8b.
Drawing Tools

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Drawing

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

Sheet metal operations

<table>
<thead>
<tr>
<th>Stresses induced</th>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shearing</td>
<td>Shearing, blanking, piercing, trimming, shaving, notching, nibbling</td>
</tr>
<tr>
<td>Compression</td>
<td>Stretch forming</td>
</tr>
<tr>
<td>Coining, sizing, ironing, hobbing</td>
<td></td>
</tr>
<tr>
<td>Tension and compression</td>
<td>Drawing, spinning, bending, forming, embossing</td>
</tr>
</tbody>
</table>

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.

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.

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

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.

Figure 8.34. Draw die types: (A) simple type; (B) simple draw die for heavy stock.

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

Figure 8-37. A typical double-action cylindrical draw die.
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

- 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.

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

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

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

\[ \text{draw radius} = 4t \text{ normal} \]
\[ = 6 \text{ to } 8t \text{ when the blank holder is used} \]
\[ = 0.8 \pi (D-d) t \]
where \( t \) = blank thickness

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.

<table>
<thead>
<tr>
<th>Blank thickness (mm)</th>
<th>First draw</th>
<th>Second draw</th>
<th>Sizing draw</th>
</tr>
</thead>
<tbody>
<tr>
<td>up to 0.40</td>
<td>1.07 to 1.09</td>
<td>1.08 to 1.10</td>
<td>1.04 to 1.05</td>
</tr>
<tr>
<td>0.41 to 1.25</td>
<td>1.08 to 1.10</td>
<td>1.09 to 1.12</td>
<td>1.05 to 1.06</td>
</tr>
<tr>
<td>1.30 to 3.00</td>
<td>1.10 to 1.12</td>
<td>1.12 to 1.14</td>
<td>1.07 to 1.09</td>
</tr>
<tr>
<td>above 3.01</td>
<td>1.12 to 1.14</td>
<td>1.15 to 1.20</td>
<td>1.08 to 1.11</td>
</tr>
</tbody>
</table>

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)

\[
D = \sqrt{d^2 + 4dh} \text{ when } d \geq 20r \\
D = \sqrt{d^2 + 4dh - r} \text{ when } 10r \leq d \leq 15r \\
D = \sqrt{d^2 + 4dh - 0.5r} \text{ when } 15r \leq d \leq 20r \\
D = \sqrt{(d - 2r)^2 + 4(dh - r) + 2\pi(d - 0.7r)} \text{ when } d < 10r
\]

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.

Drawing force

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

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

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

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.
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.

\[ F = \pi d_1 t_1 S_{av} \log_e \frac{t_o}{t_1} \]

Where:
- \( F \) = ironing force, N
- \( d_1 \) = mean diameter of the shell after ironing
- \( t_1 \) = thickness of shell after ironing
- \( t_o \) = thickness of the shell before ironing
- \( S_{av} \) = average of tensile strength before and after ironing

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.

The percent reduction is given by

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

Theoretically, it is possible to get a percentage reduction up to 50 but, is practically limited to 40.

Also because of strain hardening, the percentage reduction possible gets reduced in the subsequent draws.
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.

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.

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.

<table>
<thead>
<tr>
<th>Material</th>
<th>Drawing speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>0.90</td>
</tr>
<tr>
<td>Brass</td>
<td>1.00</td>
</tr>
<tr>
<td>Copper</td>
<td>0.75</td>
</tr>
<tr>
<td>Steel</td>
<td>0.28</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.75</td>
</tr>
</tbody>
</table>

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.