CHAPTER 8

Sheet Metal Operations

Objectives

Sheet metal operations are cold working operations that manufacture low cost parts with very high volumes and at a fast rate. After completing this chapter, the reader will be able to

- Understand the different types of sheet metal operations
- Design sheet metal dies for different applications

8.1 PRESS TOOL OPERATIONS

Many of the consumer goods enjoyed today by the modern man owe their low cost to the press tools. But for the cheap way of making these sheet metal components, we possibly could not have even thought of having automobiles, type writers, mechanical toys, etc., at such a low cost. The press tool operation is by far one of the cheapest and fastest ways to completely manufacture a component. Sheet metal is generally considered to be a plate with thickness less than about 5 mm. In the following pages, important press tool operations are described.

The various operations carried out by press tools have been classified and shown in Table 8.1 on the basis of the type of stresses introduced into the component.

TABLE 8.1 Classification of press tool 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

One of the principal concerns in sheet metal operations is the spring back of the metal. When the metal is deformed, it is first elastically deformed and then plastically. When the applied load is removed, the plastic component of the deformation remains permanently while elastic part springs back to its original shape. This can be schematically observed from Fig. 8.1 where the stress strain diagram is shown. In the stress strain diagram, a stress *OA* is applied on the material so that it reaches the point *P* and has a strain of *OB* under the load. When the load is removed, the material springs back to the position *C*, finally with a permanent deformation of *OC* only. The amount *CB* is the amount of spring back. The amount of spring back is the property of the material which depends on the modulus of elasticity. Higher the modulus of elasticity, lower would be the spring back. However, it is very difficult to estimate theoretically, the actual amount of spring back and hence it is to be determined by trial and error method for any given case.

8.2 SHEARING ACTION

The metal is brought to the plastic stage by pressing the sheet between two shearing blades so that fracture is initiated at the cutting points. The fractures on either side of the sheet further progressing downwards with the movement of the upper shear finally result in the separation of the slug from the parent strip.

The metal under the upper shear is subjected to both compressive and tensile stresses as shown in Fig. 8.2. In an ideal shearing operation, the upper shear pushes the metal to a depth equal to about one third of its thickness. Because of pushing of the material into the lower shear, the area of cross section of the metal between the cutting edge of the shears decreases and causes the initiation of the fracture. This portion of the metal which is forced into the lower shear is highly burnished and would appear as a bright band around the blank lower portion. The fractures which are initiated at both the cutting points would progress further with the movement of the upper shear and if the clearance is sufficient, would meet, thus completing the shearing action (Fig. 8.3).

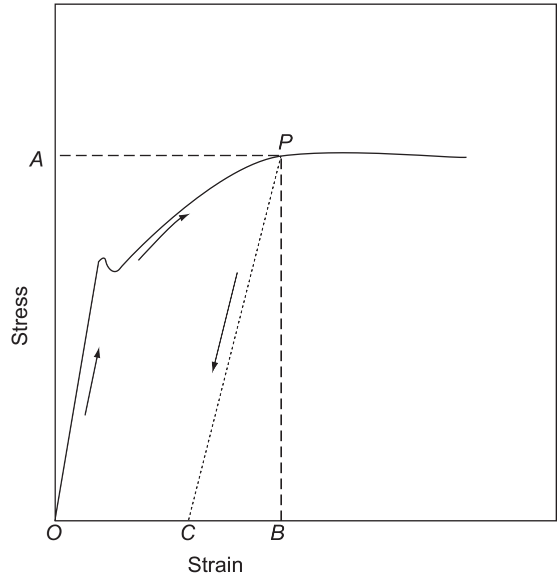

Fig. 8.1 *Spring back in metals*

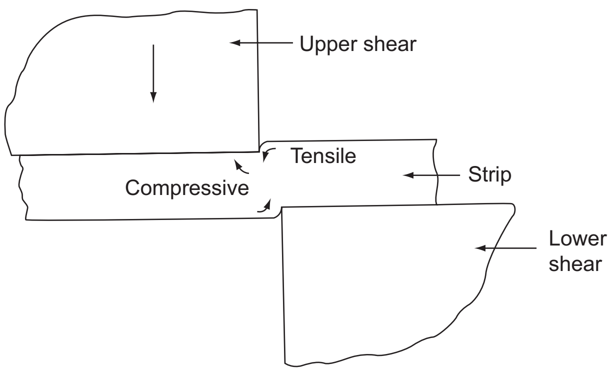

Fig. 8.2 *Stresses in shearing*

The appearance of the cut-edge of the blank is shown schematically in Fig. 8.4. When the plastic deformation starts, the material flows beneath the upper shear and would appear as an edge radius as shown at *A* in the stock. Similar flow of metal at the lower shear would result in the edge radius *B* in the slug. The metal pushed in by the upper shear before the separation would burnish the metal and result in the cut band as shown in *C* in the stock by the upper shear and *D* in the slug by the lower shear.

When correct clearances are used, a clean break would appear as a result of the extension of the upper and lower fractures towards each other. With an insufficient clearance additional cut bands would appear before the final separation. Ductile materials require smaller clearances and longer penetration of the punch compared to harder materials. The effects of clearances are shown schematically in Fig. 8.5.

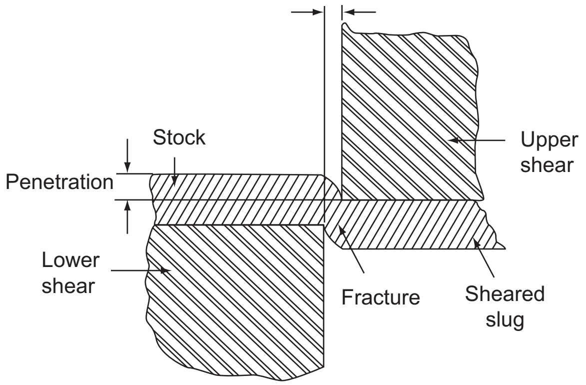

Fig. 8.3 *Material being sheared*

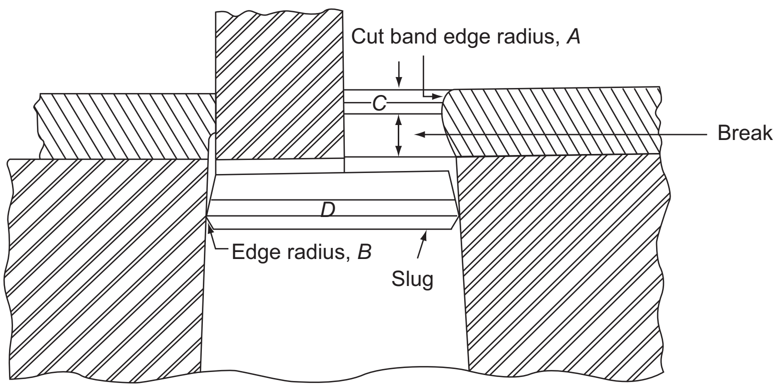

Fig. 8.4 *Characteristic of cut in shearing*

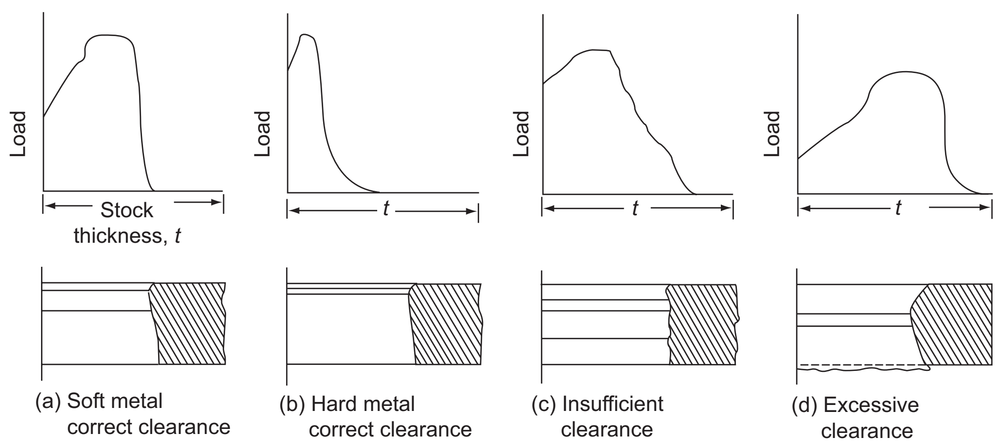

Fig. 8.5 *Effect of clearance on shearing load and edge characteristics*

Clearances

The clearance between two shears is one of the principal factors controlling a shearing process. This clearance depends essentially on the material and thickness of the sheet metal. This clearance can be approximated per side C, as

$$C = 0.0032 \times t < \sqrt{\tau} \text{ mm}$$

Where, t = sheet thickness, mm

And τ = material shear stress, MPa

The shear strength values of interest have been presented in Table 8.2.

TABLE 8.2 Shear strength and tensile strength of various materials

Material	Shear Strength, MPa		Tensile Strength, MPa
	Annealed	Not Annealed	
STEELS			
C10	235	314	390 to 490
C20	294	390	490 to 590
C30	350	470	590 to 690
C40	440	550	690 to 780
C50	490	640	780 to 880
C60	540	710	880 to 980
C80	690	880	1030 to 1180
C98	780	1030	1180 to 1370
St 32	290		310 to 390
St 37	340		360 to 440
St 50	390		490 to 590
St 63	490		620 to 740
St 78	640		770 to 880
Silicon	463		556
SAE	862		–
SAE	655		–
SAE	930		–
Stainless	470		600 to 1400
Hard spring	1120		1400 to 2200
Rolled bronze	310 to 390	390 to 590	350 to 800
Rolled copper	170 to 210	240 to 290	160 to 380
Rolled brass	210 to 290	340 to 390	250 to 450
Silver	208		285
Gold (14 carat)	324		448
Magnesium alloys	30 to 150		–
Zinc	120	200	100 to 360
Tin	30	40	30 to 40
Lead	20	30	20 to 30
Aluminium	70 to 90	130 to 160	200 to 400
Aluminium alloys	180 to 210	230 to 370	200 to 400
Leather	48 to 90		10
Asbestos sheet	70		–
Phenol fibre	180		–
Paper	44		–
Cellulose acetate	70		–
PVC	25 to 30		37 to 45

The clearances per side that are provided for normal working materials are presented in Table 8.3.

TABLE 8.3 Clearances as percentage of stock thickness

Material	Round	Other Contours
Soft aluminium < 1 mm	2	3
> 1 mm	3	5
Hard aluminium	4 to 6	5 to 8
Soft copper alloys	2	3
Hard copper alloys	4	5 to 6
Low carbon steel	2	3
Hard steel	3	5
Silicon steel	3	4 to 5
Stainless steel	4 to 6	5 to 8

8.3 SHEARING OPERATIONS

Straight line shears as described earlier are used for general purpose shearing work, for example, in cutting the small pieces from a large sheet. But the more useful are the die shearing operations where the shears take the form of the component to be made. The upper shear is called the punch and the lower shear is called the die. The two widely used processes are blanking and piercing.

Blanking

It is a process in which the punch removes a portion of material from the stock which is a sheet metal strip of the necessary thickness and width. The removed portion is called a blank and is usually further processed to be of some use, e.g., blanking of a pad lock key.

Piercing

Also sometimes called punching, the piercing is making holes in a sheet. It is identical to blanking except for the fact that the punched out portion coming out through the die in piercing is scrap. Normally a blanking operation will generally follow a piercing operation.

A typical set up used for blanking or piercing operation is shown in Fig. 8.6.

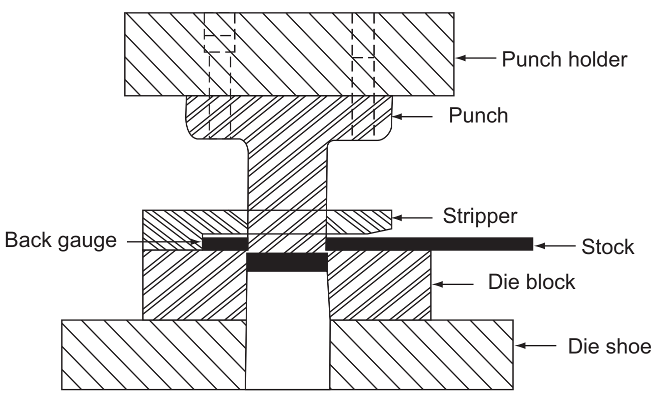

FIG. 8.6 *Simple blanking/piercing die*

Angular Clearance

In the shearing operation, first the material is elastically deformed, then plastically and finally removed from the stock strip. After the final breaking, the slug will spring back due to the release of stored elastic energy. This will make the blank to cling to the die face unless the die opening is enlarged. This enlargement is normally referred to as angular clearance or draft as shown in Fig. 8.7. The draft provided depends on the material, thickness and shape of the stock used. For thicker and softer materials, generally higher angular clearances are provided. The normal value is from 0.25 to 0.75 degree per side but occasionally a value as high as 2 degrees may be used.

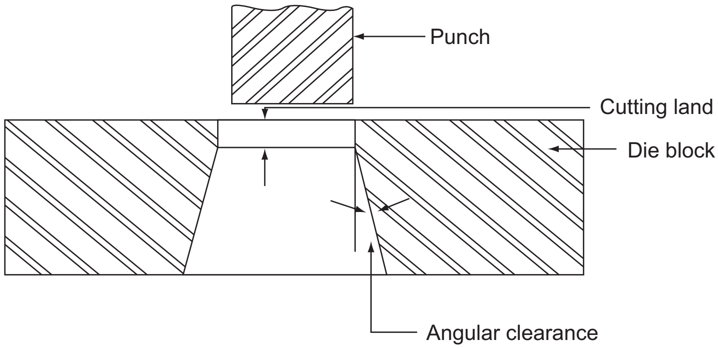

Fig. 8.7 *Angular clearance on die*

The die opening increases after every sharpening of the die because of the provision of the angular clearance. So to maintain the die size as per the design, the angular clearance is provided in the die opening along with a straight portion called as die land or cutting land. The length of the cutting land is about 3 mm for sheets which are less than 3 mm thick. For greater thicknesses, die land same as the material thickness has been found to be a good practice.

Stripper

Due to the release of the stored elastic energy in the stock left on the die, the stock tends to grip the punch as the punch moves upward. This necessitates the use of a stripper to separate the punch from the stock. The force required for stripping depends, besides the material, on other factors such as the position and size of the punched hole. For example, thicker materials or small hole in the middle of a strip require more stripping force than thin material or a hole towards one of the edges. A punch which has smooth side walls would strip very easily. Similarly more effort is required to strip punches that are close together. A general estimate of the stripping force may vary from 2.5 to 20% of the punch force but 5 to 10 percent is good for most of the applications. A formula generally used is

$$Ps = KLt$$

Where, Ps = stripping force, kN
L = perimeter of cut, mm
t = stock thickness, mm
K = stripping constant
= 0.0103 for low carbon steels thinner than 1.5 mm with cut at the edge or near a preceding cut
= 0.0145 for same materials but for other cuts
= 0.0207 for low carbon steels above 1.5 mm thickness
= 0.0241 for harder materials

Since the burr in the Fig. 8.3 represents the size of produced blank or hole, the clearances have to be accordingly apportioned to take into account the useful part obtained in the process. Thus, in blanking the die size is same as the component size whereas in piercing, the punch size is same as the actual hole size to be obtained.

Punching Force

The force required to be exerted by the punch in order to shear out the blank from the stock can be estimated from the actual shear area and the shear strength of the material. It is given by the following formula.

$$P = LtJ$$

Where, P = punching force, N

τ = shear strength, MPa

Sometimes the tensile strength may replace the shear strength in the above expression because shear is not the only active force the press has to overcome.

The punching force for holes which are smaller than the stock thickness may be estimated as follows:

$$P = \frac{dts}{\sqrt[3]{\dfrac{d}{t}}}$$

Where, d = diameter of the punch, mm

s = tensile strength of the stock, MPa

Shear

To reduce the required shearing force on the punch, for example to accommodate a large component on a smaller capacity punch press, shear is ground on the face of the die or punch. The effect of providing shear is to distribute the cutting action over a period of time depending on the amount of shear provided. Thus the shear is relieved of the punch or die face so that it contacts the stock over a period of time rather than instantaneously. It may be noted that providing the shear only reduces the maximum force to be applied but not the total work done in shearing the component. The effect of shear is shown schematically in Fig. 8.8.

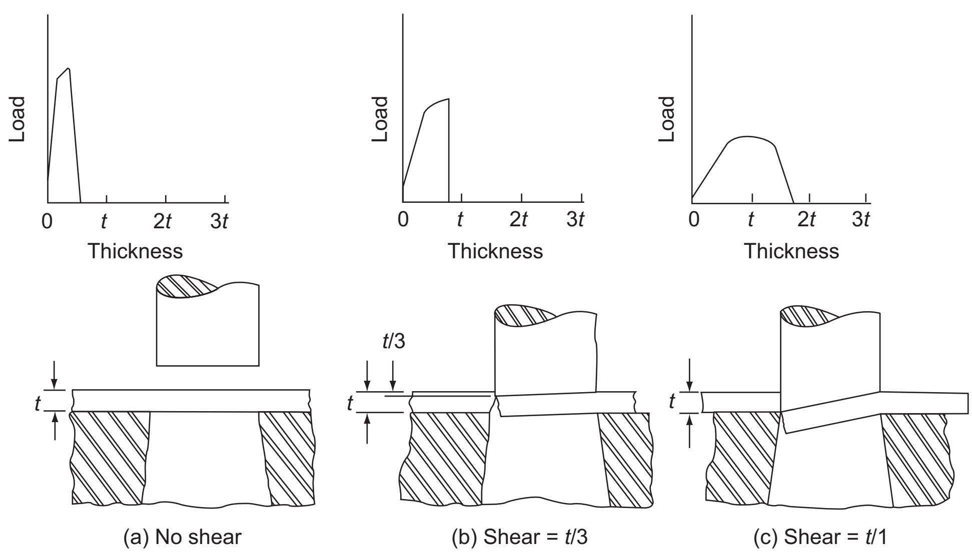

Fig. 8.8 *Effect of shear on the maximum load on punch*