8b.
Drawing Tools

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Sheet metal operations

Stresses induced	Operations
Shearing	Shearing, blanking, piercing, trimming,
	shaving, notching, nibbling
Tension	Stretch forming
Compression	Coining, sizing, ironing, hobbing
Tension and compression	Drawing, spinning, bending, forming, embossing

Drawing

- Drawing is the process of making cups, shells, and similar articles from metal blanks.
- Typical tools used for drawing are shown.

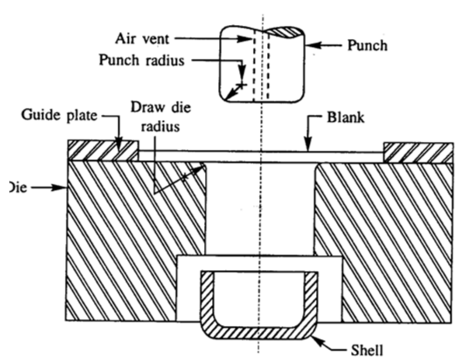

Fig. From P. N. Rao, Manufacturing Technology, Tata McGraw Hill, 1998.

- The set up is similar to that used in blanking except that the punch and die are provided with the necessary rounding at the corners to allow for the smooth flow of metal during drawing.

- The blank is first kept on the die plate. The punch slowly descends on the blank and forces it to take the cup shape formed by the end of the punch, by the time it 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 slightly due to the spring back.
- When the punch moves in the return stroke, the cup would be stripped by this counter bored portion.

Shallow drawing

- This description is true in the case of shallow drawing operation only.
- Shallow drawing is defined as that where the cup height is less than half the diameter.

Deep drawing

- For drawing deeper cups it is necessary to make specific provisions to confine the metal in order to prevent excess wrinkling of the edges.
- For this purpose, a blank holder is normally provided on all deep drawing dies.

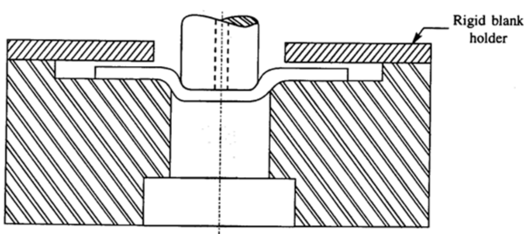

Fig. From P. N. Rao, Manufacturing Technology, Tata McGraw Hill, 1998.

Rigid blank holder

- The rigid blank holding is normally used for thicker materials which are less likely to wrinkle.
- A more common usage is the spring loaded pressure pad similar to the stripped used in cutting dies.
- The spring loaded pressure pad which moves with the punch, maintains a more uniform pressure on the blank throughout the drawing operation.

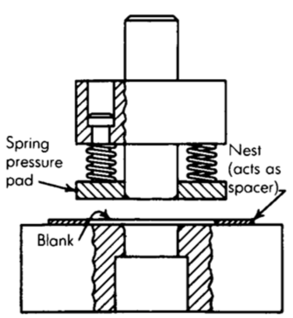

Figure 8-35. Draw die with spring pressure pad.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

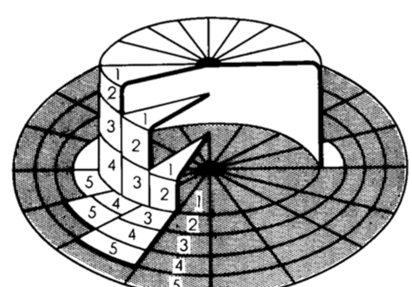

Figure 8-31. A step-by-step flow of metal.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

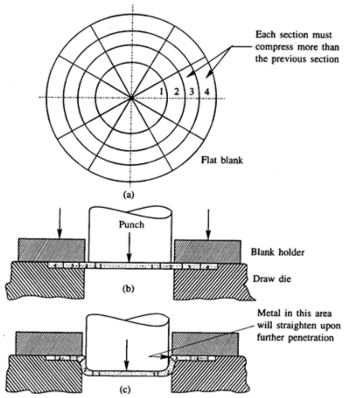

Fig. From P. N. Rao, Manufacturing Technology, Tata McGraw Hill, 1998.

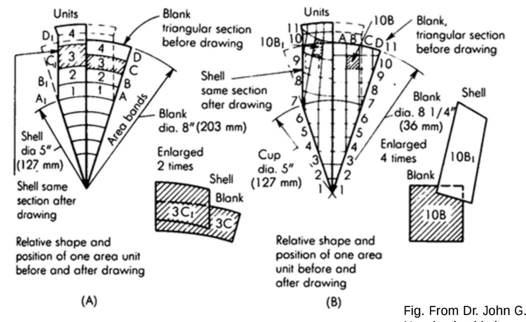

Figure 8-32. **Two methods of marking blanks to illustrate size, shape, and position of the units of area, before and after drawing.**

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

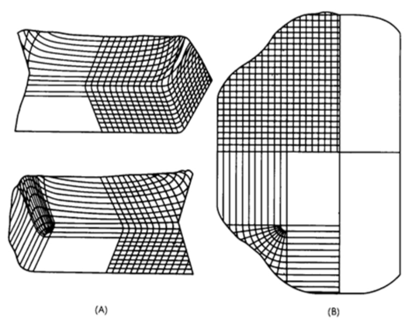

Figure 8-33. **Metal flow in rectangular draws: (*A*) blank marked before drawing; (*B*) corner areas after drawing.**

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

Ironing

- In deep drawing, because of the radial flow of material, the side walls increase in thickness as the height is increased.
- There would be a slight thinning of metal at the bottom corners.
- For applications requiring uniform side walls, an operation called ironing is carried out on drawn cups.

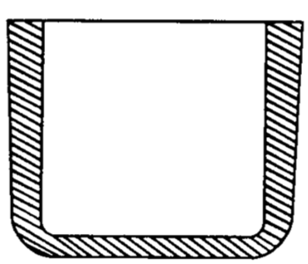

Fig. From P. N. Rao, Manufacturing Technology, Tata McGraw Hill, 1998.

Ironing

- Ironing is the operation of thinning the side walls and increasing the height.
- The die and punch set used is similar to that of drawing operation except that the clearance between the die and punch is smaller than that used in the drawing operation.

Ironing

- The material gets compressed between punch and die which reduces the thickness and increases the height, and thus is a severe operation.
- The wall thicknesses can be reduced to as much as 50 % in a single ironing operation.

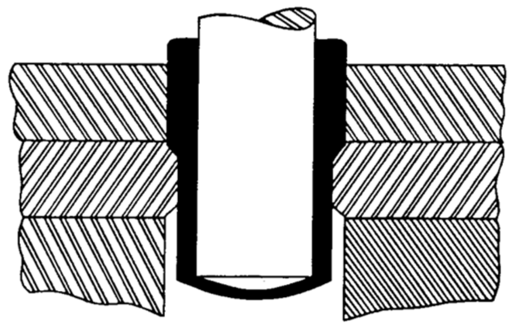

Fig. From P. N. Rao, Manufacturing Technology, Tata McGraw Hill, 1998.

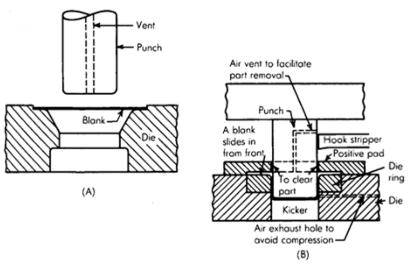

Figure 8-34. Draw die types: (*A*) simple type; (*B*) simple draw die for heavy stock.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

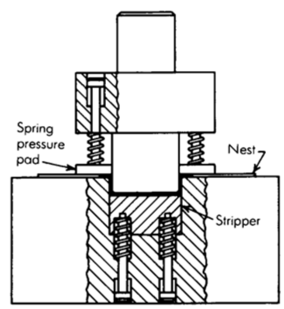

Figure 8-36. A draw die with spring pressure pad and stripper.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

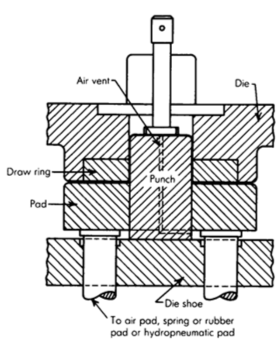

Figure 8-37. Cross section of an inverted draw die for a single-action press; die is attached to the ram; punch and pressure pad are on the lower shoe.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

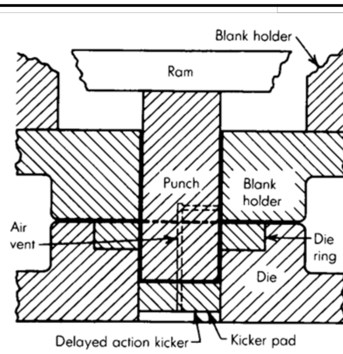

Figure 8-38. A typical double-action cylindrical draw die.

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

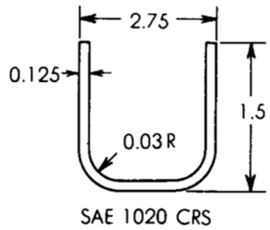

***Figure 8-39*. A drawn shell, the basis for blank development and draw die design (*Figure 8-40*).**

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

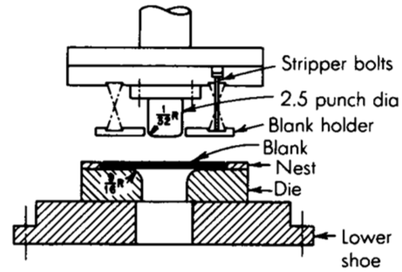

***Figure 8-40*. Draw die for producing the shell of *Figure 8-39*.**

Fig. From Dr. John G. Nee (revised by), Fundamentals of Tool Design, Fourth Edition, 1998, SME

Drawing die design

- Corner radius on punch
- Draw radius on die
- Clearances
- Blank size
- Drawing force
- Blank holding force
- Ironing force
- Percent reduction
- Air vent
- Drawing speed

Corner radius on punch

- Though there is no set rule for the provision of corner radius on the punch, it is customary to provide a radius of four to ten times the blank thickness.
- Too small a corner radius makes for the excessive thinning and tearing of the bottom of the cup.
- Ideally, the punch radius should be the same as the corner radius of the required cup, because it takes its form.

Corner radius on punch

- It is not possible in deep drawing to obtain the final cup size in a single drawing operation.
- Depending on the geometry of the cup, it may be necessary to go in for more than one drawing operations, in which case, the subsequent operations are called redrawing operations.

Corner radius on punch

- For the initial draws, larger punch radii are used and for the final draw use the requisite radius.
- If the requisite radius is less than 4 times the blank thickness, it may be necessary to obtain it by restriking after the final draw with 4 times the thickness.

Draw radius on die

- Since the draw radius on die does not contribute to the cup shape, it can be made as large as possible.
- Higher the radius, higher would be the freedom for the metal to flow.
- Too high a radius causes the metal to be released early by the blank holder and thus lead to edge wrinkling.
- Too small a radius causes the thinning and tearing of the side walls of the cups.

Draw radius on die

- draw radius = 4 t normal
  = 6 to 8 t when the blank holder is used
  = 0.8 π (D-d) t

where t = blank thickness

Draw radius on die

- In order to minimise the thinning of the stock, the centre point of the draw radius should be about 3 mm outside of the previous cup draw.
- Also the centre point of the corner radius on punch be slightly inside the shell of the next draw.

Clearances

- Ideally, the clearance between punch and die should be same as the blank thickness.
- But the blank gets thickened towards the edge because of the metal flow and hence, the actual clearance provided is slightly higher to account for this thickening.
- An allowance in the range of 7 to 20% of the blank thickness is provided depending on the cup material and cup dimensions.

Clearances

Blank thickness (mm)	First draw	Second draw	Sizing draw
upto 0.40	1.07 to 1.09	1.08 to 1.10	1.04 to 1.05
0.41 to 1.25	1.08 to 1.10	1.09 to 1.12	1.05 to 1.06
1.30 to 3.00	1.10 to 1.12	1.12 to 1.14	1.07 to 1.09
above 3.01	1.12 to 1.14	1.15 to 1.20	1.08 to 1.11

Blank size

- It is often difficult to find a blank of the exact size required for making a given shell, because of thinning and thickening of sheet during drawing.
- The calculation could be based on volume, surface area or by layout.

Blank size (cylindrical shells)

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

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

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

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

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Blank size (cylindrical shells)

- where r = corner radius on the punch, mm
- h = height of the shell, mm
- d = outer diameter of the shell, mm
- D = blank diameter, mm

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Blank size

- For practical purposes, it is necessary to add additional allowances to provide for trimming of the uneven and irregular rim of the deep drawn cup. This is termed as trim allowance.
- The trim allowance could be 3 mm for the first 25 mm cup diameter and additional 3 mm for each of the additional 25 mm of cup diameters.
- For rectangular and other types of shells, reference may be made to literature which provide the necessary formulae for other generally used shapes.

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Drawing force

- The drawing force depends on the cup material, its dimensions and the configuration. The drawing force for cylindrical shells

$$P = \pi d t s \left[\frac{D}{d} - C \right]$$

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Drawing force

- Where P = drawing force, N
- t = thickness of the blank material, mm
- s = yield strength of the metal, MPa
- C = constant to cover friction and bending. Its value is between 0.6 and 0.7

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Blank holding force

- The blank holding pressure required depends on the wrinkling tendency of the cup, which is very difficult to determine and hence it is obtained more by trial and error.
- The maximum limit is generally to be one third of the drawing force.

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Ironing force

- In ironing, the objective is only to reduce the wall thickness of the cup, and hence no blank holding is required because the punch is fitted closely inside the cup.
- Neglecting the friction and shape of the die, the ironing force can be estimated using the following equation.

Ironing force

$$F = \pi\ d_1\ t_1\ s_{av}\ \log_e \frac{t_o}{t_1}$$

- Where F = ironing force, N
- d_l = mean diameter of the shell after ironing
- t_l = thickness of shell after ironing
- t_o = thickness of the shell before ironing
- S_{av} = average of tensile strength before and after ironing

Percent reduction

- The drawing operation relies on the ductility of the blank material.
- The ductility is affected by the amount of strain a material takes.
- But there is a limit to which it can be strained.
- The amount of straining or the drawability is represented by the percentage reduction which is expressed in terms of the diameter of the blank and the shell.

Percent reduction

- The diameter of the shell to be used is either ID (internal diameter) or OD (outer diameter).
- But it is convenient to use OD since the cup is normally specified by OD.
- The percent reduction, P is given by

$$P = 100\left[1 - \frac{d}{D}\right]$$

Percent reduction

- Theoretically, it is possible to get a percentage reduction upto 50 but, is practically limited to 40.
- Also because of strain hardening, the percentage reduction possible gets reduced in the subsequent draws.

Percent reduction

Height to dia ratio	No. of draws	Percent reduction			
		First draw	Second draw	Third draw	Fourth draw
upto 0.75	1	40	--	--	--
0.75 to 1.50	2	40	25	--	--
1.50 to 3.00	3	40	25	15	--
3.00 to 4.50	4	40	25	15	10

Percent reduction

- For cup heights more than that shown in the above table, annealing is to be done on the cup preferably after the third draw to restore the ductility, and then further drawings are to be carried on.

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Air vent

- An air vent is normally provided in the punch to reduce the possibility of formation of vacuum in the cup, when it is stripped from the punch.
- For cylindrical shells, one vent located centrally would be enough, where as for other shapes it may be advantageous to provide two.

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Drawing speed

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Drawing speed

- The speed with which the punch moves through the blank during drawing, is termed as the drawing speed.
- This is a very important parameter in drawing because higher speeds are sometimes detrimental.
- Particularly harder and less ductile materials are likely to be excessively thinned out due to excessive drawing speeds.

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Drawing speed

Material	Drawing speed (m/s)
Aluminium	0.90
Brass	1.00
Copper	0.75
Steel	0.28
Zinc	0.75

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Example

- A symmetrical cup of circular cross-section with diameter 40 mm and height 60 mm, with a corner radius of 2 mm is to be obtained in AISI1020 steel of 0.6 mm thickness.
- Make the necessary design calculations for preparing the die for the above cup.

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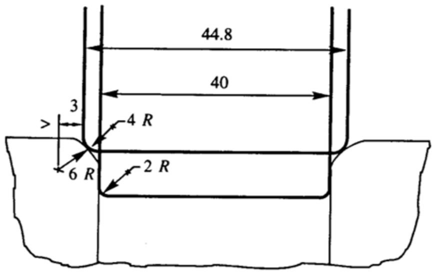
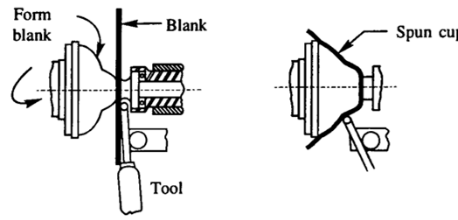


Fig. From P. N. Rao, Manufacturing Technology, Tata McGraw Hill, 1998.



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