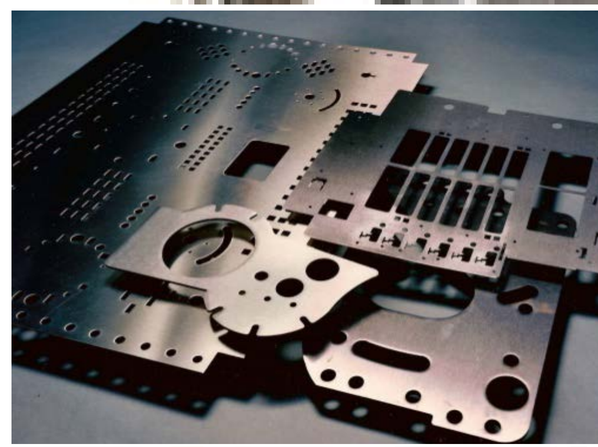
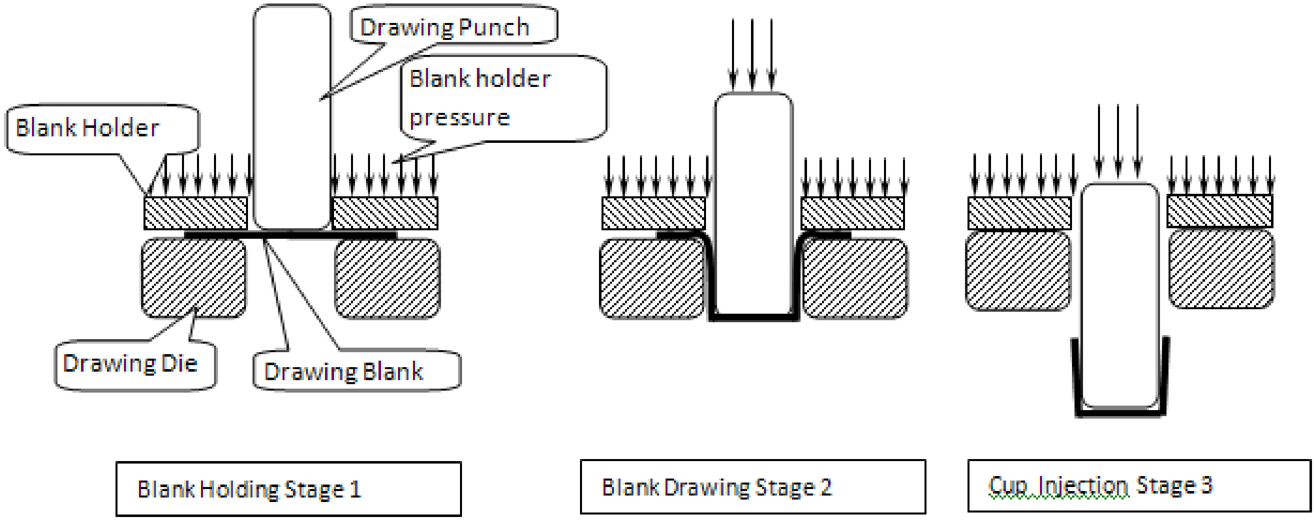
Chapter 8:

Sheet metal Forming processes



CHAPTER Eight: Sheet Metal Processes

8.1 Sheet Metal Deep Drawing Process Technology

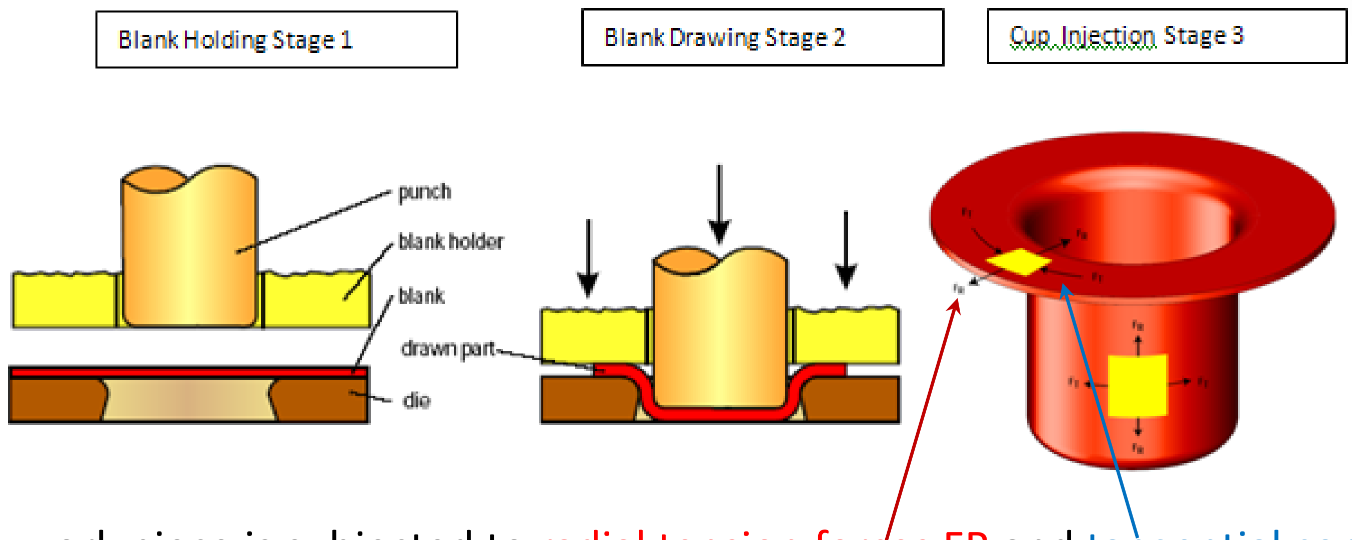


➢***Definition***: In deep drawing, as a first step, a cup is produced from the flat blank. This cup can then be further processed, for example by an additional drawing, reverse drawing, ironing or extrusion process.

➢In all deep drawing processes, the pressing force is applied over the draw punch onto the bottom surface of the drawn part.

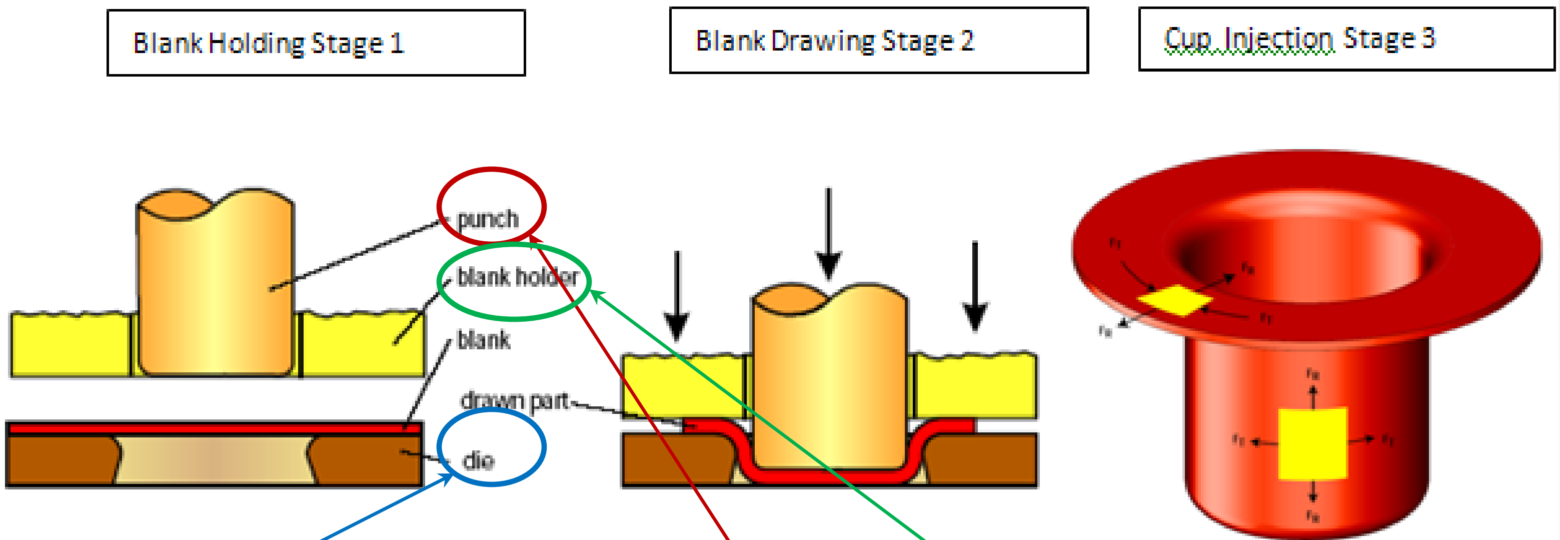
➢It is further transferred from there to the perimeter in the deformation zone, between the die and the blank holder.

8.1 Sheet Metal Deep Drawing Process Technology.. *continue*



- The work piece is subjected to radial tension forces FR and tangential compression forces FT.
- The material is compressed in the tangential direction and stretched in the radial direction.
- As the draw depth is increased, the amount of deformation and the deformation resistance are also increased.

8.1 Sheet Metal Deep Drawing Process Technology.. *continue*

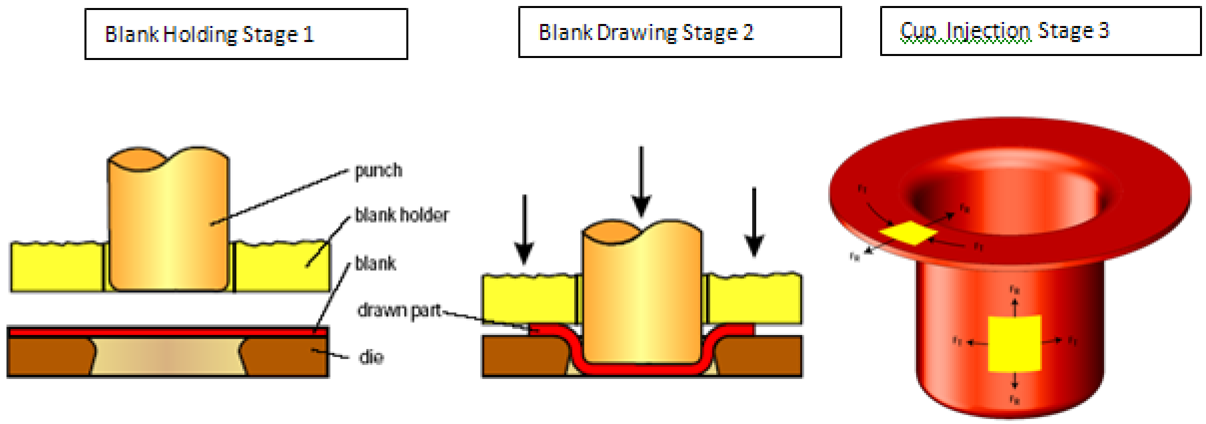


➢*Deep drawing with rigid tooling,* involving draw punches, a blank holder and a female die. The blank is generally pulled over the draw punch into the die, the blank holder prevents any **wrinkling** taking place in the flange.

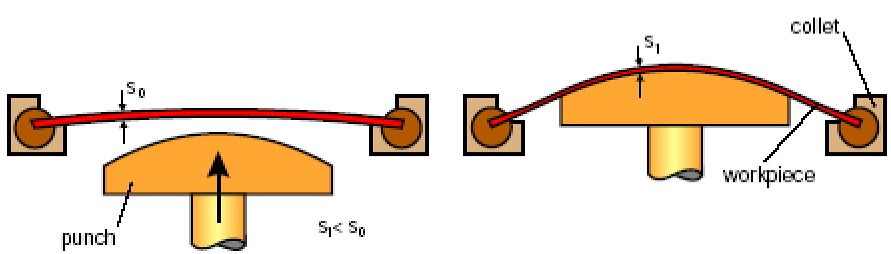
➢In pure deep drawing, the thickness of the sheet metal remains unchanged since an increase in the surface area does not occur, as it occurs in a stretch drawing process.

a. Good Cup   c. Wrinkled Cup

8.1 Sheet Metal Deep Drawing Process Technology .. continue



Deep drawing and stretching processes



Unlike in deep drawing, in *stretch forming* the sheet metal cannot flow because it is gripped by clamps or held in a blank holder. The forming process takes place with a reduction in the thickness of the sheet metal. Pure stretch drawing is a forming process conducted under tensile stresses.

8.1.1 Deep Drawing Processes

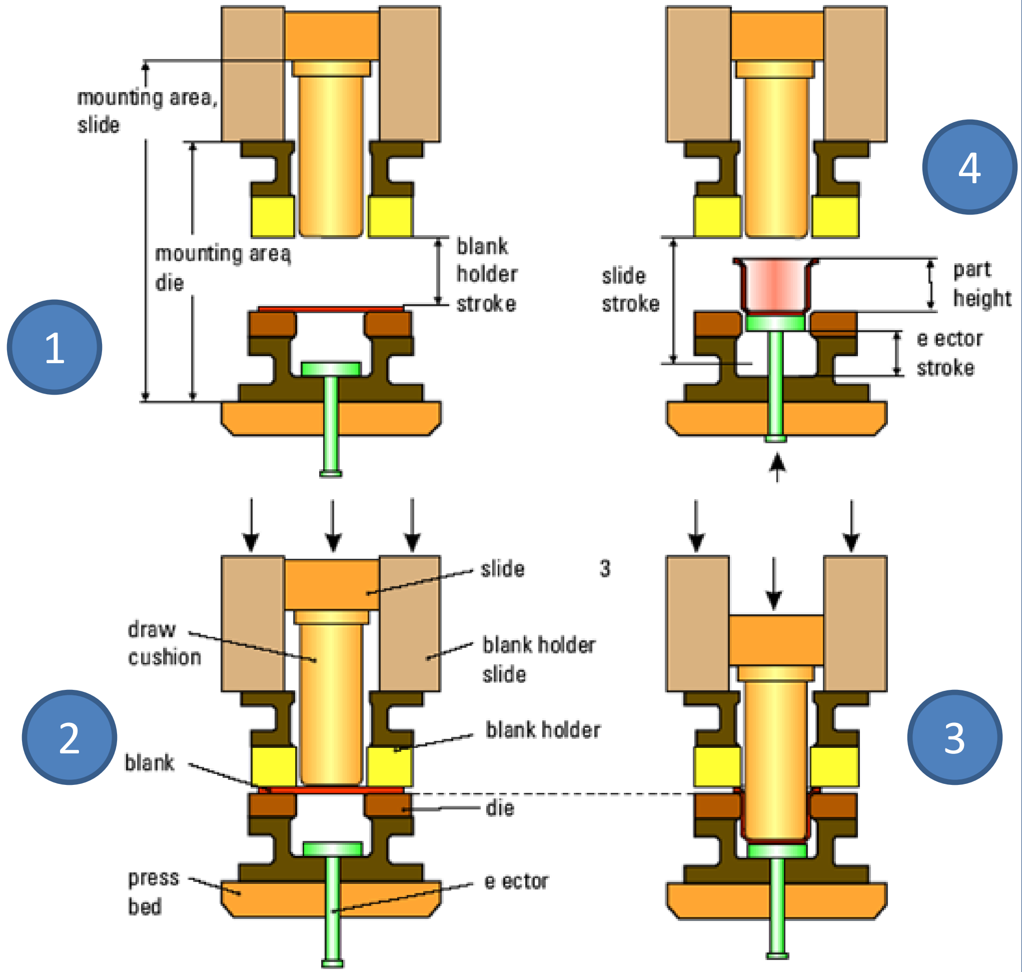
There are basically <u>three possible ways of applying blank holder force , </u>this lead us to three type of deep drawing processes.

1) **Double action deep drawing process**
2) **Single action deep drawing process**
3) **Counter drawing or reverse drawing process**

8.1.1 Deep Drawing Processes

1) Double action deep drawing process

- In *double-action drawing operations* the press has two slides acting from above: the drawing slide with the draw punch and the blank holder slide with the blank holder.
- The blank-holding slide transfers the blank-holding force via the blank holder onto the blank and the draw die.
- The die and the ejector are located in the lower die on the press bed



8.1.1 Deep Drawing Processes

2) Single action deep drawing process

- *Single-action drawing* with a draw cushion works the other way round the forming force is exerted by the slide above through the die and the blank holder onto the draw cushion in the press bed.
- The draw punch and the blank holder of the drawing tool are both located in a base plate on the press bed.
- Pressure pins, which come up through the press bed and the base plate transfer the blank holder force from the draw cushion onto the blank holder.

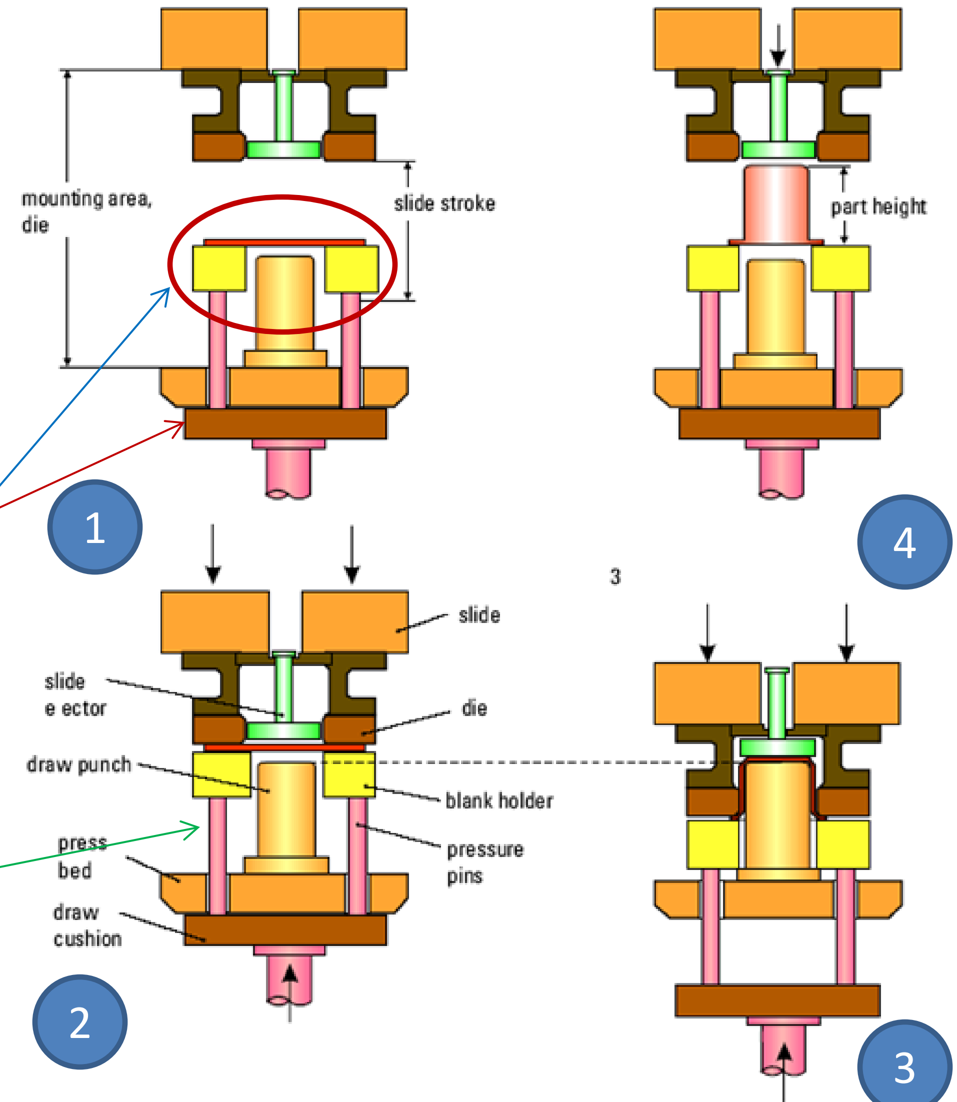


Fig 8.4 Deep drawing with single action and drawing cushion.

?

3) Counter drawing or reverse drawing process

➢Energy is saved and cost-effective alternative in **stamping** using counter drawing process.

➢The top die is attached to the slide. The lower die is mounted on the press bed with the blank holder. The punch is located in an opening in the center of the press bed on the draw cushion. During deformation, the blankholding force is transferred via the slide from above and the draw punch force acts from below through the active draw cushion. The punch forms the part by means of its upward movement while the blank holder rests on the die, see Fig 8.5.

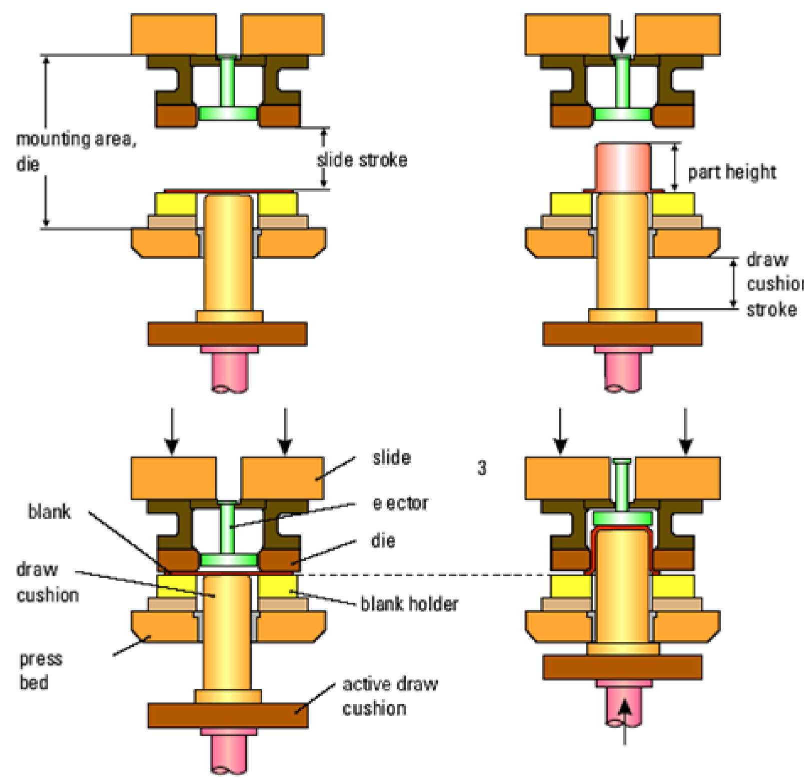
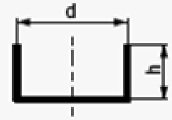


Fig 8.5 Counter deep drawing with single action and drawing cushion.

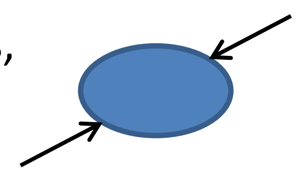
8.1.2 Calculation of the blank size in deep drawing:

- Before starting drawing operations the size and form of the blank must be determined for the desired final part geometry and die layout.
- This should be shown using the example of a simple rotationally symmetrical body.
- In order to calculate the blank diameter, volume constancy in metal forming is used. Hence, the entire ax-symmetric part is divide into various individual ax symmetric components, in accordance with Table 8.1a and then calculate the surface areas of these components.
- The total surface area as a sum of the individual areas enables the calculation of the diameter of blank D.

Table 8.1a Blank size calculation for simple geometry

Container shape *(cross-section)* rotationally symmetrical shapes	Blank diameter D =
1 	$\sqrt{d^2 + 4 \cdot d \cdot h}$ *

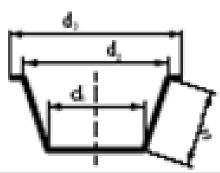
$$\cancel{\frac{\pi}{4}} D^2 = \frac{\pi}{4} d^2 + \pi d h = \frac{\pi}{4} d^2 + \frac{\pi}{4} 4dh = \cancel{\frac{\pi}{4}} (d^2 + 4dh)$$



8.1.2 Calculation of the blank size in deep drawing:

Example 8.1

A cup with a conical outline and flange is to be produced. The base diameter is 60 mm, the upper diameter 100 mm, the outside flange diameter 120mm and the can body measurement 75mm. The required diameter of the blank piece is calculated according to formula 20 from Table 8.1d.

20 	$\sqrt{d_1^2 + 2 \cdot s \cdot (d_1 + d_2) + d_3^2 - d_2^2}$

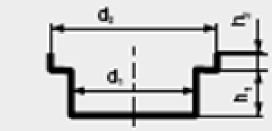
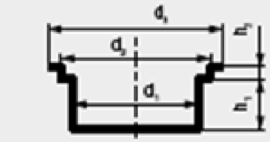
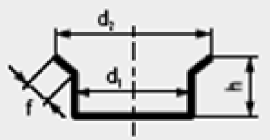
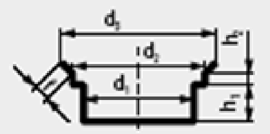
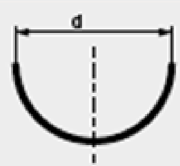
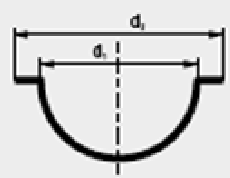
d_1=60mm, d_2=100mm, d_3=120mm, s=75mm.

$$D = \sqrt{60^2 + 2(75)(60+100) + 120^2 - 100^2} = 178.9mm \text{ or } 179mm$$

8.1.2 Calculation of the blank size in deep drawing:

More cases in Table 8.1b,c and d

Table 8.1b More cases for blank diameter calculation

	Container shape *(cross-section)* rotationally symmetrical shapes	Blank diameter D =
3		$\sqrt{d_2^2+4\cdot(d_1\cdot h_1+d_2\cdot h_2)}$ *
4		$\sqrt{d_3^2+4\cdot(d_1\cdot h_1+d_2\cdot h_2)}$ *
5		$\sqrt{d_1^2+4\cdot d_1\cdot h+2\cdot f\cdot(d_1+d_2)}$ *
6		$\sqrt{d_2^2+4\cdot(d_1\cdot h_1+d_2\cdot h_2)+2\cdot f\cdot(d_2+d_3)}$ *
7		$\sqrt{2\cdot d^2}=1.414\cdot d$
8		$\sqrt{d_1^2+d_2^2}$

8.1.3 Calculation Drawing Ratio:

Drawing ratio (β) defined by the ratio of blank diameter to punch diameter for one drawing pass:

$$\boxed{\beta = \frac{Blank\ diameter\ (D)}{Punch\ diamter\ (d)} = \frac{D}{d}}$$

Drawing for first pass will be $\beta_1 = D/d_1$, drawing for second pass will be $\beta_2 = d_1/d_2$ and so on. Where d_1 drawing punch diameter for first drawing stage, d_2 drawing punch diameter for second drawing stage, ..etc. β_{tot} is the drawing ratio for all drawing process and equal to:

$$\boxed{\beta_{tot} = \beta_1\beta_2..\beta_n}$$

Fig 8.6 shows redrawing or second drawing pass of an cup.

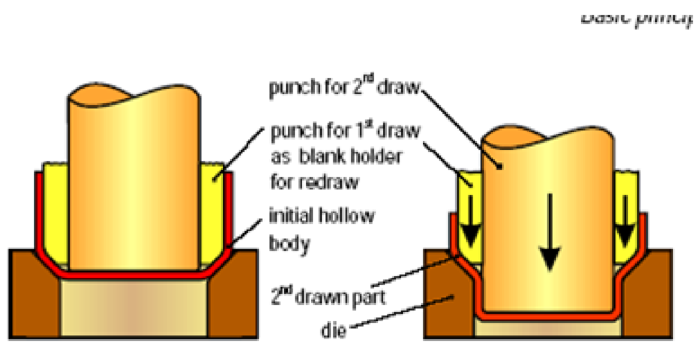


Fig 8.6 Redrawing or second pass drawing operation

The maximum drawing ratio depends on the properties of the blank material used. As a rough estimation the maximum drawing ration for first drawing is 2, ($\beta = 2$). To increase drawing ratio several drawings passes required. However, from experience the next drawing ratio is not more than 1.3 due to strain hardening condition. However, if the product annealed the next drawing ratio can be increase to 1.7.

Example 8.2

From a 1mm thick blank of sheet metal material (ST14) a hollow cylindrical part with a diameter of 45mm a can body height of 90mm is to be drawn. Calculate drawing ratio?

Solution

From Table 8.1a, blank diameter calculated as follows:

$$D = \sqrt{d^2 + 4.d.h} = \sqrt{45^2 + 4(45)(90)} = 135mm$$

Total drawing ratio $\beta_{tot} = \beta_1\beta_2..\beta_n = \frac{D}{d} = \frac{135}{45} = 3$

Since β_{tot} is greater than the remaining draw ratio of 2, several drawing operations are needed, where $\beta_1=2$, and all drawing ratio of others are less than 1.3. Hence, total drawing ratio equal to 1.95*1.25*1.25=3.

Hence, the size of punch diameters will be calculated as follows:

$$d_1 = \frac{D}{\beta_1} = \frac{135}{1.95} = 69.2mm\ or\ 69mm$$

$$d_2 = \frac{d_1}{\beta_2} = \frac{69}{1.25} = 55.2mm\ or\ 55mm$$

$$d_3 = 45mm\ (given), hence, \beta_3 = \frac{55mm}{45mm} = 1.22$$

It worth to note, maximum drawing ratio β_{max} depend however on other factors, this can be investigated in different references [].

$$\boxed{\beta_{max} = f(D, d, \mu, r - value, s, ..)}$$

For example, when friction between the drawn part and the punch is low, this will result in failures the base of the cup.

8.1.4 Calculation Drawing Force

Maximum drawing force for single drawing operation calculated from the following formula:

$$F_U = \pi.(d_1 + s)\ s\ R_m\ (1.2)\frac{\beta - 1}{\beta_{tot} - 1} \qquad Newton$$

Where

d_1 = punch diameter (mm)

S = sheet metal thickness (mm)

R_m =material tensile strength (N/mm^2)

β =Actual draw ratio

β_{max} =maximum draw ratio.

Example 8.3

For the following drawing process,
Material: 1.0338 (St 14) with tensile strength Rm = 350 N/mm2
Sheet metal thickness: s = 0.8 mm
Punch diamter: d = 240 mm
Draw ratio β_1: = 1.75 (D = 420 mm)
Max. permitted draw ratio: β_{max} = 2.0
Calculate drawing force ?

Solution

Drawing force $F_U = \pi(240 + 0.8)mm\ (0.8mm)\left(\frac{350N}{mm^2}\right)(1.2)\frac{1.75-1}{2-1} = 190637\ N = 191\ KN$

8.1.5 Calculating Blank Holding Force

The magnitude of blank holder force is not only an important factor in avoiding wrinkling of the material but also vital because of its influence on the straining of the upper surface. As the blank holder force is increased, the restraining effect on the material located between the die and the blank holder becomes stronger so that the strain on the upper surface layer is also increased. The blank holder force required for deep drawing FB [N] is calculated from D [mm], d' [mm] (die diameter), r [mm] (die corner radius) and p [N/mm2] (specific blank holder pressure):

$$F_B = \frac{\pi}{4}[D^2 - (d' + 2r)^2]\ p$$

It is often to approximate the equation by neglecting *r*, and die/punch clearance. The blank holding force can be approximated as follows:

$$F_B = \frac{\pi}{4}[D^2 - (d)^2]\ p$$

Blank hold pressure variable and depending on material, see Table 8.2

Table 8.2 Blank hold pressure for different materials:
Steel : *p=2.5 N/mm2*
Copper alloy : p=2.0 ... 2.4 N/mm2
Aluminum alloy : p=1.2 ... 1.5 N/mm2


a. Good Cup


c. Wrinkled Cup

Example 8.4

A sheet metal blank from steel ST 14, with R_m=350 N/mm^2 tensile strength is to be formed with a puch having a diameter of d=240mm and a drawing ratio of β=1.75 and blank diameter D= 420mm. Calculate blank holder force ?

$$F_B = \frac{\pi}{4}(D^2 - d^2)p = \frac{\pi}{4}(420^2 - 240^2)\left(2.5\frac{N}{mm^2}\right) = 63303\ N = 63\ KN$$

8.1.6 Calculating Drawing Energy

As simple approximation drawing energy calculated for double acting presses, is drawing force s drawing force (F_U) multiply by the drawing stroke (h) and correction factor (x).

$$W_d = x\,(F_U)h \qquad [N.m]$$

The correction factor, which is dependent on the material and the draw ratio $\beta = D/d$, takes into account the actual drawing force characteristics; this factor fluctuates between 0.5 and 0.8. The higher level is for soft materials, which can be drawn with the maximum draw ratio β_{max} and for flanged shells, which are only partially but not completely drawn through. The lower level is for a small draw ratio, that is to say for short drawing depths or for harder grades of sheet metal. When drawing normal materials, calculations can be based on x < 0.65 up to 0.75.

A sufficiently accurate rough calculation formula for estimating the draw energy of a double-action press is:

$$W_d = \frac{2}{3}(F_U)h \qquad [N.m]$$

For a single-action drawing press with draw cushion, the slide force is increased by the blank holder force F_B, hence, total energy for both drawing and blank holder force is

$$W_e = [x\,(F_U) + F_B)]\,h \qquad [N.m]$$

Example 8.5

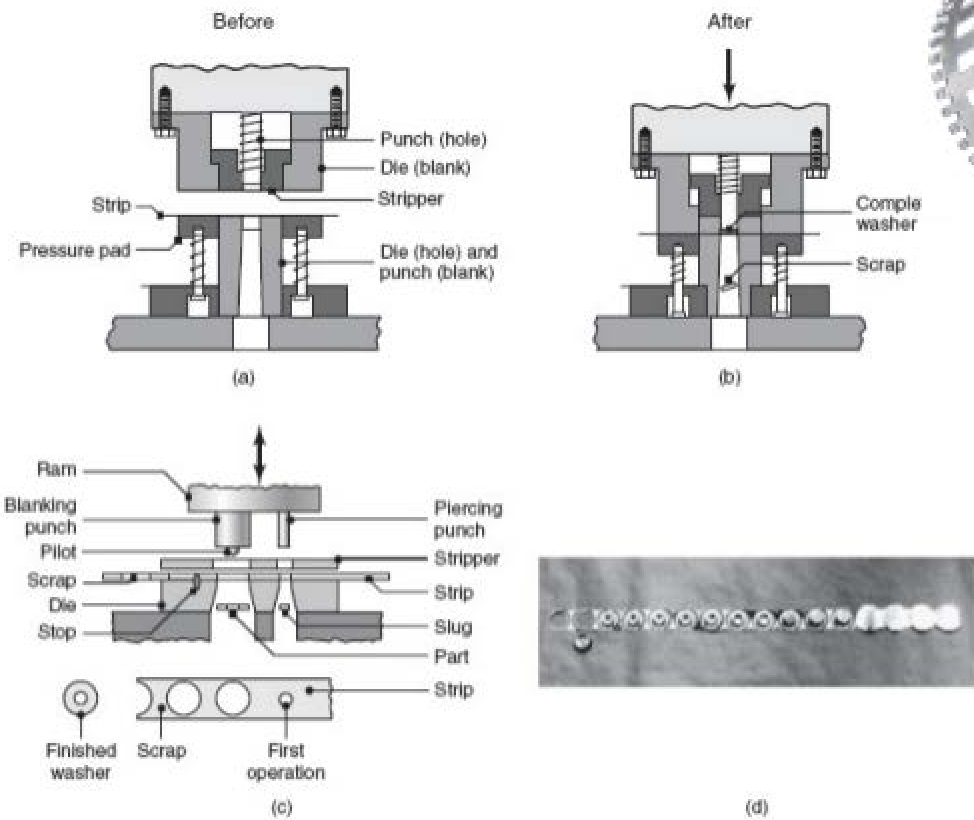
Calculate the energy required for drawing in double-acting press for a cup has 0.8 mm thickness, steel material with tensile stress R_m=350 N/mm^2 and cup diameter of 60mm and 40mm height. Given blank diameter D=115mm and drawing ratio β=1.9 ?

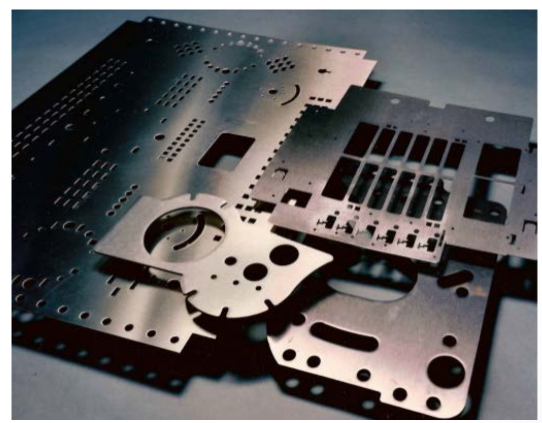
Solution

$$W_d = \frac{2}{3} F_U \, h = \frac{2}{3} \pi(d_1 + s).s.R_m.1.2\frac{\beta - 1}{\beta_{max} - 1} h$$

$$W_d = \frac{2}{3} F_U \, h = \frac{2}{3} \pi(60 + 0.8).(0.8).(350).1.2\frac{1.9 - 1}{2.0 - 1} (40) = 490.3 \, Nm = 490 \, J$$

8.2 Shear and Hole Stamping Products

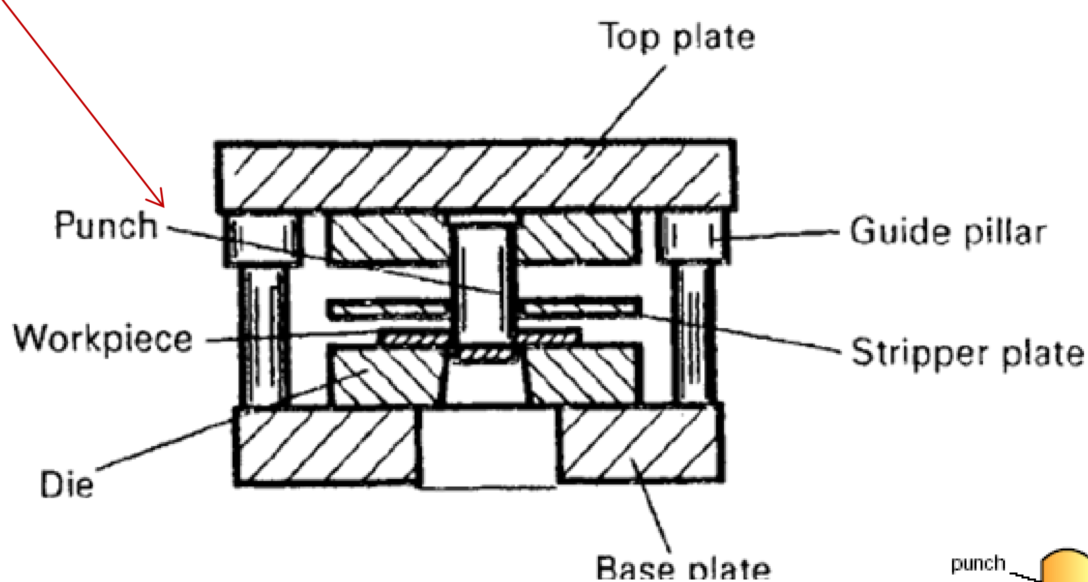


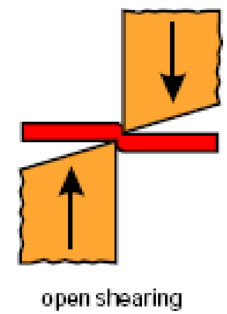


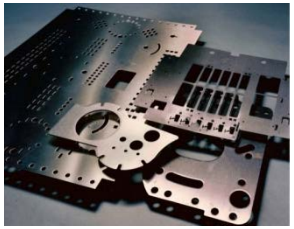
8.2.1 Sheet Metal Shearing Process

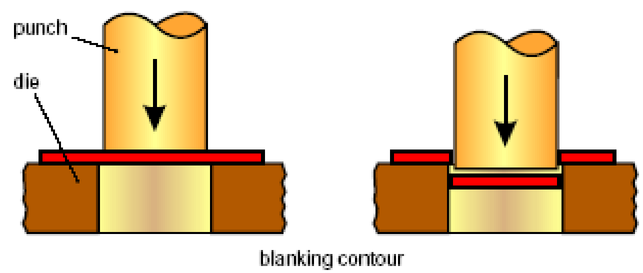
For simple shearing of a sheet of material along a straight line a guillotine is used, either hand or powered. The material is clamped on the bed of the guillotine by a clamp bar, with the line of cut along the edge of the bed, and the knife of the guillotine descends, creating a sheaving action between itself and the edge of the bed, an action similar to the cutting of paper with a pair of scissors.

For shapes the blade is replaced by a shaped punch and the edge of the bed by a correspondingly shaped die plate. This is termed 'blanking'. A die set incorporating guide pillars is provided to maintain alignment between punch and die. Such a blanking tool is shown diagrammatically in ~~Figure 3.7~~. Precise clearance is maintained between punch and die (5 per cent of the metal thickness when blanking steel) to give correct cutting conditions.



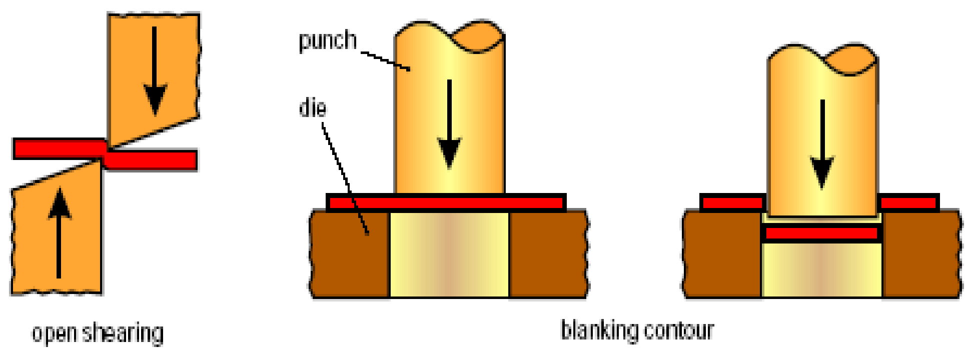






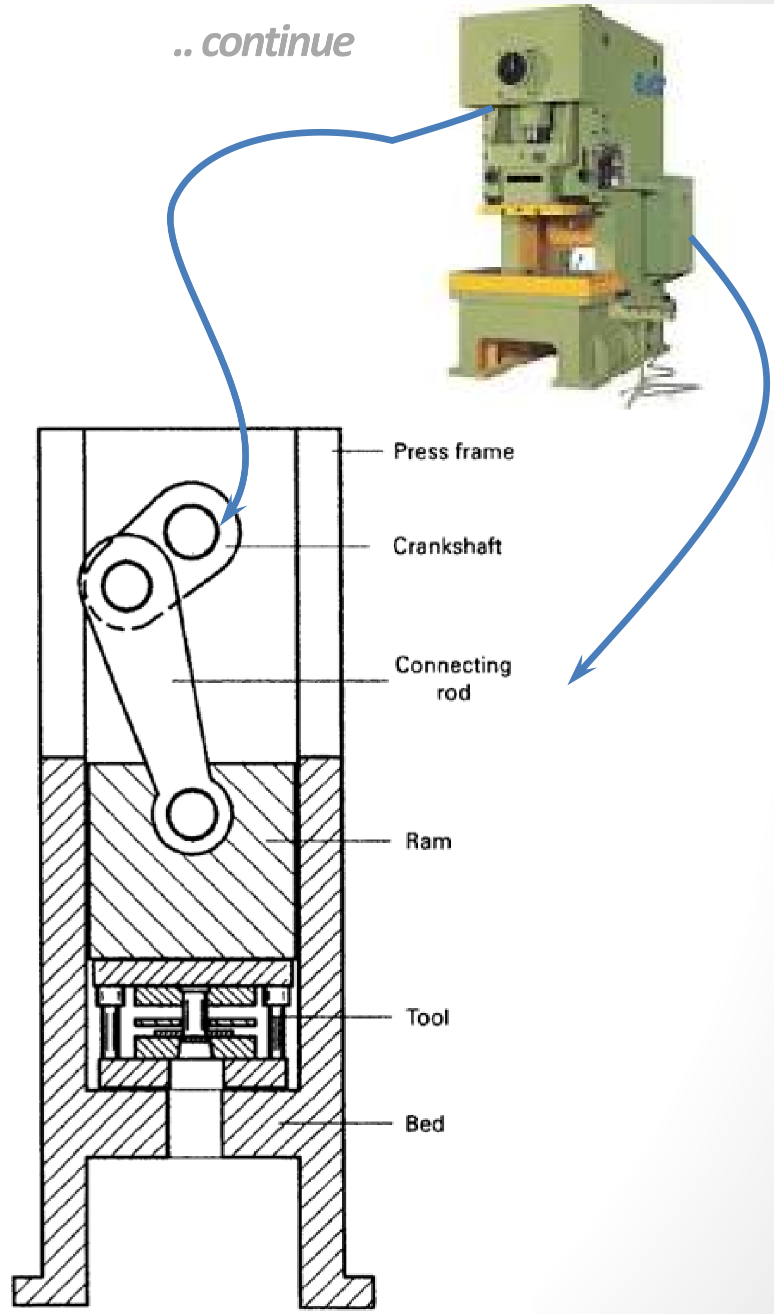
Punch and die are made from hardened alloy steel to resist wear.

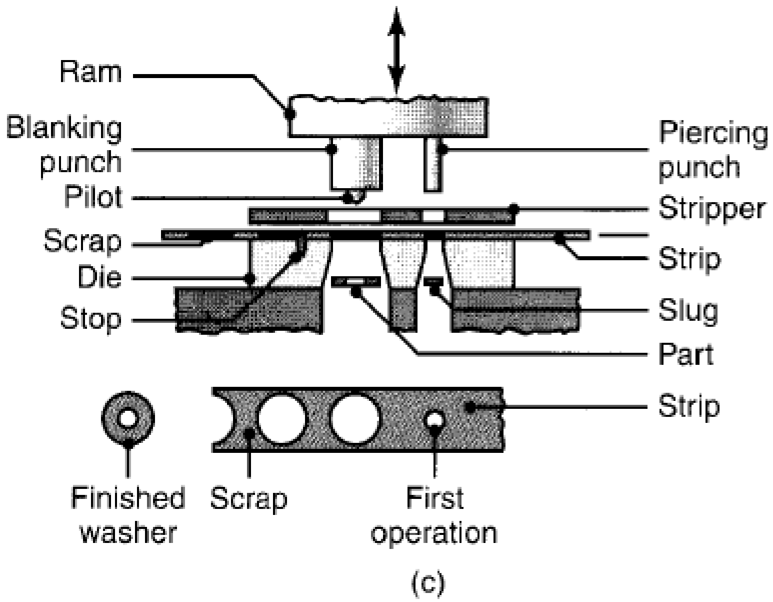
In operation the punch is pressed down on to the sheet material exerting a shear load which exceeds the shear strength of the material, and thus shears out the part, pushing it through the die. The stripper plate is provided to prevent retention of the material on the punch when the press is raised.



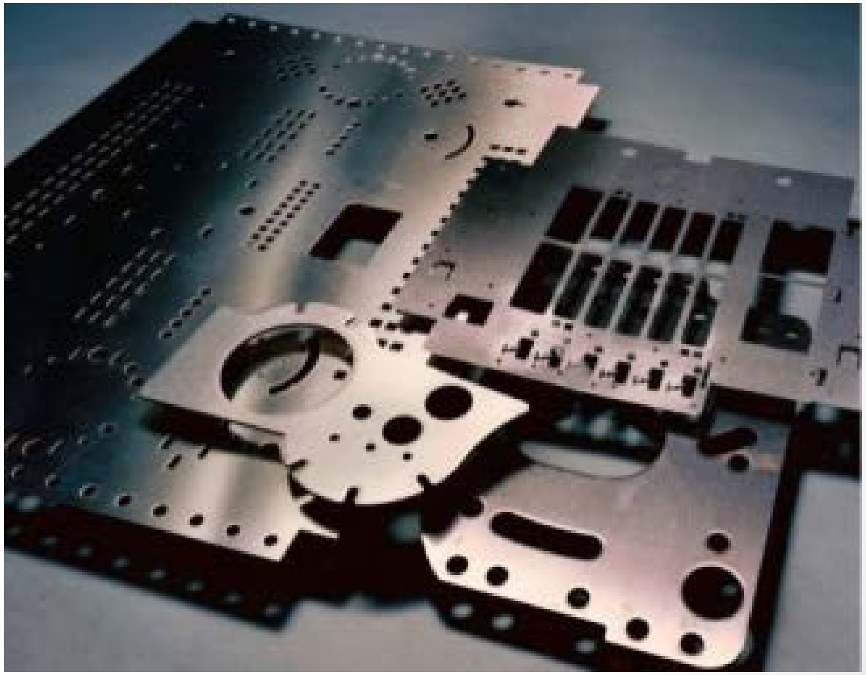
➢Blanking of this sort is carried out in a single action crank press. This press is driven by a motor which drives a flywheel. When the operator engages the clutch the rotating flywheel is coupled to the crankshaft, which rotates driving the ram of the press downwards.

➢The energy stored in the flywheel provides the force necessary to push the punch into the die and then returns the punch to the starting position, where upon the clutch disengages and the motor drives the flywheel up to speed ready for the next stroke, replacing the energy used in the blanking operation.





Blanking die of screw washer



Complex Banking die set for complex parts

Figure 8.12 shows the progressive deformation and the development of a shear fracture during the shearing process, together with a typical load-penetration graph [].

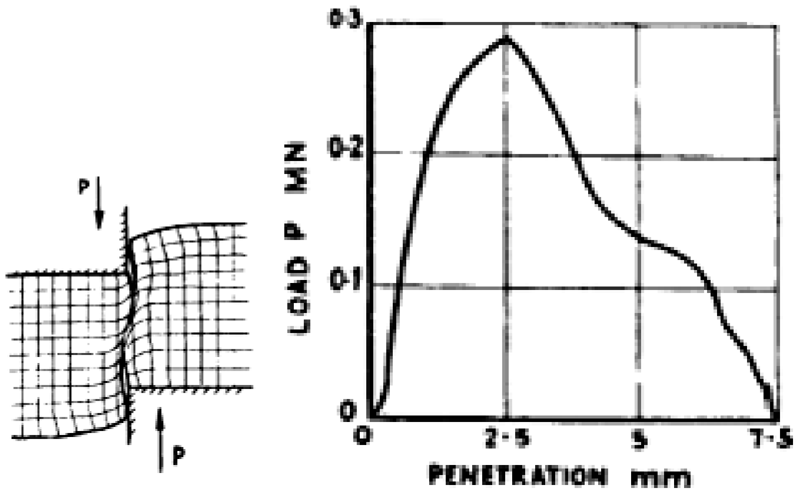
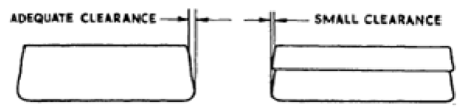
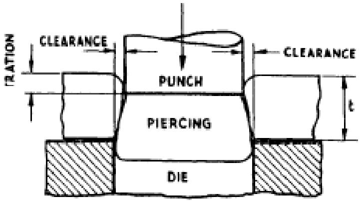
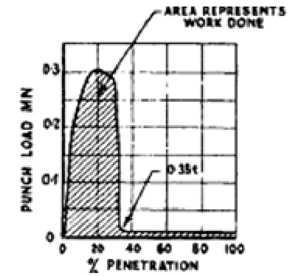


Fig 8.12 Variation of press loads with blanking penetration (no clearance).







- The effect of clearance on the piercing of a moderately ductile metal which work hardens and begins to develop cracks at an early stage of penetration.
- If the clearance is suitable the cracks run one into the other. The resulting hole is slightly tapered, the work done in shearing is somewhere near minimum, but the maximum load on the punch is almost independent of the clearance and is given by:

Material	Hardness HV	Clearance as a % of thickness
Mild steel	94–144	5–10
70/30 brass	77–110	0–10
Copper	64–93	0–10
Zinc	61	0–5
Aluminium	21–28	0–5

P_{max} = metal thickness (t) x perimeter x ultimate shear stress of sheet

Table 8.2 Penetration allowance for different materials.

	Annealed		Partially cold worked	
Material	σ, N/mm^2	p%	σ, N/mm^2	p%
Mild steel	240	50	297	38
Brass	220	50	360	20
Copper	150	55	195	30
Bronze	245	25	290	17
Aluminium	55	60	90	30

Table 8.2 Penetration allowance for different materials.

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Mild steel	240	50	297	38
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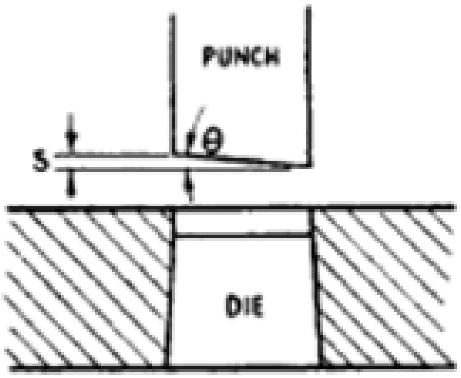
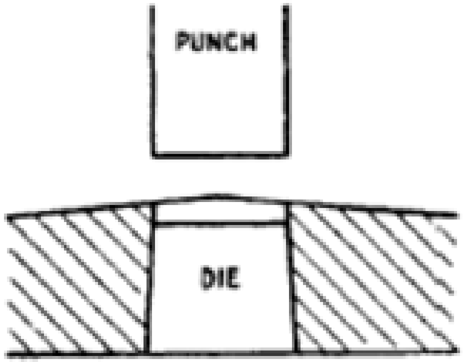
Bronze	245	25	290	17
Aluminium	55	60	90	30

Two common techniques used to decrease shearing load



Single shear in punch



Double shear in punch

Example 8.8

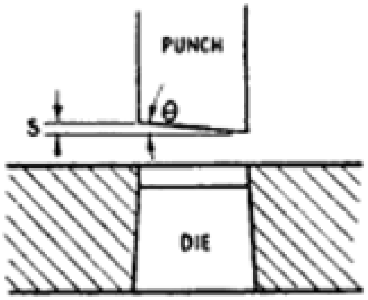
A hole, 100 mm diameter, is to be punched in steel plate 5.6 mm thick. The material is a cold-rolled 0.4 per cent carbon steel for which the ultimate shear stress is 550 N/mm 2. With normal clearance on the tools, cutting is complete at 40 per cent penetration of the punch.

Give suitable diameters for the punch and die and a suitable shear angle for the punch in order to bring the work within the capacity of a 30 ton press.

Solution

Suitable clearance on tools say 10 per cent of work thickness.
Punch diameter = 100 mm (determines smallest opening).
Die diameter = 100 + 2(0.1 x 5.6) = 101.1 mm.
Max load on punch (without shear) = 550 (N/mm2) (100) π (5.6) = = 968 kN
Which equivalent to 968000N=96800Kg=96.8Ton

Let s mm = the depth of shear required to reduce the punch load to 300 kN.
Work available during shearing stroke = (300 s) J.
Work required to shear hole = 968 x 5.6 x 0.4 = 2168 J.
Equating the amounts of work,
300 s= 2168 ====> s= 7.23 mm
7.23
Angle of shear, tan θ = 7.23/100 = 0.0723 ==> θ = 4.2°



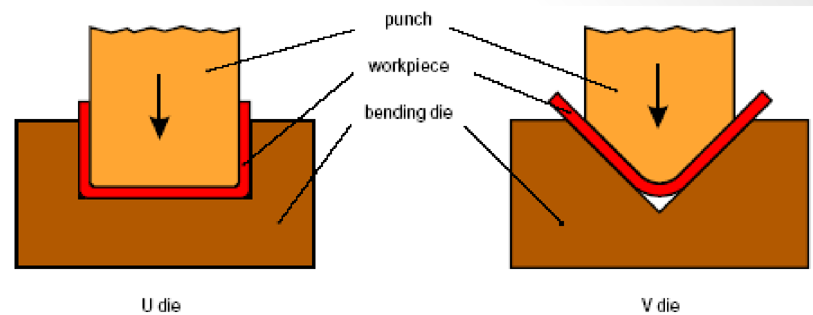
SINGLE SHEAR ON PUNCH

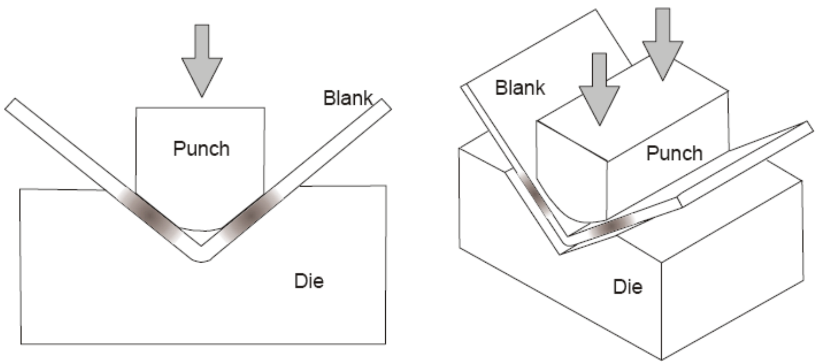
The assumption has been made that shear on the punch will spread the load uniformly over the working portion of the stroke. This is not strictly true for piercing a circular hole. Also there is an additional load, required to bend the piercing to the punch face contour, which has not been included. Since the amount of shear angle suggested is already fairly large, it would be advisable to transfer the operation to a slightly larger press if available, say 35-40 tons

8.3 Sheet metal bending technology

Bending is a manufacturing process by which sheet metal can be deformed by plastically deforming the material and changing its shape. The material subjected to stresses beyond its yielding and below its ultimate tensile strength. There is little change in surface area, about bend axis.

Bending is a flexible process by which a varity of different shapes can be produced through the use of standard die sets on bend break. The material is placed on the die, and positioned in place with stops and/or gauges. It is held in place with hold downs, where the upper part of the press is the ram with appropriately shaped punch descends and forms the blank longitudinally, see Fig 8.15.





8.3 Sheet metal bending processes

Bending is done using Press Brakes, which is hydraulic press with variable loading capacity from 20 to 200 tons and with stock length from 1meter to 4.5 meters.

Bending also can be down using rotating rolls called roll bending machine, see Fig 8.16. Rotating rolls also can be used to straighten the rod or sheet metal, see Fig 8.17. Bending also can be carried on tandem rolling stands to bend the sheet metal in incremental stages (roll forming process), see Fig 8.18. There are also other special bending processes, like swivel bending, circular bending, tube bending, ..etc., see Fig 8.19

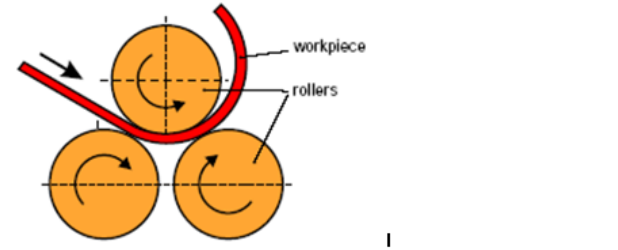


Fig 8.16 Bending using rotating rolls (roll bending process).

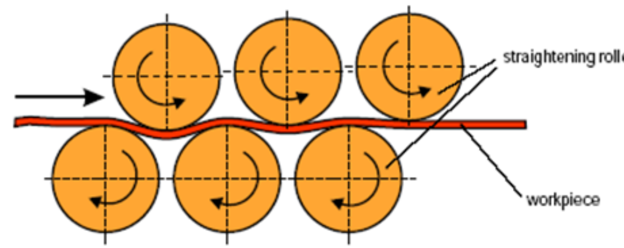


Fig 8.17 Roll straightening process.

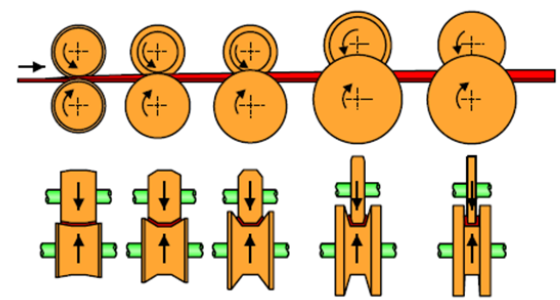


Fig 8.18 Roll forming process.

Fig 8.19 Swivel bending and circular bending process.

8.3.1 Bending radius and bending angle on press brake:

Bending dies should be designed so as to avoid sharp bent edges. The inside bending radius r_i[mm] depends on the sheet metal thickness s [mm] and should be selected to be as large as possible, because sharp bent edges may lead to material failure, see Fig 8.20.

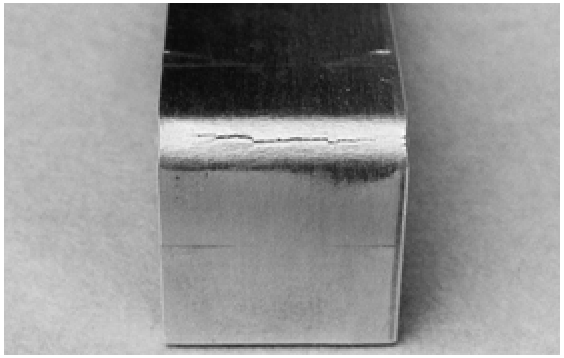


Fig 8.20 Cracks on the outer surface due to sharp bending radius.

Minimum bending radius for different materials are given in term of sheet metal thickness (s). Table 8.3 shows minimum bending radius for different materials.

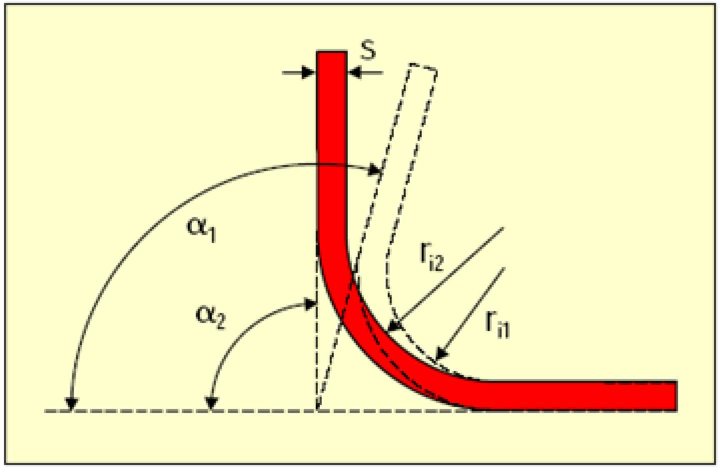
TABLE 8.3

Material	Condition Soft	Condition Hard
Aluminum alloys	0	6T
Beryllium copper	0	4T
Brass, low-leaded	0	2T
Magnesium	5T	13T
Steels		
Austenitic stainless	0.5T	6T
Low-carbon, low-alloy, and HSLA	0.5T	4T
Titanium	0.7T	3T
Titanium alloys	2.6T	4T

8.3.2 Spring-back effect in bending

When designing a bending die, it is necessary to consider spring-back that occurs after unloading. Spring-back characteristics differ depending on the material type. Spring-back occurs with all types of forming by bending, when bending in presses, folding, roll forming and roll bending.

As a result of spring-back, the bending die angle α_1 does not correspond precisely to the angle desired at the work-piece α_2 (Fig 8.21). The angle ratio is the so-called spring-back factor k_R, which depends on the material characteristics and the ratio between the bending radius and sheet metal thickness (r/s) and given by the following equation:



Elastic recovery after bending:
s sheet metal thickness, α_1 required bending angle, α_2 desired angle, r_{i1} inside radius of die, r_{i2} inside radius of workpiece

Fig 8.21 Spring-back effect in bending.

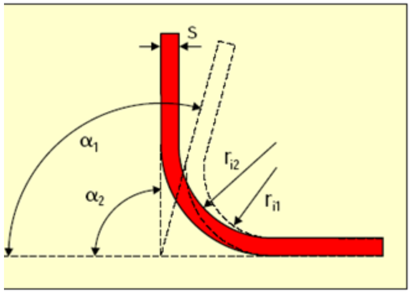
$$k_r = \frac{\alpha_2}{\alpha_1} = \frac{r_{i1} + 0.5(s)}{r_{i2} + 0.5(s)}$$

Where α_1: angle at the die (required bending angle), α_2: desired angle at the workpiece (after spring-back), s: sheet metal thickness(mm), r_{i1}: inside radius at the die (mm), r_{i2}: inside radius at the workpiece (mm).

Spring-back factor k_r is variable for different materials, see Table 8.4.

Table 8.4 Spring-back factor k_r for different materials

Material	Springback factor k_R	
	$r_{i2}/s = 1$	$r_{i2}/s = 10$
St 0-24, St 1-24	0.99	0.97
St 2-24, St 12	0.99	0.97
St 3-24, St 13	0.985	0.97
St 4-24, St 14	0.985	0.96
stainless austenitic steels	0.96	0.92
high temperature ferritic steels	0.99	0.97
high temperature austenitic steels	0.982	0.955
nickel w	0.99	0.96
Al 99 5 F 7	0.99	0.98
Al Mg 1 F 13	0.98	0.90
Al Mg Mn F 18	0.985	0.935
Al Cu Mg 2 F 43	0.91	0.65
Al Zn Mg Cu 1.5 F 49	0.935	0.85



tic recovery after bending:
eet metal thickness, α_1 required
ding angle, α_2 desired angle,
side radius of die, r_{i2} inside
is of workpiece

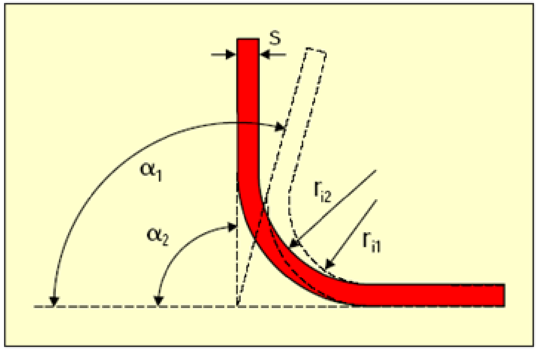
Hence, the necessary angle on the die (degree) is given as follows:

$$\alpha_1 = \frac{\alpha_2}{k_r}$$

The required inside radius at the die can thus be calculated from the following equation:

$$r_{i1} = \frac{r_{i2}}{1 + \frac{r_{i2} R_m}{s\,E}}$$

Where R_m tensile strength (N/mm^2), E elasticity module (N/mm^2).

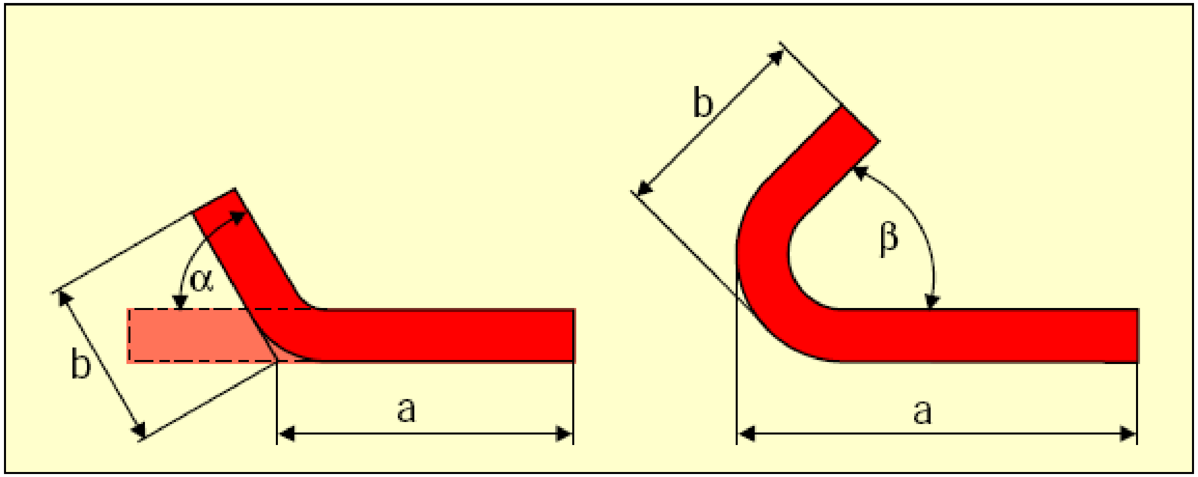


Elastic recovery after bending: s sheet metal thickness, α_1 required bending angle, α_2 desired angle, r_{i1} inside radius of die, r_{i2} inside radius of workpiece

8.3.3 Estimating the blank lengthy for bents

The blank length of the part to be bent is not equal to the fiber length located at the center of the cross section after bending. The extended length of bent components *l* [mm] is calculated as whereby *a* [mm] and *b* [mm] stand for the lengths of the two bent legs, and v [mm] is a compensation factor which can be either positive or negative, see Fig 8.22, using the following equations:

$$l = a + b + v\ (mm)\, for\ opening\ angle\ 0° \ to\ 165°$$
$$l = a + b\ (mm)\, for\ opening\ angle > 165°\ to\ 180°$$



It should be noted that *a* is the bending and *b* the opening angle of the bent part. Values for *v* are calculated for every required angle as follows:

For β=0 to 90 deg.

$$v = \pi\left(\frac{180° - \beta}{180}\right)\left(r + \frac{s}{2}K_r\right) - 2(r + s)$$

For β> 90 to 165 deg.

$$v = \pi\left(\frac{180° - \beta}{180}\right)\left(r + \frac{s}{2}K_r\right) - 2(r + s)\tan\left(\frac{180 - \beta}{2}\right)$$

Correction factor K_r:

$$K_r = 1 \qquad for \frac{r}{s} > 5\ and \qquad\qquad K_r = 0.65 + 0.5\log\left(\frac{r}{s}\right) \qquad for\ \frac{r}{s}\ to\ 5$$

The calculated extended length rounded to next higher full m/m.

Example 8.9:

It is required to bend section shown in Fig 8.23 for sheet metal thickness of 3 mm from steel having tensile strength $R_m = 360\ N/mm^2$. Calculate the blank length using compensation factor V and correction factor K_r

Leg length $L = A+B+C+D = 40+70+80+30 = 220\ mm$

For $\beta=90$, $r=5mm$, $s=3\ mm$: $K_{r1} = 0.65 + \frac{1}{2}\log\left(\frac{5}{3}\right) = 0.761$ and $V_1 = \pi\left(\frac{180-90}{180}\right)\left(5 + \frac{3}{2}0.761\right) - 2(5+3) = -6.35\ mm$

For $\beta=45$, $r=3mm$, $s=3\ mm$: $K_{r2} = 0.65 + \frac{1}{2}\log\left(\frac{3}{3}\right) = 0.65$ and $V_2 = \pi\left(\frac{180-45}{180}\right)\left(3 + \frac{3}{2}0.65\right) - 2(3+3) = -2.63\ mm$

For $\beta=135$, $r=10mm$, $s=3\ mm$: $K_{r3} = 0.65 + \frac{1}{2}\log\left(\frac{10}{3}\right) = 0.911$ and $V_3 = \pi\left(\frac{180-135}{180}\right)\left(3 + \frac{3}{2}0.911\right) - 2(10+3)\tan\frac{45}{2} = -1.84\ mm$

Then $V_t = V_1+V_2+V_3 = -6.35-2.63-1.84 = -10.82$mm, $L = A+B+C+D+V_t = 220-10.82 = 209.18mm$ or $210mm$ <<

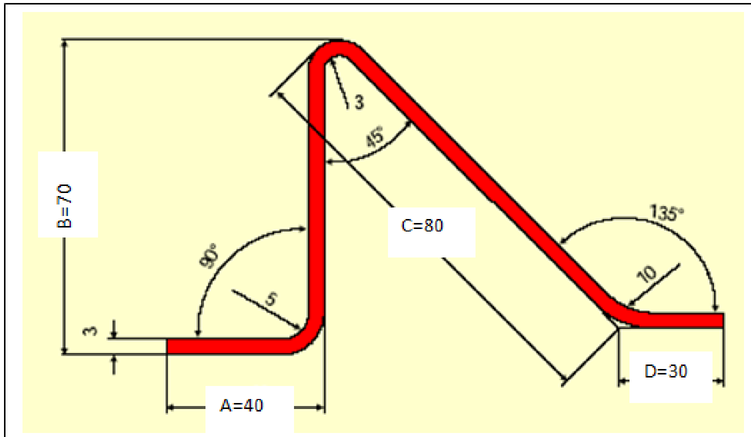


Fig 8.23 Bending section for Example 8.9

8.3.4 Estimating bending force and energy for V-bend sections

When bending angle and V-section using V-die, see Fig 8.24, die, the bending force Fb [N] required for forming depends on the die width w [mm], as this determines the bending moment. In contrast to this, the magnitude of the bending radius plays only a minor role, provided that the corresponding die width w has been correctly selected.

When using a conventional die in which the sheet metal is positioned at a distance w on both sides while the punch presses centrally onto the sheet metal, with a coil stock width of bs [mm] the following bending force is obtained:

$$\boxed{F_b = \frac{(b_s\, s^2\, R_m)}{w} \quad for\ \frac{w}{s} \geq 10 \quad or \quad F_b = \left(1 + \frac{4\,s}{w}\right)\frac{b_s\, s^2\, R_m}{w} \quad for\ \frac{w}{s} < 10}$$

The bending work can be express as:

$$\boxed{W_b = x\, F_b h}$$

Where h is impact depth of bending, which is the vertical distance to end the end of bend.

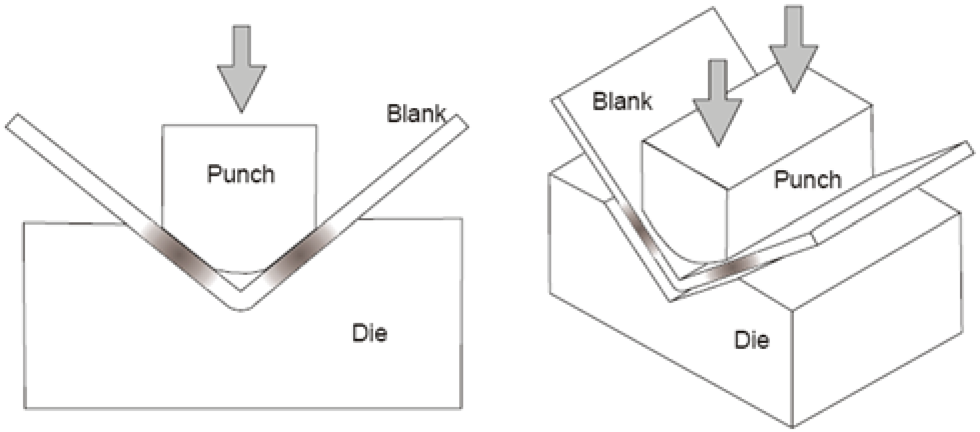


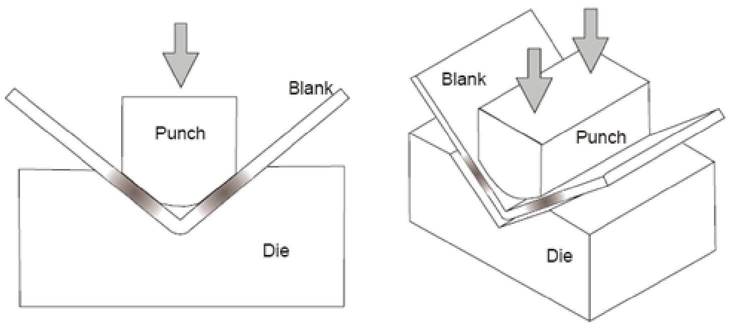
Fig 8.24 V-bend using V-die and punch tool.

$$F_b = \frac{(b_s\, s^2\, R_m)}{w} \; for\, \frac{w}{s} \geq 10 \;\; or \;\; F_b = \left(1 + \frac{4\, s}{w}\right) \frac{b_s\, s^2\, R_m}{w} \;\; for\, \frac{w}{s} < 10$$

The bending work can be express as:

$$W_b = x\, F_b h$$

Where h is impact depth of bending, which is the vertical distance to end the end of bend.



Example 8.10:

A sheet metal blank is V-bended using V-die/puch tool on press break having 2 mm thickness and 50mm wide and tensile strength of R_m=*280 N/mm²* having 2 mm sheet metal thicknes. Calculate bending force and bending work assume punch vertical displacement is h=7 mm. Calculates bending power if the punch ramp speed 0.1 m/s, assume x=1/3?

Bending force $F_b = \frac{50\,(4)280}{15} = 3733\, N$

Bending Work $W_b = \left(\frac{1}{3}\right) 3733 \left(\frac{7}{1000}\right)\, 8.7\, J$

Bending power $P_b = W_b\, v_b = 8.7\, \left(0.1 \frac{m}{s}\right) = 0.87\, KW$

Problems

Problem 8.1

A cup to be drawn with a drawing ratio of β=1.8. The cup has punch diameter d=45 mm and tensile strength of blank is $R_m=350\ N/mm^2$. Sheet metal thickness s=0.8mm. Calculate :

- Blank diameter D ?
- Cup height h ?
- Drawing force assume maximum drawing ratio of 2 ?
- Blank holding force assume blank hold pressure 2.5 N/mm^2 ?

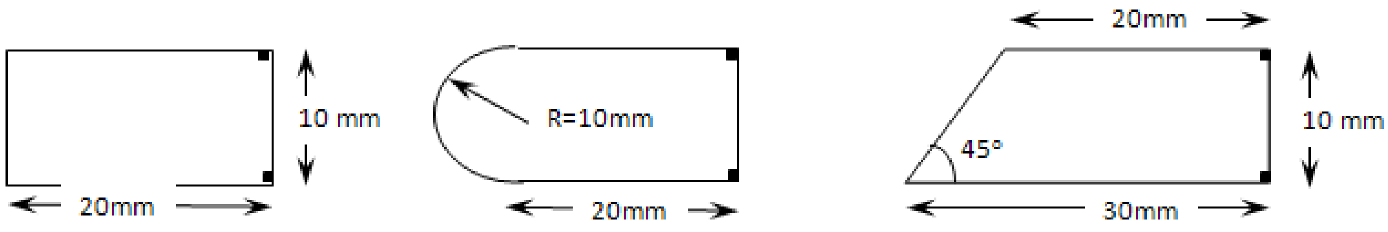
Problem 8.2

Calculates drawing energy and drawing power for drawn cup given in problem 8.1 assume drawing speed 0.02 m/s ?

Problem 8.3

Given the following sheet metal blanks pieces, shear stress is 330 N/mm^2 and sheet metal thickness 3 mm and 40% punch penetration, calculates :

- Max punch load (Ton).
- Work required to shear the given sections J.
- If punch load is limited to 5 Ton, calculates punch shear depth and punch shear angle required for the three cases?



(a) (b) (c)

Problem 8.4

Calculates blank length of the sheet metal part sing V compensation and K factor given tensile strength $R_m = 360\ N/mm^2$ Sheet metal thickness s=3 mm?