MANUFACTURING SCIENCE-I

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UNIT-4(part3)

SHEET METAL WORKING

Sheet metal operation is defined as a chip less manufacturing process by which various components are made from sheet metal this process is also known as cold stamping

A stamping is produced by the downward stroke of the ram when the punch moves towards and into the die block, the punch and die block assembly is generally termed as a die set the operations are usually done at room temperature.

PRESS OPERATIONS:

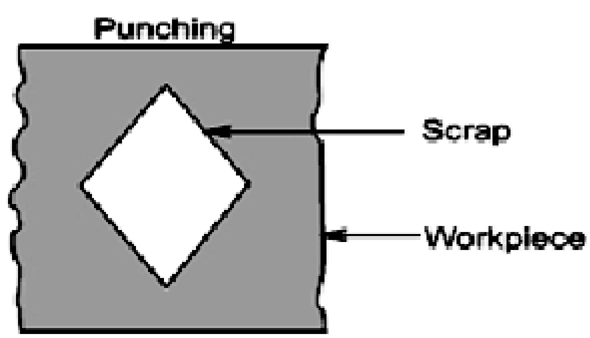
Sheet metal operations may be grouped into following two categories:

1) **Cutting Operations:** In these operations the work piece is stressed beyond its ultimate strength the stressed caused in the metal by the applied forces will be shearing stresses

2) **Forming Operations:** In these operations the stresses are below the ultimate strength of the metal there is no cutting of the metal but the shape of the work piece is changed to get the desired product.

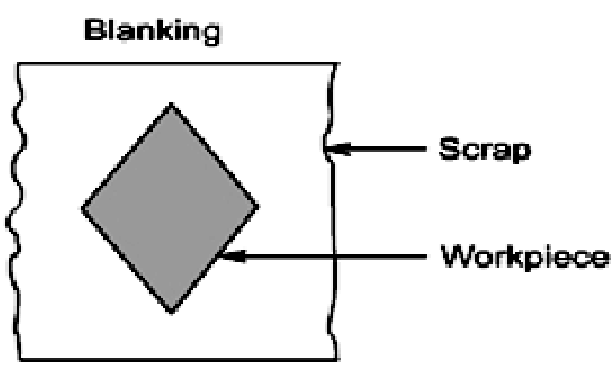
DIFFERENT PRESS OPERATIONS:

1) **Punching:**



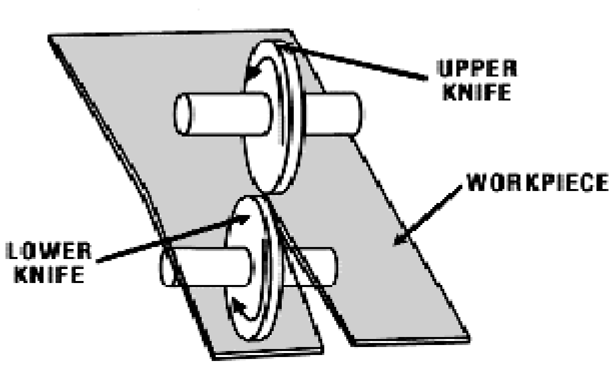
It is a cutting operation by which various shaped holes are made in sheet metal it is similar to blanking except that in punching the hole is the desired product and the material punched out to form the hole being the waste.

2) **Blanking:**



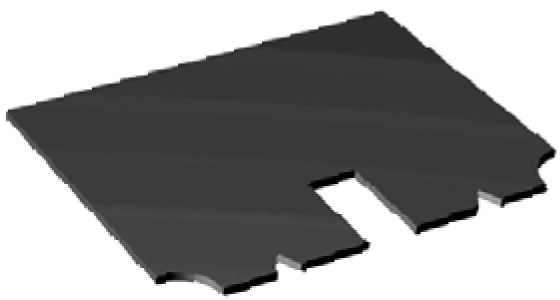
This is the operation of cutting a flat shape from a sheet metal the article punched out is called the blank and is the required product of the operation the hole and the metal left behind is discarded as waste.

3) **Slitting:**



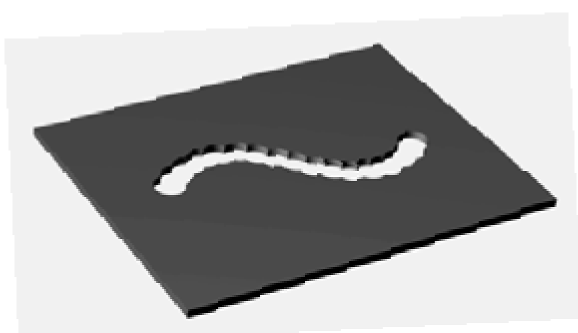
Slitting is used to cut a wide coil of metal into a number of narrower coils as the main coil is moved through the slitter

4) Notching:



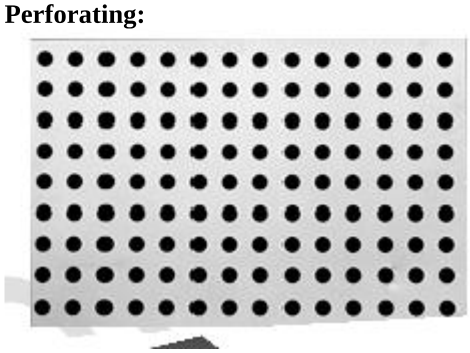
Notching is a piercing operation that removes material from the edge of the work piece.

5) Nibbling:



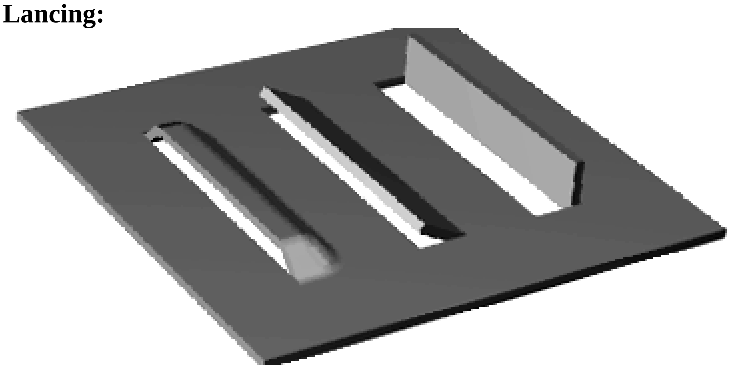
The nibbling process cuts a contour by producing a series of overlapping slits or notches. The nibbler is essentially a small punch and die that reciprocates quickly; around 300–900 times per minute

5) Perforating:



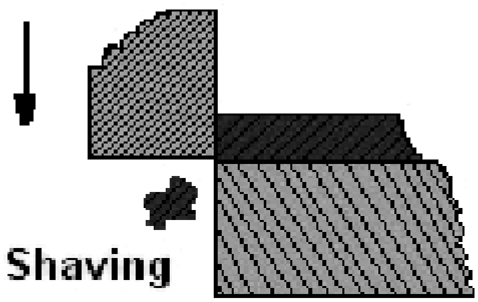
Perforating is an operation is which a number of uniformly spaced holes are punched in a sheet of metal. The holes may be of any size or shape. They usually cover the entire sheet of metal.

6) Lancing:



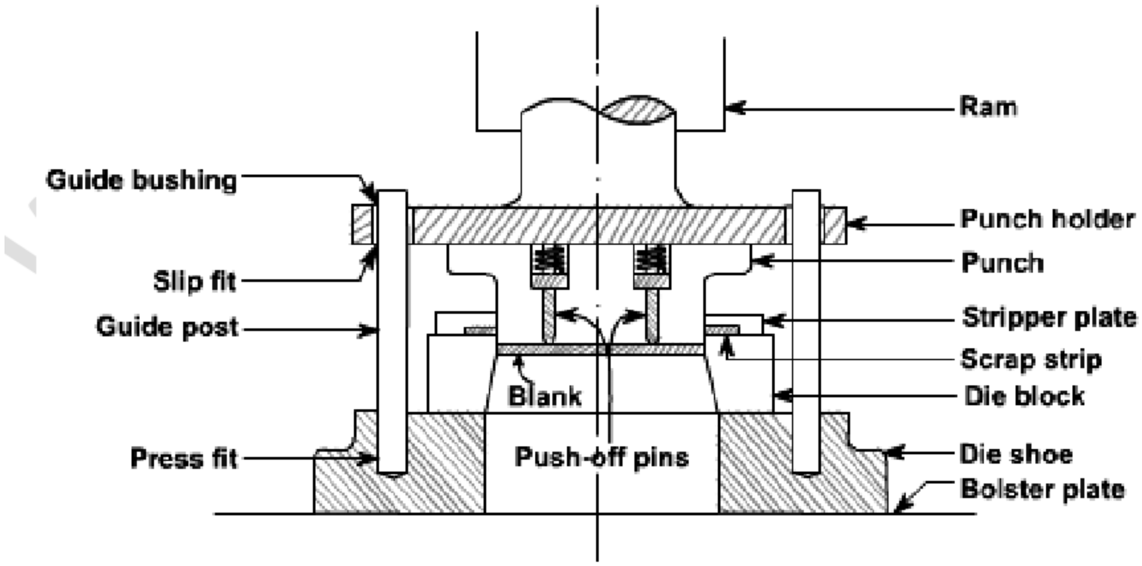
Lancing is a piercing operation in which the work piece is sheared and bent with one strike of the die. A key part of this process is that there is not reduction of material, only a modification in its geometry. This operation is used to make tabs, vents etc.

7) Shaving:



The shaving process is a finishing operation where a small amount of metal is sheared away from an already blanked part. Its main purpose is to obtain better dimensional accuracy, but secondary purposes include squaring the edge and smoothing the edge

PRESS WORK TERMINOLOGY (SHEARING OPOERATIONS):



- **a) Bed:** This is the lower part of the press frame that serves as a table to which a bolster plate is mounted.
- **b) Bolster Plate:** It is a thick plate secured to press bed which is used for locating and supporting the die assembly.
- **c) Die holder:** The lower shoe of the die set is generally mounted on the bolster plate of the press. The die block is mounted on the lower shoe also the guide posts are mounted on it.
- **d) Die Block:** It is a block or a plate which contains a die cavity.
- **e) Die:** It is defined as the female part of the complete tool for producing in a press. It is also preferred to a complete tool consisting of pair of mating member for producing work in a press.
- **f) Guide post and bushings: These** are used to hold the punch and die members in proper alignment during an operation.
- **g) Punch:** it is the male component of the die assembly which is moved by and fastened to the press ram (or slide).
- **h) Punch holder (Upper Shoe):** it is upper part of die set which contains guide post bushings.
- **i) Stripper Plate:** it is a plate which is used to strip the metal from a cutting or non cutting punch or die it may also guide the sheet.

WORKING:

According to the figure the punch holder is fasten to ram and the die shoe to the bolster plate. Guide post may be used to align punch holder with the die shoe punch holder die shoe and guide post together constitute a die set. The lower end of the guide post are press fitted into the die shoe at the upper end the guide post have a slip fit with the guide bushings. Which are press fitted into the punch holder.

The cutting action takes place during the downward movement of the punch into the die block after the cutting the elastic recovery in the strip material takes place due to which the size of the blank increases and that of the hole in the strip decreases. Hence at the end of cutting action when punch moves upwards the scrap strip sticks to the punch and blank gets clogged in the die block. To remove the scrap a stripper is used to avoid clogging of blank in the die opening the walls of the die opening are tapered.

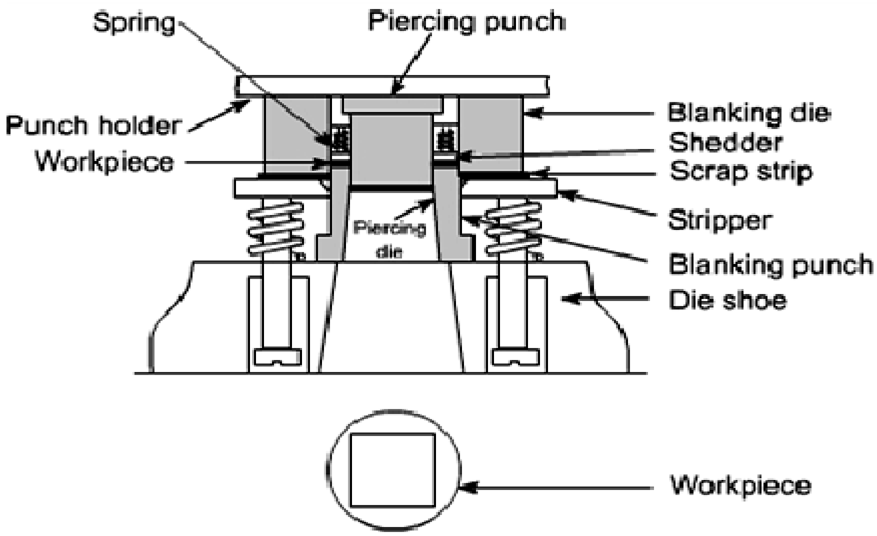
In addition to this the blank may also stick to the face of the punch this usually happens with thin blanks which have been treated with a lubricant to help the blank free itself from the punch face. Push-off pins are provided into the punch body.

CLASSIFICATION OF PRESSES:

- **A)** According to press operation:
  - **a.** Cutting Dies
  - **b.** Forming Dies
- **B)** According to method of operation:
  - **a.** Simple Die
  - **b. Compound Die:**
  - **c. Combination Die:**
  - **d. Progressive dies:**

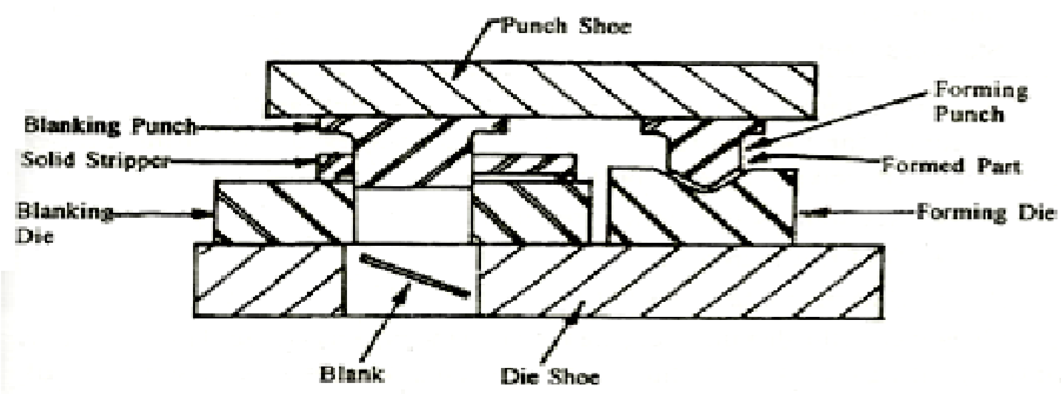
COMPOUND DIE:

Compound dies Combines the principles of the conventional and inverted dies in one station. This type of die may produce a work piece which is pierced and blanked at one station and in one operation. The piercing punch is fastened in the conventional position to the punch holder. Its matching die opening for piercing is machined into the blanking punch. The blanking punch and blanking die opening are mounted in an inverted position. The blanking punch is fastened to the die shoe and the blanking die opening is fastened to the punch holder. Washers are made by this process



COMBINATION DIE:

This type of die is similar to that of a compound die except that here non-cutting operations such as bending and forming are also included as part of the operation

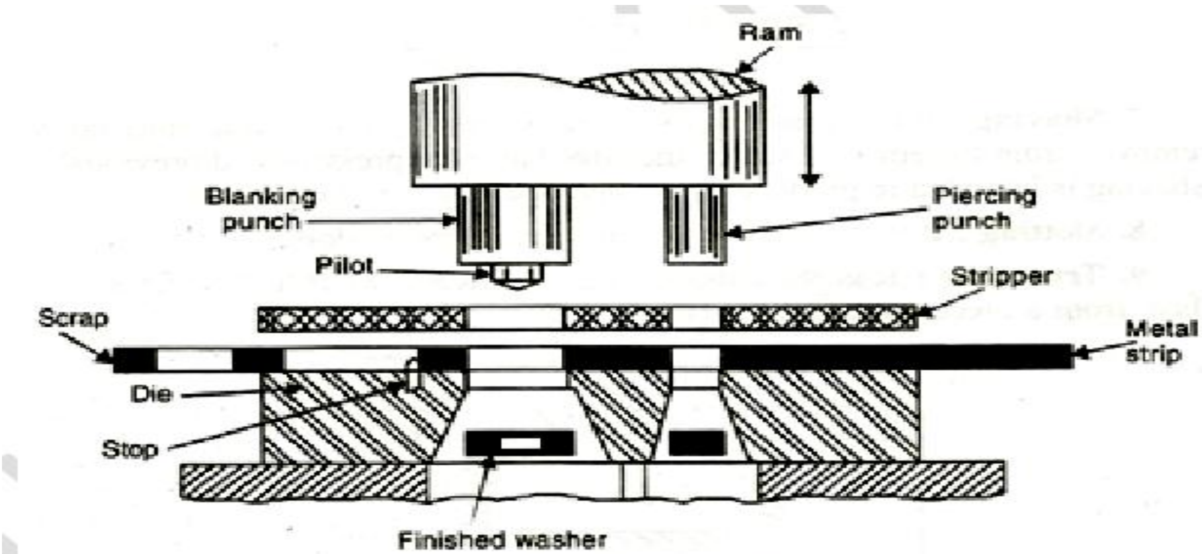


Combinaton Die.

PROGRESSIVE DIE:

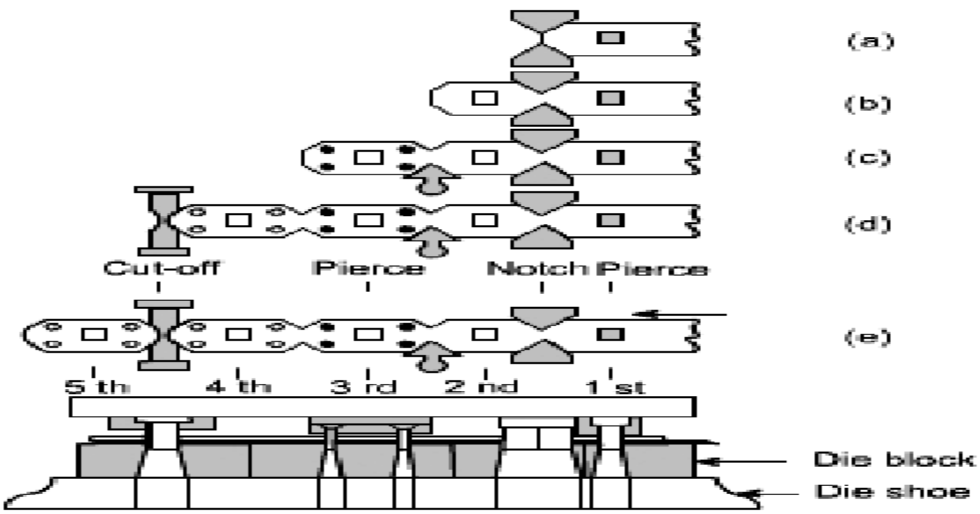
These are made with two or more stations arranged in a sequence. Each station performs an operation on the workpiece, or provides an idler station, so that the workpiece is completed when the last operation has been accomplished. Thereafter each stroke of the ram produces a finished part. Thus after the fourth stroke of a four

– station die, each successive stroke will produce a finished part. Operations which may be carried out in a progressive die are piercing, blanking, forming, drawing, cut – off, etc. The list of possible operations is long.



Washer Production in Progressive Die.

Fig shows a four – station progressive die. The first stroke of the press Fig (a) produces a square hole and two notches. These notches form the left end of the first piece. During the upstroke of ram, the stock is moved to the next station against a finger stop (not shown). The stock is positioned for the second stroke. The second station is an idler, Fig
(b). The right end of the first piece, the left end of the second piece, and a second square hole are pierced



The ram retracts and the scrap strip is moved to the third station against an automatic stop, Fig (c). This stop picks up the notched V and positions the scrap strip. The third stroke of the ram pierces the four holes as shown in Fig (c). The fourth stroke, Fig (d), cuts off and forms the radii at the ends of the finished piece. Thereafter every stroke produces a finished part, Fig (e). Progressive dies are used where higher production rates are desired and the material is neither too thick nor too thin. Their use helps in cutting down the material handling costs.

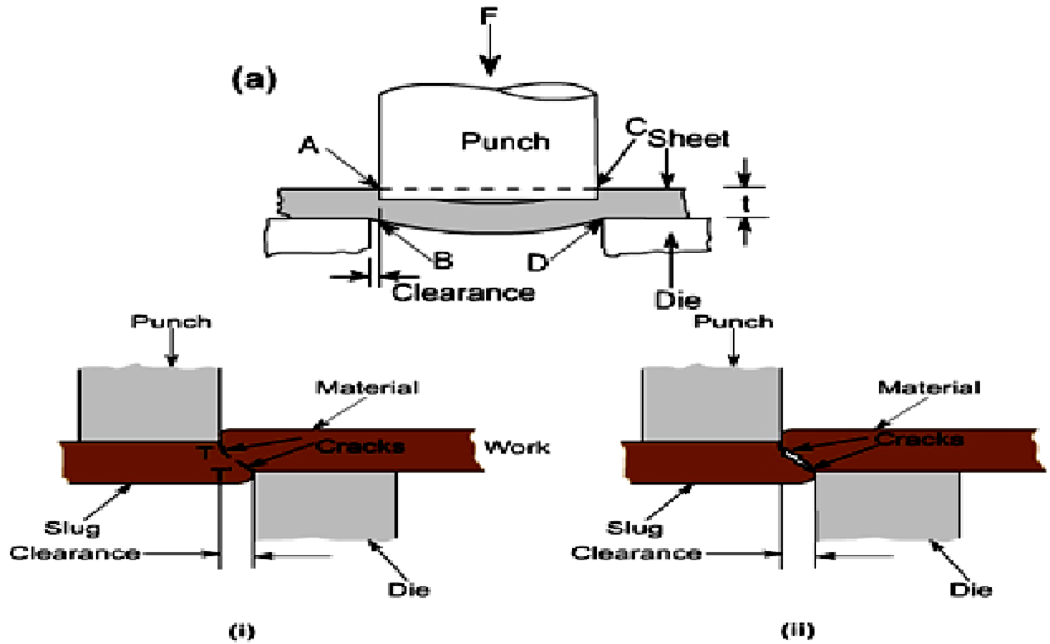
PRINCIPLE OF METAL CUTTING:

SHEARING

Shearing is a cutting operation used to remove a blank of required dimensions from a large sheet. To understand the shearing mechanism, consider a metal being sheared between a punch and a die, Fig 5.1 Typical features of the sheet and the slug are also shown in this figure. As can be seen that cut edges are neither smooth nor perpendicular to the plane of the sheet.

Fig (a) Shearing with a punch and die (b) features of a punched hole and (c) features of the slug.
The major variables in the shearing process are the punch force (F), the speed of the punch, lubrication, the edge conditions of the sheet, the punch and die materials, the corner radii of the punch and die, and the clearance between die and punch.
Fig shows the overall features of a typical sheared edge for the two sheared surfaces *i.e.* the sheet and the slug. The clearance ‘c’ is the major factor that determines the shape and the quality of the sheared edge. usually Shearing starts as the punch presses against the sheet metal. At first, cracks form in the sheet on both the top and bottom edges (marked T and T', in the figure). As the punch descends further,

these cracks grow and eventually meet each other and the slug separates from the sheet. These cracks eventually meet and complete



separation takes place.

CLEARANCE:

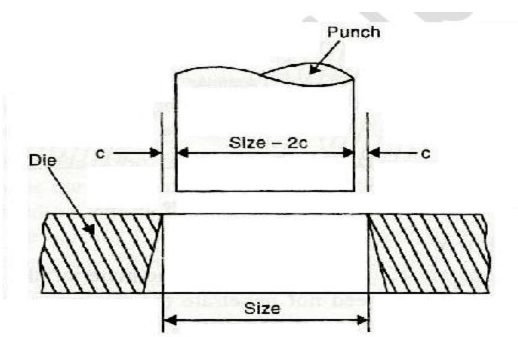
The difference in dimensions between the mating members of a die set is called clearance it is applied in the following manner:

1. In blanking operation where the slug or blank is the desired part and has to be held to size the die opening size equals the blank size and the **punch size is obtained by subtracting the clearance from the die opening size** as shown in fig.

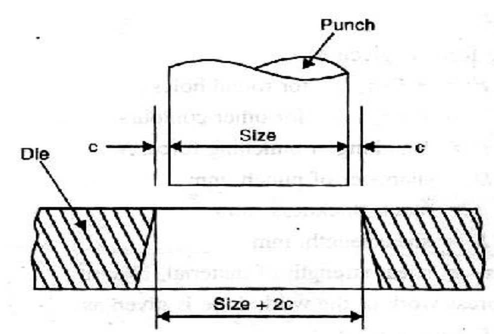
Die size = blank size
Punch size = blank size – 2 x clearance

2. In punching operation when the slug is to be discarded the punch is to be made to the size of the hole and **the die opening size is obtained by adding clearance to the punch size** as in fig.

Punch size = blank size
Die size = blank size + 2 x clearance



Blanking clearance.



Piercing clearance.

The amount of clearance depends upon the following factors:

a) Type of material
b) Thickness of material
c) Hardness of material
d) Strength of material

For thin material the punch should be a close sliding fit. For heavier stock the clearance is large to create the proper shearing action on the stock and to prolong the life of the punch. Hard materials requires large clearance than soft materials.

e)

The amount of clearance depends on the stock thickness the kind of material etc. the usual clearance per side of the die for various metals are as follows

S No.	Material	Clearance

1.	For soft aluminium < 1 mm	C=3% of t
	>1 mm	C=5% of t
2.	For hard aluminium	C = 5% - 8% of t
3.	For hard steel	C=5% of t
4.	For stainless steel	C = 5% - 8% of t

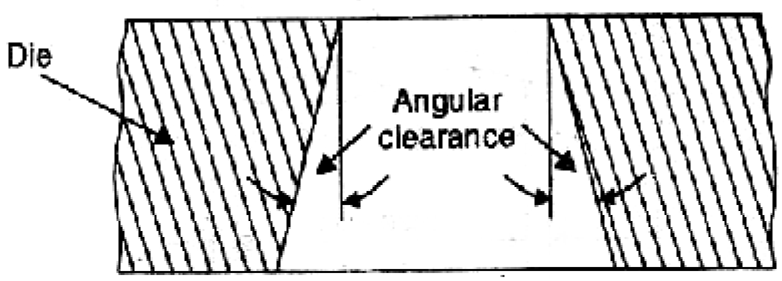
The total clearance between punch and die size will be twice these figures the clearance may be also determined by following relation:

$$C = 0.003\, t \sqrt{\tau_s}$$

Where τ_S = Shear strength of material in N/mm^2

Angular clearance:

It is the clearance below the straight portion of die as shown in fig and is provided to enable the slug to clear the die. It is of $1/2^{O}$ to 2^{O} on the either side depending on the material and shape of the workpiece



Angular clearance on Die.

CUTTING FORCES:

In the cutting operation as the punch moves downwards it need not penetrate the thickness of the stock to affect the complete rupture of the part the distance by which the punch enters in the work material to cause rupture to take place is called penetration and is usually given as the percentage of the stock thickness.

S No.	Material	Penetration (% of stock thickness)
1.	For soft aluminium	60% of t
2.	For 0.15% carbon steel annealed	38% of t
3.	For 0.5% carbon steel annealed	24% of t

The maximum force needed to cut a material is equal to area to be sheared times the shearing strength

$$F_{max} = (\pi Dt)\, \tau_s$$ for circular holes

$$F_{max} = 2(L+B)t\, \tau_s$$ for rectangular holes

$$F_{max} = L\, t\, \tau_s$$ for other contours

Where F =Blanking or punching force, N
D = Diameter of punch, mm
t = Stock thickness, mm
L = Shear length, mm

τ_s = Shear strength of material, N/mm2

ENERGY IN PRESS:

Energy in press work ideally is given as

$$E = F_{max} \text{ x } punch\ travel$$

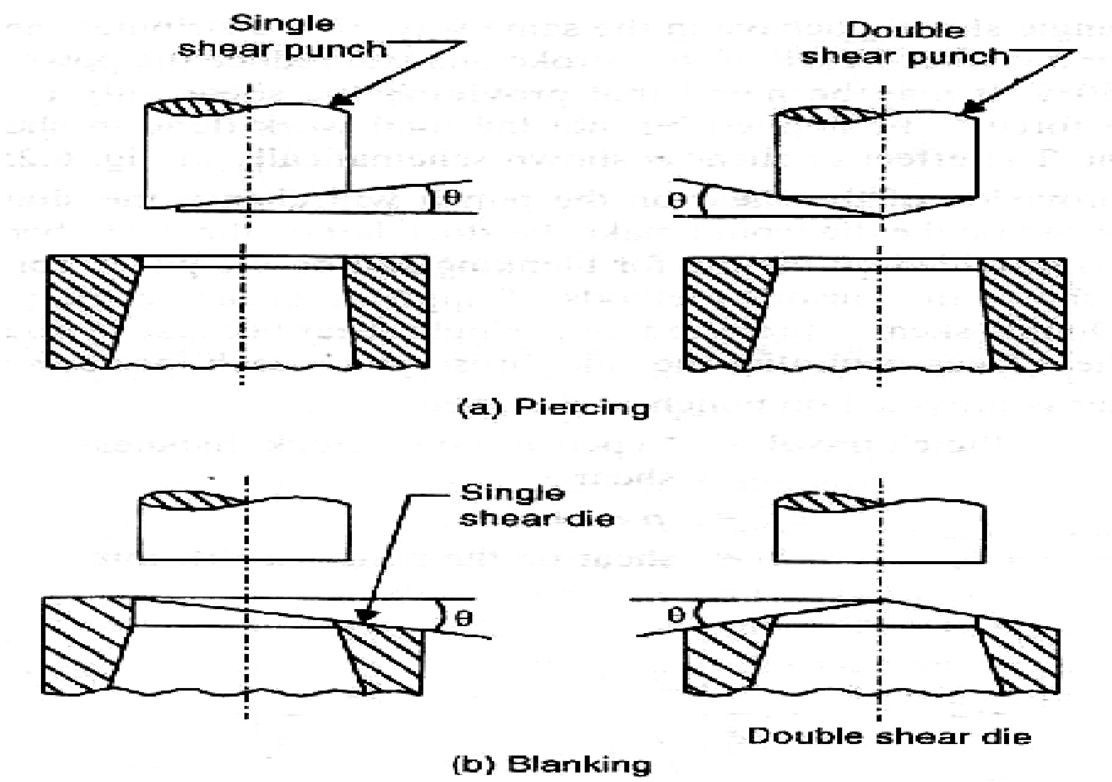
$$\boxed{E = F_{max}.\ p.\ t}$$

Where E = energy or work done, Nm

p = %age of penetration required to cause the rupture.

METHODS OF REDUCING CUTTING FORCES:

In the process of cutting, very high forces are applied for a short interval of time which gives shock or impulse. The reduction in cutting forces is achieved by arranging for a gradual cut instead of sudden cut of the stock for this following methods are applied:-
Flat punched and dies require a maximum of power. To reduce the shear force, the punch or die face should be ground at an angle so that the cutting action is progressive. Think of using scissors that cut the stock, such as paper. Punches and dies that have a die face that angle slightly behave in the same way. This distributes the greater shearing action over a greater length of the stroke and can reduce the power required up to 50%.



Methods of applying shear on punch and die.

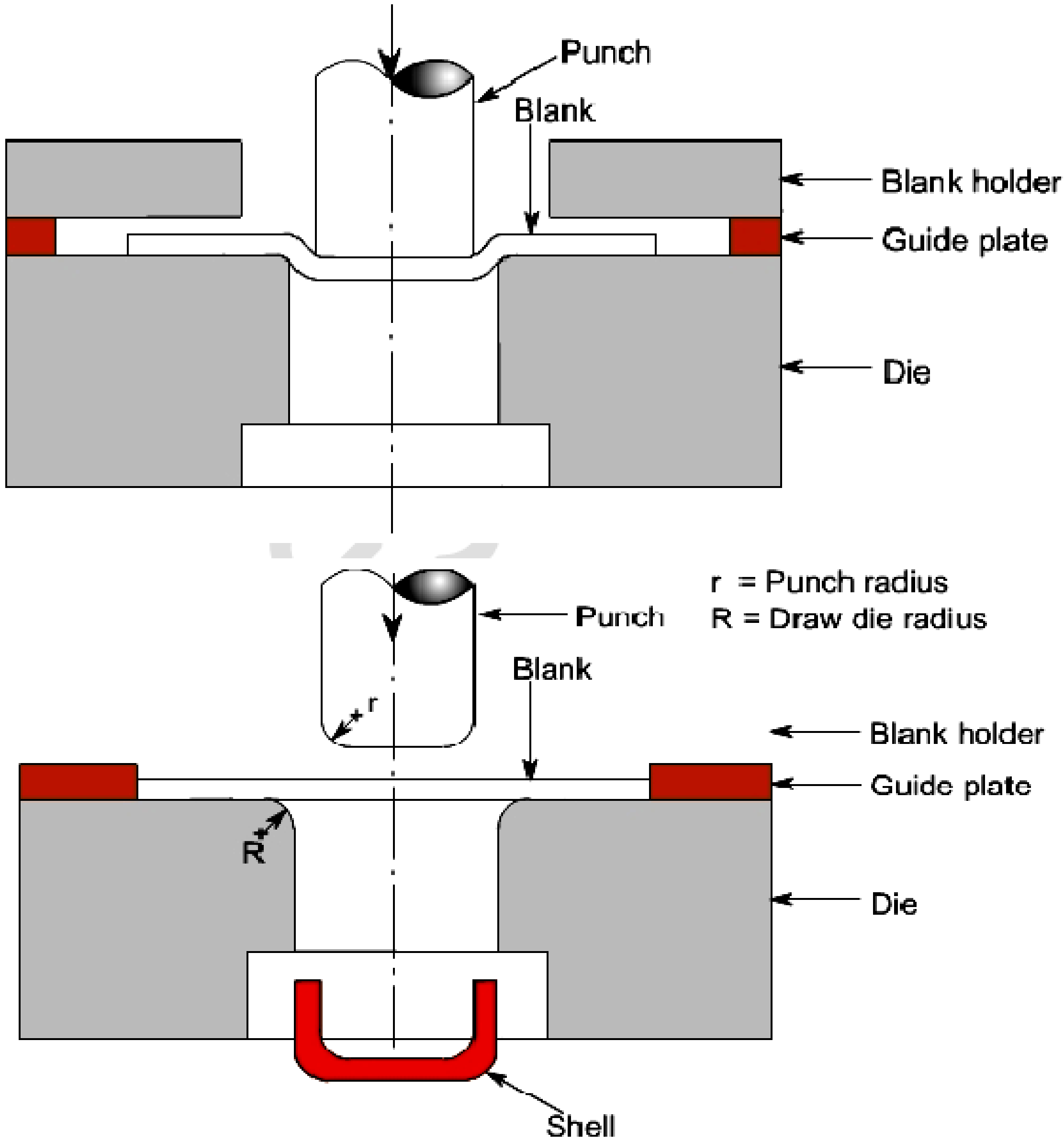
DEEP DRAWING

DRAWING

Drawing is the process of forming a flat piece of material i.e. blank into a hollow shape by means of a punch which causes the blank to flow into die cavity. Drawing is classified as shallow, moderate or deep as following:

Shallow	h/d < ½
Moderate	½ < h/d < 1
Deep	h/d > 1

It is a process of cold forming a flat blank of sheet metal into a hollow vessel without much wrinkling, trimming, or fracturing. The process involves forcing the sheet metal blank into a die cavity with a punch. The punch exerts sufficient force and the metal is drawn over the edge of the die opening and into the die, Fig 6.4. In forming a cup, however, the metal goes completely into the die,



The metal being drawn must possess a combination of ductility and strength so that it does not rupture in the critical area (where the metal blends from the punch face to the vertical portion of the punch). The metal in this area is subjected to stress that occurs when the metal is pulled from the flat blank into the die.

OPERATION:

A setup similar to that used for blanking is used for drawing with the difference that the punch and die are given necessary rounding at the corners to permit smooth flow of metal during drawing. The blank of appropriate dimensions is place within the guides on the die plate. The punch descends slowly on the blank and metal is drawn into the die and the blank is formed into the shape of cup as punch reaches the bottom of the die. When the cup reaches the counter – bored portion of the die, the top edge of the cup formed around the punch expands a bit due to the spring back. On the return stroke of the punch, the cup is stripped off the punch by this counter –

bored portion. Some lubricant is generally used over the face of the blank to reduce friction and hence drawing load.

DEEP DRAWABILITY:

Deep draw ability or drawing ratio of the metal is defined as the ratio of max blank diameter to the diameter of the cup drawn from the blank (Usually taken to be equal to punch diameter). For a given material there is limiting drawing ratio (LDR) after which the punch will pierce a hole in the blank instead of drawing the blank. The ratio depends upon many factors such as type of material, amount of friction etc. and usual range of maximum drawing ratio is 1.6 - 2.3

RADIUS OF DRAW DIES(R):

The edge radius of the die over which blank is drawn is important if it is too small. The resistance to the flow ofmetal is increases leading to cutting or tearing of material. If radius is too large it gives the formation of wrinkles in the metal. This radius usually ranges

R = 4t, normal

= 6t to 8t, when blank holder is used [Where t = blank thickness]

ORNER RADIUS OF PUNCH(r_{cp}): It should be 4 to 10 times the stock thickness.

DRAW CLEARANCE:

The side clearance between punch and die should be more than the stock thickness to take into account the thickening of metal over die radius. When the flat blank is drawn into the die cavity otherwise the blank may get jammed in the die cavity. The side clearance between punch and die is usually 7 to 20 % of stock thicknesses.

Blank Thickness (mm)	First draw	Redraw
Upto .38mm	1.07 t – 1.09 t	1.08 t – 1.1 t
0.4 – 1.27	1.08 t – 1.1 t	1.09 t – 1.12 t
1.3 – 3.18	1.1 t – 1.12 t	1.12 t – 1.14 t
3.2 and above	1.12 t – 1.14 t	1.15 t – 1.2 t

DRAWING SPEED:

The punch travels downward to force the blank into die cavity in which the ram speed is critical to initiate plastic deformation. The internal inertia must be overcome and sufficient time should be given otherwise the metal can rupture instead of being drawn.

CALCULATING BLANK SIZES:

It is generally difficult to find the exact size of the blank needed for drawing a given cup, because of thinning and thickening of the metal sheet during the drawing operation. The following simple relations can be used for determine the blank diameter D:

$$\therefore D = \sqrt{d^2 + 4dh} \quad \text{when } \frac{d}{r} \geq 20$$

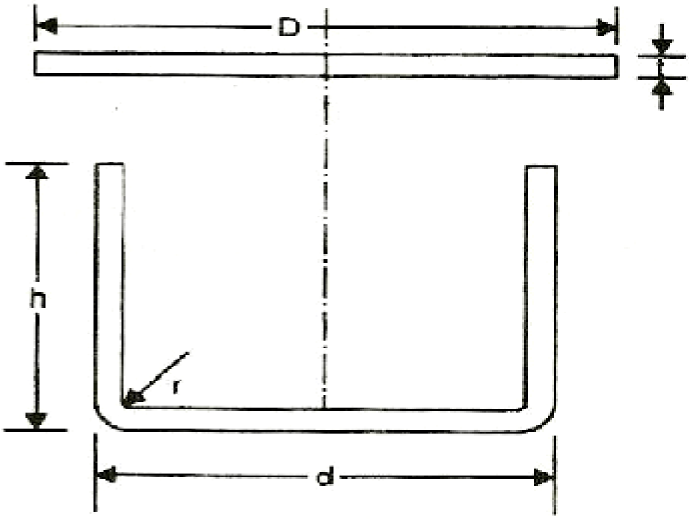
$$D = \sqrt{d^2 + 4dh - 0.5r} \quad \text{when } 15 \leq \frac{d}{r} < 20$$

$$D = \sqrt{d^2 + 4dh - r} \quad \text{when } 10 \leq \frac{d}{r} < 15$$

$$D = \sqrt{(d - 2r)^2 + 4d(h - r) + 2\pi r(d - 0.7r)} \quad \text{when } \frac{d}{r} < 10$$

Where

D= blank diameter, mm
d = outside diameter of cup, mm
h = height of cup, mm
r = corner radius on punch, mm



Drawn shell.

For drawing cylindrical shells having circular cross section, the maximum drawing force P can be determined from the relation

$$F = \pi . d . t . \sigma_Y . [D/d - C]$$

Where d = outside diameter of cup, mm
t = thickness of material, mm
σ_Y = yield strength of material, N/mm^2
C= constant from 0.6- 0.7 and its account for friction and bending effects
D = blank diameter, mm

NUMBER OF DRAWS:

The stresses which are imposed on the work material during drawing limits the amount of reduction in blank diameter if the reduction required is greater than one draw will be needed.

%age reduction = [(D-d)/D] 100

Number of draws can be determined from the ratio of inside shell height and mean shell diameter.

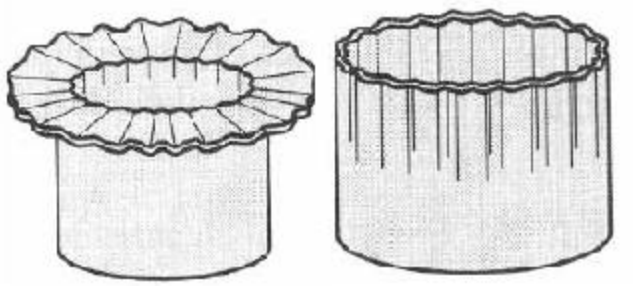
S No.	h/d	No. of draws
1.	Up to 0.7	1
2.	0.7 – 1.5	2
3.	1.5 – 3.0	3
4.	3.0 – 7.0	4

DEFECTS IN DEEP DRAWING:

1. **Earing:** It is the formation of ears or scalloped edges around the top of a drawn shell which results from directional differences in the plastic working properties or rolled metal with, across, and at

angle to the direction of rolling

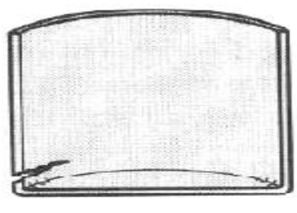
2. **Buckling:** an uncontrolled deformation pattern perpendicular to the surface of a sheet caused by compressive stresses is known as buckling. Buckling in flanged part is referred to **Wrinkling.** And buckling in the wall of the part is referred to **puckering.**



3. **Bulging:** In this the diameter of a cylindrical shell (usually to a spherical shape) increases or it is the expanding of the outer walls of any shell or box shape whose walls were previously straight.

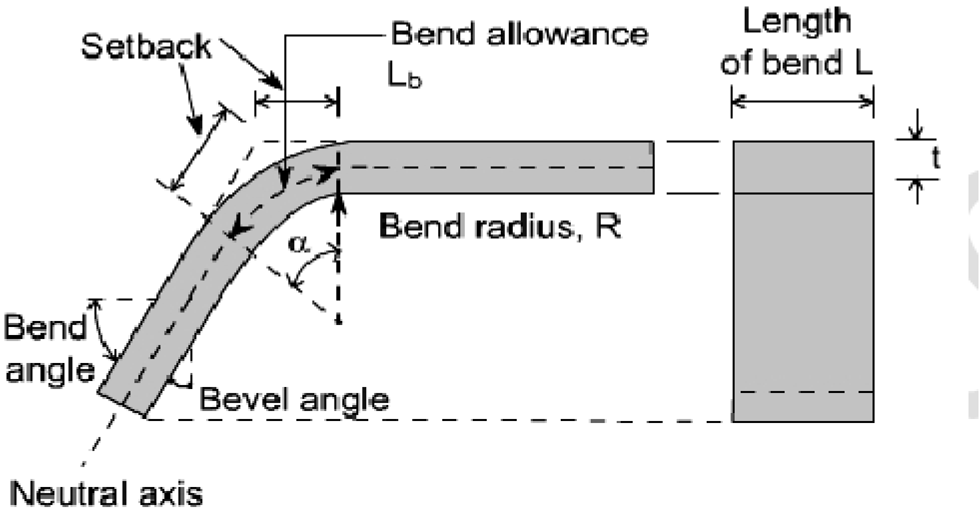
4. **Surface scratch:** This occurs on the surface of the draw cup.

5. **Tearing:** This also occurs on the surface of the draw cup**.**



BENDING

Bending is one very common sheet metal forming operation used not only to form shapes like seams, corrugations, and flanges but also to provide stiffness to the part. (by increasing its moment of inertia).
As a sheet metal is bent (Fig 6.1), its fibres experience a distortion such that those nearer its outside, convex surface are forced to stretch and come in tension, while the inner fibres come in compression. Somewhere, in the cross section, there is a plane which separates the tension and compression zones. This plane is parallel to the surface around which the sheet is bending, and is called neutral axis. The position of neutral axis depends on the radius and angle of bend. Further, because of the Poisson's ratio, the width of the part L in the outer region is smaller, and in the inner region it is larger, than the initial original width.



Sheet Metal Bending.

It may be noted that the bend radius is measured to the inner surface of the bent part.

BEND ALLOWANCE

It is the length of the neutral axis in the bend, Fig 6.1. This determines the blank length needed for a bent part. It can be approximately estimated from the relation

$$L_b = \alpha\,(R + kt)$$

where, L_b = bend allowance (mm)

α = bend angle (radian)

R = bend radius (mm)

t = thickness of sheet (mm), and

k = constant, whose value may be taken as 1/3 when $R < 2t$, and as 1/2 when $R \geq 2t$.

SPRINGBACK:

In bending when the applied load is removed, the metal tries to regain its original position. This results in a smaller bend angle and a larger bend radius than before. Such a phenomenon is termed as springback.

Springback for some common metals are:
Low carbon steel – $1^{O} – 2^{O}$
Medium carbon steel - $3^{O} – 4^{O}$