Forging die design and Forging defects

1.1 Forging die-design aspects:

Die design is more empirical and requires experience. Design of die depends on the processing steps, nature of work piece material, its flow stress, temperature of working, frictional condition at interface etc.

Volume of billet is to be accurately calculated so that there is neither under filling nor excess filling.

Proper selection of parting line – the line where the two dies meet is very important. Parting line is so chosen that the flow of material is uniform ly divided between the two dies – as far as possible.

Maximum of 3% of the forging thickness is allowed for flash thickness. Flash gutter is to be provided in order to reduce forging loads.

Draft angles between 3^o and 10^o are normally provided for easy ejection of forging.

Corner radii are to be larger as far as possible to facilitate smooth flow of material.

Forging temperature decides the type of die material for forging.

Commonly, for ferrous alloys, a forging temperature of 900 to 1200^o C is used. For aluminium alloys, it is from 400 to 450^o C. For copper alloys, it is 625 to 950^o C.

Die materials commonly used are tool steels, high carbon high chromium die steels, high carbon, high chromium, molybdenum die steels etc.

Lubrication also plays a role in the accuracy and surface finish of forging. Commonly, for hot forging, glass, graphite, molybdenum disulfide are used as lubricants. For cold forging, mineral oils are used.

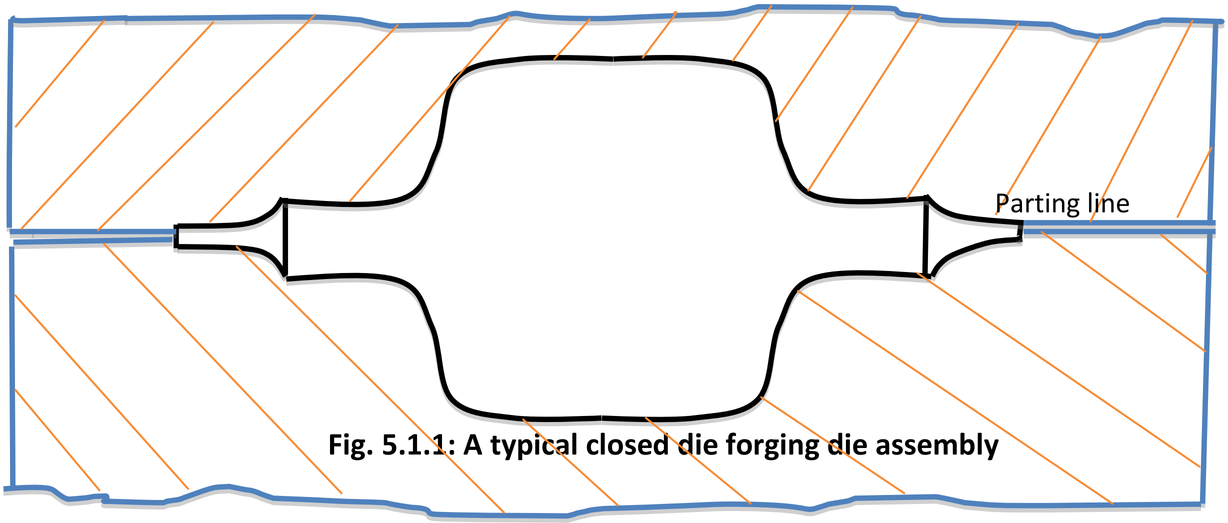


Fig. 5.1.1: A typical closed die forging die assembly

1.2 Forging defects:

One of the major defects in upset forging or open die forging is the surface cracks originating on the bulged or barreled surface due to excessive tensile hoop stress. Surface cracks may be longitudinal or inclined at 45^{o} angle. If the circumferential stress is tensile, longitudinal cracks occur. If hoop stress is compressive, 45^{o} cracks are originated.

Another problem come across in open die forging may be buckling if the height of the billet is high – if the h/D ratio exceeds 2.

In closed die forging if volume of material taken is excess or if the thickness of flash is too large, then the excess metal from flash recess may flow into the already forged part and lead to internal cracks.

In impression die forging, the radii of internal sections are to be designed properly. If corner radii are too small the material may fold against itself and produce cold shut. However, internal cracks are avoided due to compressive stress induced by die wall.

Another defect is due to grain flow lines in closed die forging. If grain flow lines reach the surface [end grains], grain boundaries are exposed to surface. Such exposed grain boundaries are easily attacked by corrosive media.

Cracks on the surface may also be caused due to die wall chilling, thereby increasing the resistance to flow on the surface. Surface cracks are also caused due to excess working as the surface gets cooled faster due to heat loss.

Forged parts have characteristic fibrous structure due to grain flow. This may result in anisotropic properties of forged parts. In order to avoid this problem, the maximum deformation is restricted to 60 to 70% area reduction.

Presence of residual stress in large forgings may lead to formation of internal cracks when such forgings are subjected to fast cooling after heat treatment. To avoid internal cracks, the cooling rate is reduced by keeping the hot forgings buried in sand.

Summary of forging defects:

<u>Coldforging:</u>

Dead metal zone/shear band

Centre burst

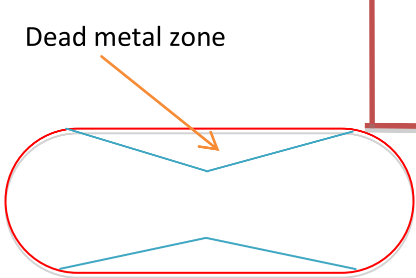
Surface crack

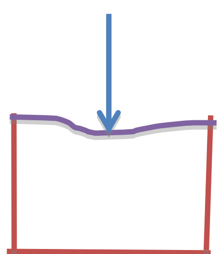
<u>Hot forging:</u>

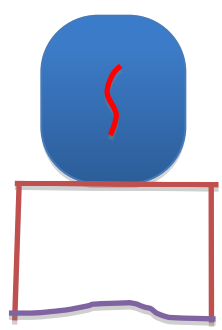
Shear bands

Hot shortness

Grain boundary cavitation







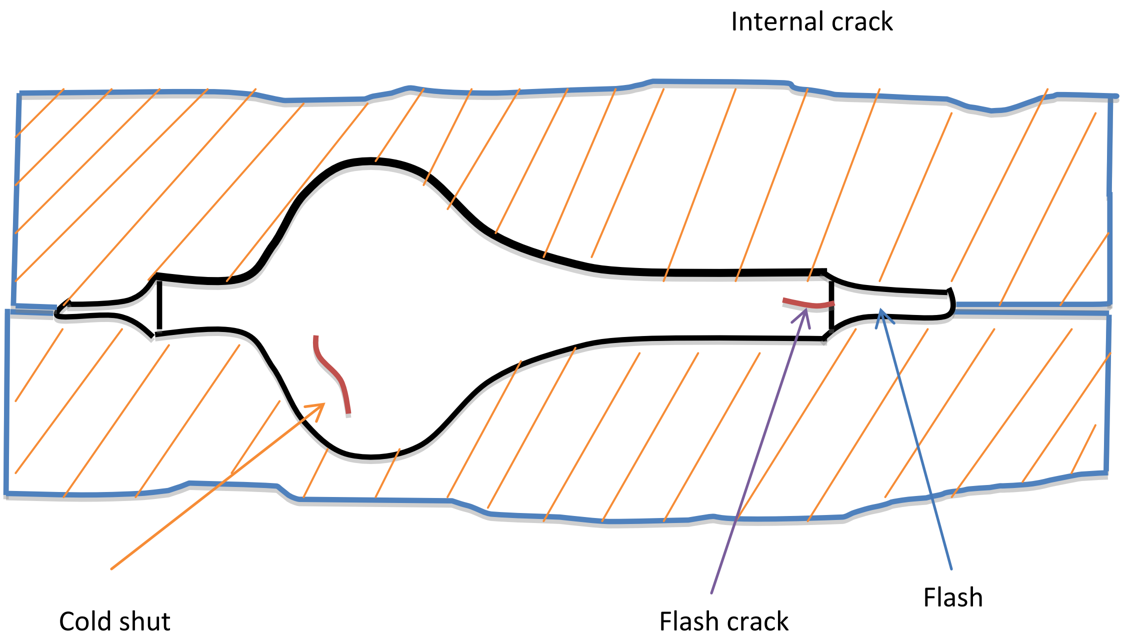


Fig. 1.2.1: Some forging defects

1.3 Introduction to powder forging

Powder metal technology is one of the most economic productions methods extensively used in modern industries. Near-net-shape manufacturing of small parts is one of its advantages. Due to inherent porosity in sintered metal, the compacted and sintered alloys have limited applications. To eliminate porosity, post-sintering processing such as forging, rolling etcare employed. Powder forging serves as a very essential, industrially important process, due to its advantages such as high strength, high fatigue limit. In powder forging, preforms are obtained through the blending, compaction and sintering route. The sintered compacts with porosity in the range of 12 to 8% are then subjected to closed die forging or upset forging or extrusion forging in order to obtain the finished product with very little subsequent machining.

Behaviour of porous sintered preforms is different from wrought metals. Porous preforms are compressible, therefore there is considerable volume reduction during forging. Yield criteria for porous preforms, therefore, include density as one of the parameters. Poisson's ratio for porous materials also is a function of density.

It is of the form: $\upsilon = 0.5(\frac{\rho}{\rho_t})^2$

The yield criterion for porous solids is given in the form as followed:

$$Y^2(\rho, \varepsilon) = [\frac{[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]}{2} + (1 - 2\upsilon)[\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1]]$$

As seen from the equation above, the yielding of a porous material depends on density also.

Powder compaction using die set is shown in diagram below:

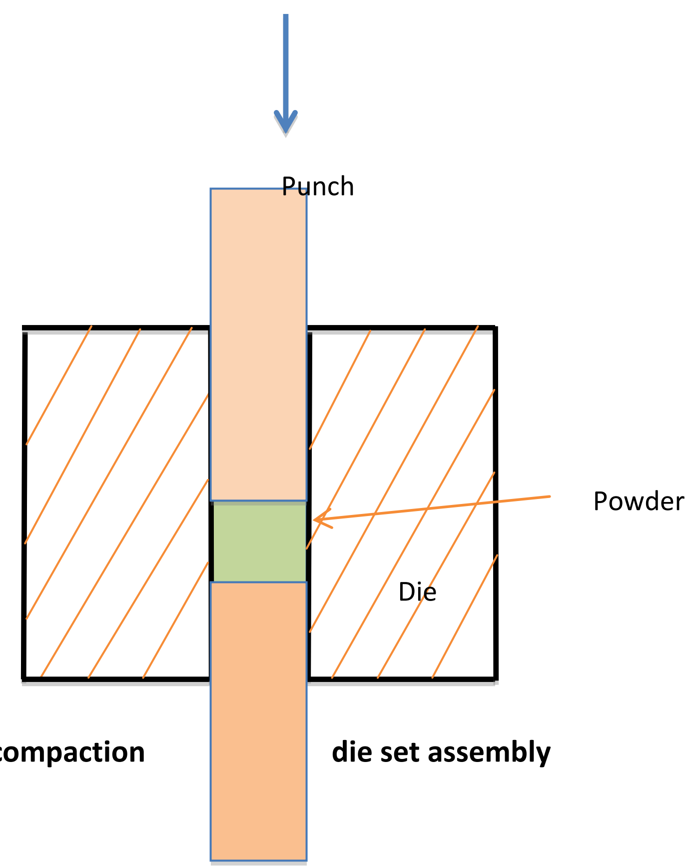


Fig. 1.3.1: Powder compaction die set assembly

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