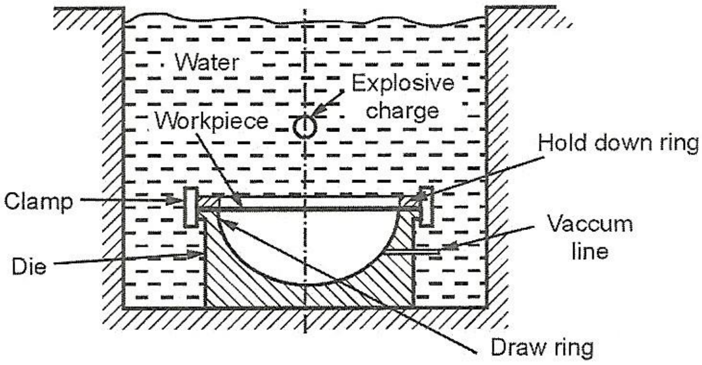


Figure 4.36 Explosive Forming Operation

Figure 4.36 shows the explosive forming for stand-off operation. In this method, the explosive charge is placed at some known distance from the workpiece. When the explosive is detonated, its energy is transmitted through a fluid medium (here water) to the workpiece held on a die. To avoid adiabatic compression and heating of the entrapped air, the space in the die behind the workpiece is generally evacuated. If vacuum is not created between the workpiece and die, then an air cushion would develop as the metal is being forced into the die. It also prevents the metal from seating in the die and assuming its shape. When the explosive detonates under water, it produces a shock wave and a bubble of hot gaseous detonation products. At any given distance from the explosive charge centre, the high intensity portion of the pressure pulse produced by the detonating explosive is represented by,

$$P = \quad /$$

Where, P = Pressure as a function of time

P_m = Peak pressure for that distance

t = Time arrival of pressure front at the blank surface

= Time constant characteristics of the charge weight,

Type of explosive and distance from the explosive

The time constant represent the time that it takes the pressure to fall upto 50% of its peak value and it defines the limit of the straight line portion of a time curve. Explosive forming process is used for the following operations:

Blanking, Embossing, Coining, Drawing, Sizing, Expanding, Cutting, etc.

Advantages of explosive forming:

- For forming purpose, large and expensive presses are not required.
- Component is mostly formed in one cycle only.
- Only one die (male or female) is required which reduces the tooling cost.
- By using this method, ultimate and yield strength of sheet metal are improved.
- Large size components can be formed easily.

- Low capital investment is required.

Disadvantages of explosive forming:

- High skilled operators are required.
- Some complex components cannot be formed in one cycle only.
- Due to noisy operation, this process is located form the main city which increases the transportation and handling costs.
- Suitable only for low quantity production.
- Applications of explosive forming
- This process is mainly used in aerospace industries.

4.10.2.1 Explosives

Explosives are substances that undergo rapid chemical reaction during which heat and large quantities of gaseous products are produced. Explosives can be solid (TNT-trinitro toluene), liquid (Nitroglycerine), or gaseous (oxygen and acetylene mixtures). Explosives are divided into two classes; Low Explosives in which the ammunition burns rapidly rather than exploding, hence pressure build up is not large, and High Explosives which have a high rate of reaction with a large pressure build up. Low explosives are generally used as propellants in guns and in rockets for the propelling of missiles.

4.10.2.2 Die materials

Different materials are used for the manufacture of dies for explosive working, for instance high strength tool steels, plastics, concrete. Relatively low strength dies are used for short sun times and for parts where close tolerances are not critical, while for longer runs higher strength die materials are required. Kirksite and plastic faced dies are employed for light forming operations; tool steels, cast steels, and ductile iron for medium requirements.

4.10.2.3 Transmission medium

Energy released by the explosive is transmitted through medium like air, water, oil, gelatin, liquid salts, etc. water is one of the best media for explosive forming since it is available readily, inexpensive and produces excellent results. Water is more suitable medium than air for producing high peak pressures to the workpiece.

4.10.3 Rubber Pad Forming

Rubber pad forming process is also known as **marform process**. It is a metal working process where sheet metal is pressed between a die and rubber block. Under pressure, the rubber and sheet metal are driven into the die and confirm to its shape by forming the part.

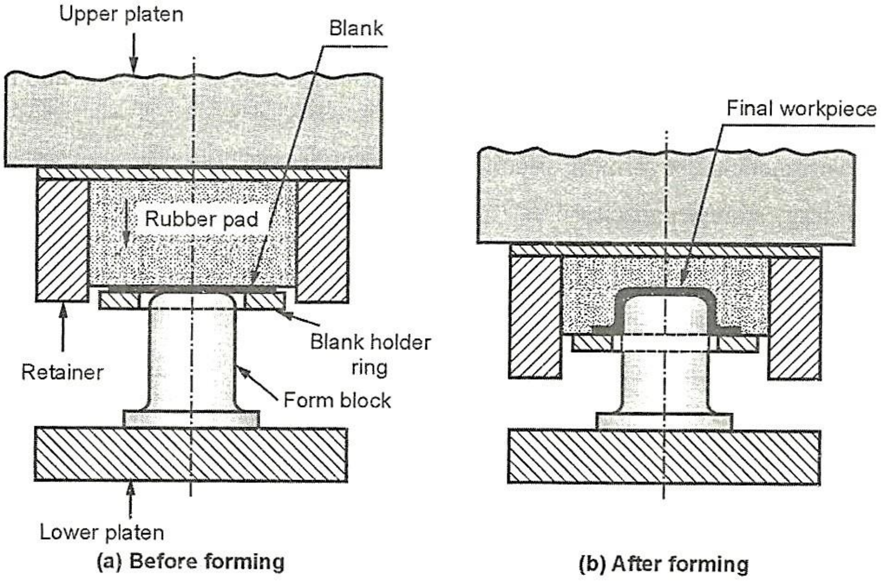


Figure 4.37 Rubber Pad Forming

This process is mostly used for bending and drawing operations. In this method, number of different form blocks (punches) is arranged at regular intervals along the pressing pad (rubber pad) Refer figure 4.37.

Initially the blank is placed on the form block and the stationary blank holder. The force is applied on the blank with the help of hydraulic cylinder through the ram and rubber pad. The pad is generally made of rubber of polyurethane. During forming, the upper platen is moved to just touch the top surface of the blank and after this, the force is applied and gradually increased by using rubber pad. Thus, the required shape is obtained (formed) on the sheet metal and the cycle is repeated. The retainers, placed both sides of rubber pad, are used to apply essential hydrostatic pressure on the blank and prevent sideward motion.

Advantages of rubber pad forming:

- Cost of tooling is less.
- The process is more flexible.
- Time required for tool setting is less.
- Lubricants are not required.
- Thinning of metal blank does not take place.
- Deep sheets can be produced.
- A formed components doesn’t have any wrinkles.
- Process is more economical.

Disadvantages of rubber pad forming:

- There is difficulty in the forming of sharp corners.
- Rubber pad will wear out at faster rate.

Application of rubber pad forming

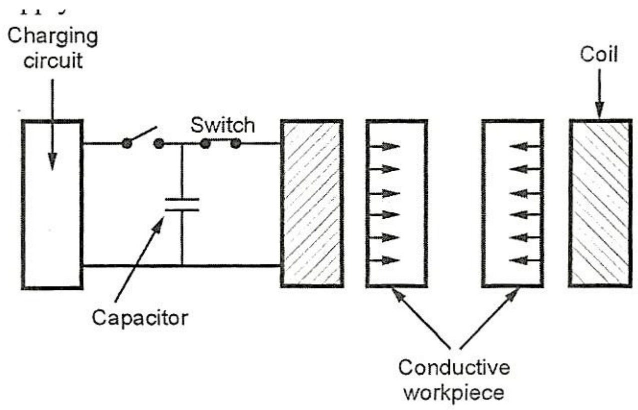
This process is used for producing flanged cylindrical and rectangular cups, spherical domes, shells with parallel or tapered walls. Also used for producing variety of unsymmetrical shapes.

4.10.4 Magnetic Pulse forming

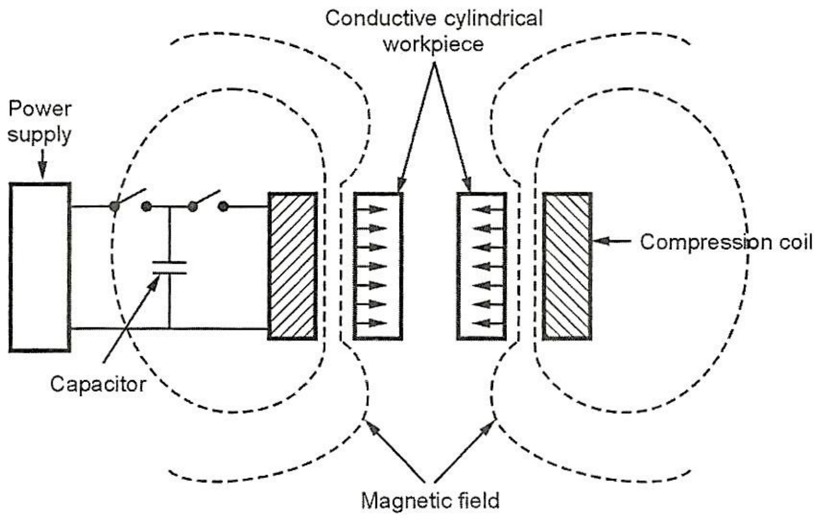
By using this method, it is possible to apply a powerful uniform magnetic pulse on a metallic workpiece, to swage and expand tubular forms, also to coin, shear and form flat sheets.

A basic magnetic pulse forming circuit consists of

- Energy storage capacitor
- Switch
- Power supply
- Coil



(a) Magnetic pulse forming process



(b) Magnetic pulse forming operation

Figure 4.38 Magnetic Pulse forming

An insulated induction is either wrapped around or place within the workpiece, depending on the requirement as shown in figure. The coil is shaped to produce the required shapes on the workpiece and power source is a capacitor bank. The capacitor can be charged slowly, generally in 3 to 6 sec. and discharged rapidly around 15 to 20 s, delivering a high current and power for a short time. When very high currents for a short time are passed through the coil, an intense magnetic field is developed which causes the workpiece to collapse, compress, shrink or expand as per the design and placement of the coil. Energy storage capacity and ability of the unit determines the size of the workpiece that can be formed.

Advantages of magnetic pulse forming:

- Highly conductive metals can be formed easily.
- The pressure is applied on the workpiece without any physical contact.
- As there is no friction, lubricants are not required.
- There are no tool marks on the workpiece.
- Machines can be designed for repetition rates.

Disadvantages of magnetic pulse forming

- Because of short duration of pressure pulse, deep drawing is not possible.
- Difficulty in the forming of unsymmetrical parts.
- Irregularities like slots, holes, grooves and difficult to form, because magnetic field is disrupted.

Applications of magnetic pulse forming

It is used for the attachment of rubber boots, as used in automotive ball joints. It is used to expand, compressor to form tubular shapes and also conical, ellipsoidal and flat workpiece. It is used in the forming of excellent conductors like aluminium, copper, brass, low carbon steel, etc. This method is also used for piercing shearing, cupping, embossing, sizing, etc.

4.10.5 Peen forming

Peen forming is also called as shot peening. Shot peening process consists of throwing a blast of metals shots on to the surface of a component. The blast may be thrown either by using air pressure or by a wheel rotating at high speed. This high velocity metal blast shot provides a sort of compression over the surface of a components. This increases the strength and hardness of the surface and also its fatigue resistance. Figure 4.39 shows shot peening action on a component.

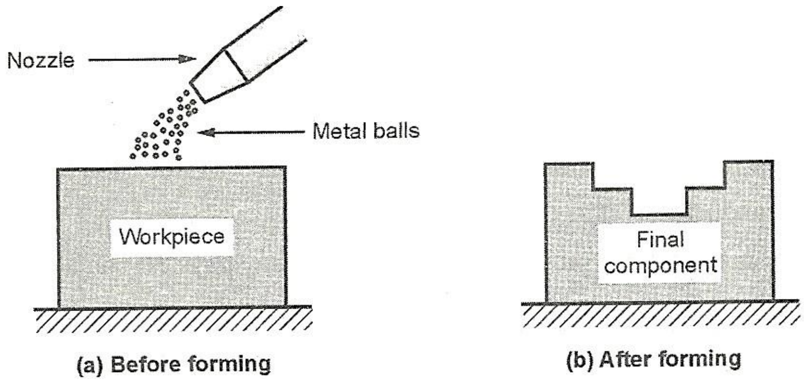


Figure 4.39 Peen Forming

Shot peening is also performed to prevent the cracking of workpiece in corrosive media and to improve the oil retaining properties of the processed surfaces. Generally, the shots are made of cast iron, steel, aluminium or glass. Cast iron or steel shot is used in peening steel workpiece whereas, aluminium or glass shot is used for non-ferrous alloys. The efficiency of the process mainly depends on angle between the path of the shot and the surface being peened. Another factor which affects the efficiency is the duration of peening which is generally 10 minutes. Shot peening is generally used for the manufacturing of coil springs, leaf springs, gear wheels and other complex parts.

4.10.6 Superplastic forming

Superplastic forming (SPF) is a metal working process used for forming sheet metal. It works upon the theory of superplasticity, which means that a material can elongate or stretch beyond 100% of its original size. Superplasticity is the ability of certain materials to undergo extreme elongation at the proper temperature and strain rate. Superplasticity of metals is defined by very high tensile elongations, ranging from two hundred to several thousand percent. The Superplastic process generally conducted at high temperature and under controlled strain rate which can give a ten-fold increase in elongation as compared to conventional room temperature processes.

Components are formed by applying gas pressures (generally argon) between one or more sheets and a die surface, causing the sheets to stretch and fill the die cavity. As the alloys of interest only exhibit Superplastic behaviour for certain temperature dependent range of strain rates, the evolution of pressures must be closely controlled during the process. Specific alloys of aluminum, stainless steel, and titanium are commercially available with the fine-grained microstructure and strain rate sensitivity of flow stress which is necessary for Superplastic deformation.

Process:

During the SPF process, the material is heated to the SPF temperature within a sealed die. For titanium this is around 900ºC and for aluminium its between 450ºC to 520ºC. Inert gas pressure is then applied, at a controlled rate forcing the material to take the shape of the die pattern. Refer figure 4.40.

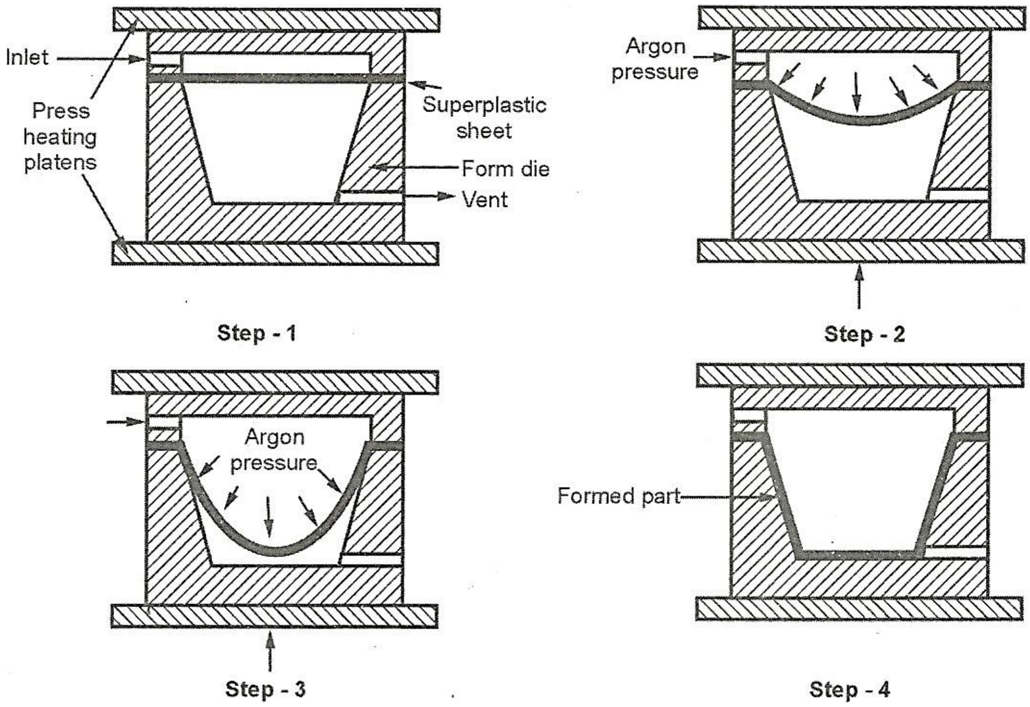


Figure 4.40 Superplastic forming

The flow stress of the material during deformation increases rapidly with increasing strain rate. Superplastic alloys can be stretched at higher temperatures by several times of their initial length without breaking. Typical aluminum alloy sheets can elongate 10-30% during forming. Forming must also be done at low strain rates on the order of 10-3 to 10-4 s-1. There are several different types of super plasticity in terms of the microstructural mechanisms and deformation conditions. These are:

- Micrograin Superplasticity
- Transformation Superplasticity
- Internal stress Superplasticity

Some of the materials developed for super plastic forming are:

- Bismuth – tin (200% elongation)
- Zinc-aluminum
- Titanium (Ti-6AI-V)
- Aluminum (2004, 2419, 7474)
- Aluminum – lithium alloys (2090, 2091, 8090)

Advantages of Superplastic forming

- Superplastic forming technique offers the potential to reduce the weight and cost of large automotive structural components for advance vehicle applications.
- The main advantages of this process are:

- The major advantage of this process is that it can form large and complex components in one operation only.
- The process can be used to form complex components in shapes which are near to the final condition.
- The process eliminates unnecessary joints and rivets.
- After forming subsequent machining is not required.
- It minimizes the amount of scrap produced.
- It also does not suffer from springback or residual stresses.
- Less tooling cost.

Disadvantages of superplastic forming

- Its forming rate is slow.
- Cycle time may vary from two minutes to two hours, hence it is generally used for low volume production.
- Sometimes materials must not be superplastic at service temperatures.

Applications of superplastic forming

The process is increasingly being applied in the aerospace industry as a way of manufacturing very complex structures.

- In automotive body panels.
- In forming of aircraft frames.
- Diaphragm forming of plastics.
- Complex shape parts like window frames, sent structures, etc.

4.10.7 Metal spinning Process

The process of forming seamless metal parts from a circular sheet metal or from a tube length on a lathe is called as spinning process. Only symmetrical shapes can be produced from metal spinning process.

First, the circular blank is centered on a lathe which is placed against a form block. The form block is mounted on the head stock of the spinning lathe. The blank is tightly held between from block and tail stock spindle. The required contour surface is made on the form block. The pressure is applied by the roller type forming tool which is placed on the tool post of the spinning lathe.

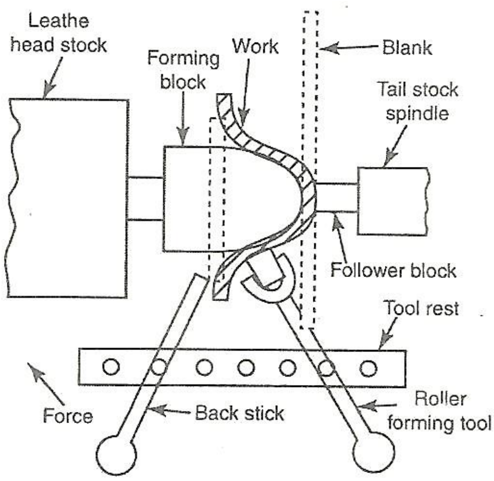


Fig.4.41. Spinning

The required shape is gradually formed by continuous application of pressure by the roller. During spinning process, some stretching and thinning of material take place. Metal spinning cam be done both is cold and hot states. Heat generation due to friction between spinning tool or roller type forming and blank can also be used to retain the plastic state of sheet metal. Spinning speed varies with size, design, type of metal and thickness of sheet metal.

Aluminum copper, brass and stainless steel can also be spun in spinning process. This process is mainly suitable for producing conical shape parts and suitable for low volume production. Components produced in this process do not require any trimming or beading operations. For producing more complex shapes, segmental chucks made from cast aluminum, magnesium alloys or hard wood reinforced with cold rolled steel sheets are used. The lubricants of grease, linseed oil and bees wax are used while using bead and tallow between form tool and blanks during spinning process.

Advantages

1. The parts not be drawn by drawing operations can be easily spun.
2. Heat generated due to friction is used to retain the sheet metal in the plastic state.
3. The process is more economical for low volume production.

Disadvantages

1. Thinning takes place during spinning process.
2. More complex shapes require segmental chucks. Finally, it leads to increase in cost.
3. Accuracy and quality of finished products mainly depend on the skill of the operator.

4.10.8 Micro Forming in Sheet Metal Processes

It is well known that the sheet metals thickness is between 0.4 and 6 mm but while micro-sheet forming usually handles the sheet metals of which the thickness is less than 0.3 mm. Therefore, it is called as thin strips or coils. The major sheet processes in micro sheet forming are shearing, cutting, bending, unbending, stretching, compressing, stress relaxation etc.,

Similar to conventional sheet metal, the mechanical properties of the materials such as elasticity, plasticity, stress strain relations, strain rate, work hardening, temperature effect, anisotropy, grain size and residual stress involve in analysing the deformation of micro-forming products. the effects of grains sizes, orientations of micro-forming products. the effects of grains sizes, orientations and grain boundary properties are more significant in micro-sheet forming while considering the effects of overall stress-strain relationships, sheared-section qualities, spring back phenomenon, stress relaxation, etc.

Generally, the micro forming processes are used to make parts of the followings:

- Cellular Telephones
- IC Lead frames
- Electronics
- Healthcare
- Miniature Fasteners
- Hard Disc Driver
- National Security & Defense
- Automobiles
- Sensors

Sheet metal components are mainly used in various applications such as vehicles, aircraft, electronics products, medical implants and packaging for consuming goods, car panels, aircraft skins, cans for food and drinks and frames of: TV, computer screens, monitors and displays, etc.

Especially, micro-formed components are used in high precision applications such as electrical connectors and lead frames, micro-meshes for masks and optical devices, micro springs for micro switches, micro-cups for electron guns and micro-packaging, micro laminates for micro-motor and fluidic devices, micro gears for micro mechanical devices, casings for micro-device assembly, micro knives for surgery etc.,