UNIT 5 DESIGN OF DIE MAKING TOOLS

Structure

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5.1 INTRODUCTION

Sheet metal has its own advantage in production. Many products such as household components, decorative articles, indispensable engineering components (whose production by other manufacturing process is uneconomical) are made from sheets. The sheet metal operations include blanking, piercing, lancing, cutting off and parting, notching, shaving, trimming, nibbling etc. The thickness of sheet used in these operation is generally 20 mm. As far as sheet metal working is concerned, the die design is very important aspect. Many parameters have to be considered while designing the dies for various sheet metal working operations.

Objectives

After studying this unit, you should be able to

- know the basics of sheet metal working,
- familiarise yourself with the various sheet metal working operations, and
- understand principles of die design.

5.2 PRINCIPLES OF DIE DESIGN

Generally, a die consists of screws, dowel pins, die block, punch, punch plate, punch support, punch shedders, pilots, strippers, pressure pads, stock stops and automatic stops.

5.2.1 Screws and Dowels

Components of dies are held together by using socket head cap screws. The dowel provides and maintains accurate positioning of the component, i.e. dowel avoids misalignment. To avoid projection of screw heads, the head is recessed in counter bored hole. Cap screws that are used to hold die components are counter bored and 1/8 inch deeper than cap screw head. This allows additional material for die sharpening.

To position and hold a die component accurately, minimum one cap screw or dowel is necessary for positioning. Designer can use two dowels but one can also use two or more cap screws. One cap screw is generally sufficient for small components, whereas in order to hold the die components at least two cap screws are required for large components.
Normally, screws of diameter 3/8 inch are used for die components of area up to
6 square inch and screws of diameter 1/2 to 5/8 inch are opted for heavy die components.
Dowel diameter is same as that of cap screws. Dowels should be located diagonally from
each other and as farthest as possible to increase accuracy of location.

![Diagram showing the application of screws and dowels](image)

All the screws and dowels should be located at 1.5 to 2 times the diameter of screws or
dowels from the component edge. Screw and dowel hole should be placed near to the
outer edge of the die block and as far as possible from blanking contour. Dowel holes
extrude through the die components so that dowels can be easily removed. The effective
thread depth for screws should be 1.5 times the screw diameter for general applications
and two times the screw diameter when subjected to shock loads. Threading hard
components should be avoided as far as possible. The die block should be drilled with
clearance and counter bored to accept the cap screw. The thread should be cut in the die
shoe. The application of screws and dowels has been shown in Figures 5.1(a) and (b)
respectively.

### 5.2.2 Die Block

The design of die block depends upon workpiece size and thickness. The type of die and
contour of workpiece also play an important role while designing of the die block. The
selection of size of die block also depends upon experience. The die blocks are made
from a solid block of tool steel for small workpieces. Table 5.1 gives die block thickness
with respect to strip thickness. The distance between the die opening and outside edge of
the die block should be 1.25 times the thickness of the die block for smaller dies.

#### Table 5.1 : Die Block Thickness for Mild Steel Strip

<table>
<thead>
<tr>
<th>Strip Thickness (inch)</th>
<th>Die Block Thickness (inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1/16</td>
<td>3/4 to 1</td>
</tr>
<tr>
<td>1/16 to 1/8</td>
<td>1 to 9/8</td>
</tr>
<tr>
<td>1/8 to 3/16</td>
<td>9/8 to 11/8</td>
</tr>
<tr>
<td>3/16 to 1/4</td>
<td>11/8 to 13/8</td>
</tr>
<tr>
<td>Over 1/4</td>
<td>13/8 to 2</td>
</tr>
</tbody>
</table>
This distance should be 1.5 to 2 times the die thickness for large dies or when sharp corners are present in the die opening contour. The solid blocks that are symmetrical face the problem of incorrect assembly, which can be avoided by fool proofing the die block. Fool proofing is achieved by placing one dowel at some other distance from its nearest screw hole. It is possible to save a large amount of material by using insert dies in the construction of die blocks. In the construction of large die block or the complex contour die, die blocks are made in two or more sections in order to save the tool steel. The die may also be sectioned when the size of the die opening is not large enough to permit internal machining. In case of failure, only one component needs to be replaced and hence, it is one of the advantages of sectional die blocks. Figure 5.2 shows the method of sectioning large die. Sectional components may be screwed and doweled to a die holder with sections butting against each other. These sections are wide enough to avoid tilting.

![Figure 5.2: Method of Sectioning Large Die](image)

Sometimes sectional components are used to tip other components to avoid lateral displacement of the die sections. This lateral displacement is due to heavy cutting force. This arrangement reduces the cutting forces.

### 5.2.3 Punch

The design of the punch mainly depends upon the plan area to be blanked or pierced. Design of the punch also depends upon the pressure which is required to penetrate through the workpiece. The method of mounting the punch is determined by the plan area to be blanked or pierced. For example, a punch for small workpiece may require a punch block for mounting the punch into the die holder, whereas a punch of large workpiece may be made up of solid block of tool steel and bolted to the punch holder. A punch must withstand the maximum blanking or piercing pressure. Small punches require a punch support to avoid breakage.

The basic types of punches can be summarised as plain punch, pedestal punch, perforated punch and punches mounted in punch plate.

**Plain Punch**

This type of punch is economical and easy to operate. It is a simple block of hardened tool steel. The shape of punch depends upon the required profile. Plain punch is directly mounted onto the punch holder of die set. A plain punch is shown in Figure 5.3. When extra length is needed, plain punch is mounted on to the flat punch plate. Screws and dowels hold plain punch in the same way as they hold solid die blocks. The length and width of plain punch should at least be equal to the punch height for the stability. When high and unbalanced blanking and piercing pressures are required, it is necessary to use heights greater than either punch length or width. In such situations, some other kind of punch should be considered.

![Figure 5.3: Plain Punch](image)

**Pedestal Punch**
These are constructed by machining in a way that leaves a flange around the base of the punch. The pedestal punch is shown in Figure 5.4. Its base area is larger than its cutting face area. Pedestal punches are advantageous because of large base and solid construction, hence, are stable. As cutting force distributed uniformly over large base, pedestal punches are capable of withstanding heavy cutting force. The flange of pedestal punch should be wide and thick enough to provide space for holes. These holes are used for mounting.

![Figure 5.4: Pedestal Punch](image)

**Perforator Punches**

These types of punches may be fabricated or purchased from market.

**Punches Mounted in Punch Plate**

Punch plates are used to hold and position the punch. The punch plate is also used to increase the strength of punch. Perforated punch has rounded head and shank; hence they are easily mounted in punch plates. Rectangular or odd shaped punches are not easily mounted in punch plates. Figure 5.5 shows method of mounting punches.

![Figure 5.5: Method of Mounting Punches in Punch Plate](image)

### 5.2.4 Punch Support

Diameter of piercing punches should not be smaller than thickness of the strip which is to be pierced. If diameter of piercing punch is smaller than thickness of the strip, diameter of punch shank should be at least twice the hole size and cutting face should be ground to the hole size for a distance about twice the stock thickness. The punches having more than 4 inch unguided length are avoided. If the length of the punch is more than 4 inch, a spacer block should be used in between punch and punch plate. Various methods of supporting slender punches are shown in Figures 5.6 and 5.7. A quill that is used to
increase the strength of slender punch is shown in Figure 5.6(a). The punch is made up of tool steel and can be easily replaceable if it fails. The punch is assembled in a quill with tight press fit. The quill is made up of mild steel.

![Figure 5.6 : Methods of Mounting Slender Punches](image)

Slender punches in stripper plate are supported and guided by sliding fit is shown in Figures 5.6(b) and 5.7(a). The use of more than one perforator in a single quill is shown in Figure 5.7(b). This permits piercing small holes near to each other.

5.2.5 Punch Shedders

The slug and blank sticks to the punch face and comes out with punch during blanking and piercing operation. The slug sticks to the die wall due to spring back in the blank and slug during normal operation. When the amount of spring back is proportionate to the stock thickness and area of slug, small holes in thin material show very little spring back and doesn't stick to the die wall. Hence slug may adhere to the punch face. Slug may also stick to the punch face due to heavy lubrication. Sticking of slug can be reduced by using low viscosity lubricants. The sticking of slug can also be reduced by using shedder pins. Shedder pins break the oil bond between punch face and slug. Shedder pins break the bond between punch face and slug. The spring operation of shedder pin is shown in Figure 5.8. The shedder pin is located in the centre of the punch. The use of shedder pin is limited only for punches of diameter greater than 3/32 inch. For diameter below 3/32 inch, concave shear may be provided on the face of the punch. This helps to avoid it from sticking to the punch face.
5.2.6 Pilots

The main purpose of a pilot is to position the stock strip accurately. Pilots also bring the stock strip into proper position for blanking and piercing operation simultaneously. If strip is fed by hand, it may go beyond proper position due to strip stop. In such a situation, pilot takes it back to proper position in a direction away from the strip stop. Pilot also prevents buckling of strip. When the strip is fed by hand, under feeding of strip occurs and pilot pulls the strip forward. Diameter of pilot is generally 0.002 to 0.003 inch smaller than punch diameter for average work and 0.0005 to 0.001 inch smaller than punch diameter for precision work.

Length of pilot is at least 1/4 inch longer than punches. In this way, pilot will take care of proper positioning before actual cutting. Pilot nose contour is shown in Figure 5.9.

Classification of Pilot

Pilots are classified as: direct pilot, indirect pilot and spring loaded pilot.

Direct Pilot

Direct pilots are mounted on punch face. A direct pilot is shown in Figure 5.10. It acts as a misfeed detector, which detects overfeeding or underfeeding of strip. If it finds misfeed, it actuates a switch to cut off the electric power to press.
Indirect Pilot

Indirect pilot is used with previously pierced hole at a certain distance from blanking punches. Figure 5.11 shows typical indirect pilot. The distortion is avoided by using indirect pilot as it provides support to strip.

![Figure 5.11 : Indirect Pilot](image)

Spring-loaded Pilot

Spring-loaded pilot is generally used for workpiece having more than 1/16 inch thickness. A spring-loaded pilot is shown in Figure 5.12. Spring retracts the pilot from misfeed. This pilot pierces the hole if it is used for thin plate.

![Figure 5.12 : Spring Loaded Pilot](image)

5.2.7 Strippers

The main purpose of stripper is to remove the stock from the punch after blanking or piercing operation.

Classification of Strippers

- **Fixed Stripper**
  
  Fixed stripper is solid attached to the die block or die shoe as shown in Figure 5.13.

- **Spring Operated Stripper**
  
  Spring operated stripper goes up and down on the shank of the punch.

- **Channel Strippers**
  
  Channel strippers are widely used because they are simple in construction and easy in operation.
Fixed Stripper

A rectangular plate is mounted on the top of the die block. The strip is passed through the milled channel. In general, the height of the channel should be 1.5 times the stock thickness whereas width must be equal to the summation of strip width and clearance. The clearance is provided to take care of dimensional variation in the width of strip. Enough clearance is provided around the punch for its easy removal; but clearance should be less than 1.5 times the thickness of strip. The back edge of the channel is used as a back gauge to position the strip accurately. A stock pusher is used to hold the strip against the back edge. It is also desirable to help in reducing the wear. The wear resistance is also increased by using inserts of mild steel. The wear resistance is increased by pressing hardened dowel pin along with the back guide. This is shown in Figure 5.13. The thickness of channel stripper is found out from the size of the socket head cap screw which is used to hold the strip in position.

Spring Operated Stripper

This type of stripper is also called pressure pad stripper. Its main advantage over other stripper, is that it holds the strip flat during the operation. Spring operated stripper is shown in Figure 5.14.

Spring operated stripper is generally mounted on socket head stripper bolts. Spring stripper may also be mounted on rods. To minimize the bending, length of the rod should provide adequate support to the inner diameter of the spring. This is achieved by pressing a dowel of proper diameter and length into one plate and drilling a clearance hole in other plate to provide passage for dowel to pass through other plate.

5.2.8 Guiding Stock with Spring Operated Strippers

Guide stock consists of guide rail which is mounted on the die block as shown in Figures 5.15(a) and (b). Figure 5.15(a) shows a stripper acting as a pressure pad and withstanding against the workpiece. The stock guide does not make contact with the
If clamping of strip is not practical, guide rails may be used to avoid stripper from clamping the work. This is shown in Figure 5.15(b). If space is limited, button stock strip guide may be used as shown in Figures 5.16(a) and (b). Minimum 3 button guides on each side of the strip will satisfactorily guide the strip. But best method for guiding the strip is the use of guide rails.

**Figure 5.15 : Method of Guiding Stock with Spring Operated Stripper**

**Figure 5.16 : Method of Guiding Stock with Spring Operated Stripper**

### 5.2.9 Stock Stops and Automatic Stops

The device by which the strip has to be advanced correctly after each blanking is called stock stops. Sometimes dowel pin is used as a stock stop. After each stroke of the press, an edge of previously blanked hole is pushed against a dowel pin. To release the strip from the pin, enough clearance is provided in a strip channel to allow the stock to be lifted above the pin during upward stroke of the press. Skilled operator is required for such type of operation.

**Trip Stop**

Trip stop is shown in Figure 5.17. The pawl rises on ratchet principle as the stock is fed forward manually. The pawl drops and positions the stock accurately against the vertical surface of the pawl after the stock is pulled back by operator.

**Figure 5.17 : Trip Top**
The shoulder stop is shown in Figure 5.18. It is widely used on progressive dies especially when last operation is cut off or trimming. When workpiece has same width as the stock and feeding is from one side and scrap is not passed through the other side, a shoulder stop is easy to use. Shoulder stop is wide and is attached to the die.

![Figure 5.18: Shoulder Stop](image)

**Automatic Stop**

Automatic stop is shown in Figure 5.19. It uses pin-ended finger. On the forward stroke, the pin end of finger is lifted by the trip screw. The pin end of finger is dropped onto the top surface of the stock during return stroke. The finger is mounted loosely on pivot so that it can move endwise. Due to this endwise movement of the finger, its pin end does not drop onto the top surface of the stock instead of into the former position. The pin drops into the next blank, as the stock is fed forward. This helps the operator to locate the stock strip accurately.

![Figure 5.19: Automatic Stop](image)

**SAQ 1**

Explain briefly the principles of die design.

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### 5.3 COMPOUND DIE DESIGN

The die in which two or more cutting operations are performed in one stroke of the press and at one station only, is called compound die. In compound die, only cutting action, i.e. blanking and piercing is possible. A simple compound die is shown in Figure 5.20. The washer is produced by simultaneous blanking and piercing operation. Compound die is suitable for mass production.
Simultaneous blanking and piercing is achieved by providing blanking and piercing element in both the member of die, i.e. the upper and the lower member of the die. These elements are set exactly opposite to each other so that piercing punch acts in the opposite direction with respect to the blanking punch. In this way blanking and piercing operations are performed simultaneously. Angular clearance is provided in the piercing die. This helps in easy removal of scrap from the die. The blanking punch acts as a piercing die. The sidewall, which is adjacent to cutting edges of blanking die opening, is straight so that the blank does not pass through the die. Knock out stroke is actuated during the return stroke of the press. It ejects the blank. Compound dies are slow in operation but give close tolerance on workpiece.

The flatness of the blank is achieved during cutting operation by knock out plate.

Large parts can be blanked in a smaller press by using compound die. In compound die, very high force is required. Design of punch and die is also difficult for number of operation (more than five). Compound die is excellent for two operations.

**SAQ 2**

Explain the principle of working of compound die.

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**5.4 SUMMARY**

As in sequel, one can say that sheet metal is much important for making the decorative articles; indispensable engineering components etc. For making these articles, a number of operations are performed on the sheets like blanking, piercing, notching, shaving etc. The die design is an important feature for sheet metal working. For die design, several parameters are taken in the considerations. This unit also deals with design of combination dies. In a compound die, two or more cutting operations are performed in one stroke of the press and at one station only. In a compound die, only cutting actions, i.e. blanking and piercing is possible.

**5.5 KEY WORDS**

- **Blanking** : The operation in which produced blank is useful is known as blanking.
- **Piercing** : The operation in which the hole produced is useful is called piercing.
- **Lancing** : Lancing is the combination of cutting and bending operations.