The upset-forging cycle starts with the movable die sliding against the stationary die, to grip the stock. The two dies when in closed position, form the necessary die cavity. Then the heading tool advances against the stock and upsets it to completely fill the die cavity. Having completed the upsetting, the heading tool moves back to its back position. Then the movable gripper die releases the stock by sliding backwards.

Similar to drop forging, it is not possible to get the final shape in a single pass in machine forging also. Therefore, the operation is carried out in a number of stages. The die cavities required for the various operations are all arranged vertically on the gripper dies. The stock is then moved from one stage to the other in a proper sequence till the final forging is ready. A heading tool each, for every upsetting stage is arranged on the heading slide of the upsetting machine. A typical upsetting die and heading tool are shown in Fig. 7.24.

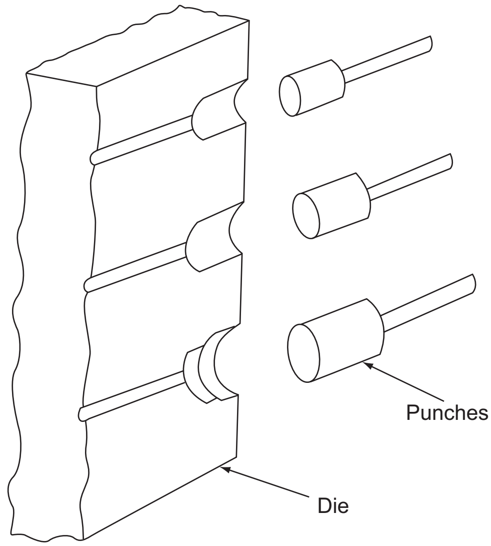


Fig. 7.24 *Upsetting die*

7.3.6 Forging Defects

Though the forging process generally gives superior quality products compared to other manufacturing processes, still there are some defects that are likely to come if proper care is not taken in the forging-process design. A brief description of such defects and their remedial methods is given below:

Unfilled Sections In this, some sections of the die cavity are not completely filled by the flowing metal. The causes of this defect are improper design of forging die or using faulty forging techniques.

Cold Shut This appears as a small crack at the corners of the forging. This is caused mainly by the improper design of the die wherein the corner and fillet radii are small as a result of which the metal do not flow properly into the corner and ends up as a cold shut.

Scale Pits This is seen as irregular depressions on the surface of the forging. This is primarily caused because of the improper cleaning of the stock used for forging. The oxide and scale present on the stock surface gets embedded into the finished forging surface. When the forging is cleaned by pickling, these are seen as depressions on the forging surface.

Die Shift This is caused by the misalignment of the two die halves, making the two halves of the forging to be of improper shape.

Flakes These are basically internal ruptures caused by the improper cooling of the large forging. Rapid cooling causes the exteriors to cool quickly causing internal fractures. This can be remedied by following proper cooling practice.

Improper Grain Flow This is caused by the improper design of the die, which makes the flow of metal not following the final intended directions.

7.3.7 Forging Design

Before the dies are designed, it is necessary to design the shape of the forging to be obtained from the die.

Parting Plane

A parting plane is the plane in which the two die halves of the forging meet. It could be a simple plane or irregularly bent, depending on the shape of the forging. The choice of a proper parting plane greatly influences the cost of the die as well as the grain flow in the forging.

In any forging, the parting plane should be the largest cross-sectional area of the forging, since it is easier to spread the metal than to force it into deep pockets. A flat parting plane is more economical. Also the parting plane should be chosen in such a way that equal amount of material is located in each of the two die halves, so that no deep die cavities are required. It may be required to put more metal into the top die half, since metal would more readily flow in the top half than in the bottom one. Some examples of proper parting plane choices are as below.

The example shown in Fig. 7.25(a) means that the required holes in the lever are to be obtained by drilling after forging. But the surface to be drilled is not flat but tapered because of the draft provided on the sides for withdrawal of the forging. This taper causes the drill to wander and therefore is not desirable. Therefore, a parting line, as shown in Fig. 7.25(b) would be desirable since it facilitates the generation of the holes by forging itself. But this brings in another problem of an inclined parting plane, which causes a sideward thrust (towards the left) as shown with an arrow. This sideward thrust may cause misalignment of the two die halves. To take care of this, the counter locking of the die is to be done as shown in Fig. 7.25(c), which is the final desirable parting plane.

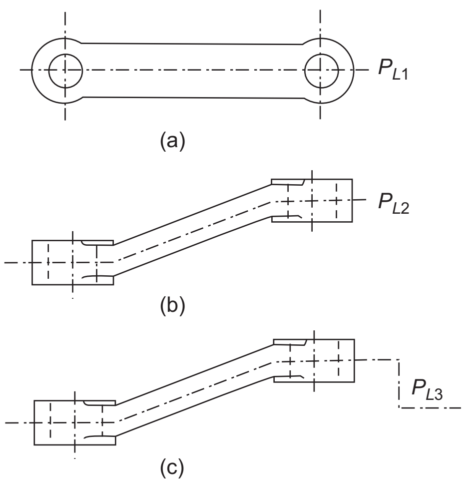


Fig. 7.25 *Parting planes in a bent lever*

Whenever the counter lock is provided, care should be taken to see that enough resisting area is provided, so that the sideward thrust generated is properly counter balanced. The thickness of counter lock should at least be 1.5 times the height for providing enough strength. The height of the counterlocking portion should at least be the same height as the forging detail which causes the sideward thrust. The counterlocked portions cannot be adequately lubricated and hence they wear out quickly, and call for reworking of the dies. Therefore, it is necessary that counter locking of dies should be eliminated as far as possible.

The elimination of counter locking can be done to a great extent by properly orienting the forging in the die. The web in the example shown in Fig. 7.26(a) causes the sideward thrust for the chosen parting plane. A slightly redesigned component as shown in Fig. 7.26(b) cannot be produced with a flat parting line but calls for a counter locking as shown. But orienting the component (as shown in Fig. 7.26(c)) so that the 90 degree angle is inclined to the parting line, makes for an easier forging of the angle as well as reduces the counter locking completely. For the design shown in Fig. 7.26(a) two components are produced in a die, the sideward thrust can be compensated. The components can be parted off after forging. This will facilitate making the die completely in one half only.

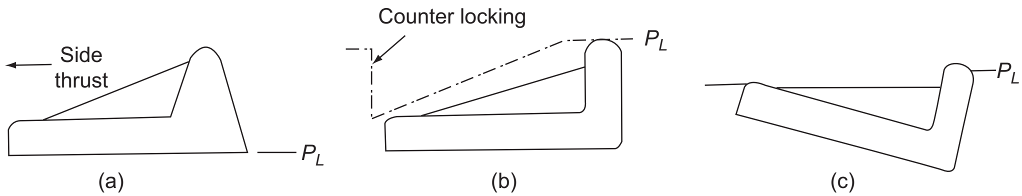


Fig. 7.26 *Counter locking reduced by changing the parting plane*

The other aspect to be considered in the choice of parting line is the punching of holes that are perpendicular to the parting plane. Depending on the depth of the hole compared to the diameter, it may be necessary to choose such a parting line that the hole is properly distributed, and the punch used for making the hole has enough strength. In Fig. 7.27(a) is shown one possibility of a parting plane, which simplifies the lower part of the die. But the punch in the upper die half becomes excessively long and hence higher draft. By changing the parting line as shown in Fig. 7.27(b), it is possible to punch from both sides, thus reducing the machining which was associated with the parting line as shown in Fig. 7.27(a). Also, this parting line gives a smaller height-to-diameter for the punch increasing its rigidity.

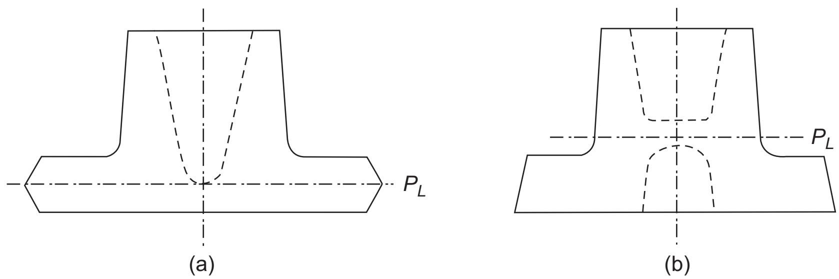


Fig. 7.27 *Parting line to reduce the depth of a punched hole*

Draft

Similar to castings, it is necessary to provide draft on forging surfaces, which are at right angles to the die movement. Natural draft is provided by the cylindrical or tapered surfaces. Otherwise it is necessary to provide draft on straight surfaces. Internal surfaces require more draft than external surfaces. During cooling, forging tend to shrink towards its centre and as a result, the external surfaces are likely to be separated, whereas the internal surfaces tend to cling to the die more strongly. The forged part is likely to be left in the die-half, which does the punching of the hole. In upset forgings, the draft problem is minimised because the part is held securely by the gripper die during the punch withdrawal and the gripper itself gets opened to release the component. Thus, in upset forgings a very small draft is normally used. The recommended draft angles are presented in Table 7.7. The tolerance applied on all draft angles is +2 deg and –1 deg.

Table 7.7 Recommended draft angle

Draft Position	Height or Depth (mm)	Drop Forgings		Upset Forgings	
		Normal (deg)	Close (deg)	Normal (deg)	Close (deg)
Outside	up to 25 above 25	5 to 7 5 to 10	3 to 7 3 to 7	3 to 5	2 to 4
Inside	up to 25 above 25	7 to 10 8 to 12	5 to 8 5 to 9	5 to 7	4 to 6

Fillet and Corner Radii

Forging involves the flow of metal in an orderly manner. Therefore, it is necessary to provide a streamlined path for the flow of metal so that defect free forging is produced. When two or more surfaces meet, a corner is formed that restricts the flow of metal. Therefore, these corners are to be rounded off to improve the flow of the metal. Fillets are for rounding off the internal angles, whereas corner is that of the external angle. For example, consider the flow of metal over a corner as shown in Fig. 7.28(a). Because of the large corner radius provided, metal is allowed to flow smoothly into the pocket. But when the corner radius is small, or not provided, as in Fig. 7.28(b), the metal flow is first hindered and when it enters finally the cavity, the metal would fold back against itself forming a defect called **lap** or **cold shut**.

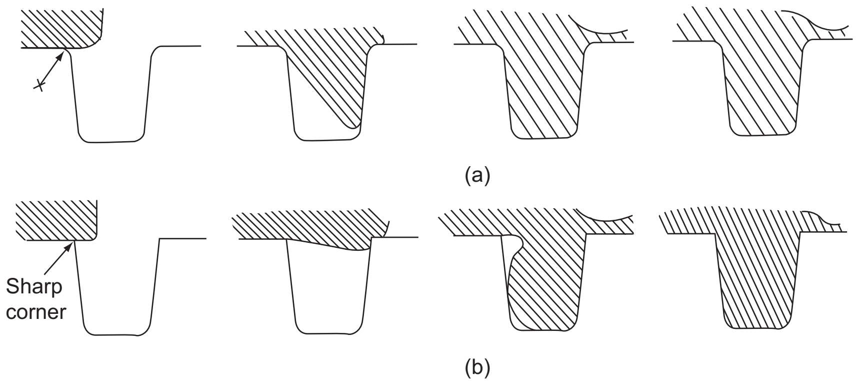


Fig. 7.28 *Effect of edge radius on the flow of metal*

Recommended fillet and corner radii are given in Tables 7.8 and 7.9.

Table 7.8 Recommended fillet and corner radii for drop forgings

Depth or Height, mm	Fillet Radius, mm	Corner Radius, mm
15	5	2.5
25	8	4.0
40	12	4.5
50	15	5.0
65	18	5.5
75	20	6.0

Table 7.9 Recommended fillet and corner radii for upset forgings

Upset Diameter / Stock Diameter	Fillet Radius, mm	Corner Radius, mm
up to 1.25	6.5	6.5
1.25 to 3.00	3.5	3.5
over 3.00	3.0	3.0

Shrinkage Allowance

The forgings are generally made at a temperature of 1150 to 1300°C. At this temperature, the material gets expanded and when it is cooled to the atmospheric temperature, its dimensions would be reduced. It is very difficult to control the temperature at which forging process would be complete, therefore we need to precisely control the dimensions. Hence a shrinkage allowance is added on all the linear dimensions as given in Table 7.10.

Table 7.10 Shrinkage allowance

Length or Width, mm	Commercial + or – mm	Close + or – mm
up to 25	0.08	0.05
26 to 50	0.15	0.08
51 to 75	0.23	0.13
76 to 100	0.30	0.15
101 to 125	0.38	0.20
126 to 150	0.45	0.23
Each additional 25	add 0.075	0.038
For example 400	1.200	0.830

Die-wear Allowance

The die-wear allowance is added to account for the gradual wear of the die which takes place with the use of the die. The suggested values are presented in Table 7.11.

Table 7.11 Die-wear tolerance

Net Mass of Forging (kg)	Commercial + or – (mm)	Close + or – (mm)
upto 0.45	0.80	0.40
0.46 to 1.35	0.88	0.45
1.36 to 2.25	0.95	0.48
2.26 to 3.20	1.03	0.53
3.21 to 4.10	1.11	0.55
4.11 to 5.00	1.18	0.60
Each additional 1 add	0.083	0.041
For example 15.00	2.010	1.010

Finish Allowance

Machining allowance is to be provided on the various forged surfaces, which need to be further machined. The amount of allowance to be provided should account for, besides the accuracy, the depth of the decarburized layer. Also, the scale pits that are likely to form on the component should also be removed during machining. A guideline for finish allowance is provided in Tables 7.12 and 7.13.

Table 7.12 Finish allowance for drop forgings

Greatest Dimension (mm)	Minimum Allowance per Surface (mm)
upto 200	1.5
201 to 400	2.5
401 to 600	3.0
601 to 900	4.0
above 900	5.0

TABLE 7.13 Finish allowance for upset forgings

Greatest Diameter (mm)	Minimum Allowance per Surface (mm)
up to 50	1.5
51 to 200	2.5
above 200	3.0

The component as affected by the various allowances is shown in Fig. 7.29.

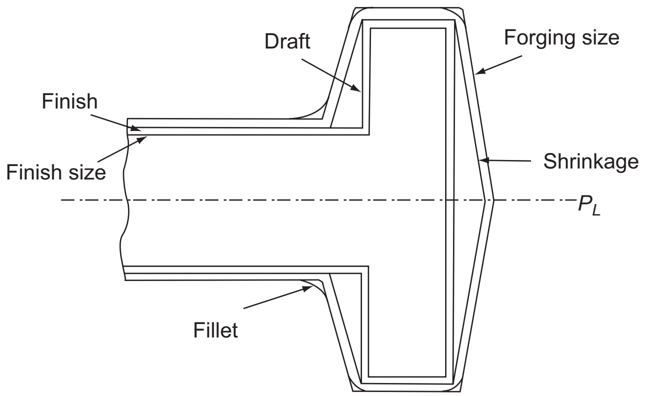


FIG. 7.29 *Allowances shown on forged component*

Cavities

The cavities and ribs including holes can be produced up to a certain depth only in drop forging. The main reason for the limitation is that the punch needs to have the necessary strength to withstand the forging load. Thin, long punches are likely to wear out quickly and need reconditioning of the die. The common limits for the depth of rib-to-web enclosures and for cavities are presented in Table 7.14 with reference to Fig. 7.30.

TABLE 7.14 Maximum limits of depth

Materials	Ratio of h : W	
	$L = W$	$L > 2W$
Aluminium, Magnesium	1.0	2.0
Steel, Titanium	1.0	1.5

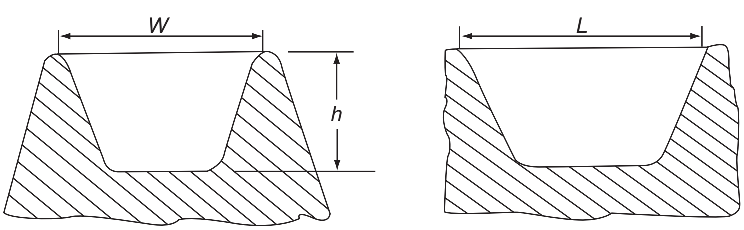
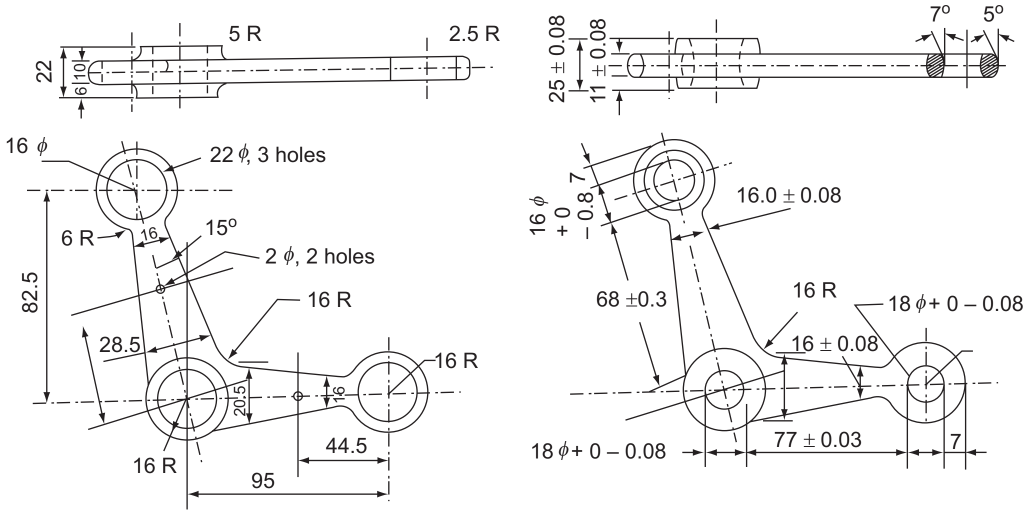


FIG. 7.30 *Cavity configuration in drop forging*

In addition to these allowances shown, the various tolerances that are applicable to forgings such as mismatch tolerance, weight tolerance, residual flash tolerance, thickness tolerance, burr tolerance, etc. are given in handbooks and standards which are listed at the end of this chapter in references. A sample component after providing the necessary tolerances and allowances is shown in Fig. 7.31.



(a) Actual part (a) Final component showing draft and tolerances

Fig. 7.31 *Forging component as affected by allowances and tolerances*

7.3.8 Drop-Forging Die Design

The first step in the design of a drop-forging die is the decision regarding what impressions (or stages) are necessary to achieve the necessary fibre-flow direction so that the requisite strength is obtained. Normally fullering, edging and finishing impressions are necessary. The other types of impressions are only required in special situations.

A blocking impression becomes a necessity only when the component is to be accurately made or the component has deep pockets or thin ribs, which are difficult to be obtained in a single finishing impression. A bending impression is required when the part is of bent nature and the grain direction is to be along the bend line. In such a case, the bending impression is to be obtained before the blocking impression or finishing impression when no blocking is used. Similarly, a flattening impression is used when the component is thin and perpendicular to one plane.

Flash

The excess metal added to the stock to ensure complete filling of the die cavity in the finishing impression is called flash. Flash acts as a cushion for impact blows from the finishing impression and also helps to restrict the outward flow of metal, thus helping in filling of thin ribs and bosses in the upper die. The amount of flash depends on the forging size and may vary from 10 to 50 percent. The flash flows around the forging in the parting plane as shown in Fig. 7.32. The flash is provided uniformly around the periphery of the forging in the parting plane. The minimum flash allowances suggested are given in Table 7.15.

It has been found that the forging load is greatly influenced by the flash thickness and width. The forging load can thus be decreased by increasing the flash thickness. However, this increases the metal to be left in flash, increasing the scrap losses. Also, the forging load decreases with an increase in the average thickness of the component. Thus it is more difficult to forge thin components than the thicker ones.

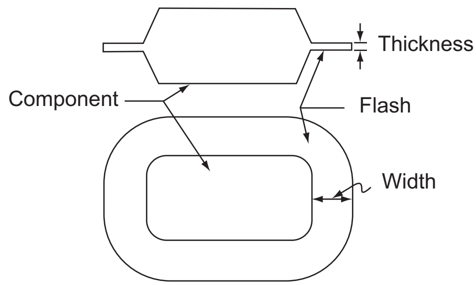


FIG. 7.32 *Proportions of flash in drop forging*

TABLE 7.15 Flash and gutter sizes

Stock Size (mm)	Flash		Gutter	
	Width (mm)	Thickness (mm)	Width (mm)	Thickness (mm)
upto 35	4.5	0.8	25	3.0
36 to 50	5.3	1.0	25 to 32	4.5
51 to 65	6.5	1.5	32 to 38	4.5
66 to 75	8.0	2.0	32 to 38	4.5
76 to 100	10.0	3.0	38 to 44	6.5

In addition to the flash, provision should be made in the die for additional space so that any excess metal can flow and help in the complete closing of the die. This is called **gutter**. Without gutter, flash may become excessively thick, not allowing the dies to close completely. The gutter as shown in Fig. 7.33 should be more than the flash provided. The preferred gutter sizes are presented in Table 7.15. The flash land provided in the die should be about 3% of the maximum forging thickness (0.5 to 8.0 mm). If the flash land is too small, then the energy required for the forging increases because of the excess metal trapped in the finishing impression and the flash land wears out quickly. Similarly, too high a flash land lets the work material to flow into the gutter and thus the die cavity gets unfilled.

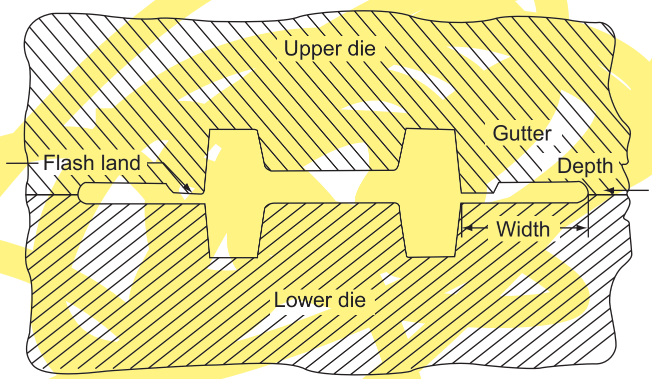


FIG. 7.33 *Gutter proportions*

Stock

As a rule, drop forgings do not get upset and therefore the stock size to be chosen depends on the largest cross-sectional area of the component. To get the stock size, the necessary flash allowance is to be provided over and above the stock volume as shown in Table 7.12. The stock to be used is either round, rectangular or any other section depending on the nature of the component. Having decided on the cross section of the stock, and from the total volume of the component and the flash, it is possible to find the length of the stock. The stock in the die is to be moved from one impression to the other, and hence a tong hold is provided in addition to the stock length. The tong hold of about 50 to 60 mm normally is required.

Example 7.1

Determine the stock size required for the air-radius arm shown in Fig. 7.34(a).

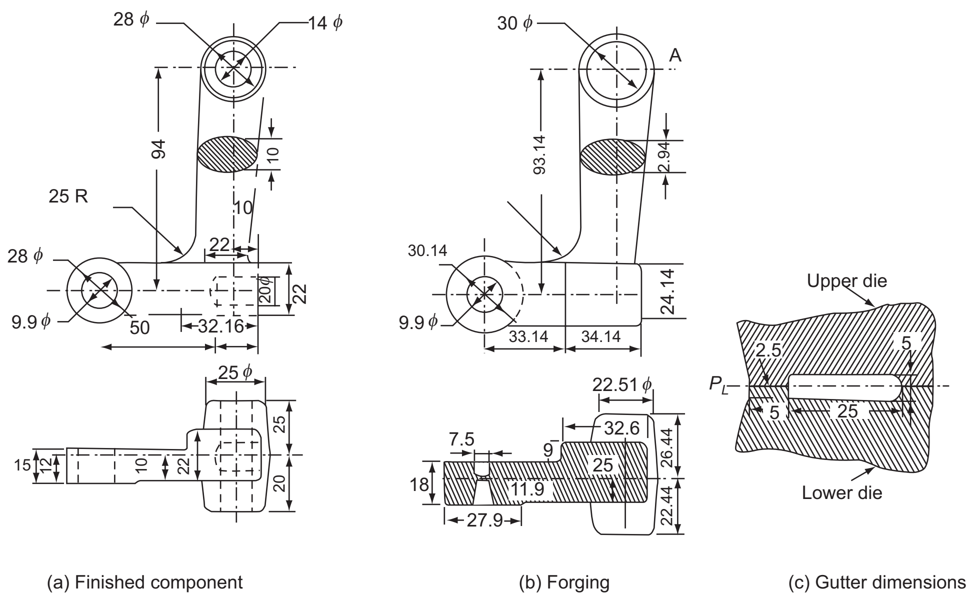


Fig. 7.34 *Air-radius arm*

Solution For the example shown in Fig. 7.34(a), the first job is to decide on the parting line, which is chosen as the one shown in Fig. 7.34(b) for its simplicity, and also it satisfies all the criteria laid out earlier.

The next job is to prepare the forging drawing. The first to be decided is the choice of the holes. The holes whose axes are perpendicular to the parting line can be produced by forging, unless they are too deep as per Table 7.14. On this account, only one hole as shown in Fig. 7.34(b) can be produced whereas the rest are to be obtained by drilling later.

The necessary allowances are added and the final forging drawing is shown in Fig. 7.34(b).

The maximum area of cross section occurs at section AA and its area is 1440 mm^2.

Hence, stock diameter = 42.82 mm

From Table 7.15, flash width = 5.3 mm, and flash thickness = 1.0 mm

Area of stock with flash = $1440 + 5.3 \times 1 \times 2 = 1450.6$ mm^2

Stock diameter with flash = 42.976 mm ≈ 45 mm

Volume of the forging = 72 870 mm^3 ≈ 73 000 mm^3

$$\text{Perimeter of forging} = \frac{\pi \times 30}{2} + 33 + 34 + 24 + 78 + \frac{\pi \times 30}{2} + 78 + 33 = 408.25 \text{ mm}$$

Flash volume = 5.3 × 1 × 408.25 = 2163.725 mm^3

This being too small, consider the flash to be 10% of forging volume.

Hence, flash volume = 7300 mm^3

Total stock volume = 73 000 + 7300 = 80 300 mm^3

Cross-sectional area of stock = 1590 mm^2

$$\text{Length of stock} = \frac{80300}{1590} = 50.50 \approx 55 \text{ mm}$$

The shape of the gutter in the finishing impression would be as shown Fig. 7.34(c).

Fullering Impression

The first operation to be done in drop forging is to draw-out the stock at the necessary portions by striking the metal with sharp and rapid blows. The amount of drawing-out depends on the differences in the maximum and minimum cross sections of the component. If the drawing-out is large, an auxiliary helve hammer is used with standard round and square dies for drawing-out. After this drawing-out operation, the stock is then taken to the drop-forging die.

For smaller drawing-out applications, the fullering impression is made along with the other impressions in the same die. The stock is fullered to the required shape in approximately 4 to 5 blows in the fullering impression. The die shape required for fullering is shown in Fig. 7.35. The consideration in designing are to keep the two die-halves away from completely closing and to allow for the smooth flow of metal.

The gap between the crests of the fullering impressions in the two die halves is kept apart a distance of 1.5 to 5.0 mm less than the minimum area of the component. This reduction is made to ensure that the two die halves do not come into physical contact and thus provide cushioning effect.

The length of the impression could be either 0.25% of the fullered length or half of the stock length without flash and tong hold, whichever is smaller. The distance between the relief portions of the impressions should be twice the diameter of the stock.

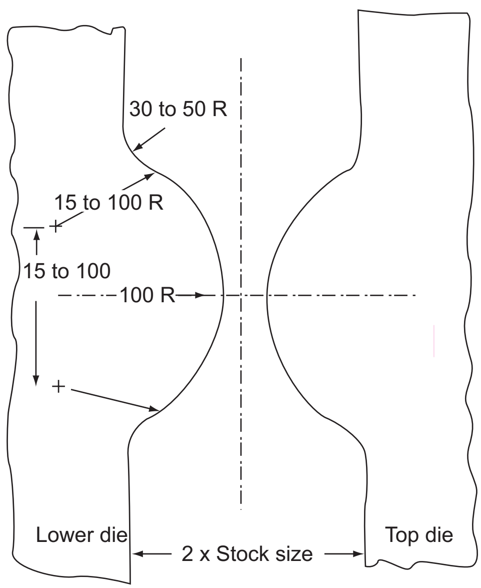


Fig. 7.35 *Fullering impression*

Edging Impression

The edging impression or preform, gathers the material as required in the final forging. As explained earlier this is the most important impression in a die. This gathering helps in the proper flow of metal and complete filling of the die cavities in the later impressions. The preform shape also helps in proper location of stock in the blocking impressions.

For irregular shapes with large variation in cross section, and which are extra-long compared to other dimensions, it is very difficult to gather the material. In such cases, it would be desirable to have two edging impressions.

In an edging impression, the area at any cross section should be same as that of the corresponding section in the component and the flash allowance. For simple shapes, it can be very easily calculated. For complex shapes or with continuous variation in cross section, it may be desirable to adopt a graphical approach as shown in Fig. 7.36.

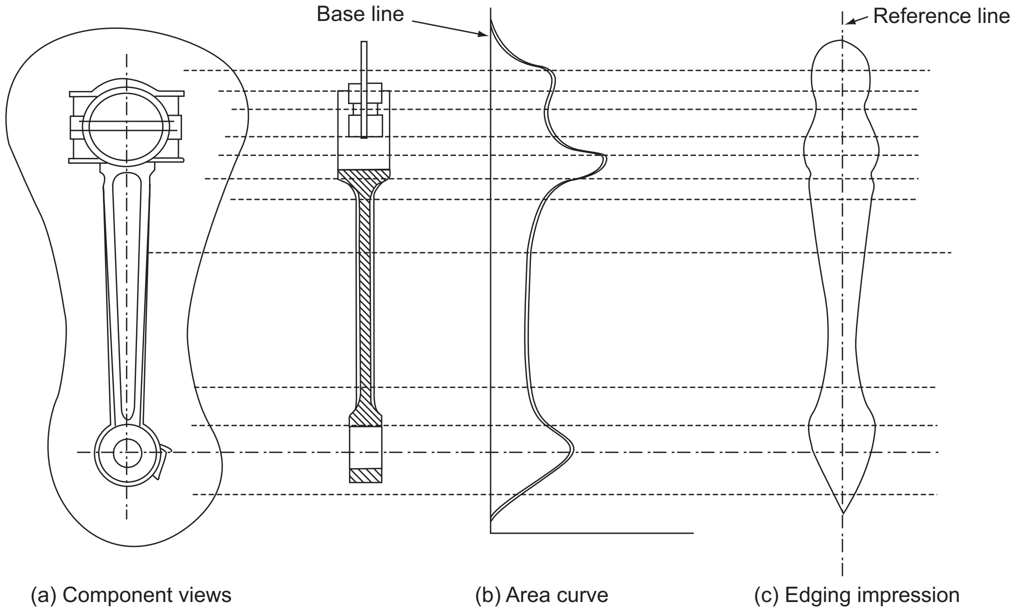


Fig. 7.36 *Graphical method of finding the edging impression of a drop-forged component*

The following procedure may be used for arriving at the preform shape.

(a) The plan and elevation views of the forging should be drawn side by side to a convenient scale, preferably full size. On the same views, the flash outline around the component is to be laid out. The flash proportions can be obtained from Table 7.14.

(b) As shown in Fig. 7.36(b), a base line is to be drawn parallel to the longitudinal axis of the component, at a small distance from the component views in Fig. 7.36(a).

(c) Next, the component is divided into a number of elements, as shown by the horizontal lines. The choice of the elements is based on the geometric shape of the component and the variation in the cross section. If the cross section is uniform over a length then only one section is enough. Whereas, when the cross section is changing drastically then it may be necessary to divide the component into a large number of sections over the change.

(d) The cross section of each of the elements chosen are calculated by simply multiplying the elements in the two views of the component. The areas of these various elements from the base line to any appropriate scale may be plotted as in Fig. 7.36(b). These plotted points are joined with a smooth curve. In this process, if there are any abrupt variations in the areas, then some more sections may be chosen to get a smooth curve.

(e) The flash area provided at each of these elements are calculated and added to the areas already plotted in Fig. 7.36(b).

(f) Having known the cross-sectional area of the component and flash at each of the elemental sections, the radius of preform at these elements given by the formula

$$\text{Radius, } R = \sqrt{\frac{\text{area}}{\pi}}$$

These radius values plotted on either side of a reference line drawn at Fig. 7.36(c) to the same scale as that used for drawing the component views at Fig. 7.36(a), provides an approximate contour that would promote smooth flow of metal into the final forged component.

Blocking Impression

Blocking or semi finishing impression resembles the final shape with liberal radii at corners. No gutter is provided in blocking. The area at each section is roughly 15 to 20% greater. The height of the blocked forging is large and breadth is smaller by an amount of the order of 0.8 to 1.5 mm. The length of the blocking impression remains the same and the centres correspond to that of the finishing impression. The edge and fillet radii are generously provided to aid the flow of metal in the blocking impression. For very complicated shapes with rapid changes in section, deep pockets or thin ribs, it may be necessary to include more than one blocking impression. A typical guideline for the blocking-impression dimensions in terms of finish dimensions is given in Table 7.16.

Table 7.16 Blocking impression proportions in terms of corresponding finishing dimensions

Dimension	Aluminium Alloys	Titanium Alloys
Web thickness	1 to 1.5 t	1.5 to 2.2 t
Fillet radius	1.2 to 2 R	2 to 3 R
Corner radius	1.2 to 2 R	2 to 3 R
Draft angle	2 to 5°	3 to 5°
Rib width	W – 0.8 mm	W – (1.6 to 3.2) mm

A few more rules derived from practical experience for blocking impression are summarised below:

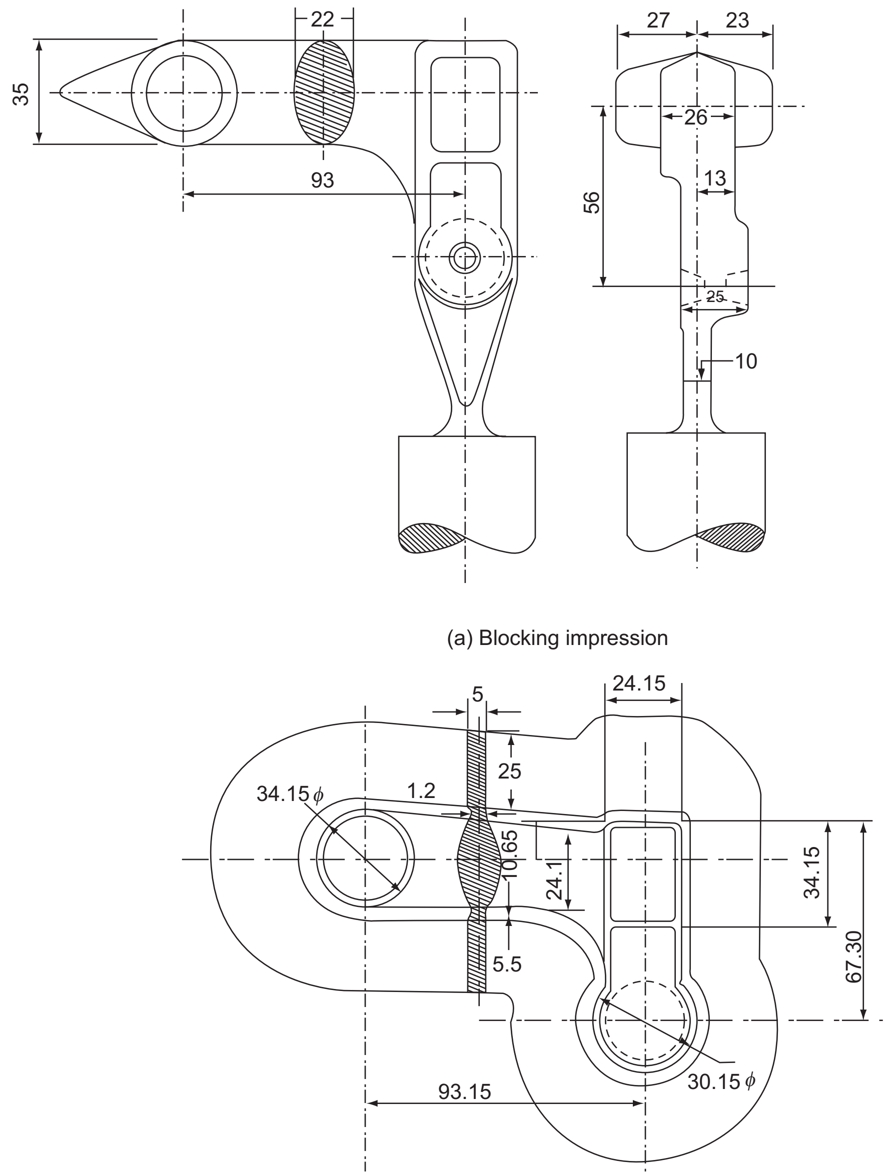
- In plan view, the blocking impression is slightly narrower than the finishing impression (about 0.5 to 1 mm on each side), such that the blocked component will fit the finishing impression.
- For forging high ribs in the finishing impression, it is at times necessary to have lower ribs in the blocking impression. The web thickness in the blocking impression is larger than that in the finishing impression.
- In order to enhance metal flow towards the ribs, it is useful to provide an opening taper from the centre of the web towards the ribs.

Finishing Impression

The dimensions of the finishing impression are same as that of the final forging desired with the necessary allowances and tolerances. Gutter should be provided in the finishing impression as detailed earlier. The blocking and finishing impressions for a typical component are shown in Fig. 7.37.

Location of Impressions

The various forging impressions should be located in the die block in such a way that the forging force be as nearer to the centre as possible. This will minimise the likely mismatch of the two die halves, reduce the wear on the ram guides of the drop hammer and will help to maintain the thickness dimensions of the forging. To do this, the operation requiring the maximum forging force (usually blocking or finishing) should be placed at the centre with the other impressions distributed as nearly equal on either side of it in the die.



(a) Blocking impression

(b) Finishing impression

Fig. 7.37 *Blocking and finishing impressions of air radius arm*

It is the normal practice to provide the fullering impression on the left-hand side and the edging impression on the right-hand side with the blocking and finishing impressions at the centre.

It is necessary to provide enough clearance of the order of 10 to 15 mm between the impressions in the die. If too little space is provided, then upsetting of the die block is likely to take place, which would decrease the thickness of the final forging.

Die Inserts

Die inserts are generally used for economy in the production of some forgings. Preparing inserts is cheaper than the whole die. Similarly, replacement of an insert is far more economical and less time consuming than the remaking of a complete forging die. Also, it is possible to use hard materials such as stellite or hard alloy steels for inserts, whereas they are not suitable or are very expensive to be of use for a complete die.

Die inserts are of two types. For certain forgings, specific portions of details such as deep pockets which are likely to be worn out quickly are used as inserts. These are called **plug-type inserts**, an example of which is shown in Fig. 7.38. A single plug type insert could be used or a number of inserts could be arranged with varying hardnesses related to the respective wearing tendencies.

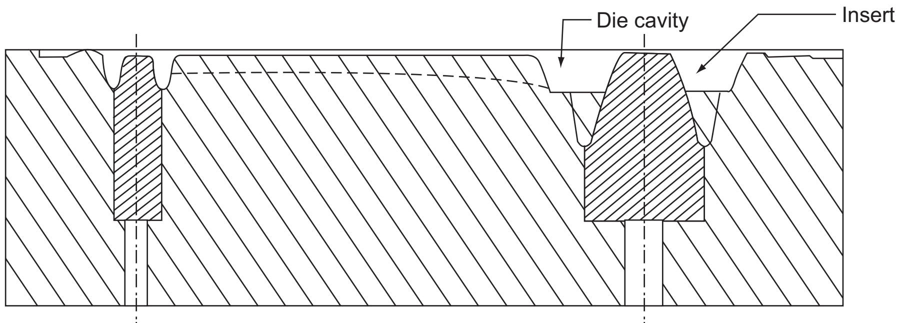


Fig. 7.38 *Plug-type insert in a drop-forging die*

A full insert is one where the complete forging impression is sunk into a harder insert which is then arranged in a softer die steel block (Fig. 7.39). These are generally used for shallow impressions. The main advantage of the full insert is that the same die block could be used for different forgings by changing the inserts. Also, any changes in forging design could be easily incorporated by changing the insert.

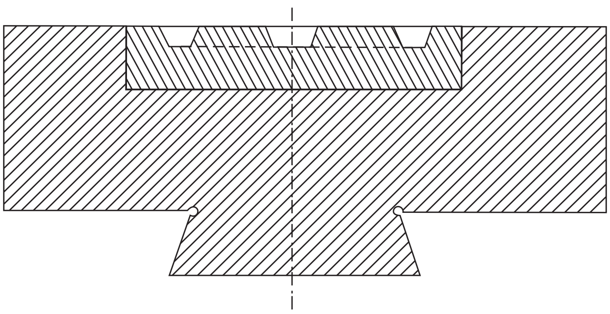


Fig. 7.39 *A full-die insert in a drop-forging die*

7.3.9 Upset-Forging Die Design

In upset forgings, as a rule, no reduction in cross section occurs and, therefore, the stock to be chosen is of the smallest area of cross section of the component. Also, very small or negligible flash is provided in upset forgings.

Depending on the shape of the upsetting to be done, the number of passes or blows in the die are to be designed. The amount of upsetting to be done in a single stage is limited. To arrive at the safe amount of upsetting in a given pass, the following three rules are to be satisfied, to achieve defect free upset forgings.

1. The maximum length of the unsupported stock that can be gathered or upset in a single pass is not more than three times the stock diameter. Beyond this length, the material is likely to buckle under the axial upsetting load rather than be upset, as shown in Fig. 7.40.

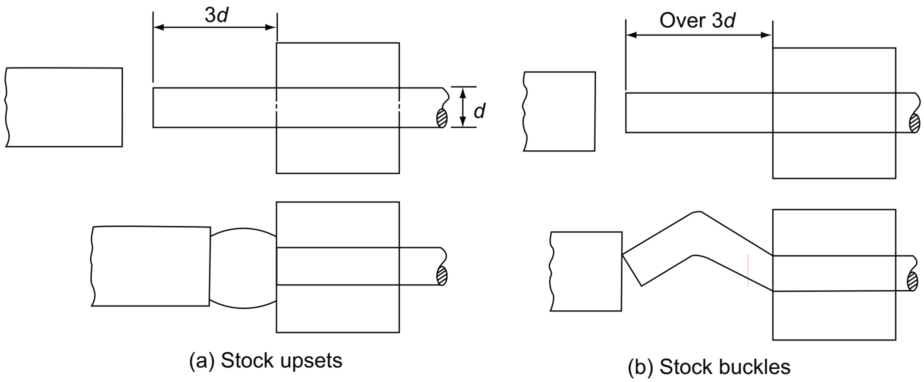


Fig. 7.40 *Application of rule one for proper upsetting*

2. If the stock longer than three times the diameter is to be upset in a single blow then the following conditions should be complied. The die cavity should not be wider than 1.5 times the stock diameter and the free length of the stock outside the die should be less than half the stock diameter. When these conditions are not complied, the stock would bend as shown in Fig. 7.41.

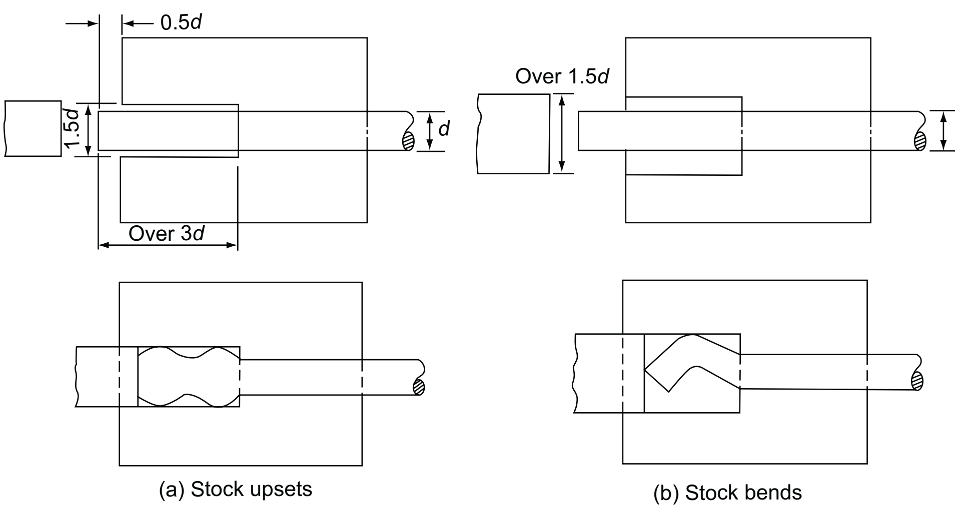


Fig. 7.41 *Application of Rule 2 for proper upsetting*

3. For upsetting the stock which is longer than three times the diameter and the free length of stock outside the die is up to 2.5 times the diameter, the following conditions should be satisfied. The material is to be confined into a conical cavity made in the punch with the mouth diameter not exceeding 1.5 times

the stock diameter and the bottom size being 1.25 times the stock diameter. Also, it is necessary that the heading tool recess be not less than two thirds the length of the working stock or not less than the working stock minus 2.5 times the stock diameter. The application of this rule is shown in Fig. 7.42.

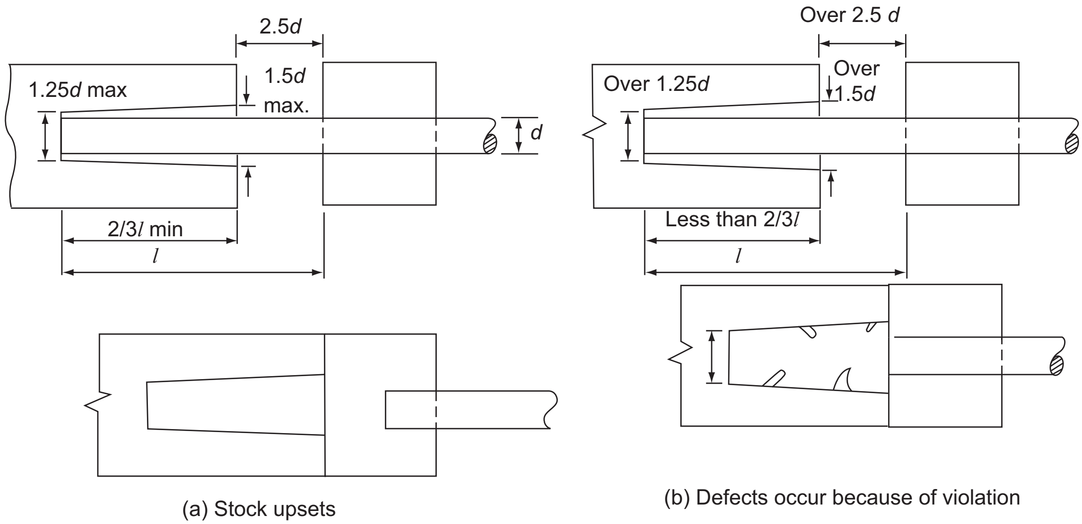


FIG. 7.42 *Application of rule three for proper upsetting*

The above are the absolute limits for proper upsetting. But in practice, it may be possible to cross these absolute limits. The condition of the stock end as is cut, would also affect the maximum permissible upset lengths as presented in Table 7.17.

TABLE 7.17 **Permissible stock lengths for free upsetting**

Condition of Stock End	Angle of Cut (deg)	Shape of Heading Tool End Face	Permissible Length (Stock Diameter, d mm)		
			< 25	50	100
Even	< 1	Hollow	2.4 d	—	—
		Flat	2.2 d	2.5 d	3.0 d
		With preforming punch	1.8 d	2.0 d	2.0 d
	> 3	Flat	1.8 d	2.0 d	2.5 d
		With preforming punch	1.25 d	1.5 d	1.5 d
Uneven	< 1	Flat	1.8 d	—	—

Location of Cavities

The upset cavities may entirely be kept in the gripper dies, or in heading tool or part in gripper and part in heading tool. The choice of location mainly depends on the severity of the upsetting and the convenient location of flash for trimming. Simple forgings requiring smaller upsetting may contain the complete die cavity in the heading tool. Also complex shapes requiring severe upsetting are obtained with the die cavity completely in the gripper die.