FORGING DIES AND THEIR USE

A forging is a metal part which has been hammered to shape while hot. Forgings invariably are used as fittings in the airplane and, as such, have more mass than the thin sheet metal parts made on the drop hammer. In most forging operations a falling punch forces the hot metal to assume the shape of the punch and die.

Both aluminum alloy and steel forgings are being widely used in the aircraft of today. As production volume increases, the tendency is to replace highly stressed riveted and welded parts with forgings.

Forgings may be advantageously designed for carrying loads and consequently their use often results in weight savings. Once the dies have been made, forgings can be turned out quickly. Also, forgings are very consistent as to size and shape. They can be depended upon to fit into a jig or machine fixture without trouble. This isn't always true of parts machined out of bar stock, since they usually vary with the man and the equipment making them.

Forgings are not made in the aircraft plant. Neither are the punches and dies for making the forging. The usual procedure is for the aircraft company to furnish a forging drawing of the required part. This is sent to a reliable forging manufacturer who then makes the forgings. These are then sent back to the aircraft plant for inspection and subsequent heat-treatment and machining. In order to save time, the forgings are usually ordered directly by Engineering. Of course, this would normally be the function of Tool Planning.

Although the aircraft tool designer does not have to design forging dies, a brief outline of forging operations will be useful. The engineer, tool planner, tool designer, toolmaker, machinist, and inspector must possess at least a fair knowledge of forging methods and problems, in order to adequately use this rapidly growing method of fabrication.

Advantages of the closed die forging

1. Higher production rate to several hundred forging per hour.
2. More complex shapes without flooding may be forged.
3. Less allowences may be applied and even without them that allows to eliminate further machining.
4. Less wastage of material (the grater utilization factor).
5. Greater impact toughness.
6. It is possible to apply less skill of the worker.

Advantages of the closed die forging

1. Less overall dimensions of the forging
2. Greater total loading is required for closed-die forging
3. Specialized tool is used for closed die forging

Forging Methods

There are various forging methods in common use today. Of these, *drop forging* is the most common for turning out aircraft parts. In its simplest form it consists of a board lift hammer in which a cam and revolving rollers serve to lift the hammer head. Board lift hammers vary in size from 800 to 5000 Ib. Ability to vary the force of the hammer blow is, of course, a decided advantage in forging work. Air and steam hammers are made in sizes from 800 to 18,000 Ib.

Press forgings are made either on a hydraulic press or, a crank press which is similar to a punch press. Any machine is suitable, which has sufficient power to press the material into

the die in a single blow. This type of work is limited to simple parts. The dies are, therefore, usually quite simple also.

Another type of forging is known as the *upset forging*. This is usually accomplished in a horizontal position and the forge is commonly called a *header*. Bolts and rivets are made on automatic forges of this type. The dies often are designed in from two to six stages, depending on the size of head to be made.

Dies and Punches

Drop forging dies and punches are made of heat-treated steel blocks machined to shape. They are matched with locating pins and then the punch attached to the hammer head while the die is fastened to the bed or anvil. The customary practice is to include two or three stages in a single block.

The cavities in a punch and also a die block are usually sunk with a special vertical miller. Special cutters are used which give the required draft as they mill. Templates are often used in machining these dies.

Carefully note that the punch and die are both female parts, with respect to the piece being forged. Often they will be identical, one forming the upper half and the other the lower half of a symmetrical part. The punch and die meet at the parting line. This is where the excess metal, known as the flashing, occurs. Also note that the moving tool is called the punch.

A fairly good polish is needed on the punch and die for forging steel parts. A much better polish is required if aluminum alloy forgings are to be made. The reason for this is that the aluminum alloy does not flow as easily as the steel. There is a tendency for it to drag and for that reason well-polished tools are essential. A forging punch and die for an aluminum alloy part are more expensive to make than a set for a similar steel part.

The three stages commonly built into forging dies are termed edging, blocking, and finishing. Edging is the first operation. In this the forger holds the hot billet with tongs and hammers the piece into the "edger." This roughly sets the stock. Then the second operation is performed on the "blocker" in which the piece is made to assume the shape of the finished part. The final operation finishes the piece; that is, sets it to the exact shape and size.

Thus the finishing operation is comparatively mild and greatly prolongs the life of the expensive portion of the die.

After a forging has been made, excess metal will appear at the parting line between the punch and the die. This is known as the flash. It is usually removed with a trimmer punch and die in a punch press.

The punch and die must contain shrink allowances since the metal is worked in the hot state. Aluminum alloy is usually forged at a temperature of 900° F.; steel is heated to a much higher temperature. The shrink allowances are of the order 0.0085 inches per inch for aluminum alloys and .015 for steel. Actually dural shrinks more than steel per degree change in temperature but since the steel is heated to a much higher temperature, it undergoes a greater over-all change per inch of length.

Life of Dies

The service of the dies will vary. In some cases they are worn to their limits within a comparatively short time. Usually wear will occur at certain critical points. When the punch and die fail to produce parts within the allowable tolerances, they have to be reworked.

Forging tools can be made true again, only by resinking the original impressions. A new, correct outline is then obtained in the die. In order to get the proper depth the top is machined down. This procedure can be repeated until the die blocks become so thin that they are unable to stand the shock of the forging blows. They may be 10 inches thick when new so that many reworkings are usually possible.

A high grade steel is used in making the punch and die. After machining they are not heat-treated. The reason is this: A highly heat-treated part is very hard and wear resistant but it is also very brittle. A slight blow will usually be sufficient to shatter such a part. Therefore, the forging dies must represent a compromise between toughness and hardness. As a result they do wear fairly rapidly.

Classification of Closed-Die Forgings

Blocker-type forgings are produced in relatively inexpensive dies, but their weight and dimensions are somewhat greater than those of corresponding conventional closed-die forgings. A blocker-type forging approximates the general shape of the final part, with relatively generous finish allowance and radii. Such forgings are sometimes specified when only a small number of forgings are required and the cost of machining parts to final shape is not excessive.

Conventional closed-die forgings are the most common type and are produced to comply with commercial tolerances. These forgings are characterized by design complexity and tolerances that fall within the broad range of general forging practice. They are made closer to the shape and dimensions of the final part than are blocker-type forgings; therefore, they are lighter and have more detail.

Close-tolerance forgings are usually held to smaller dimensional tolerances than conventional forgings. Little or no machining is required after forging, because close-tolerance forgings are made with less draft, less material, and thinner walls, webs, and ribs. These forgings cost more and require higher forging pressures per unit of plan area than conventional forgings.

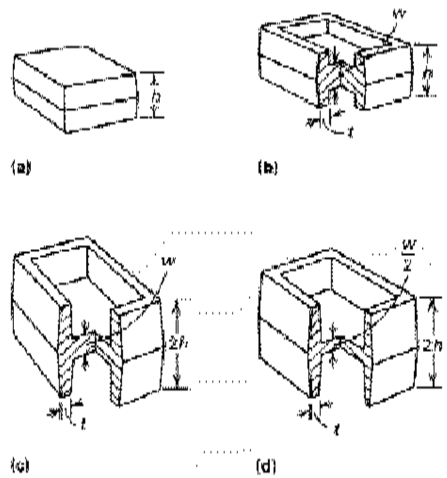


Fig. 3 Forging difficulty as a function of part geometry. Difficulty in forging increases from (a) to (d). (a) Rectangular shape. (b) Rib-web part. (c) Part with higher rib. (d) Part with higher rib and thinner web

Shape Complexity in Forging

Metal flow in forging is greatly influenced by part or die geometry. Several operations (preforming or blocking) are often needed to achieve gradual flow of the metal from an initially simple shape (cylinder or round-cornered square billet) into the more complex shape of the final forging. In general, spherical and blocklike shapes are the easiest to forge in impression or closed dies. Parts with long, thin sections or projections (webs and ribs) are more difficult to forge because they have more surface area per unit volume. Such variations in shape maximize the effects of friction and temperature changes and therefore influence the final pressure required to fill the die cavities. There is a direct relationship between the surface-to-volume ratio of a forging and the difficulty in producing that forging.

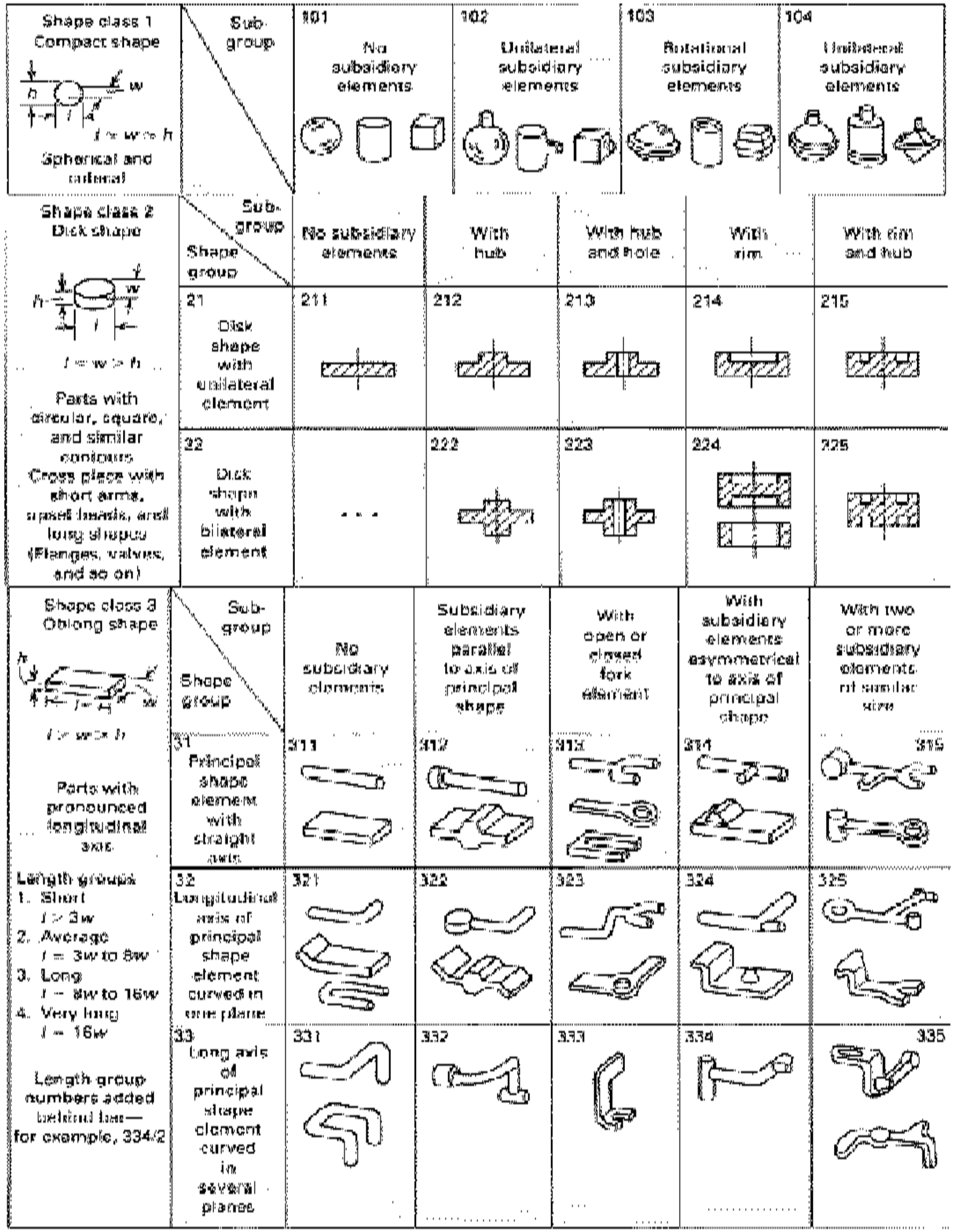


Fig. 4 Classification of forging shapes.

The ease of forging more complex shapes depends on the relative proportions of vertical and horizontal projections on the part. Figure 3 shows a schematic of the effects of shape on forging difficulties. The parts illustrated in Fig. 3(c) and 3(d) would require not only higher forging loads but also at least one more forging operation than the parts illustrated in Fig. 3(a) and 3(b) in order to ensure die filling.

As shown in Fig. 4, most forgings can be classified into three main groups. The first group consists of the so-called compact shapes, whose three major dimensions (length, *l*; width, *w*; and height, *h*) are approximately equal. The number of parts that fall into this group is rather small. The second group consists of disk shapes for which two of the three dimensions (*l* and *w*) are approximately equal and are greater than the height *h*. All round forgings belong in this group, which includes approximately 30% of all commonly used forgings. The third group consists of long shapes that have one major dimension significantly greater than the other two (*l* > *w* Ï*h*). These three basic groups are further divided into subgroups depending on the presence and type of elements subsidiary to the basic shape

Design of Blocker (Preform) Dies

One of the most important aspects of closed-die forging is proper design of preforming operations and of blocker dies to achieve adequate metal distribution. Therefore, in the finish-forging operation, defect-free metal flow and complete die filling can be achieved, and metal losses into the flash can be minimized. In preforming, round or round-cornered square stock with constant cross section is deformed such that a desirable volume distribution is achieved prior to the final closed-die forging operation. In blocking, the preform is die forged in a blocker cavity before finish forging.

The primary objective of preforming is to distribute the metal in the preform in order to:

· Ensure defect-free metal flow and adequate die filling

· Minimize the amount of material lost into flash

· Minimize die wear in the finish-forging cavity by reducing metal movement in this direction

· Achieve desired grain flow and control mechanical properties

Common practice in preform design is to consider planes of metal flow--that is, selected cross sections of the forging—as shown in Fig. 5. Several preforming operations may be required before a part can be successfully finish forged. In determining the various forging steps, it is first necessary to obtain the volume of the forging,

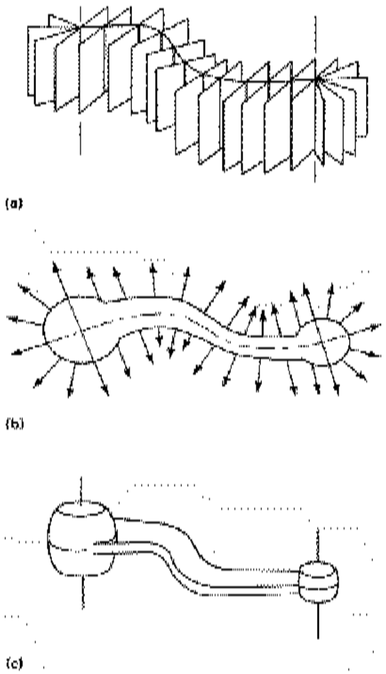


Fig. 5 Planes (a) and directions (b) of metal flow during the forging of a relatively complex shape. The finished forging is

based on the areas of successive cross sections throughout the forging. A volume distribution can be obtained by using the following procedure:

· Lay out a dimensioned drawing of the finish configuration, complete with flash

· Construct a baseline for area determination parallel to the centerline of the part

· Determine maximum and minimum cross-sectional areas perpendicular to the centerline of the part

· Plot these areas at proportional distances from the baseline

· Connect these points with a smooth curve. In cases in which it is not clear how the curve would best show the changing cross-sectional areas, plot additional points to assist in determining a smooth representative curve

· Above this curve, add the approximate area of the flash at each cross section, giving consideration to those sections where the flash should be widest. The flash will generally be of a constant thickness, but will be widest at the narrower sections and smallest at the wider sections

· Convert the maximum and minimum area values to round or rectangular shapes having the same crosssectional areas

In designing the cross sections of a blocker (preform) die impression, three basic rules must be followed:

· The area of each cross section along the length of the preform must be equal to the area of the finish cross section augmented by the area necessary for flash. Therefore, the initial stock distribution is obtained by determining the areas of cross sections along the main axis of the forging

· All the concave radii (including fillet radii) of the preform should be larger than the radii of the forged part

· When practical, the dimensions of the preform should be greater than those of the finished part in the forging direction so that metal flow is mostly of the upsetting type rather than the extrusion type. During the finishing operation, the material will then be squeezed laterally toward the die cavity without additional shear at the die/material interface. Such conditions minimize friction and forging load and reduce wear along the die surfaces

Application of these three principles to steel forgings is illustrated in Fig. 6 for some solid cross sections. The qualitative principles of preform design are well known, but quantitative information is rarely available.

For the forging of complex parts, empirical guidelines may not be sufficient, and trial-and-error procedures may be time consuming and costly. A more systematic and well-proven method for developing preform shapes is physical modeling, using a soft material such as lead, plasticine, or wax as a model forging material and hard plastic or low-carbon steel dies as tooling.

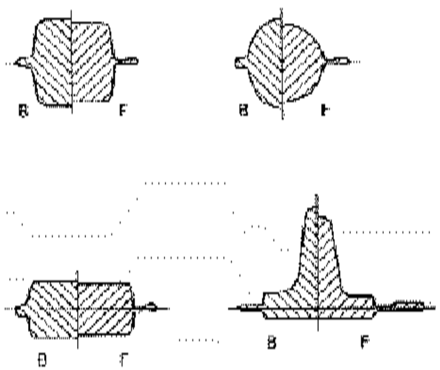


Fig. 6 Suggested blocker cross sections for steel forgings. B, blocker; F, finished forging.

Therefore, with relatively low-cost tooling and with some experimentation, preform shapes can be determined.

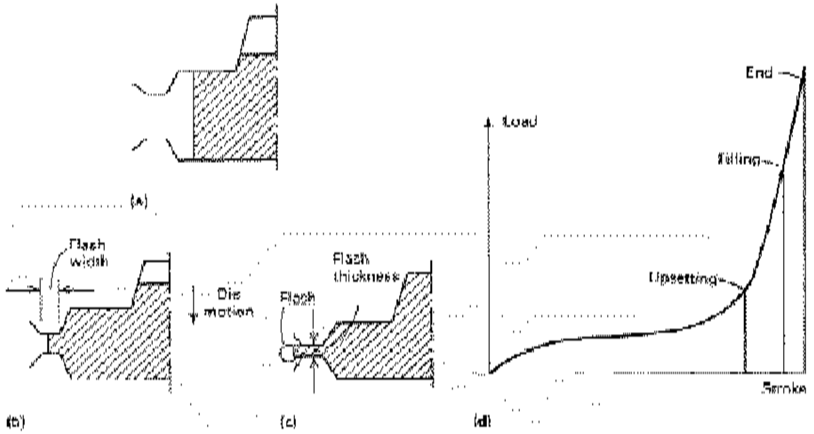


Fig. 7 Metal flow (a to c) and load-stroke curve (d) in closed-die forging. (a) Upsetting. (b) Filling. (c) End.

A typical load-versus-stroke curve for a closed-die forging is shown in Fig. 8. Loads are relatively low until the more difficult details are partly filled and the metal reaches the flash opening (Fig. 7). This stage corresponds to point $P1$ in Fig. 8. For successful forging, two conditions must be fulfilled when this point is reached. First, a sufficient volume of metal must be trapped within the confines of the die to fill the remaining cavities, and second, extrusion of metal through the narrowing gap of the flash opening must be more difficult than filling the more intricate detail in the die.

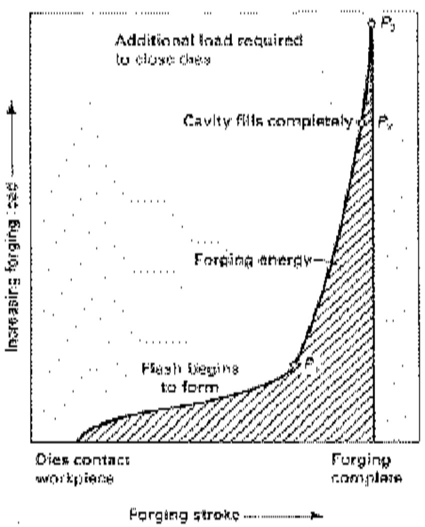


Fig. 8 Typical load-stroke curve for a closed-die forging showing three distinct stages.

As the dies continue to close, the load increases sharply to a point $P2$, the stage at which the die cavity is filled completely. Ideally, at this point, the cavity pressure provided by the flash geometry should be just sufficient to fill the entire cavity, and the forging should be completed. However, $P3$ represents the final load reached in normal practice for ensuring that the cavity is completely filled and that the forging has the proper dimensions. During the stroke from $P2$ to $P3$, all metal flow occurs near or in the flash gap, which in turn becomes more restrictive as the dies close. In this respect, the detail most difficult to fill determines the minimum load for producing a fully filled forging. Therefore, the dimensions of the flash determine the final load required for closing the dies. Formation of the flash, however, is greatly influenced by the amount of excess material available in the cavity, because this amount determines the instantaneous height of the extruded flash and therefore the die stresses.

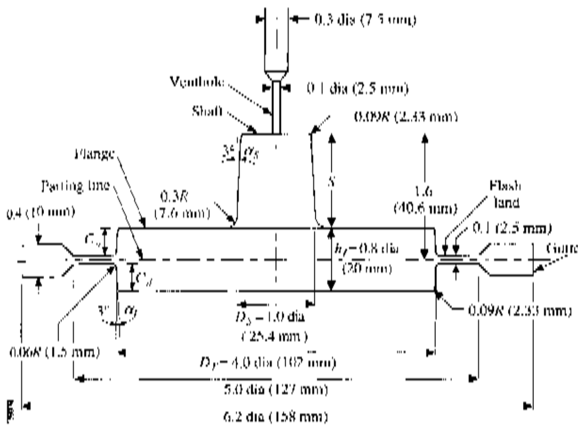
A cavity can be filled with various flash geometries if there is always sufficient material in the die. Therefore, is it possible to fill the same cavity by using a less restrictive (thicker) flash and to do this at a lower total forging load if the necessary excess material is available (in this case, the advantages of lower forging load and lower cavity stress are offset by increased scrap loss) or if the workpiece is properly preformed (in which case low stresses and material losses are obtained by additional preforming).

Design of Parts

There are a few common sense rules which should always be observed when designing forgings. The draft angle is a necessary evil in every case. Thus in Figs. 54 and 55, the sides of the boss are seen to slope inward, when going out from the parting surface. This is true of every outside surface on the part. 3 These outside surfaces incline inwards at an angle of 7°. This allows the punch and die to easily separate from the part. In very deep forgings this draft angle may have to be increased to as much as 10°. These draft angles emanate from the parting line and therefore the forging drawing will have to show where this occurs. The punch and die meet at the parting line.

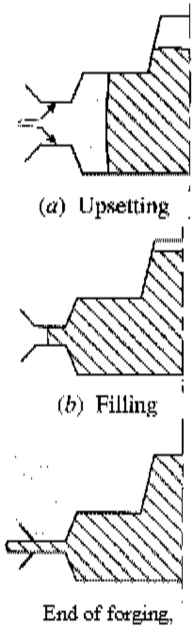
To prevent the forging from cracking in the corners, generous fillets or radii should be specified. Judgment should be used when calling for a web. Rapid change of section should be avoided. The design engineer will recognize these items as being extremely detrimental from a strength viewpoint. The forging operator knows that they greatly complicate the making of the parts.

1. DESIGN OF A FORGING



Forging in the conventional sense may be classified as (1) open-die (flat-tool or smith forging), and (2) closed-die or impression-die forging, sometimes called drop forging; however, both of these categories are subject to some confusion. *Closed-die forging* is the term applied to all forging operations involving three-dimensional control. Sometimes the distinction between open- and closed-die forging is not too clear, such as, for example, in swaging and edging operations, in which a considerable amount of lateral confinement may occur. In these cases, however, the nature of the forging operations and the equipment used will definitely place them in one category or the other.

Closed-die forging is used (1) when the desired shape is complicated, (2) when the quantity of forgings required is large so the time and cost of making closed dies may be justified, (4) where the forging isn't so large as in open-die forging.



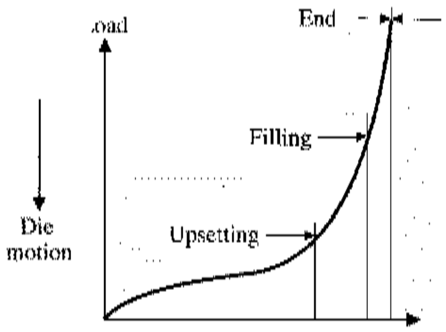


FIGURE 1.2*(a)* to (c)
Illustration of metal flow and *(d)* the load-stroke curve in forging with the die shown in Fig 10.1

The three main stages of deformation and the load-displacement curve during the forging cycle of such a part are shown in Fig. 1.2 as follows:

1. *Upsetting,* in which the forging slug is initially compressed resulting (a) in outward flow of metal to form the flange, and (fc) inward and upward flow to extrude the boss or shaft, as was discussed in extrusion forging
2. *Die filling,* in which the lower cavity is essentially filled, except perhaps for the upper portion of the shaft, and the flash begins to form
3. End of forging in which the dies are completely filled as the load and the pressure within the die cavity rapidly rises due to the restriction of the metal flow to form the colder, thinner flash with any excess metal flowing into the flash gap and gutter.

The purpose of the land of the die, as shown in Figs. 9.1 and 9.2, is to restrict the flow of metal into the gutter and thereby control the back pressure to the flow of metal in the die and thus promote the filling of the die. The longer the effective land and the thinner and colder the flash, the greater the back pressure.

It is important to keep the amount of flash formed to a minimum for two reasons: (1) excess flash increases the peak die loads as shown in Fig. 1.2 and therefore reduces die life, and (2) it increases the loss of material, which is economically significant. According to one estimate, on the average 50 percent of the total cost of forgings is made up of material cost.

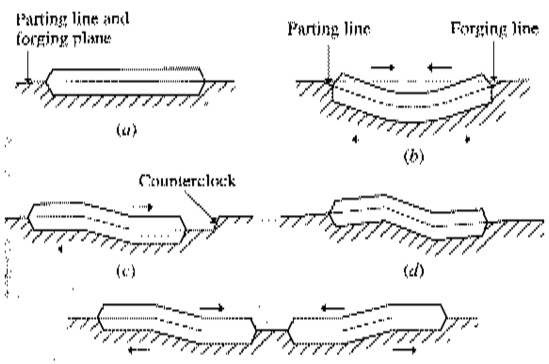


FIGURE 1.3
Drawings illustrating the design rules for use of straight and broken parting lines for closed impression forging dies

The material yield in closed-die forging can vary between 50 to 70 percent of the original workpiece material, with the average yield of 70 percent. A 10 percent decrease in the material, which results in a 5 percent decrease in the cost, may be appreciable. The dies, therefore, should be designed so that the dimensions of the flash and stock are just sufficient to fill the die cavity completely. The stock, however, must be cut to provide an excess of metal (1) because of the variation in the dimensions of the forging blank, and (2) because of the wear that occurs in the die cavity. Material wastage due to the latter effect may be reduced if all of the blanks are not cut at once.

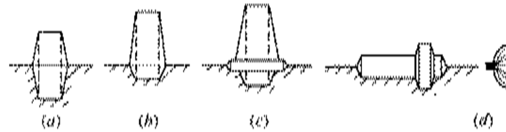


FIGURE 1.4
Drawings illustrating the design rules for positioning the die parting line on axisymmetric forgings so as to divide the forging to two equal halves as shown in (a) and *(d)*

The degree of filling of the die cavity just prior to the initiation of the flash formation is a good indication of the optimum blank geometry. In order to determine the degree of filling of the die cavity quantitatively, a coefficient of filling, $k = V_m / V_d \times 100$ has been used, where V_m is the volume of the metal in the die cavity and V_d is the volume of the die cavity.

Since the volume of the workpiece remains constant, the portion of the metal in the flash can also be considered as a measure of the die-filling. The volume of the flash can be determined readily from the flash thickness and width. All of the metal not in the flash is in the die cavity. The smaller the volume of the flash and the later its formation begins, the better is the die-filling capacity

Design of a closed-die forging process is started with forging design on the base of working detail drawing of the part. For this purpose the tolerances and allowances are selected according to standards and the flooding is applied if it is necessary.

Design of the forging

1. The design of the part itself, which in many cases is a finished machined part such as a connecting rod for an internal combustion engine. This stage in the design process provides the required geometry and the necessary mechanical properties. The design may originally have been made with or without a forging in mind. With perhaps some redesign, the part may finally be made from a ductile (nodular) cast iron or even from a heavy metal stamping, for example, instead of a forging.

2. Once the decision is made to make the part by the hot-forging process, the finished forging and its dies are designed by the addition of the machining allowance and the necessary taper or draft so that the part may be readily removed from the die during the forging operation. At this stage, the forging and its die are designed so as to fill the die cavity completely (by the addition of some extra metal that overflows to form the flash) and to forge the part without any defects such as folds or overlaps. The power and energy requirments for making the finished forging are also determined at this stage.

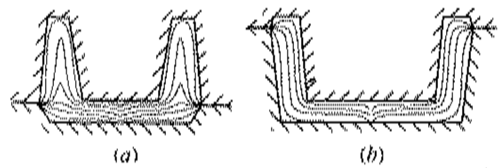


FIGURE 1.5
Drawings illustrating the design rules for positioning the die parting line to facilitate the flow of metal into the die cavity

3. If the forging is complex at all, it may have to be made in stages, so that the necessary preform or blocker dies may have to be designed to distribute the metal adequately. The geometry of the forging slug (stock) or multiple is determined

The forging differs from a machined finished part, first of all, by dimensions, increased by machining allowances, the less accurate dimension tolerances and simplified shape which is more convenient for close-die forging.

The design of forging involves the following:

1. The selection of the die parting plane.
2. The allocation of machining allowance and tolerance to the various surfaces.
3. The adjusting of flooding, if required.
4. The selection of the draft angles.
5. The addition of edge and fillet radii.
6. The selection of proper rib width and web thickness.

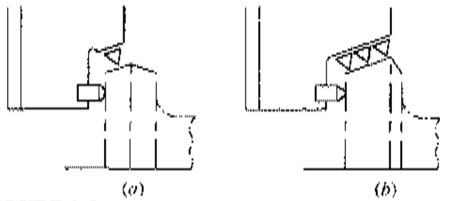


FIGURE 1.6
Drawings illustrating the design rules for the positioning the die parting line to facilitate the clamping of the workpiece for subsequent machining

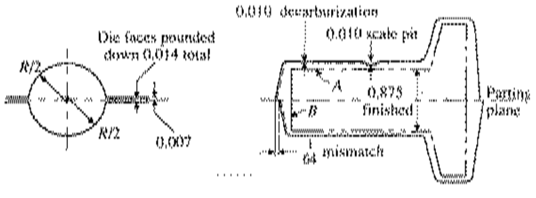


FIGURE 1.7
Drawings illustrating the various allowances included in the machining allowance

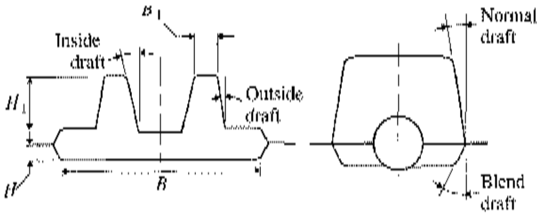


FIGURE 1.8
Nomenclature for the draft angles of closed-die forgings

Parting lines usually are straight, although they may have a contour shape. Some empirical rules for choosing a parting line are:

1. The parting surface should be a plane, if possible.

2. For symmetrical parts, the parting line should divide the forging symmetrically into two equal halves.

3. The parting line should be chosen to facilitate the flow of metal into the die cavity.

4. The parting line should be positioned to facilitate the clamping of the workpiece for subsequent machining such as to provide for a larger clamping surface.

The **machining allowance** will include the finishing allowance, scale pitting, decarburization, shrinkage allowance, and all **tolerance** such as for die wear, mismatch, etc.

From the working detail drawing of the part, the faces which require a machining allowance are identified and the **allowances** are applied on the basis of past experience and/or recognized standards.

Allowance is specified forging size excess in comparison with nominal size of the part, which provides the dimensions and surface finish after machining according to finished part drawing. The **tolerance** is the difference between the upper and the lower forging limiting dimensions. The lower forging limiting dimension is equal to sum of part reference dimension and required (minimal) allowance from both sides of the part. As there is no possibility to forge a forging accurately according to required dimension, the forging maximum limiting dimension is normalised.

The **allowance necessity** is explained by the fact that a forging has a defect surface layer and geometrical inaccuracy. The defect surface layer consists of decarbonisated layer, scale dent, forging surface fracture and folds, and surface defects transfered from the stock on the forging surface. While assigning the allowance one should bear in mind the machining error, whereas the tolerance is depends on the forging methods only.

The difference between the upper and the lower forging dimensions is determined by the **forging dimensional tolerance** ∇. As a rule the nominal forging dimension B with deviation are put down on drawings. The value of $\delta + \nabla п = a$ is reference or tabular allowance and Δ_l is a lower deviation. Δ_B is a upper deviation. The forging machining allowance is assigned on one side from part reference dimension and tolerance is assigned on the dimension, i. e. on both sides of the part.

Draft angles are applied on the vertical faces to facilitate the flow of metal into the die cavities and the removal of the forging from the dies. In order to remove the forging from the die without distortion, the drafts in the die are made larger than in the casting and molding processes. The inside draft is greater than the outside draft since the material shrinks on cooling onto the boss of the die.

Too small **die radii** might inhibit metal flow during forging and might cause stress concentrations in the part.

It is customary to put the deepest cavity in the upper die since a downward blow tends to force the metal upward and since the falling scale can be removed more easily for the shallower lower die.

To ensure that the main die cavity is completely filled, **excess metal is provided** in the forging slug, and the flow of the excess metal out of the die cavity is **restricted by the clearance in the flash impression** on the **flash land.** Any excess metal beyond that required for the flash flows into the **gutter**. The flash and gutter impressions must therefore be added to the die.

In addition, flooding is applied or difficult-to-forge deep **recesses** and **holes** are eliminated and thin and tall **ribs** are thickened. The **flooding** is a local allowance increasing which simplify the forging shape in view of the fact that manufacturing of the part of such shape is impossible or unprofitable. There is an extra metal that have to be removed by machining and wasted.

Once the forging is designed, it must be converted into the shape of the finished die cavity of the finishing die and any required preform shapes designed. The cavity of the finishing die consists of the final forging shape, with a suitable flash land and gutter around the parting line. The purpose of the flash land is to restrict the lateral flow of metal to facilitate die filling without subjecting the die to excessive loading.

Multistage (**multiimpression)** forging

The block form of the mass distribution represents the idealized form of the stock after the fullering operation is completed, without any radii, etc., omitted. The length of bar required is determined by reducing the smaller sectioned blocks of material to the bar size as shown in Fig. 9.38. During the forging operation, the stock form is then altered to the idealized block form shown in Fig. 9.38(c), by one or more fullering operations, to reduce the bar down to the next largest section size, and so forth. It is unusual for more than two fullering stages to be used.

As indicated above, the object of fullering is to reduce the cross-sectional area of the stock in various regions while at the same time increasing the length of the drawn down portion. In hammer forging, this is accomplished by giving repeated blows to the bar between the horizontal faces of the fuller dies, while rotating the bar, usually by 90°, after each blow. For hammer forging, the mass distribution preforming is done largely by open-die forging techniques as described above, whereas for press forging preforming is usually done by the use of reducer rolls as shown in Fig. 9.38(e) and (*f*).

One of the purposes of using a blocking impression in a forging operation is to control the flow of material in the individual cross sections of the final die. Also, optimum die design should ensure die filling with a minimum of stock and of die wear. Large radii are used to promote good metal flow.

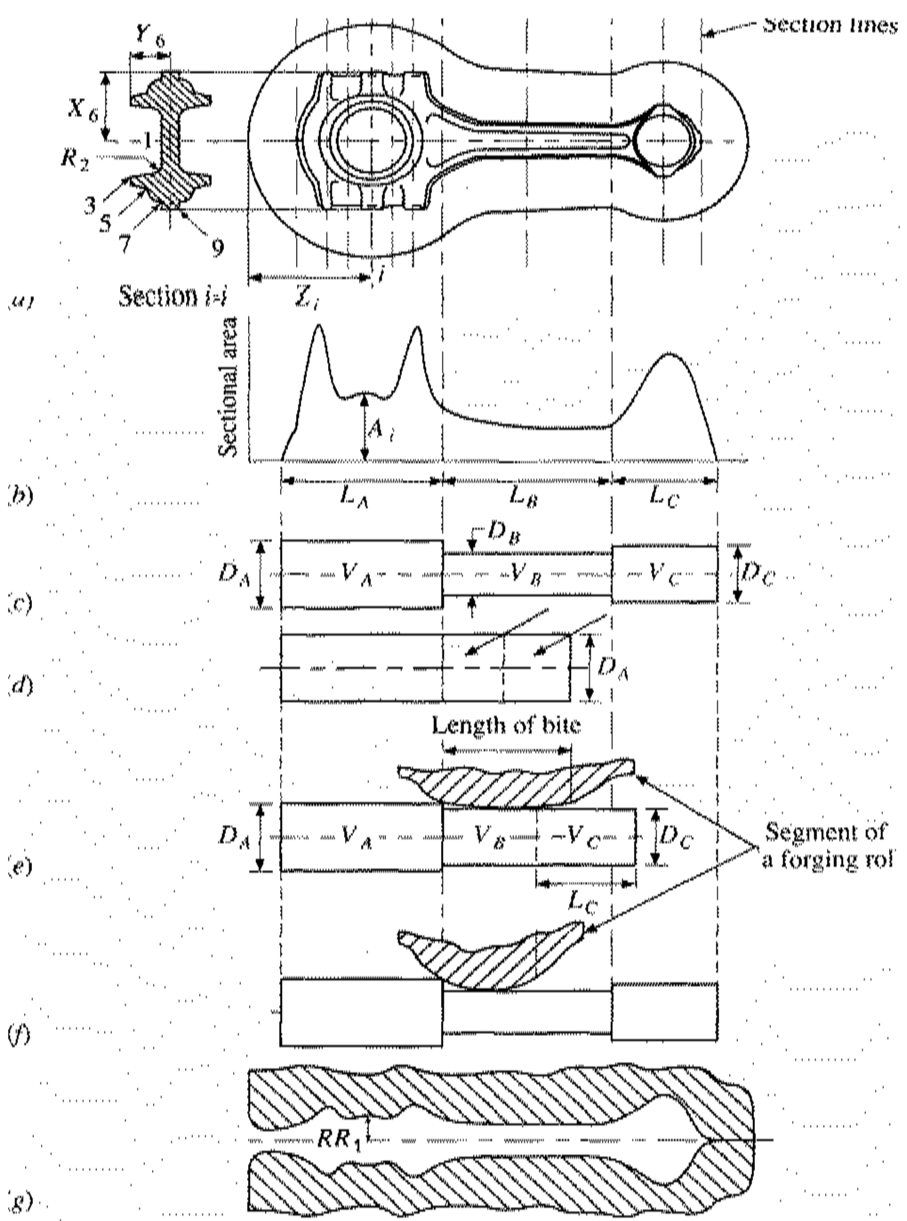


FIGURE 9.38 General design procedure for mass distribution in the preforms: (a) final forging including the flash; *(b)* mass distribution diagram for the final forging; (c) block form of the mass distribution of the preform (idealized fullered stock); *(d)* equivalent bar stock or forging multiple; (e) first fuller stage formed by roll forging; *(f)* second fuller stage formed by roll forging; and *(g)* longitudinal roller die profile for forming the final preform for the blocker die impression

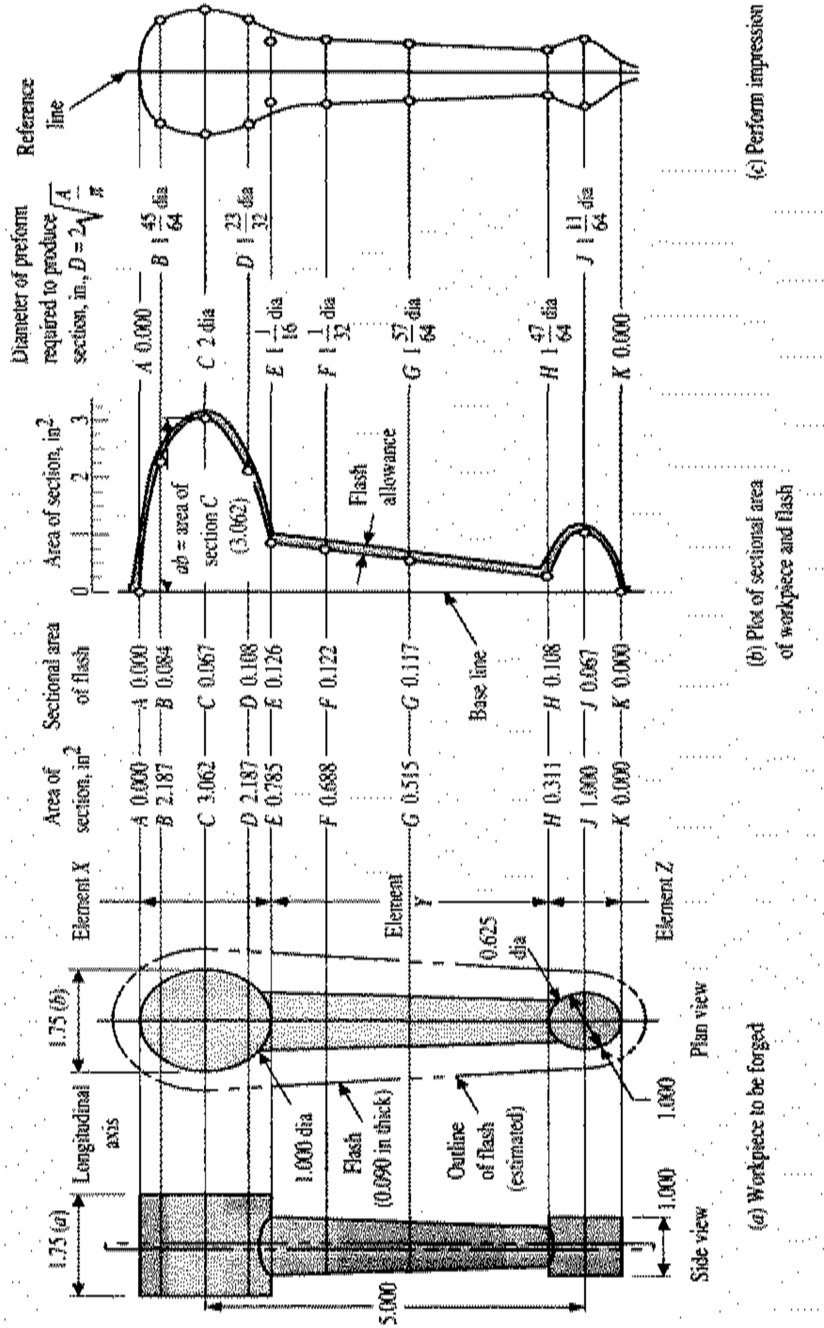


FIGURE 9.39 Example of a layout procedure of a forging to determine the shape of the preform impression and the equivalent stock or blank diameters. (*After L. G. Drabing.*) [9.25]

Typical Forging Sequence

The forging of automotive connecting rods is a good example of the various steps taken to produce a closed-die forging. As shown in Fig. 12, the sequence begins with round bar stock. The bar stock is heated to the proper temperature, then delivered to the hammer. Preliminary hot working proportions the metal for forming of the connecting rod and improves grain structure.

Preparation of Forging Stock

Cold and hot shearing are the most commonly used methods of preparing blanks for hot upset forging. Sawing, cutting with abrasive wheels, and flame cutting are also used, but less frequently. The use of machined or previously forged blanks for hot upsetting is usually confined to applications involving special requirements.

Cold shearing blanks from mill-length hot-rolled bar stock is the most common method of preparing stock for hot upsetting. Cold shearing is the most rapid method of producing blanks, and it involves no waste of metal. One shear canaccommodate a wide range of sizes, and equipment is adaptable to mass production when used in conjunction with tables and transfer mechanisms. Magnetic feed tools and proper bar hold-down devices are usually required for efficient operation.

With the types of shearing equipment available, it is not uncommon to cold shear medium-carbon alloy steels in diameters to 125 mm (5 in). If section thickness and hardness of material permit, it is usually economical to shear as many bars in one cut as possible, using multiple-groove shear blades. It is common practice to use multiple shearing on low-carbon steel up to 50 mm (2 in.) in diameter.

For medium-diameter bar stock, it is common practice to forge from the bar progressively, cutting off each forging on the last upsetter pass. This method produces a short length of bar scrap, which can be held to a minimum by careful selection of bar length in relation to blank length. This method is widely used for producing small, simple forgings that can be upset in one blow. A secondary cold trimming operation may be necessary to remove flash.

For small-diameter blanks, it is often advantageous to use coiled cold-drawn wire. This wire is straightened and cut off, and the blanks are stacked by means of high-speed machines. The use of blanks made from wire is especially beneficial when shank diameter on the upset forging must be held to closer tolerances than can be obtained with hot-rolled bars..

Hot shearing is recommended for cutting bars more than 125 mm (5 in.) in diameter, and it can be used for smallerdiameter bars in semiautomatic operations. For diameters up to about 28.6 mm and when the upset can be made in one blow, the preliminary preparation of individual blanks can be avoided. Mill-length bars are heated and fed into a semiautomatic header. The blank is cut off at the same time the upset is made. A stock gage between the gripper dies and the header die locates the stock before it is held by the gripper dies. The gage, mounted on a slide that is actuated by the header slide, retracts as the header tool advances. A typical tooling arrangement is shown in Fig. 4.

Cold sawing is used in conjunction with or as an alternative to shearing. The saw is power fed and may have an automatic clamping device to hold the stock. It has a pump and supply tank to feed coolant to the cutting edge of the blade. Stock gages are used to set cutting lengths.

Sawing is useful for those sizes or materials that cannot be readily sheared. It produces a uniform edge and can be used for sampling and where distortion is a problem. Sawing is a comparatively slow operation and wastes a significant amount of metal. Maintenance costs are also higher in sawing than in shearing. In sawing, however, set-ups can be made quickly; therefore, sawing is often preferred for preparing small quantities of blanks.

Abrasive cutoff wheels are sometimes used for preparing blanks from high-alloy or extremely hard metals. This method must be used with extreme care if the material being cut is susceptible to grinding cracks. Except for this warning, the advantages and disadvantages of abrasive cutting are essentially the same as those of cold sawing.

Gas cutting is generally used only for the preparation of large-diameter blanks. In this operation, the cost of the fuel gases and the resulting melted metal on the ends of the cut stock must be considered.

Special Methods. Some forgings require an unusual distribution of metal, which necessitates some preliminary gathering of material before the final upset forging operation. This can be accomplished in several ways, such as using rolled sections, machining the blank, or preshaping the blank on a hammer or press.

Descaling

Preventing the formation of scale during heating or removing the scale between heating and upsetting will result in longer die life, smoother surfaces on the forging, and improved dimensional control. The presence of scale on forgings also makes hot inspection unreliable and increases cleaning cost. When controlled heating methods for minimizing scale formation are not available, scale can be removed from the heated metal before forging, either by mechanical methods or by the use of high-pressure jets of water.

Mechanical Methods. One effective method of descaling is to brush the heated bar with rotating wire brushes. In another method, knifelike tools are shaped to the periphery of the heated bar, and the bar is scraped across the knife-edge to dislodge and remove scale. For example, for descaling a round bar, a curved knife section having the shape of a half circle is used. The heated round bar is placed in the half-circle knife section and drawn through the knife to remove the scale from half of the surface of the bar. The bar is then rotated 180°, and the operation is repeated to remove scale from the remaining surface of the bar length. Although economical, this method is less effective than wire brushing.

High-Pressure Water Jets. The use of high-pressure water jets is the most effective method of descaling. Four or more high-pressure nozzles are used; they are positioned equidistantly from one another to impinge simultaneously on all sides of the workpiece. These nozzles are usually placed inside a cabinet that is shielded at the opening into which the hot bar is inserted. Water is supplied to the nozzles at 8 to 12 MPa (1200 to 1800 psi). Nozzle openings vary with stock diameter, but an opening of 0.75 × 1.3 mm (0.030 × 0.05 in.) is common for stock diameters from 38 to 75 mm (1 to 3 in.). A 35° angle of the water stream relative to the workpiece provides optimal efficiency. The water spurts are only a fraction of a second in duration in order to prevent excessive lowering of the workpiece temperature.