

# **Forging Equipment and General analysis of forging**

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# 1. Forging Equipment and General analysis of forging

## 1.1 Forging equipment

Forging presses apply the required force gradually. Presses are of hydraulic type, mechanical or screw type. Eccentrics, knuckles or cranks are used in these presses for converting rotary motion into linear motion of the ram. The stroke of ram decides the energy available at the end of stroke. Hydraulic presses use hydraulic power. They are power driven machines. They are usually slow in operation. Screw presses operate based on friction wheel and screw. Both presses operate at slower ram speeds and can provide constant ram force. Presses give a squeezing type of action on the workpiece. They are suitable for forging and long stroke operations. Hydraulic presses are suitable for extrusion type operations as full load is available at all times. In power hammers, the total energy available for forging is equal to the kinetic energy of the ram plus the hydraulic pressure energy. In case of flywheel operated presses, the energy available is dependent on the moment of inertia of flywheel as well as its rotational speed.

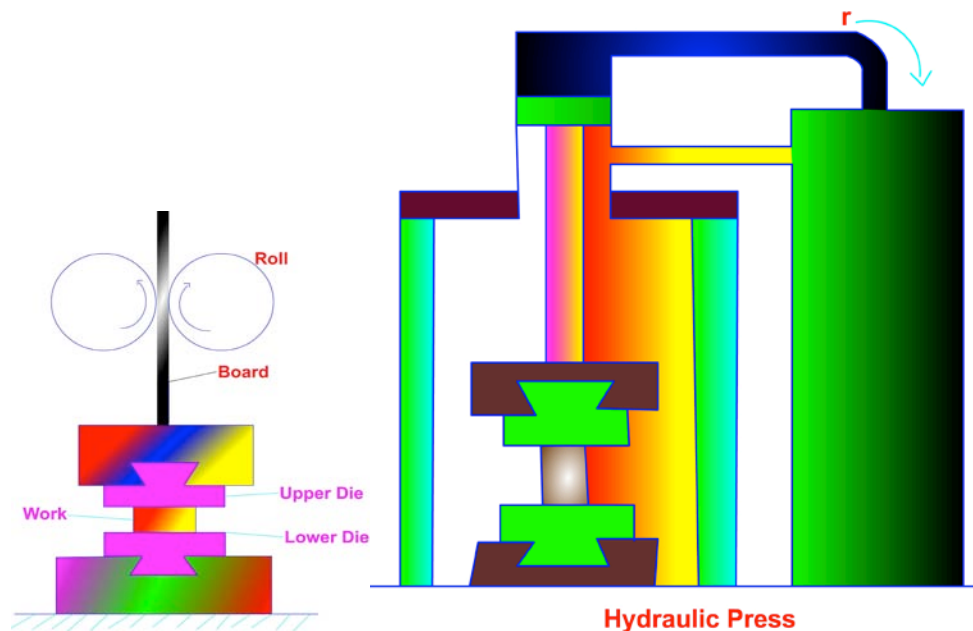


Fig. 1.1.1: A board hammer and hydraulic press

Forging hammers provide impact loads. Gravity hammers provide the forging load by the falling weight of the ram. One half of the die is fixed on the ram and the other half is fixed on machine table. They are suitable for impression die forging, where a single blow or a few blows will deform the metal inside the cavity. Board hammers operate by frictional rising of the board with ram. Power hammers use pneumatic or steam power additionally to accelerate the ram. Total energy available at ram end is the sum of kinetic energy of the ram and the power of the air or steam used.

## **1.2 Analysis of forging:**

A number of methods are available for the analysis of metal forming processes. Slab method is based on mechanics approach, in which we consider the static equilibrium of forces on the billet. In another method, the velocity field of the deforming material is found first. From kinematically admissible velocity field, the work done during the process is formulated. The formulated work equation is then solved. This approach is known as upper bound analysis.

In this section we analyse the open die forging processes – upsetting of plane strip and circular disc in order to determine the forging force, using slab method. First we ignore friction and write down the theoretical equation for the forging load. Then we consider the effect of friction.

### **1.2.1 Homogeneous upsetting:**

Considering a cylindrical billet of initial height  $h_o$ , the strain rate in upset forging can be expressed as:  $\dot{\epsilon} = -v/h$  where  $h$  is the instantaneous height and  $v$  is the velocity of the ram. As the height of the billet gets reduced the strain rate increases to very high values.

The true height strain of the billet can be found from the formula:

$$\epsilon = \ln \frac{h_o}{h_f} \quad \text{-----} \quad 1$$

where  $h_o$  is initial height and  $h_f$  is final deformed height of billet.

Neglecting friction at interface between the billet and die, the ideal forging force at the die-work interface is given by:

$$F = Y A, \quad \text{-----} \quad 2$$

$A$  is area of billet at any instant.  $Y$  is yield stress of the material of billet.

Applying volume constancy principle we have:

$$A h = A_o h_o$$

Therefore,  $F = Y A_0 h_0 / h$  ----- 3

Here,  $Y$  can be taken to be the flow stress of the material at a given strain.

Work done during the deformation is given as:

$$W = A_0 h_0 \int_0^\epsilon \sigma d\epsilon \text{----- 4}$$

The average flow stress  $\bar{Y}$  is given by:  $\bar{Y} = \frac{k\epsilon^n}{n+1}$  ----- 5

Therefore, work done is given by  $W = \bar{Y} \epsilon \text{Volume} = \bar{Y} \epsilon A_0 h_0$ -----6

And the forging load is  $F = \bar{Y} A$  -----7

The area of the forged disc keeps increasing as forging proceeds. As a result the force required increases.

Flow stress also increases due to work hardening. This also leads to the application of greater forging load with continued deformation.

Friction at work-tool interface makes the flow of metal nonhomogeneous. Metal in contact with the die surface is subjected to maximum restraint due to friction shear stress. Flow here is the least. Whereas, at the central section the restraint being the lowest, material flow is the maximum here. This kind of non-uniform flow results in bulging of the lateral surface of the disc. This is called barreling. In case of rectangular billets, there will be double barreling.

In case of hot forging, the material in contact with the dies gets cooler and hence offers more resistance to deformation. The central section is offering least resistance to flow. Further, the coefficient of friction in hot forming is high. All these result in barreling.

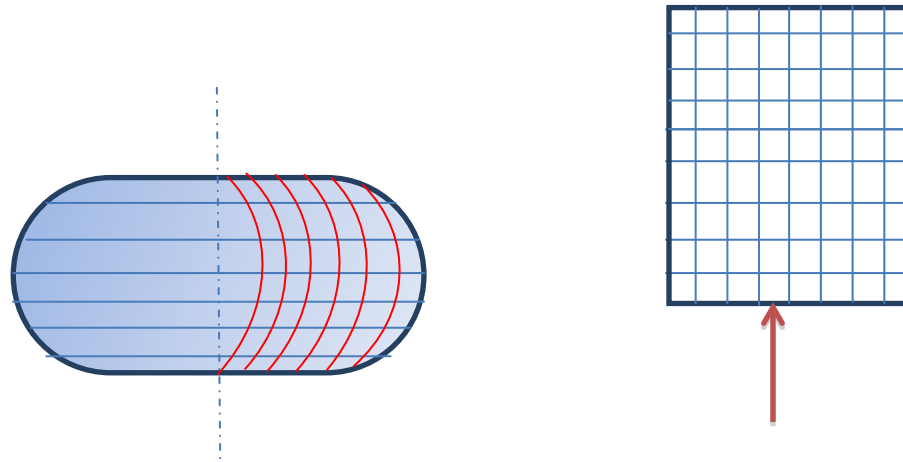
Due to barreling, the forging load required is higher than that predicted by the theoretical equation above.

We can write the forging force for non-homogeneous upsetting as:

$$F = \bar{Y} A k_f \text{-----8}$$

where  $k_f$  is a forging shape factor, given by:

$$k_f = 1 + \frac{0.4 \mu D}{h}$$



**Fig. 1.2.1.1: Barreling during upset forging due to friction**

**Example:** Cold upset forging of a cylindrical billet of initial height 60 mm and initial diameter 30 mm, results in a final reduced height of 40 mm. The material of the billet has flow stress given by the expression:  $Y = 300\varepsilon^{0.2}$  MPa. The coefficient of friction between the billet and die surfaces can be assumed to be 0.1. What is the forging force required at the reduced height?

Solution:

We may use the approximate expression, equation 8, for solving this problem.

$$F = \bar{Y} A k_f$$

**F** is forging force,  **$\bar{Y}$**  is average flow stress, **A** is area of billet.

**K<sub>f</sub>** is a factor which accounts for friction and is given by:

$$k_f = 1 + \frac{0.4\mu D}{h}$$

Applying the principle of volume constancy,

$$A_o h_o = A_f h_f \rightarrow A_f = A_o h_o / h_f \rightarrow d_f = 51.97 \text{ mm}$$

$$\text{True strain} = \ln(h_o / h_f) = 0.405$$

$$\text{Average flow stress} = \frac{k\varepsilon^n}{n+1} = 208.65 \text{ MPa}$$

$$K_f = 1.052$$

$F = 275.68 \text{ kN}$  Answer