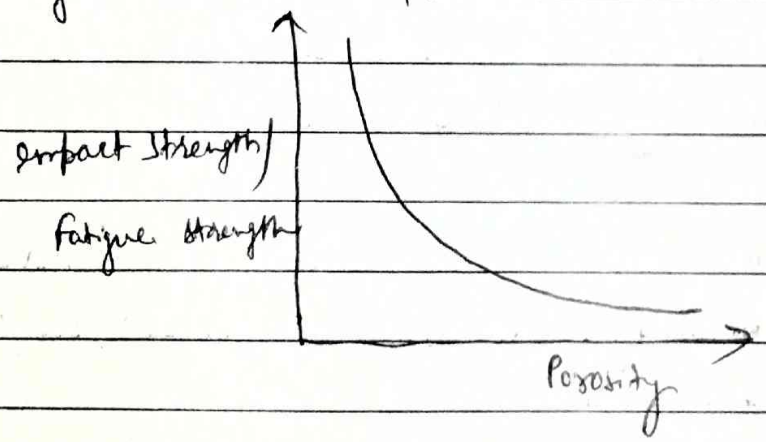
@. ASM handbook vol 14 Forging & Forming.
ⓑ. Cold & hot forging Application → T. Altan. Date 3/8/18 Page
ⓒ Forging Die - design - SN prasad.

Forging Die Design :-

* Impact strength — measure of toughness.
  Fatigue strength — cyclic loading ; tensile - compressive load
  → measured by Izod & charpy test.

* casting process does not improve Impact strength and fatigue strength due to the presence of porosity and blow holes, whereas in forging, porosity is eliminated.



* Any rotating component cannot be made by casting process.

* $\rho_{Fe} = 7.8$ cc
  $\rho_{Al} = 2.7$
  $\rho_{mg} = 1.3$] Heat treatment process used is Precipitation hardening.

Journal of Material processing technique

Metal Forming

Bulk deformation	Sheet metal deformation
1) ex → wire drawing, extrusion, rolling	1) ex → Stretching, bending, punching, deep drawing.
2) can be performed at Room temperature as well as high temperature (below M.P.)	2) Mainly performed as room temperature.
3) $\frac{S.A}{Volume}$ is more	3) $\frac{S.A}{Volume}$ is less.
4). Elastic deformation is negligible in comparison to plastic deformation	4) Elastic deformation cannot be neglected.

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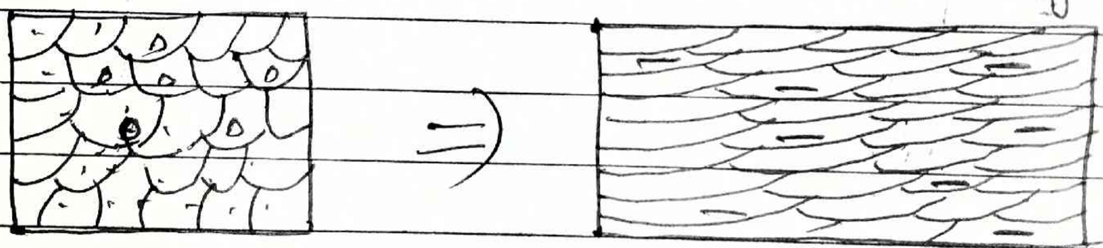
* Configuration of billet is almost continuous in rolling. Configuration of billet changes during forging.

* Stimulation process is more complicated in forging as compared to rolling.

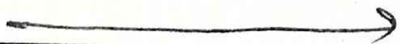
* A cast product is composed of grain, segregation and 2nd phase (carbides, sulphides, oxides). Grains are oriented randomly.

Rolling at Room temperature or Cold working



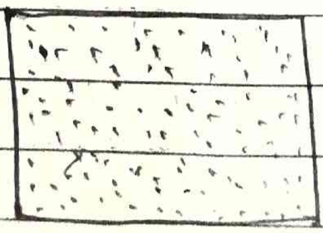
Isotropic (same properties in all direction)

Grain, segregation & 2nd phase elongate in the direction of working.



Direction of rolling | Direction of working

Hot Rolling or hot working :-



After re-crystallisation

The segragation and 2nd phase are not recrystallised in hot working because these re-crystallisation temperature is very high.

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Above recrystallisation (0.6 X melting temp) temp, (strain free and finer grains are obtained above that temperature) no elongation will take place.

* All the rolled product or forged product comes under anisotropic

* Single phase has more deformability so we go for higher temperature in forging

* Maximum directional properties are obtained in Cold working process as compared to hot working.

* Cast iron has very high compressive strength.

* Catastrophic failure → Sudden failure

* Simple supported w/p → Izod test
  Cantilever support w/p → Charpy test

* Flow stress = true stress = $\dfrac{\text{Load}}{\text{instantaneous cross-sectional area}}$

(c) Temperature gradient is very very less in forging.

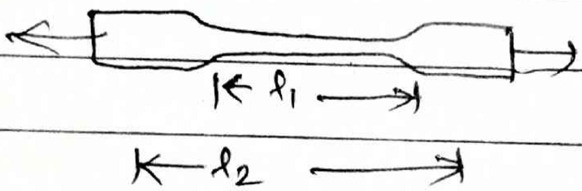
(b) Brittle material can be deformed plastically by hydro-static extrusion. (% elongation < 5%)

* Engg. stress-strain curve has been plotted according to original cross-sectional area.

$$UTS = \frac{\text{load}}{\text{original cross-sectional area}}$$

$$\text{Yield stress} = \frac{\text{Yield load}}{\text{original cross-sectional area}}$$

* Ductility = % elongation = $\frac{l_2 - l_1}{l_1} \times 100$ [Can also be measured by % reduction in area]



* 1) Longitudinal sample (Tensile Test piece T.T.P.)
[Ductility, Impact strength and fatigue strength are very large]

2) Transverse sample.

3). Short transverse sample.

→ Find the Yield stress, U.T.S, Impact strength, fatigue strength...

* Ductility, impact strength and fatigue strength are crack sensitive property).

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sample not broken → Y.S
sample is broken → % elongation, I.S, F.S

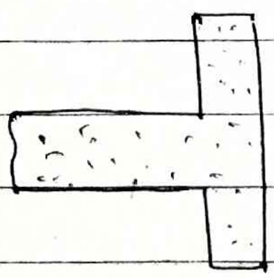
	Y.S	% elongation	I.S	F.S
Longitudinal.	200	40		
Transverse	199	15		
Short transverse.	198	10		
	value is almost ~~change~~ same.	$\underbrace{\quad}$ considerable change (4-5 times difference is observed).		

In longitudinal sample, the direction of crack propagation is $\perp^r$ to grain flow.
whereas in the next two cases, the direction of crack propagation is $||^{al}$ to grain flow.

Crack sensitive properties faces high resistance in longitudinal direction so, the % elongation, I.S & F.S have high value in case of longitudinal sample.

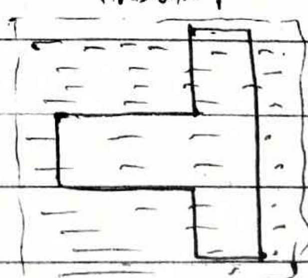
#

Isotropic



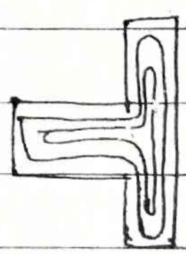
Cast product
(grains are randomly oriented)
(grains are coarser and have lower strength).
stress raiser points will be available

Anisotropic



Rolled & machined
(grains are aligned)
(grains are exposed on the surface)
(not following the contour).

Anisotropic.



Forging
(Grain is following the contour of the component)
(not exposed)

* In Cold Forging, the tensile strength will increase due to the property of work/strain hardening.

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* Mechanical property $= f(\mu\text{structure})$.

* Characteristic of Forging :-

(i) High strength to weight ratio.
(ii) Directional properties.
(iii) Structural integrity.
(iv) Consistency, uniformity.
(v) Yield. (out/in) is more.

* Limitations of forging :-

(i) Overall cost is more,
(ii) Brittle material cannot be forged.

* Forging temp of mild steel is very high. So flow stress will be more and hence less load will be required, whereas, for
Al (7075) the forging temp is low, so flow stress increases and hence more load will be required.

* Simple Shape $\rightarrow l \simeq h \simeq w$.

* ~~Compact~~ ~~Complex~~ oblong shape $\rightarrow l \neq h \neq w$

* Compact shape $\rightarrow l \simeq w >> h$

Two dimension are approximately equal — Third dimension is less.

$\sigma = K\epsilon^n$ For room temp | $\sigma = C\dot{\epsilon}^m$ For high temp — m = strain rate sensitivity

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Power law or Holoman eqn.

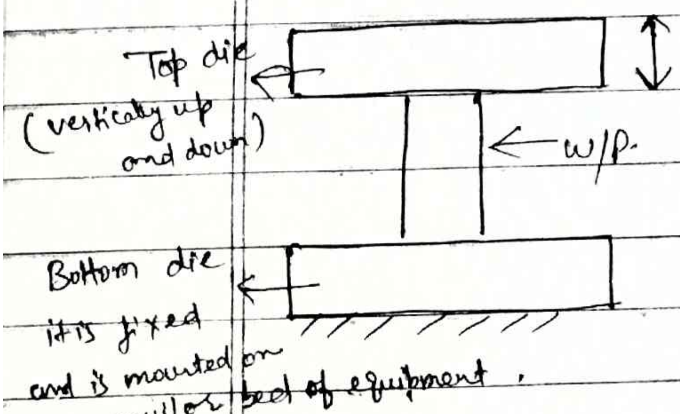
* Classification of forging process:-

① Open die forging (Flat die forging)

→ die Does not have impression.

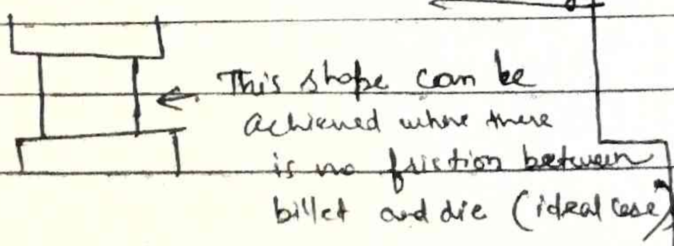
→ Free to move in all directions

→ Also known as free forging.



→ Top die is mounted on the ram of ~~bar~~ hammer or press.

→ when length decreases and cross-sectional area increases then it is known as Upsetting. and its vice-versa is called drawing.

→ 

② closed die forging (Impression die forging).

→ Impression is there on die surface

→ Restriction in metal flow.

→ used for mass production

a) closed die forging with flash → (conventional forging) (impression die forging)

b) closed die forging without flash → (closed die forging). (True closed die forging) (Flashless forging). (Precision forging).

a) closed die forging with flash

→ used for mass production.

- Single impression die
- Multi impression die

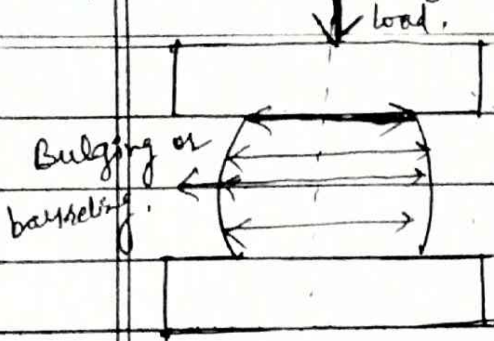
→ Volume of raw material (forging) = Volume of material without flash + loss due to flash + scale loss. (depends upon temperature

Flow stress is strain rate sensitive at high temp.

Flow stress or True stress is calculated on instantaneous c/s area

Yield stress is called at room temp,

→ **Reason of bulging in open die**



a) Friction is present at iterface, which opposes the flow of metal and so a bulging is developed.

b) Temperature loss of billet i.e flowability of material. (forgability).

→ Bulging can be harmful because it imposes tensile load and the material cannot be deformed further so lubricants are applied at the interface to reduce bulging.

when friction is not present.

$$\text{Flow stress} = \frac{\text{Load}}{\text{Final area}}$$

$$\Rightarrow \boxed{\text{Load} = \sigma \times A_f}$$

$$\sigma = f(\epsilon, \dot{\epsilon}, \overset{\text{temp}}{\theta}, M_{\text{structure}})$$

→ ~~hammer → impact load~~
~~Press → Gradual load~~
(strain rate is low)

→ Hot die forging / Isothermal forging process are used for materials like nickel alloys because there forging temp. range is very narrow and cannot be forged by conventional forging.

→ 70% defect in forging is underfilling

→ Scale loss is minimum in induction billet heating furnace.

→ RCS (Round corner square) and cylindrical billets are mostly used.

→ Function of Preforming die :-

a) Gathering raw material as required.

b) Saving the raw material.

→ Different Preforming dies are :-

a). Fuller die → Reduce c/s area at required location

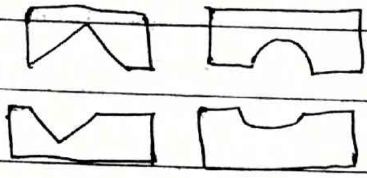
b). Edger die

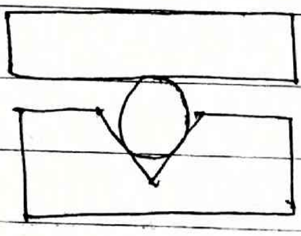
c) Blocker die → Provide approx shape.

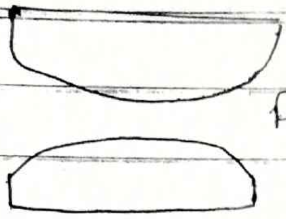
d) Finisher die → Give exact shape

e). Bender die.

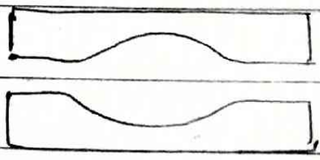
Simple shapes such as swage die (Semi circular) V-shape comes under open die forging







fuller die



Edger die.

→ Function of Blocker is to fill the finisher die.

→ Finisher die has one more impression known as flash land and after this one more deeper impression is present known as gutter.

→ For circular forging → upsetting → Blocker → Finisher.

→ Edger and fuller die are only used when there is variation in cross-section, eg → crankshaft, camshaft,

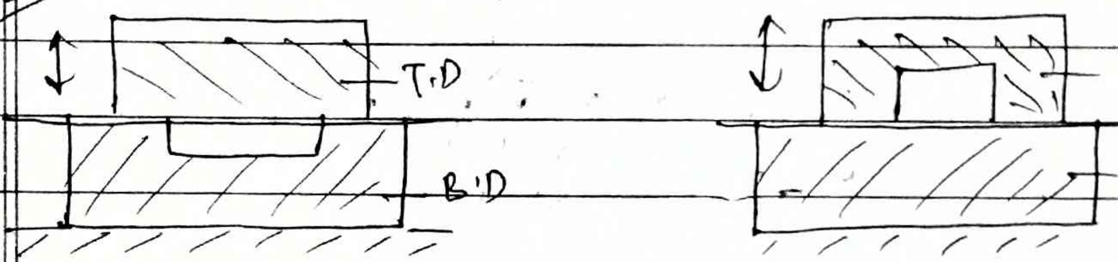
→ Edger and fuller operation can be combined in reduce rolling and the machine used is reduce rollers.

★ STEPS IN FORGING DIE DESIGN :-

Step-1 → Conversion of Machine drawing into forging drawing. (Forging Design).

a) Selection of suitable parting line / parting plane.

Closed die forging



Mechanical press (Best for mass production)
(load restricted) or (stroke restricted)
Hydraulic press.

Hammer
(energy restricted)

More tolerance is required in hammer as compared to press.

b). To provide tolerances, Allowances (Finish, draft, Machining).

c). Provide suitable fillet and corner radius. (They help in smooth metal flow in die cavity).

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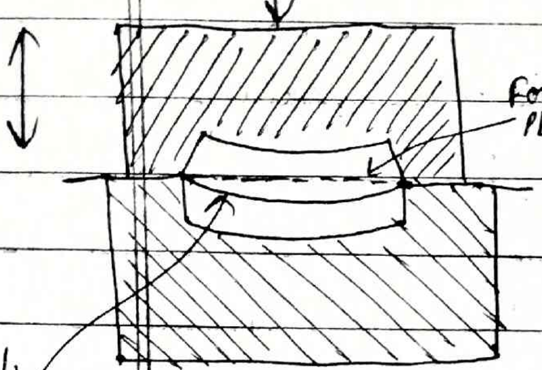
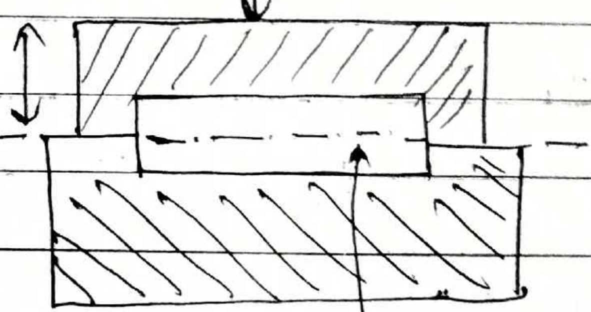
~~Selection~~ Types of Parting line :-



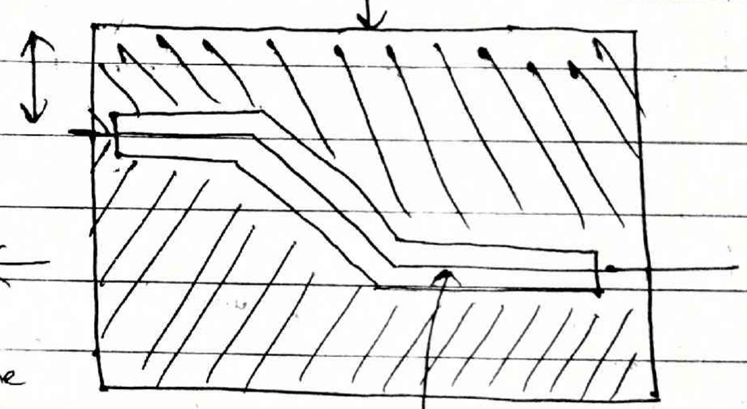
P/L

Curved Parting line



Straight Parting line

(Forging plane = parting line).



Guiding of ram is provided by V-runner. (mounted on the column ~~in~~ which ram moves).

P/L.

Inclined Parting line

(irregular parting line).

=) Parting line is also known as flash line and is a line where two die halves meet along forging.

=) Forging plane → Normal to the direction of ram movement

Problem occuring in case of not selecting a proper P/L

(i) Amount of draft will increase

(ii) Die filling is incomplete

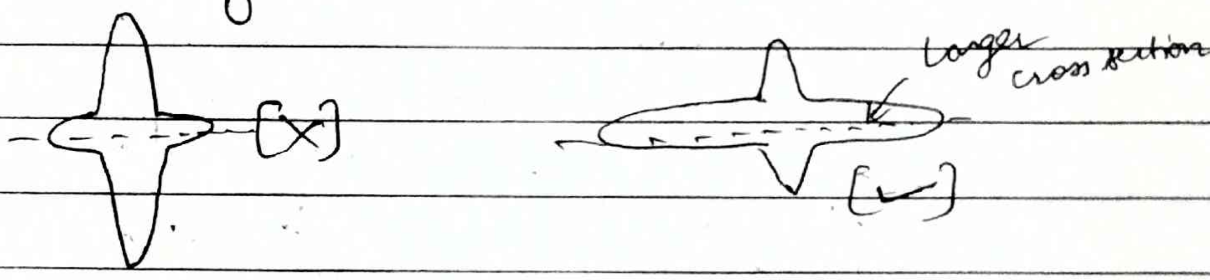
(iii) Mismatch, runout will increase

(iv) Grain flow is not favourable.

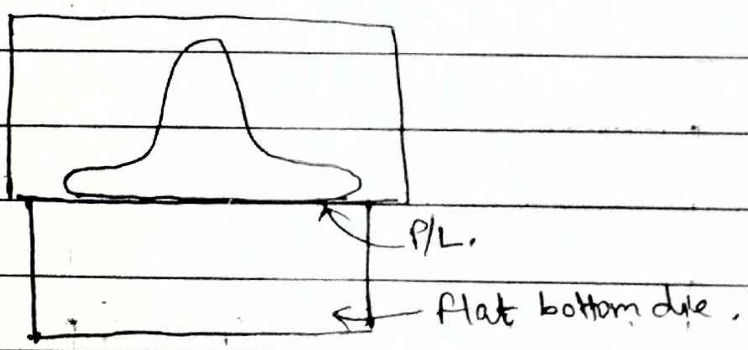
(v) Trimming will be difficult.

Basic criteria for selection of correct parting line

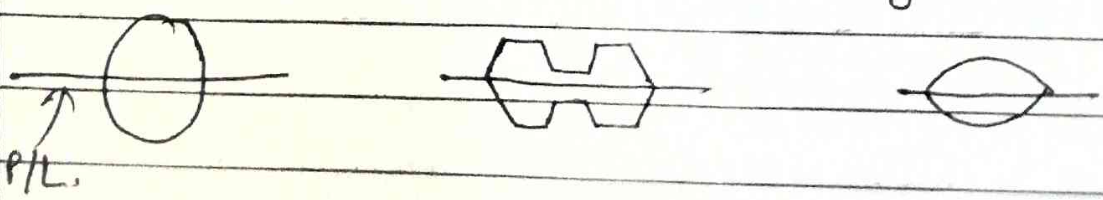
(a) (i) Deep impression should be avoided when selecting proper parting line. (because of die breakage).



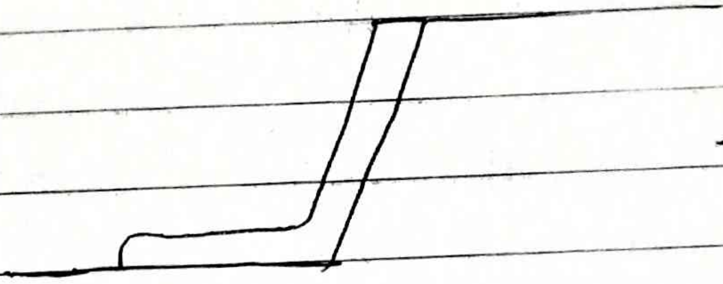
(ii) Try to make edge or flat surface as parting line to avoid mismatch.



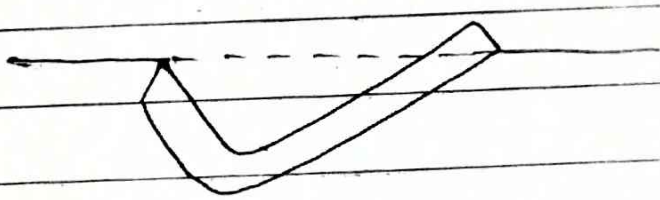
(iii) For simple, symmetrical and shallow forging, centre of height is selected as a parting line.



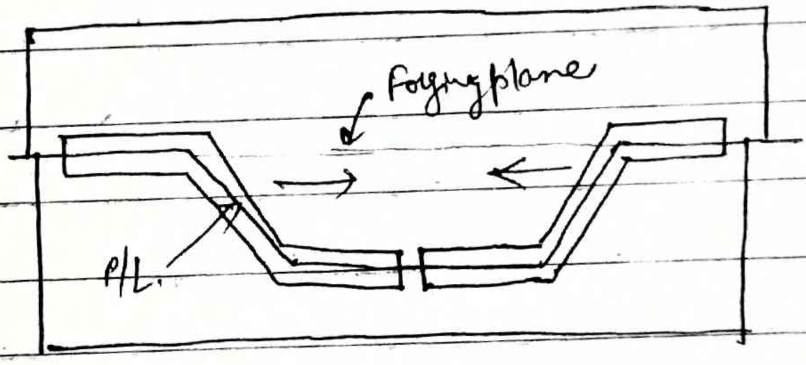
(b). To Avoid side thrust.

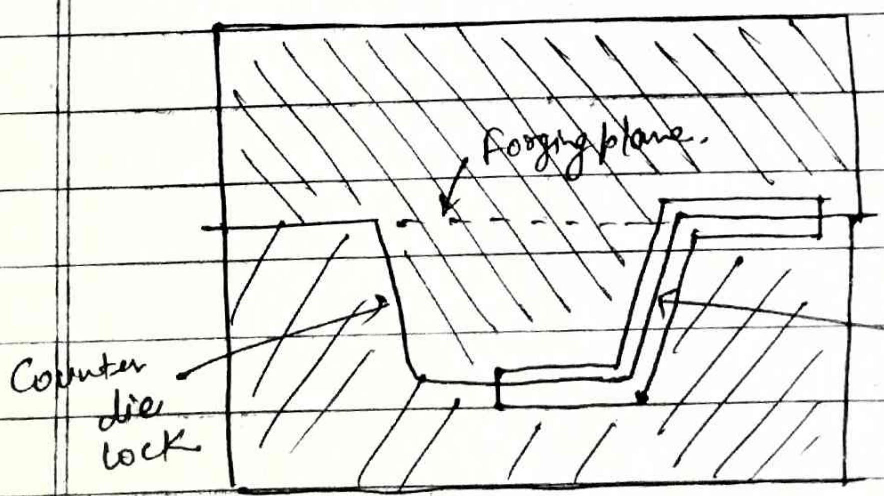


← Side thrust



No side thrust
(Modified parting line)





(Expensive;
Maintainence is costly;

Fatigue strength can be improved by shot-pinning.

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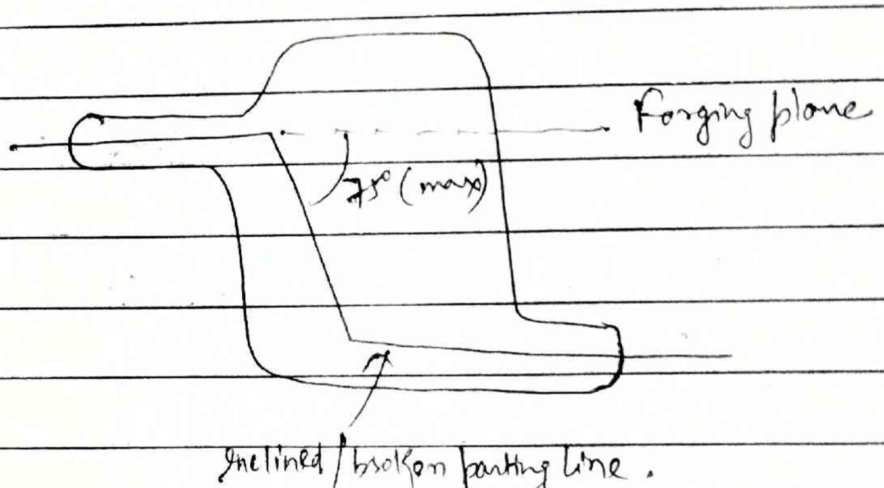
(C) Favourable Grain Flow:-

→ Grain should not overlap, should not cut, should not reverse. It should be continuous.

→ It should be parallel to the maximum applied load.

→



Trimming will be difficult if angle is greater than 75°.

DRAFT :- (3° to 7°) for conventional forging

↳ Taper from vertical.

↳ Surface roughness of Die Cavity is $\nabla 8 = 0.625\ \mu m$.

↳ Provided for easy withdrawal of pattern.

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Factors affecting the amount of draft

① **Forging equipment** ⇉ Hammer & press
(Impact load) ('Gradual load).

lesser amount of draft is applied in press because press has an ejector system which helps in easy removal of w/P.

② **Forging material (to be forged) :-**

low alloy steels or plain Carbon steel
Ti - alloys
Ni - based superalloys

↓ Draft angle.

→ It will form thick oxides and thus works as a parting agent which will prevent the sticking of billet to the die. That's why low draft angle is required.

③ **Height / depth of forging :-**

Height / Depth is more, so more tendency of sticking and hence more draft is provided.

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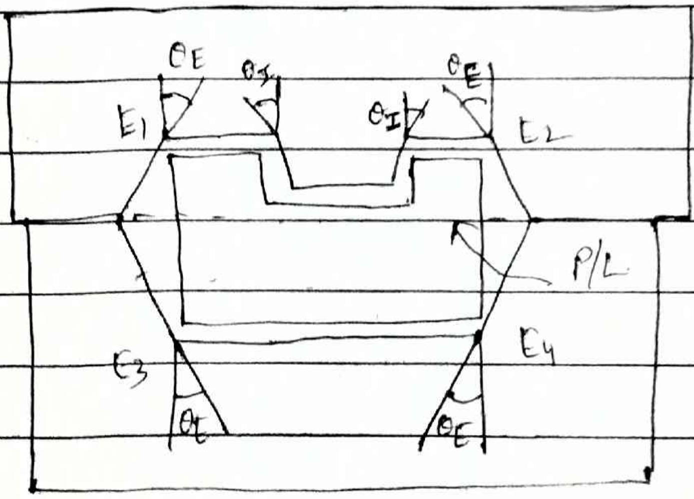
Types of draft:-

1. External draft. (outside draft). (small value)
2. Internal draft. (Inside draft). (large value)
3. Natural draft.
4. Match draft.
5. Shift draft.
6. No draft.
7. Back draft.



1. Metal on external surface will shrink away from the die-wall.

2. Metal on internal surface (during cooling) will have tendency to shrink towards (projection / plug of) the die.

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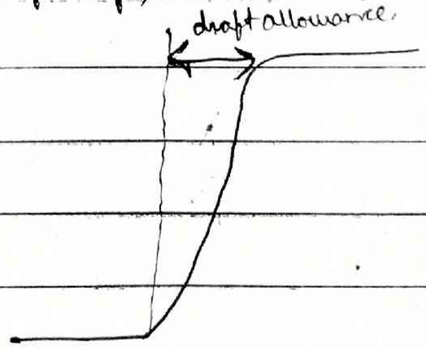
(Draft in degrees)

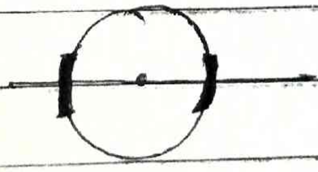
Alloys	Hammer		Press	
	External draft	Internal draft	External	Internal
Carbon and low alloy steel.	5–7	7-11	3-5	5-7

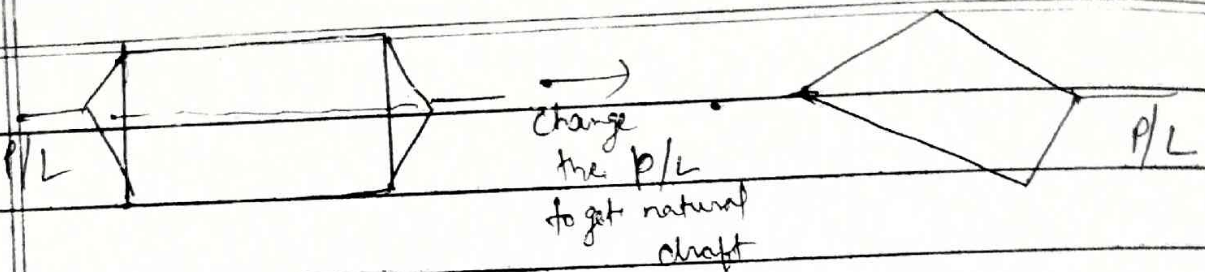
$$\boxed{\text{tolerance} \rightarrow \pm \frac{1}{2}^\circ \quad \text{or} \quad \pm 1^\circ}$$

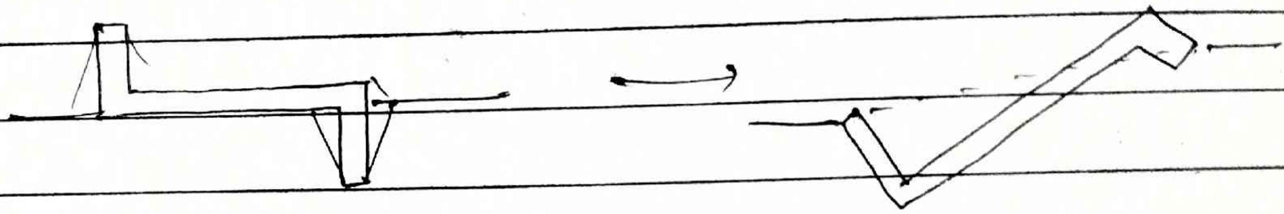
→ Draft allowance is expressed in (decimal of mm/inch) (max^m thickness of draft)



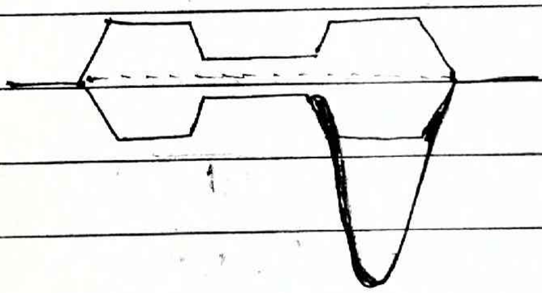
(5) Natural draft → may be inherent in the component



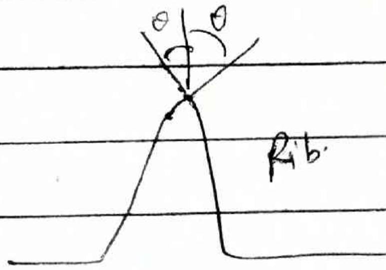


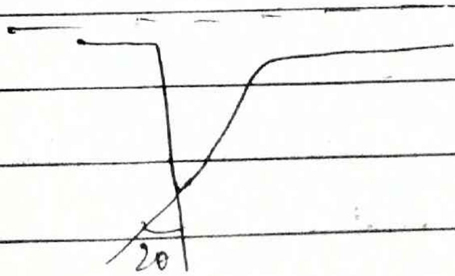


(4) Match draft (blend draft) :-



(5) Shift draft





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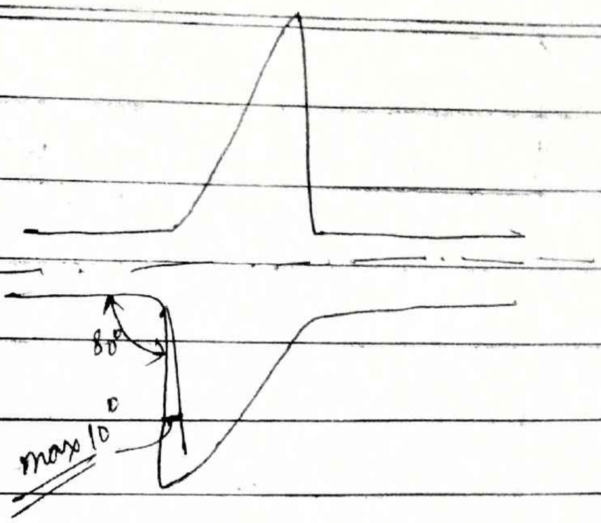
(6) **Back draft :-**
(negative draft).

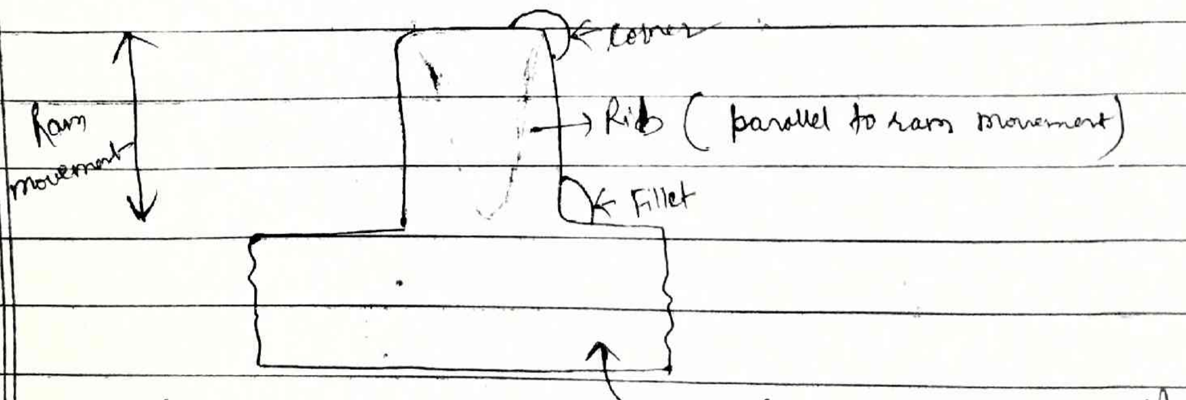


It is provided only in the fixed die.

(7) **No draft :-**
(Draftless forging)
(Precision forging)

[Grains will not be exposed in the end and thus life will increase ; Corrosion resistance will increase].

FILLET AND CORNER :-



Section of forging.

Corner is a Convex arc which joins two intersecting side tangentially so that the external angle between them is more than 180°.

Corner joins side of the rib to top of the rib.

Fillet is a concave arc that joins two intersecting sides tangentially so that the external angle between them is less than 180°.

Fillet joins web to rib tangentially.

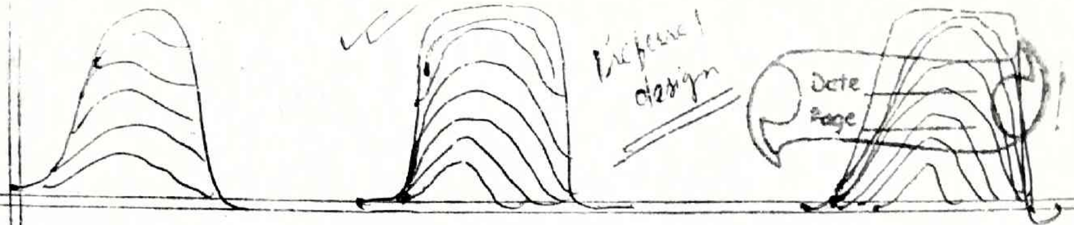
→ Fillet and corner affects the grain flow, load requirement, energy requirement, defect formation.

→ Stress concentration is avoided.
Smooth flow of the metal is achieved.

Fillet and corner depends upon :-

(i) Forging material :-
Carbon & low alloy steels
Al - alloys
Ti - alloys
Ni - based superalloys

(ii) Height & depth :- measured from parting line.



	Fully rounded top	Flat top with large radius	Flat top with small radius
load req.	minimum	Intermediate	maximum.
Material req.	Maximum	———	minimum

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DIE DESIGN.

* Crankshaft, connecting rod, gears are made by forging because they require better mechanical property.

* Definition of forging :-

Forging is a mechanical working process where material is hammered (by hammer or press) to have a shape (formation) of a required dimension.

* Advantages of forging process :-

(i). Fibrous structure is obtained which leads to better mechanical properties.

(ii). Structural Integrity is obtained (Porosity is reduced and pockets or void are welded up).

(iii). Uniformity is achieved i.e consistency from product to product (or component to component).

(iv). Strength weight ratio is more.

(v). Substantial saving in space in assembly.

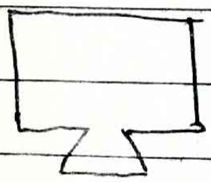
(vi) close tolerance is possible.
(vii). Rejection is less as compared to casting.

* Disadvantages of forging :-

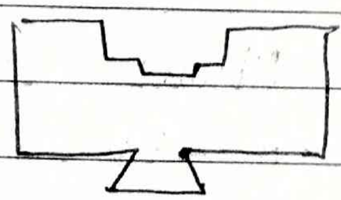
(i) Initial investment is very high.
(ii) Costly process.
(iii) Time taking process.
(iv). Trimming / coining process are to be followed.
(v) Heat treatment is also required.

* Types of forging :-

Open die Forging



closed die forging



1) Does not have cavity in die i.e they are flat — It has cavity in the die.

2). Metal can flow in any direction

3). Die does not have impression in themselves.

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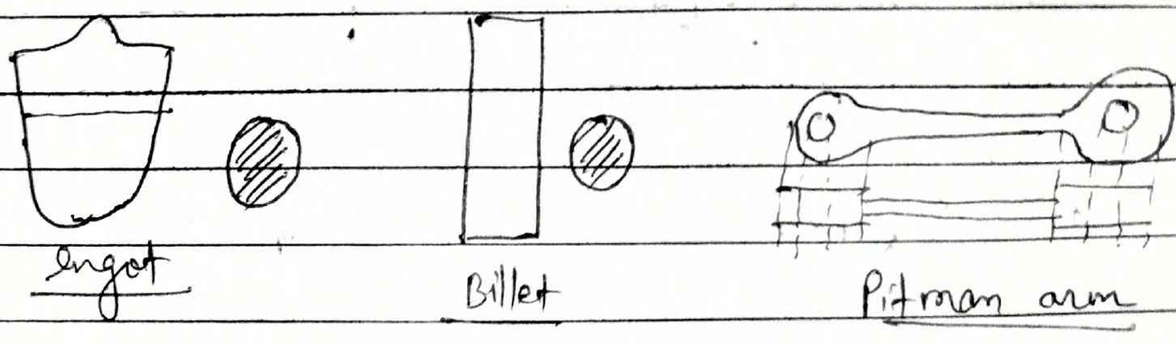
* Medium carbon Alloy steel forging temperature is 1250°C - 1300°C.



* Criteria for selection of Open die & close die :-

(i) Size (Big / Small)
(ii) Shape (Complex / Simple)
(iii) Quantity
(iv) Quality (Good quality is obtained in closed-die)
(v) Time taking

Process of forging :-

(i) Smith forging
(ii) Drop forging
(iii) Press forging
(iv) Machine forging

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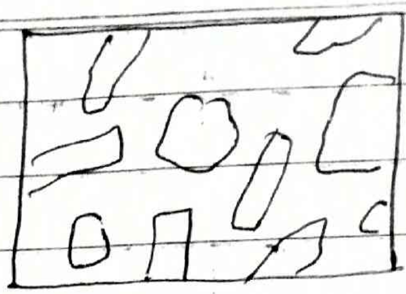
*  Swage block

* Deformation criteria
  - → Temperature
  - → Strain
  - → Strain Rate.

(i) Smith Forging :-

- → old method ; heating in open hearth furnace
- → Manually hammed
- → cheap
- → Less time consumption
- → Trial purpose
- → Good skills required.
- → Mostly used for making agricultural tools.
- → Not used for mass production.

(ii) Drop forging :-

- → Top & bottom die
- → closed die forging
- → equipment is hammer
- → Draft angle is given (More draft angle is required)

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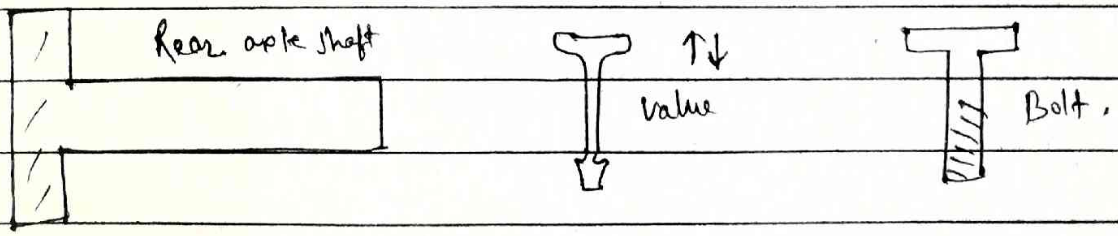
→ Problem in ejection
→ less yield (Die setting / die making take more time).

(iii) Press forging :-
→ Press (Mechanical / hydraulic)
→ Top & bottom die
→ closed die forging
→ Minimum draft angle.
→ More yield.

(iv) Machine forging :-
→ Also called upset forging or upsetting which means increase in cross-sectional area.
→ Metal is free to flow (Free upsetting).



* Types of forging according to temperature :-

(i) Hot forging
upto 0.8 Tm forging temperature
(ii) Warm forging.
upto 0.5 - 0.6 Tm.
(iii) Cold forging (upto 0.3 Tm).

Isothermal Forging :-

→ Dies and billet have same temperature.

→ Narrow range of temperature.

→ Basically used for Non-ferrous.

→ Ex → Ti, Ni etc.

* Forging Unit :-

1). Planning & scheduling.
2). Die Design and development.
3). Die manufacturing.
4). Billet Cutting.
5). Production.
6). Heat Treatment.
7). Quality Assurance.
8). Maintainence.
9). Finishing.
10). Dispatch.

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Books:-

(i). Forging Die Design by A. Thomas
(ii). Forging Methods by A. Thomas.
(iii). Forging Die Design & Practice by Alton.
(iv). Forging Die Design, by S.N. Prasad.
(v). Forging Design & Practice by Sabroff.
(vi). Metal handbook, Vol IVX (14).
(Forging and forming).
(vii). Forging Plant (Equipment), by A. Thomas

(1) Planning & scheduling:-

→ Responsible for taking order / making schedule.
→ Deciding about selection of Equipment.
→ with design expert / Incoming material.

(2) Die Design and development:-

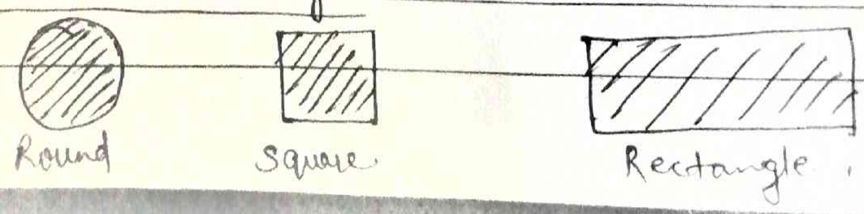
Component drawing + Allowance ⇒ Forging drawing.

(3) Die manufacturing:-

(i). Die block preparation.
(ii). Die sinking.
(iii) Die fitting.

} Steps involved.

(4) Billet cutting:-



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→ Cutting can be done by Sawing or Shearing.

(V) <u>Production:-</u> Heating using Conduction furnaces/ Rotary hearth furnace.

<u>Advantages of Induction heating:-</u>

→ Working atmosphere improves / Less noise
→ Efficiency is more.
→ Quality consistency (temp.)
→ Better temp. control.
→ Easy automation
→ High productivity.
→ oxidation may be eliminated.
→ No leakage, leads to keep it closer to the hammer / press.

<u>Limitations</u> → (i) High cost
(ii) Continuous power requirement.

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(5) * Production → Heating
→ Descaling
→ Forging
→ Trimming
→ Coining

Embossing → to have required design on surface.
→ used for decorative purpose
→ increasing rigidity
→ Making symbols or some pattern on surface.

Coining → Top & bottom are different.

Coining is a precision forging process where metal deformation takes place only in top and bottom surfaces. This is done to have close tolerance and maintain relations ~~between~~ among different locations of a component.

Generally it is a cold working process. Hot working can also be possible.

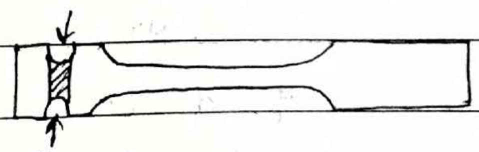
(9) Finishing :- Check all dimensions. If the dimensions are not accurate then we go for Rework

Defects → underfilling; overlap; seam; Crack; Dent.

Die Design :-

Steps :-

1). Job Analysis.
2). Development of forging.
3). Selection of Tolerance.
4). Selection of Parting line.
5). Design of preform.
6) Design of Finisher.
7) Design of trimming tool.
8). Design of Piercing tool.
9). Design of coining.
10). Selection of Equipment.
11). Die modification. (if required). [Cro for Simulation].

* 

Piercing.

For piercing, press is used.

* Equipment → Hammer
  Press.

Grain Flow Pattern :-

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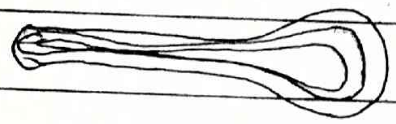
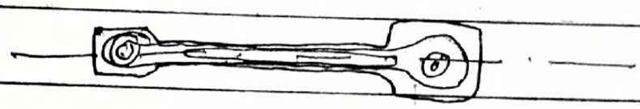
Practical class 4/9/18

choose any component and show grain flow pattern at different locations of components.
(Choosing 4 parting line).



Plan view.

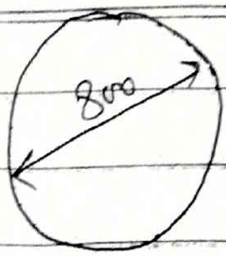


② Development of forging design.

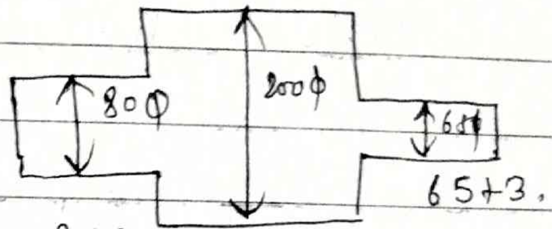
Component drawing + allowance

Minimum Finish allowance as per IS ~~3044~~ 3469.

Dimension	Per surface (mm)
0 - 205	1.5
205 - 410	2.5
410 - 610	3
610 - 915	4
> 915	5.



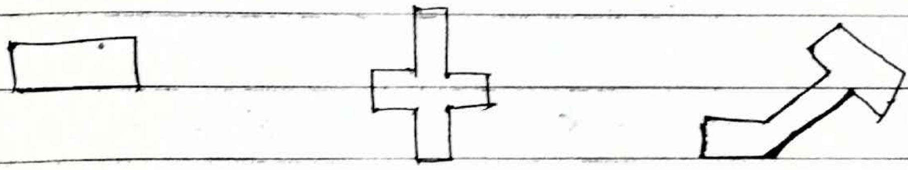
800 + 4 + 4



80+3 200 + 1.5 + 1.5

(3) <u>Selection of Tolerance</u> :-

ⓐ Shape - Simple or complex.



<u>Simple</u> Complex Complex.

(i) Complexity = $\frac{\text{weight of forging}}{\text{weight of overall envelope}}$.

(ii) <u>Material difficulty</u>

(iii) size.

M₁ → carbon % upto 0.65 % and total alloying elements is upto 5 %.

M₂ → above 0.65 % carbon and total alloying element above 5 % is M₂.

Assignm

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(i) Complexity → $S_1 > 0.63 \leq 1$ (Simplest).

$S_2 > 0.32 \leq 0.63$

$S_3 > 0.16 \leq 0.32$

$S_4 \leq 0.16$.

(iii) Size

0-32	32-100	100-160	160-250	250-400	400-630	630-1000
						→

1000-1600	1600-2500

say for $M_1 S_2$,

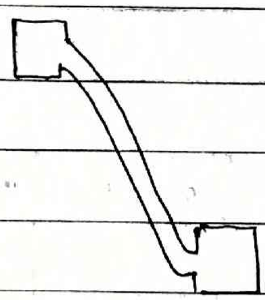
wt	M_1	M_2	S_1	S_2	S_3	S_4
						Go to the column of dimensions.

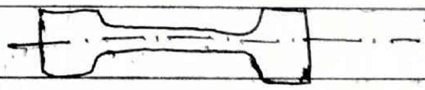
Assignment 3 → Selection of tolerance for closed die forging.

Parting plane :- where two die halves meet.
Parting line.
Forging plane :- Imaginary plane taken for ~~reference~~ ($\perp^{r}$ to ram movement)

* Parting ~~line~~ plane → Plane where Top and bottom dies meet / separate.

Steering Arm





* <u>Criteria for Selection of parting line:-</u>

(i). Favourable grain flow.
(ii). Maximum area at parting plane
(iii). Minimum depth of cavity.
(iv). Minimum draft.
(v). Minimum side thrust.
(vi). Easy for die-sinking.
(vii). Easy for trimming.
(viii). Proper billet positioning.

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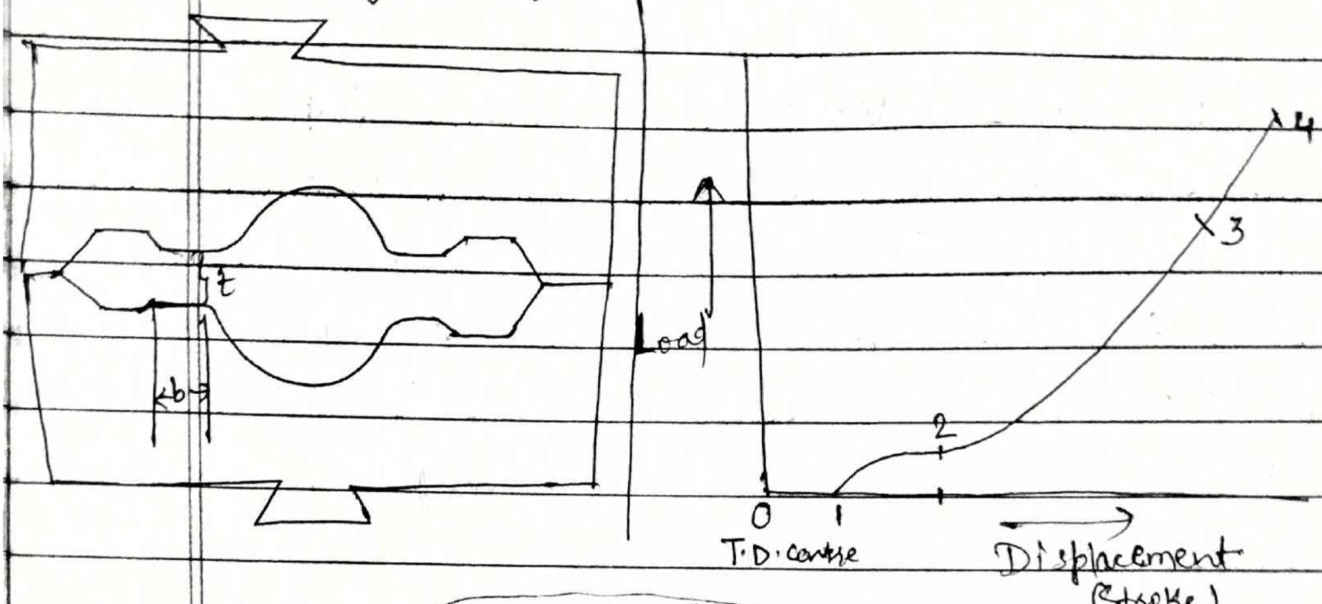
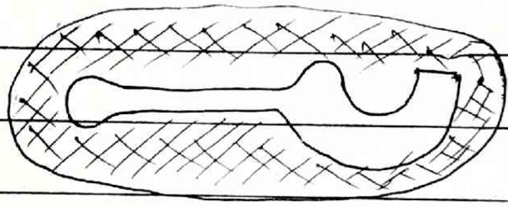
* Design of Flash :-





Flash :- Flash is an extra material other than component which is provided intentionally to ensure complete filling of the die.

0 → Top dead centre (T.D.C)
1 → Top die touches billet.
2 → Flash formation takes place (starts).
3 → Dies are completely filled
4 → Bottom dead centre (B.D.C). **Dies** are closed

Q) What is flash? How flash works in metal flow? Discuss with the stroke curve.

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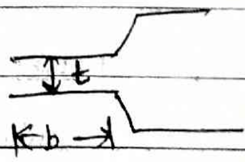
⇒ Function of Flash :-

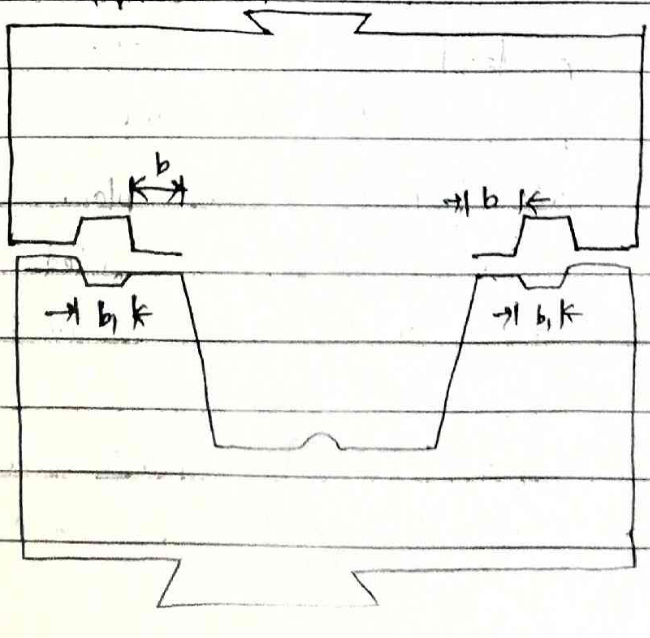
(i). It works like cusion from impact blows.
(ii). It initially restricts metal flow outside cavity to ensure complete filling of die.
(iii). At last portion of stroke it allows metal to flow outside.
(iv) It works just like a valve.

⇒ Gutter is extra cavity in the die to accomodate extra material coming from cavity at last portion (part) of stroke.

* Flash width = b
Flash thickness = t
Gutter width = b_1
Gutter depth = t_1



Gear Blank



Book A. Thomas

$\frac{b}{t} \equiv 4 \text{ to } 6.$

Pg - 25, A. Thomas

Formulae :-

(i) $t = 0.015\sqrt{A}$

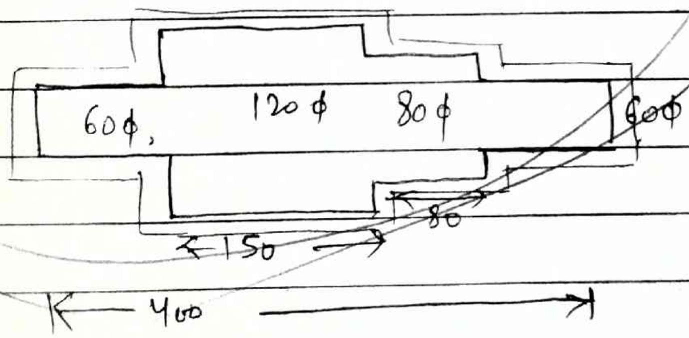
A = Plan projected area at parting plane.

(ii) $t = 0.018 D$; $63/\sqrt{D}$ (b/t).

Table of b_1 & t_1 :-

$\frac{b}{b_1} \equiv \frac{1}{3.5}$	$\frac{t}{t_1} \equiv \frac{1}{2.5}$

* Component drawing of a drive shaft has been shown in the fig. Determine Flash dimension.



Let, $t = 2.5$ (say)

we know, $\frac{b}{t} = 4 - 6$, say $b = 5t$

$\therefore b = 2.5 \times 5 = 12.5$,

R → Fillet radius.

r → Corner radius.

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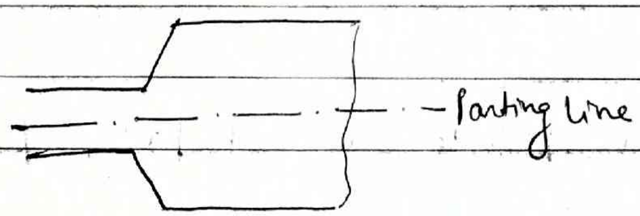
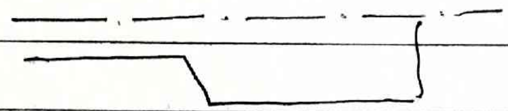
* Types of Flash :-

i).



Symmetrical, (In both dies).

ii)



Flash only in one die.

(iii) Corrugated type.

Blocker Design Consideration :-

* Need of blocker :-

(i). Present just before finisher

(ii). The main objective is to distribute fullered or edged pre-form nearer to finisher impression.

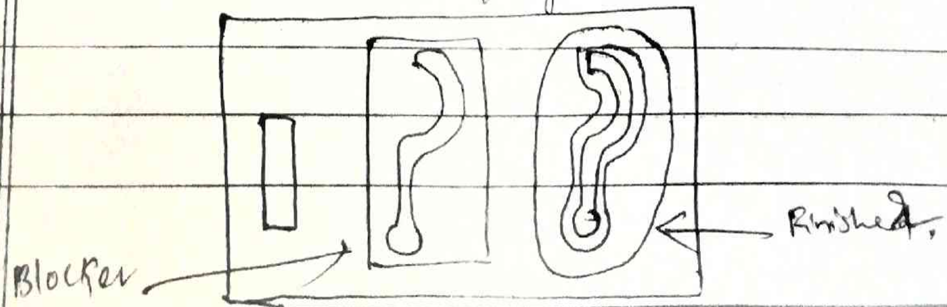
(iii). It reduce severity of deformation.

(iv). Reduce in die wear.

(v). More die life.

(vi). Yield is more i.e. R & r are less.

(vii). Complete die filling.



Draft depends upon equipment.
hammer has more draft as compared to press.

(i). Volume of blocker is more as compared to finisher.

(ii). Rapid change in Dimensions (thickness) are to be avoided.

(iii) Thinner sections with more surface area is avoided.

(iv). Width of blocker is to be less. i.e blocker is $\boxed{\text{narrow by } 0.5-1.5 \text{ mm.}}$ ← Design Consideration.

(v). Depth of blocker is more (atleast 0.5mm more).

(vi). Draft angle remains same.

(vii) Generally Flash and gutter impressions are not provided.

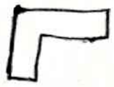
(viii). Sometimes more numbers of blockers are required.

Crankshaft:-

i) Fuller
ii) Edger
iii) Bender
iv) Blocker I / Buster
v) Blocker II
vi) Finisher

Finisher Design:-

Forging Load
Trimming Load
Piercing Load

 allen bolt

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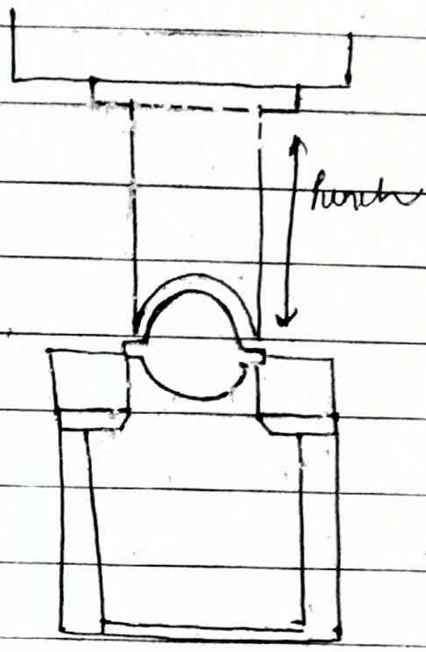
Design of Trim Punch :-

- Material is die steel.
- Profile of punch is similar to that of finishes top die



- Material outside impression is machined.
- Punch is fitted with plate.
- Stripper plate is used to avoid sticking of trimmed flash with punch during its return stroke.
- Total tool height will depend upon shut height of trimming press.
- Piercing :- making hole in thick component with help of punch and die.

Capacity of Trim press :-

(a) $P_{trim} = 1.4 \times \text{perimeter} \times \text{thickness} \times \sigma$ (tensile strength at trimming temp.)

$= 1.4 \times \pi D \times \underset{\text{Flash thickness}}{t} \times \sigma.$ (kg).

 wad

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(b) $P_{Pierce} = 1.4 \times \text{perimeter} \times \underset{\text{(wad thickness)}}{\text{thickness}} \times \sigma$ (tensile strength at piercing temp).

(c) Total load $= P_{tum} + P_{pierce}$

Capacity of press / Hammer :-

(i) Thumb rule (in Kg). {A = plan area at parting plane including flash land}

Capacity of press, $\boxed{P_{kg} = A \times M.F \text{ (multiplying factor)}}$ {M.F → 50–65 Kg/mm²}

In case of low carbon alloy steel → 50–55 Kg/mm² (M.F)

In case of die steel, stainless steel, high alloy steel → 55–60 Kg/mm²

In case of superalloys → 60–65 Kg/mm².

(ii) For circular forging :-

$$P_{kg} = 8\left[1 - 0.001\,D\right]\left\{1.1 + \frac{20}{D}\right\}^2 \cdot \sigma \cdot A$$

where, σ = tensile strength at forging temperature.
A = plan area including flash land

(iii) For non-circular forging :-

$$P_i = 8\left(1 - 0.001\,D_i\right) \times \left\{1.1 + \frac{20}{D_i}\right\}^2 \cdot \sigma \cdot A$$

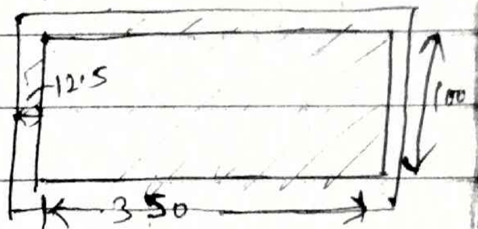
where, $D_i = 1.13\sqrt{A}$

Example:- For a steering knuckle,

plan area $= A = 35000 \text{ mm}^2$

average width $= b = 100$ mm,

$\sigma = 8 \text{ Kg/mm}^2$.



Calculating the flash thickness,

$$t = 0.015\sqrt{A} = 0.015\sqrt{35000} = 2.8062$$

Now we take, $\frac{b}{t} = 5$

$$\Rightarrow b = 5 \times t.$$

Then, we calculate the total area including flash land,

therefore, area $= (350 + 12.5 + 12.5) \times (100 + 12.5 + 12.5)$.

$\therefore A_1 =$

$=$

$\therefore$ Required press capacity for non-circular forging :-

$$\boxed{P = P_i \left\{ 1 + 0.1\sqrt{\frac{2L}{A}} \right\}}$$ (in Kg).

For turn press;

$$P_{turn} = 1.4 \times \text{perimeter} \times t \times \sigma.$$

Here, perimeter will be $= 2(350 + 100)$.

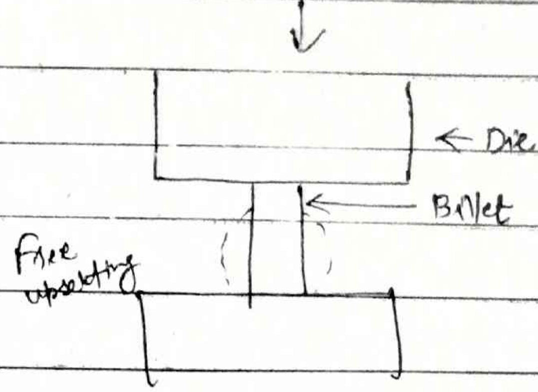
— X —

Equivalent Hammer :-

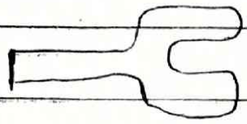
capacity of hammer in Kg,

$$P_{kg} = 1.1 \times \text{capacity of press in tonns.}$$

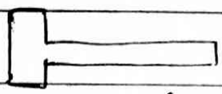
UPSETTING



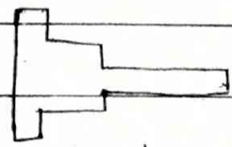
→ Increase in area.



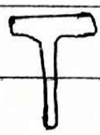
Socket



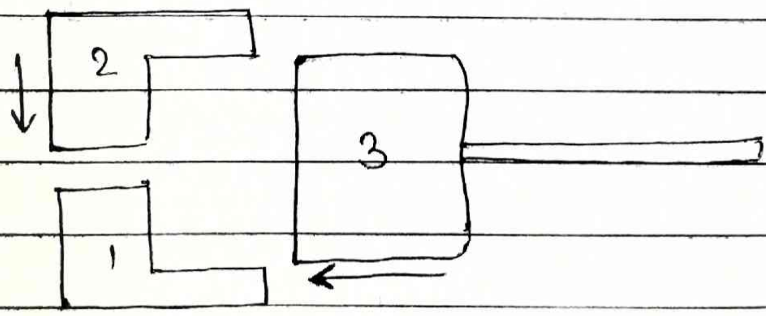
Axle (rear shaft) or bolt.



Counter gear



Value



1, 2 — Gripper dies.

3 — Header Die. / Tool.

2, 3 — Movable.

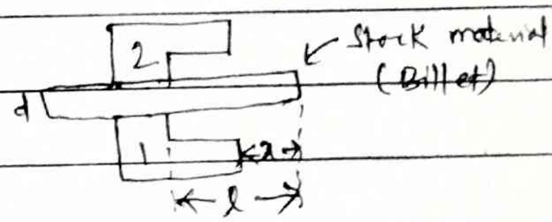
1 — Fixed.

* Upsetting design rules :-

Rule-1 → unsupported length of a bar stock (greater than 3d) may be upset in a single blow without buckling provided its length is limited to 3d.

i.e l/d max 3.

In practice, $l/d \simeq 2.5$.



Rule-2 → It is possible to upset next dia (d_1) upto 1.5 i.e

$$\frac{d_1}{d} = 1.5$$

In practice, $\frac{d_1}{d} \simeq 1.3$.

So, $\left.\begin{aligned} d_1 &= 1.3\,d \\ d_2 &= 1.3\,d_1 \\ d_3 &= 1.3\,d_2 \end{aligned}\right\}$ Progressive upsetting.

Rule-3 → Length beyond die face (x) is limited to $(x = d)$.

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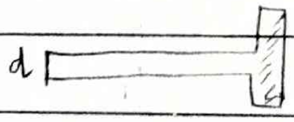
To reduce number of stages in upsetting ;

i) Coning Tool.

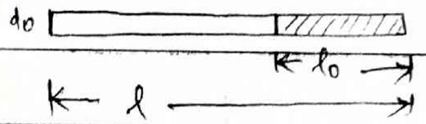
ii). Square hole scheme.

(1) Coning Tool method :- To reduce number of stages.



Steps :-

1) select proper stock material. (diameter & length). (d_0 & l_0).



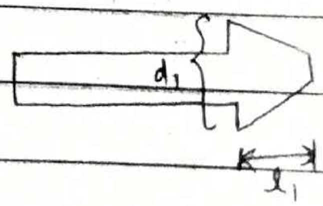
2) Calculate volume to be gathered (to get 'l_0')

3) Find '$\frac{l_0}{d_0}$' ratio.

Case I → If $\frac{l_0}{d_0} \leq 2.5$, no buckling takes place and there will be direct upsetting. no need for cone design.

Case II → If $l/d > 2.5$, need for cone design.

The first cone is designed as

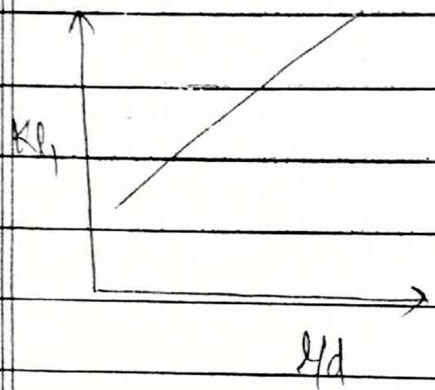


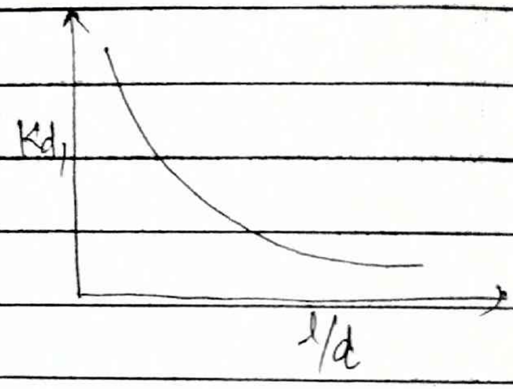
d_1, l_1.

$l_1 = K_{l_1} \times d_0$

$d_1 = K_{d_1} \times d_0$.

K_{l_1} and K_{d_1} are from data book. (Pg 57, Thom

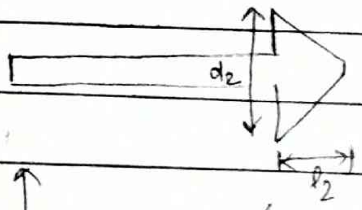


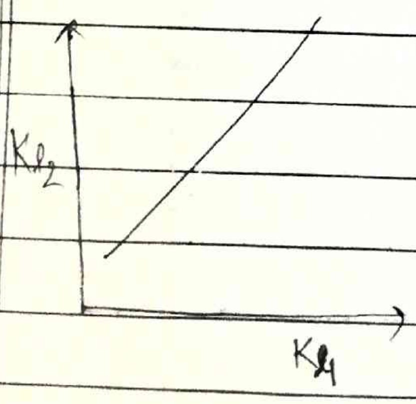


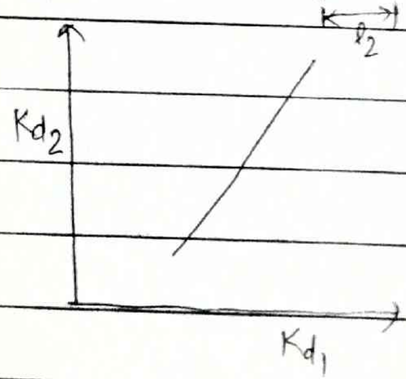
4) check '$\dfrac{l_1}{\frac{d_1+d_0}{2}}$'.

If the above ratio is ≤ 2.5; no buckling takes place. No 2^{nd} cone design required.

If the above ratio is ≥ 2.5; then design 2^{nd} cone.







K_{l_2} & K_{d_2} → are from data book / graph.

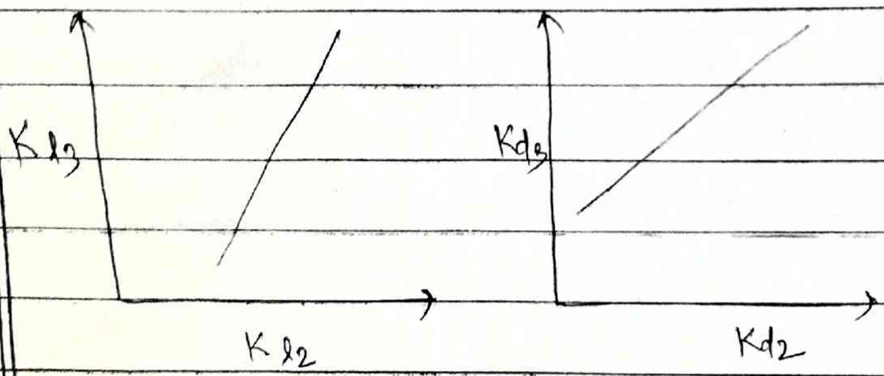
$l_2 = K_{l_2} \times d_o$

$d_2 = K_{d_2} \times d_o$.

5) check $\dfrac{l_2}{\frac{d_2 + d_o}{2}}$.

If the above ratio ≤ 2.5 ; no need for 3rd cone.

If the above ratio > 2.5 ; then 3rd cone is designed as



K_{l_3} and K_{d_3} are taken from data book.

$l_3 = K_{l_3} \times d_o$

$d_3 = K_{d_3} \times d_o$.

6) Continue the above steps ~~till~~ till 'l/d' is less than 2.5.

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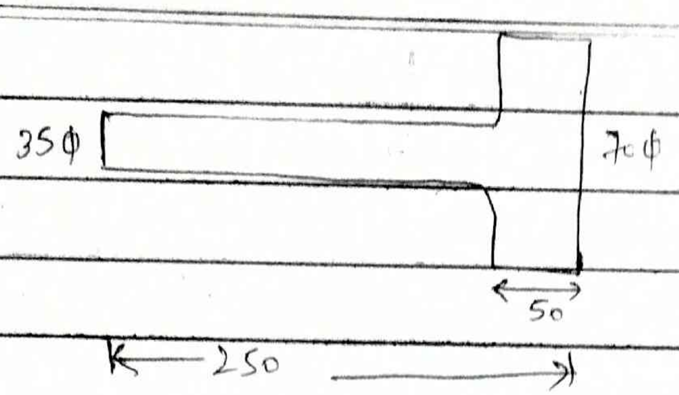
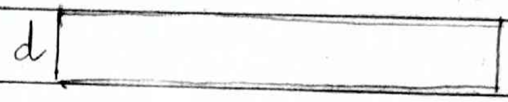
(Q1)



Allowance = 1·1 × dim.

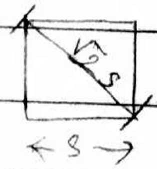
Design steps for manufacturing above component by upsetting.

(2) Square hole method :-
(round)



Initial bar ⇒ round

1st impression ⇒ Square



$S = 1.5 d.$

2nd impression ⇒ round

3rd impression ⇒ square

$D = 1.5 \cancel{\times} \sqrt{2}\, s$

$= 1.5 \times \sqrt{2} \times 1.5\, d$

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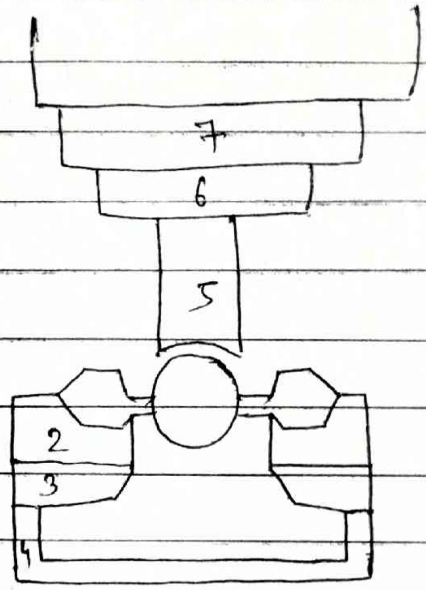
#

Bottom set :-

1. Component with flash
2. Trim Die
3. Back plate.
4. Shoe / Parallel.



Top set :-

5. Trim punch
6. Punch plate.
7. Punch plate holder.

Trimming Die Design Consideration :-

- Trim die material
- Profile of trimming die contours is similar to that of finisher bottom die.
- Material inside impression is machined out to make it hollow type so that component may fall easily.
- Flash and gutter impressions are also provided in trimming die for proper sitting.
- Cutting edge is built up by welding of stellite material over mild steel.

(stellite → Co – 50-57% ; Cr – 27-32% ; W – 11-14% ; C – 2-3%).

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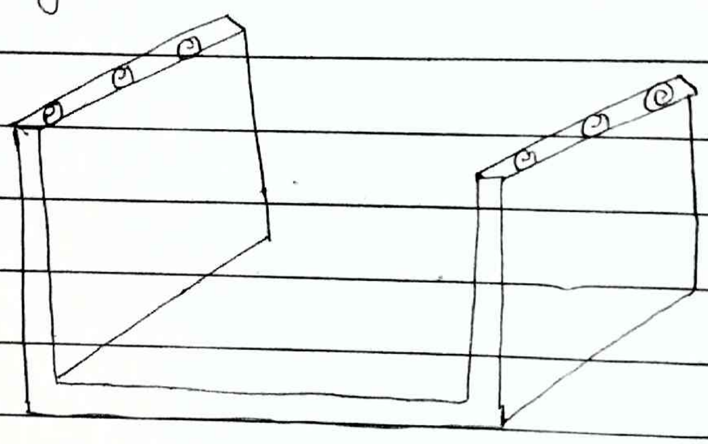
- Cutting edge is made by milling | grinding top surface.
- Cutting edge thickness is given atleast 1.5 time flash thickness to have more die life.
- Trimming die is supported by a back plate.
- Trimming die with back plate is fitted on a shoe.



shoe.

computer based experiments can be conducted on :-
DEFORM, QFORM, Simufact, Forge

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Simulation :- It is a process of designing a mathematical or logical model of a real system and then conducting computer based experiments to analyse the behavior / properties of that real system.

Advantages of Simulation :-

(i). It reduces number of shop floor trials.
(ii). Re designing / modification is easier.
(iii) Lead time is reduced. (from initial).
(iv). It is easier to have a new product design.
(v). Defects are reduced.
(vi). Material wastage is reduced.
(vii) Yield is more.
(viii). Data at any point is available.

Disadvantages of Simulation :-

(i). High skilled man power.
(ii). Software is costly.
(iii). It cannot give 100% accurate results, it is to be validated.
(~~iv~~).

Validate.

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Steps of Simulation :-

(i) Pre-processor — Input parameters → Forging temp ; Die temp ; Die material ; billet material ; strain ; strain rate ; elastic property ; boundary condition ; μ ;

object geometry.

(ii) Processor → Simulation engine

→ Automatic mesh generation / regeneration.

(iii) Post-processor. → History available for any type of data.

— X —

Die Manufacturing :-

(i) Die Material —

Die steel.	Standard IS
DIN 2713.	3748
DIN 2714.	3749

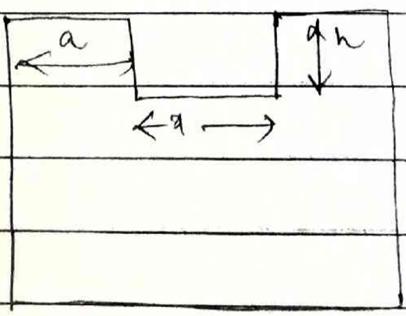
(ii) Die size —

L → Length.

W → Width.

T → Thickness.

(minimum 2.5 times of maximum depth).



$a > 1.5h$.

Piping Defect.

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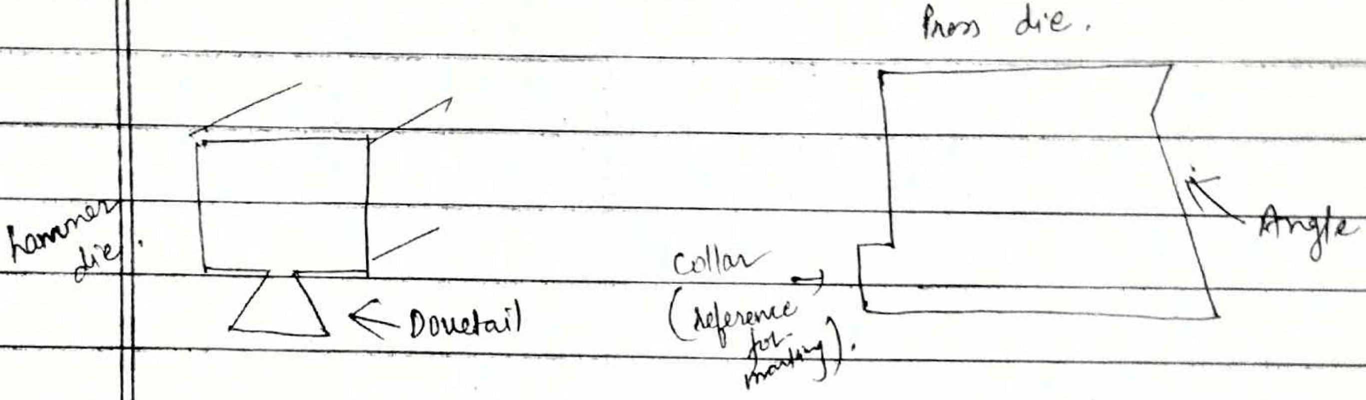
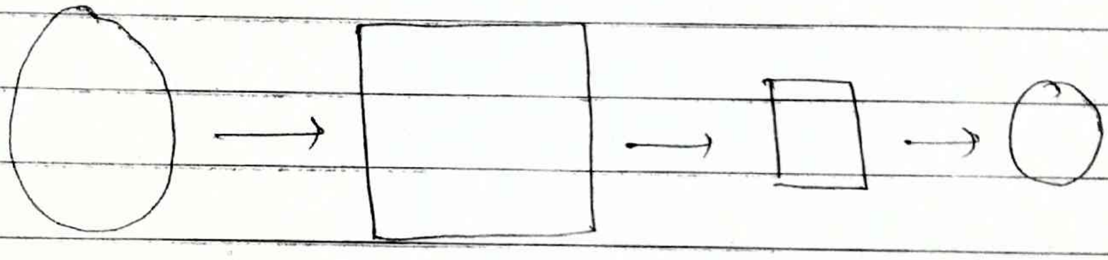
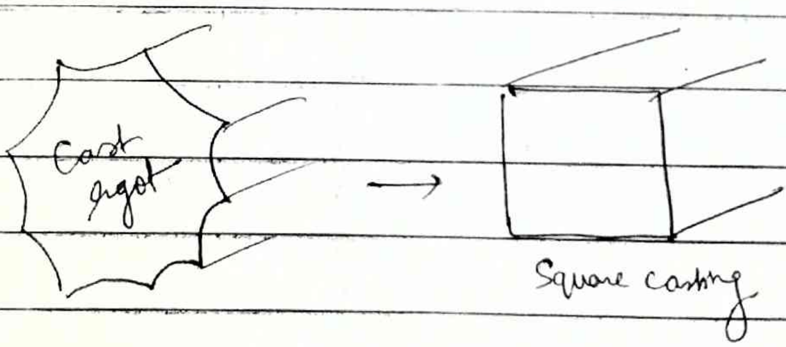
Stages :-

1st stage :- Die block preparation.







(a) Sizing :- Can be done [redacted] using milling | Shaping | planning machine.

(b) Grinding.

(c). Marking. { In case of dovetail; reference is the centre of dovetail }.

4) Comparison of press and hammer

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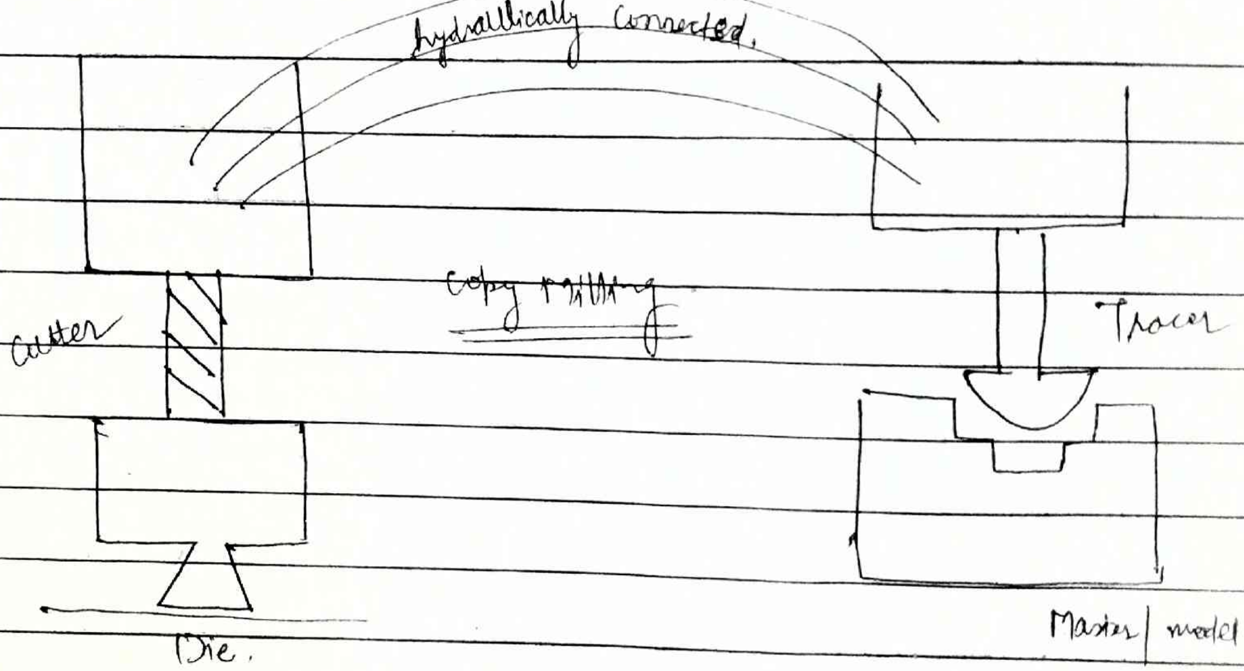
→ 10 – 12% cost of forging is due to die only

2nd stage :- Die sinking.

i). Copy - milling.
ii). CNC milling.
(iii). EDM.



→ The tracer is bigger than cutter. i.e,

Tracer diameter = cutter diameter + Finish allowance + deflection.

$$V = \frac{\pi D N}{1000} \text{ m/min.}$$

→ Advantages & disadvantages of EDM and CNC w.r.t die sinking.

→ Insert design ; Re-sinking .

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(iii) For EDM, we require a tank ; di-electric ; pump ; power source (D.C.) ; servo controller ; filter unit ; heat exchanger .

Electrode materials :- W, Copper, brass, Molybdenum, Graphite. (Any conductor material).