a) **Wrinkling in the flange:** wrinkling in a drawn part consists of a series of ridges that form radially in the undrawn flange of the workpart due to compressive buckling.
b) **Wrinkling in the wall:** If and when the flange is drawn into the cup, these ridges appear in the vertical wall.
c) **Tearing:** Tearing is an open crack in the vertical wall, usually near the base of the drawn cup, due to high tensile stresses that cause thinning and failure of the metal at this location. This type of failure can also occur as the metal is pulled over a sharp die corner.
d) **Earing:** This is the formation of irregularities (called ears) in the upper edge of a deep drawn cup, caused by anisotropy in the sheet metal. If the material is perfectly isotropic, ears do not form.
e) **Surface scratches:** Surface scratches can occur on the drawn part if the if the punch and die are not smooth of if lubrication is insufficient.

4.8 Stretch Forming Operations

This method is used for producing large accurately contoured sheets. It has been developed in Second World War period itself.

Stretching is the process of stressing the work blank beyond its elastic limit by moving a form block towards the blank or sheet metal. The form block has projections of exact size required on the blank which is in the form of depressions on the same blank. Stretching is mainly done for straightening a part to obtain a straight axis and uniform cross-section. During stretching the blank, the spring back occurs after completing the stretching process.

Spring back is defined as the movement of the metal to resume its original position causing a decrease in ben angle after the applied force is withdrawn. So, this spring back has to be considered to obtain exact shape and size of the blank after the stretching process. Spring back always depends on material type, thickness of the blank, hardness of the blank and bend radius. Generally large bend radius produces greater spring back on the blank. But, this spring back can be avoided by

i. Over stretching using V-type form blocks, and
ii. By coining the metal slightly at the corners of the blank to remove elastic stresses called corner setting.

4.8.1 Methods of Stretch Forming

The stretch forming process can be done in two methods such as

1. Form – block method
2. Mating – die method

1. Form-block method

In this method, the two ends of the blank or sheet metal is tightly held by an adjustable grippers are fixed but adjustable. Then, the form block is moved towards the blank to make the required shape. In this case, the form-block is operated by hydraulic cylinder. When the form-block moves towards the blank, the hydraulic fluid inside cylinder gets compressed and delivered through the outlet valve. The movement of the form always depends the hydraulic fluid pressure inside cylinder. The fluid is entered the cylinder when the form-block moves away from the blank after completing stretching process. In a single stretching process, we can get no need of stages in stretching. Force exerted on the piston is calculated as

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Where, d= Diameter of the piston

P= Hydraulic fluid pressure

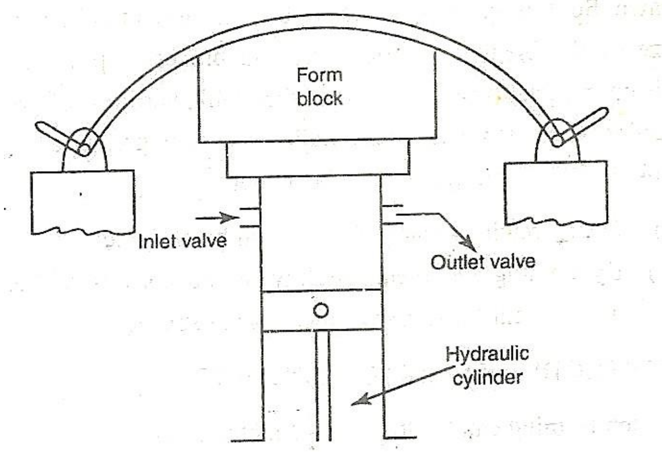

Figure 4.29 Form-block method

Stretching the blank can also be done by fixing the form block stationary and moving the grippers towards the form-block. It is performed by holding the blank ends in movable grippers.

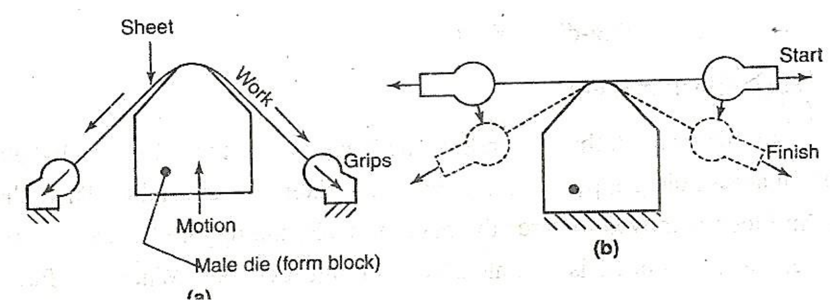

Figure 4.30 Stretch Forming

2. Mating-die method

In this method, the blank is held in movable grippers. The blank is placed between the lower and upper die. The lower die is kept stationary and the upper die is movable one which is operated by hydraulic or pneumatic cylinders.

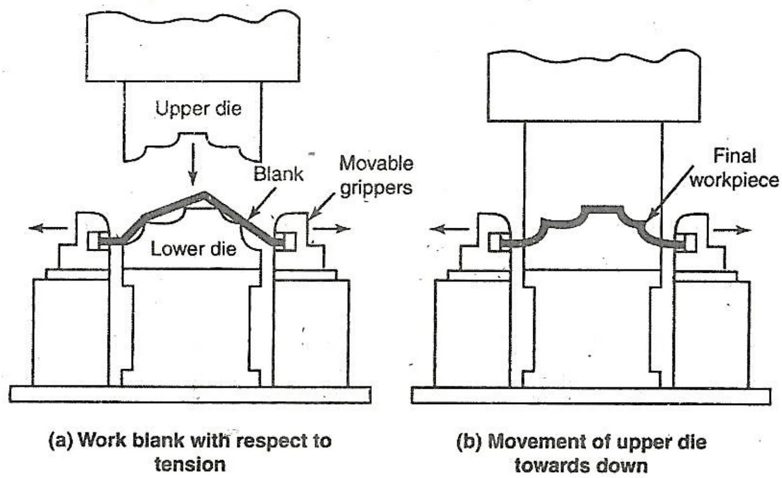

Figure 4.31 Stretch draw forming with Mating-dies

First, the movable grippers are moved towards the lower die on which only elastic deformation takes place. Next, the upper die is moved towards the blank. When the upper die touches the blank, only elastic change takes place. Due to continuous stretching of the blank by the upper die, plastic flow of sheet metal takes place between lower and upper dies. When the upper die edges reach the top surface of the blank, the stretching process is completed.

Materials for die and form blocks

Wood, Masonite, zinc alloys and cast iron.

Advantages

Blanks can be stretched in a single operation.

1. No need of any heat-treatments before and after the stretching process.
2. Spring back is reduced or eliminated when compared to other forming methods.
3. Direct bending is not introduced.
4. Plastic deformation is due to pure tension only.
5. Tooling costs are low.
6. This method is more suitable for low volume production.

Disadvantages

1. Blank thickness should be uniform throughout the length. (Thin sections are to be overstretched).
2. Sudden changes in contour surfaces cannot be stretched.
3. Maintenance cost of hydraulic cylinders is high.
4. The process requires high quality form-blocks.

Limitations

1. Uneven thickness of blank cannot be stretched.
2. Stretching of blank to the required shape of contour is limited.

Applications

1. Production of aircraft wing and fuselage parts.
2. Production of contoured panels for truck trailer and bus bodies in automobile industry.

4.9 Formability of sheet metals

Sheet-metal formability is of great technological and economic interest. It is normally defined as the ability of the sheet metal to undergo the desired shape change without such failure as necking or tearing, sheet metals may (depending on part geometry) undergo two basic modes of deformation: a) stretching and b) drawing.

There are important distinctions between these two modes, and different parameters are involved in determing formability under these different conditions.

4.9.1 Formability test methods

The two important test methods are carried out while processing the sheet metals.

They are:

1. Cupping test
2. Forming-Limit Diagrams (FLD)

1. Cupping tests

Because sheet-forming is basically a process of stretching the material, the earliest, test developed to predict formability were cupping tests.

The sheet-metal specimen is clamped between two circular flat dies, and a steel ball or round punch is pushed hydraulically into the sheet metal until a crack begins to appear on the stretched specimen.

The greater the valve is of the punch depth d, the grater is the formability of the sheet.

Although such test are easy to perform (and are approximate indicators of formability), they do not simulate the exact conditions of actual sheet-forming operations.

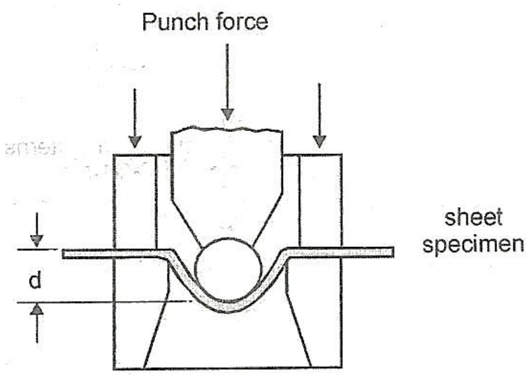

Figure 4.32 Cupping tests

2. Forming – Limit Diagrams (FLD)

An important development in testing the formability of sheet metals is the forming limit diagram (FLD).

The sheet is marked with a grid pattern of circles, typically 2.5 to 5 mm (0.1 to 0.2 in) in diameter, using electrochemical or photoprinting techniques.

The blank is them stretched over a punch, and the deformation of the circles is observed and measured in regions where failure has occurred. For improved accuracy of measurement, the circles are made as small as practicable.

In order to develop unequal stretching, as in actual sheet-forming operations, the specimens are cut to varying widths (figure4.33)

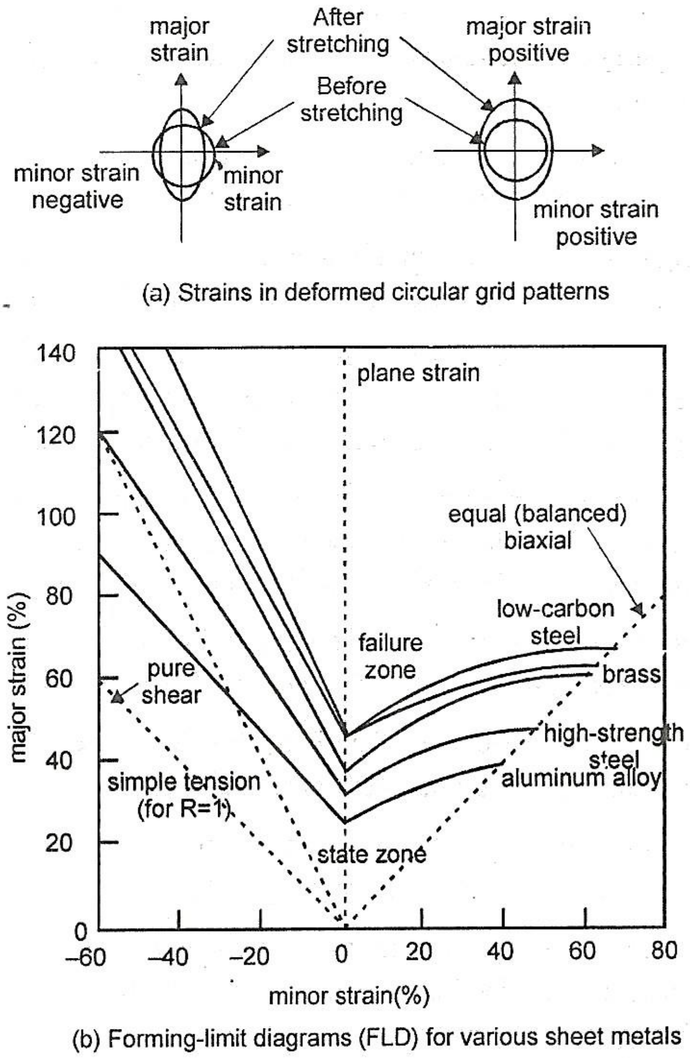

Figure 4.33 Forming – Limit Diagrams

Note that a square specimen (farthest right in the figure) produces equal biaxial stretching (such as that achieved in blowing up a spherical balloon), whereas a narrow specimen (farthest left in the figure) approaches a state of uniaxial stretching (simple tension).

After a series of such tests is performed on a particular sheet metal at different widths, a forming-limit diagram showing the boundaries between failure and safe regions is constructed (figure).

In order to develop the forming-limit diagram, the major and minor engineering strains, as measured from the deformation of the original circles, are obtained as follows.

Note in figure that the original circle has deformed into an ellipse. The major axis of the ellipse represents the major direction and magnitude of stretching.

The major strain is the engineering strain in this direction, and is always positive, because of sheet-metal stretching. The minor axis of the ellipse represents the magnitude of the stretching or shrinking in the transverse direction of the sheet metal.

Note that the minor strain can be either negative or positive. If, for example, a circle is placed in the center of a tensile-test specimen and then stretched, the specimen becomes narrower as it is stretched (Poisson effect), and the minor strain is negative.

On the other hand, if we place a circle on a spherical rubber balloon and inflate it, the minor and major strains are both positive and equal in magnitude.

By comparing the surface areas of the original circle and the deformed circle on the formed sheet, we can also determine whether the thickness of the sheet has changed.

The data obtained from different locations in each of the samples shown in figure are plotted in the form shown in figure.

The curves represent the boundaries between failure and safe zones. Thus, if a circle underwent major and minor strains of plus and minus 40%, respectively, there would be not tear in that region of the specimen.

On the other hand, if the major and minor strains in an aluminum – alloy specimen were plus 80% and minus 40%, respectively, there would be a tear in that region of the specimen.

An example of a formed sheet-metal part with a grid pattern is shown in figure. Note the tear, and note the deformation of the circular patterns in the vicinity of the tear region.

Figure 4.33 shows that different materials have different forming-limit diagrams and that the higher the curve, the better the formability of the material.

The effect of sheet-metal thickness on forming-limit diagrams is to raise the curves in figure.

The thicker the sheet, the higher its formability curve, and the more formable it is. On the other hand, in actual forming operations, a thick blank may not bend as easily around small radii without cracking.