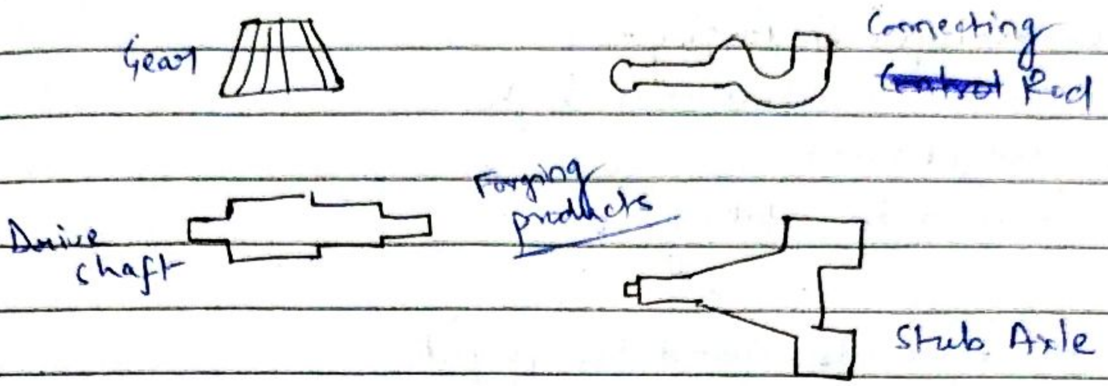
Forging Die Design & Manufacturing



Forging – Process where metal is hammered (press, hammer, upsetting machine, etc.) to have a product of required dimensions and quality.

Advantages of Forging –

1) Fibrous structure is obtained
→ Better properties.

2) Uniformity from lot to lot or piece to piece.

3) Structural Integrity (i.e. No void, No crack).

4) Substantial saving in weight.
($\frac{\text{strength}}{\text{weight}}$ is more)

5) Saving in space in assembly
(Purpose → for fitting other items)

6) Rejection is less.

7) Close tolerance is obtained.

Disadvantages of forging -

1) Initial investment is high.
2) Costly Process
3) It is a time taking process.

4) All materials cannot be forged.

5) Heat treatment is required.

6) In case of closed-die forging, trimming is required.

Types of Forging -

1) Open die forging (Free Forging) — Hydraulic Press
2) Closed die Forging

Free forging - Metal is free to flow i.e. dies do not have cavity.

Closed die forging - In case of closed die forging, metal is not allowed to flow freely rather, it is restricted to flow into cavities.

Types

1. Smith forging
2. Drop forging
3. Press forging
4. ~~[illegible]~~ Machine Forging

1. Hot die forging
2. Warm forging
3. Cold forging

1. Isothermal forging
2. Liquid forging
3. Orbital forging

Hot Die forging – billet temp. upto 0.8 Tm
Warm forging – billet temp 0.5 to 0.6 Tm
Cold forging – billet temp ~~to~~ upto 0.3 Tm

Smith Forging : Old Process
Objective – Trial / Demo
Not suitable for mass production.

Drop Forging :
Equipment – Hammer
Die is closed die
Mass production

Press Forging :
Hydraulic Press / Mechanical Press
(Open die) (Closed die)
Mass production

Machine Forging

Steps for die design -

1) Analysis of component design
2) Development of forging design
3) Selection of parting line
4) Selection of Tolerance
5) Design of ~~perform~~ preform impressions
6) Design of flash & gutter
7) Design of finisher ~~dies~~
8) Design of ~~trimming / piercing tool etc~~. Trim/Pierce / Coining Tool etc
9) ~~Capacity calculation~~ Load calculation for equipments
10) ~~Trial~~ Die Manufacturing
11) ~~Modification~~ Trial
12) Modification (if required).

① Analysis of Component Design -

② Development of Forging Design -

Forging ~~Design~~ Drawing = Component drawing size + Allowance + Fillet & Corner radii + Draft

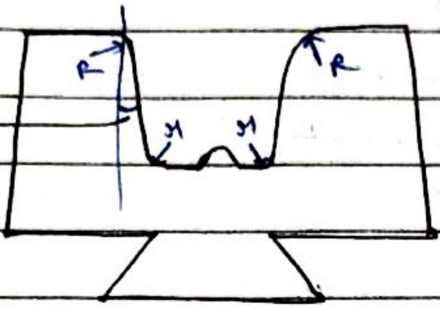
Allowances

Dimension upto	Allowance per surface (mm)
- 205	1.5
205 - 410	2.5
410 - 610	3
610 - 915	4
> 915	5

So, If component drawing is 150

Then, forging drawing $= 150 + 1.5 + 1.5$

$= 153$



Draft Angle (1°, 3°, 5°....)

R: Fillet radius

r: Corner radius

What is forging drawing?

How is forging drawing developed?

③ Selection of Tolerance –

Criteria for selection of tolerance :-

- → weight
- → M – material difficulty

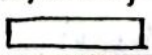
  M_1 : Carbon is upto 0.6 & Total Alloying element upto 5%

  M_2 : carbon above 0.6 & Total Alloying element above 5%

More tolerance required in this case

- → Complexity (shape)

S_1 Simple Shaft



1st Component

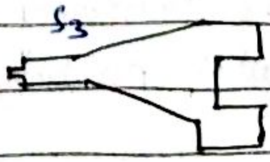
Cross

S_2

~~less than 1~~

2nd Component

S_3



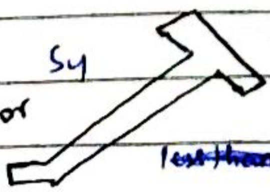
Stub Axle

~~less than 1~~

3rd Component

S_4

Shiftor



~~less than 1~~

4th Component

$$\text{Complexity} = \frac{\text{wt. of Forging}}{\text{wt of overall envelope}}$$

$S_1 > 0.63 \leq 1$

$S_2 > 0.32 \leq 0.63$

$S_3 > 0.16 \leq 0.32$

$S_4 \leq 0.16$

→ Size

Size (in mm)

0-32	32-100	100-160	160-250	250-400	400-630	630-1000	1000-1600
		$(1.1)^{+.7}_{-.4}$					

1600-2500

If Material difficulty 150

Then

$150^{+.7}_{-.4}$

(4) Selection Criteria for Parting Line (PL) -

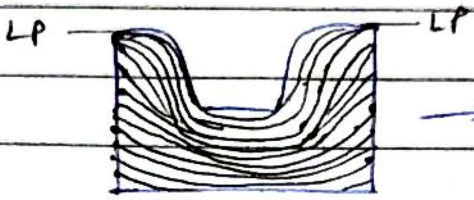
- → Favourable grain flow
- → Maximum area at parting line.
- → Minimum depth of cavity
- → Minimum side thrust
- → Minimum draft / Natural draft
- → Easy for die sinking
- → Easy for trimming
- → Proper billet positioning

Grain Flow Pattern

→ Favourable Grain Flow :

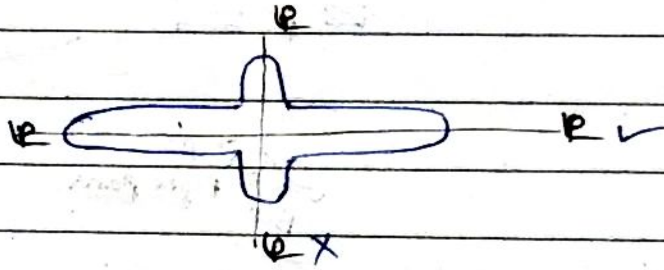
Plan.

Elev.

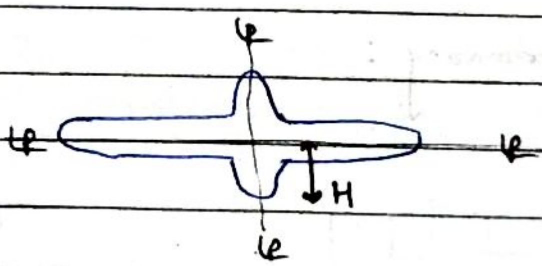


→ Suitable ~~LP~~ Parting Line

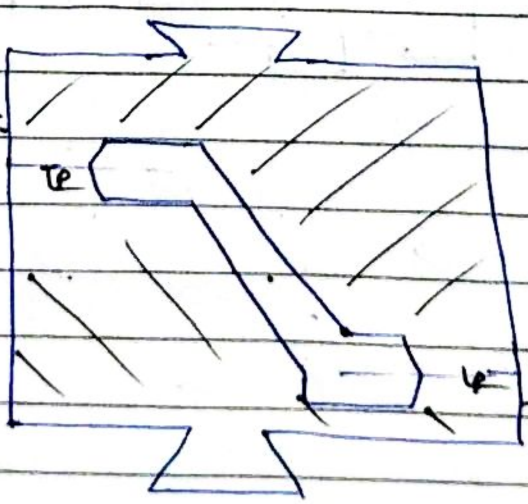
→ Maximum Area at LP :



→ Minimum depth of cavity :



→ Minimum side thrust :

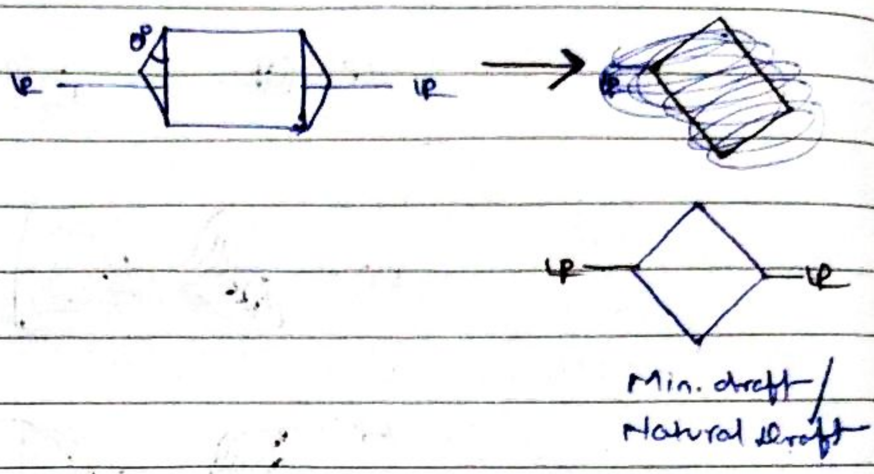


→ Die Shift

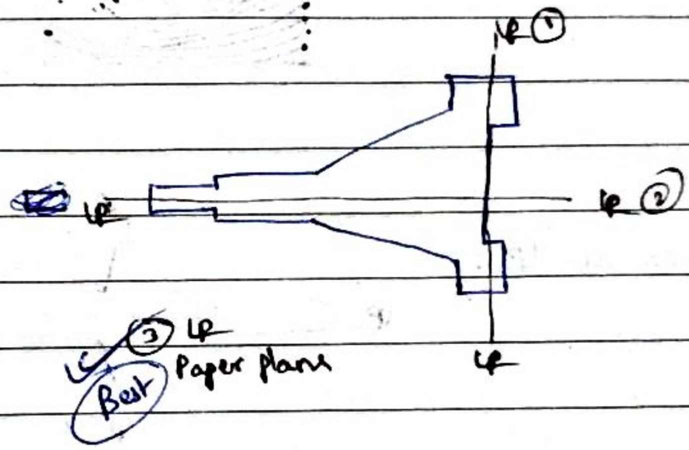
Defect regarding die shift

Mismatch or offset

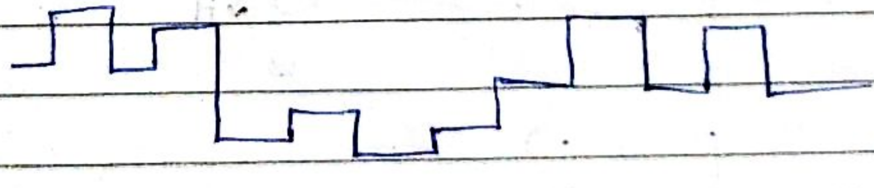
→ Minimum draft / Natural Draft :

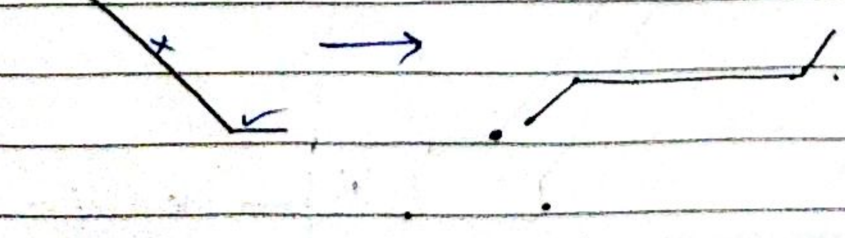


→ Easy for die sinking :



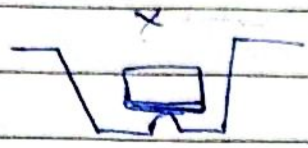
→ Easy for trimming :



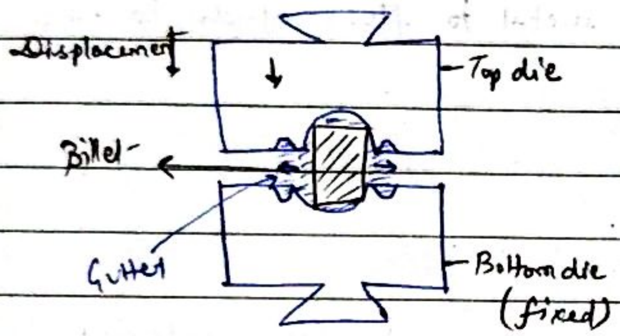


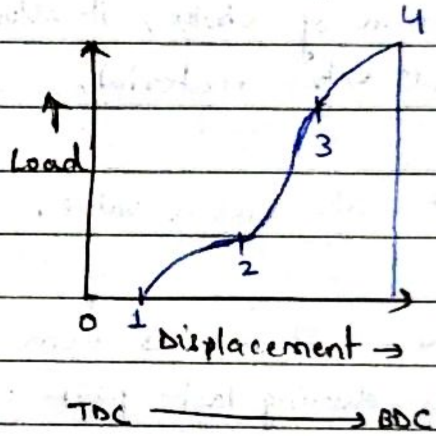
Books – Die Design by A. Thomas
Die Design by T. Altan
Forging Plant – by A. Thomas
Die Design & Practice by S N Prasad.

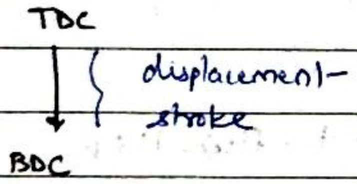
→ Proper Billet positioning :



⑤ Design of Flash & Gutter –

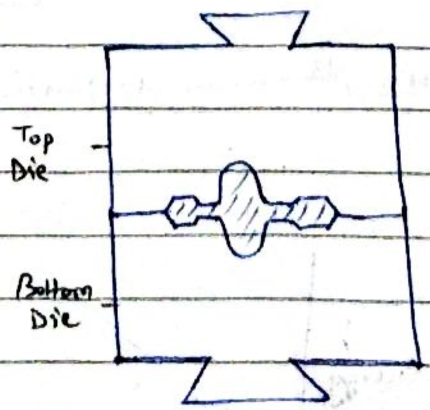


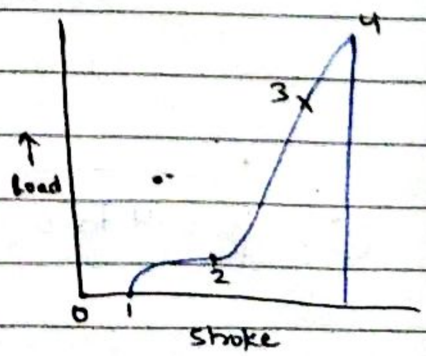




1. Top die touches billet –
2. Formation of flash starts
3. Dies are completely filled
4. Dies are closed.

Function of Flash –





1 –
2 –
3 –
4 –

Suppose

Machined Crankshaft weight = 65 kg

Billet weight = $65 + \boxed{20}$ → extra ~~metal~~ material

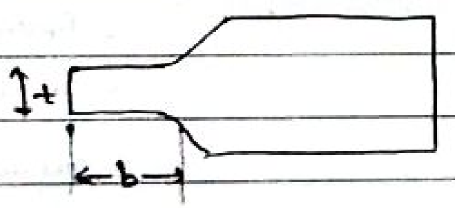
= 85 kg

Function of Flash –

1) It works as a cushion b/w top and bottom dies.
2) Initially it allows metal to flow outside and then puts restriction. At last portion of stroke, it allows metal to flow outside to take out extra material.

3) It works like a valve.

Gutter – It provides room for coming out extra material from dies during last part of stroke.

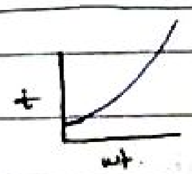


t : flash thick

b : flash width

Formulae –

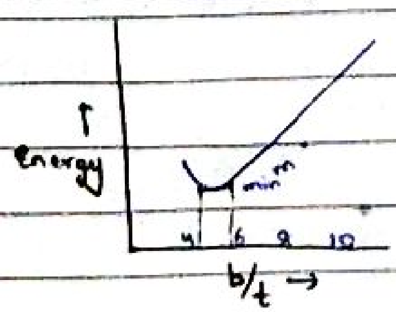
① $t = 0.015\sqrt{A}$



where,

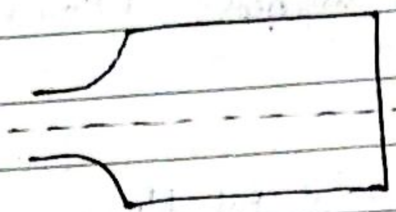
A – plan area at parting line. $\frac{\pi}{4}d^2$

② $\frac{b}{t} = 4 \text{ to } 6$



Types of Flash

i)



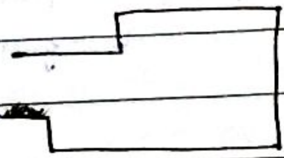
Symmetrical i.e. flash in both dies.

ii)

Flash in one die i.e. either in top die or in bottom die.

iii)

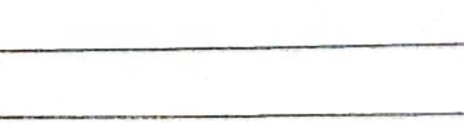
Serrations →



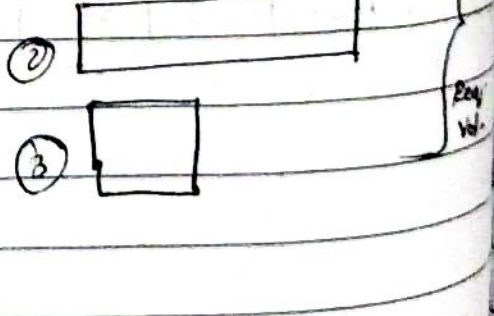
Corrugated type

iv) Thick not same all over.
E.g. more complex contour

Pitman Arm [Design of Preform Impressions]



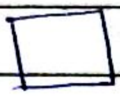
Billets Selection



Edging (inc. in X sec. Area) at 2 places

1

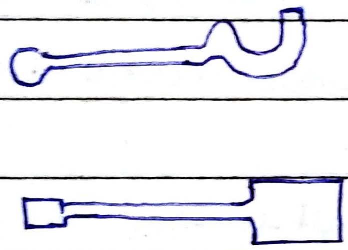
②  Fullering (dec in X-sec. Area)
+ Edging

③  Fullering – 3 stages

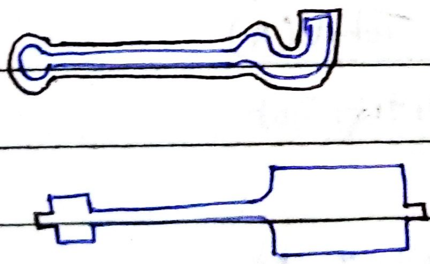
Design of preform -

Steps involved :-

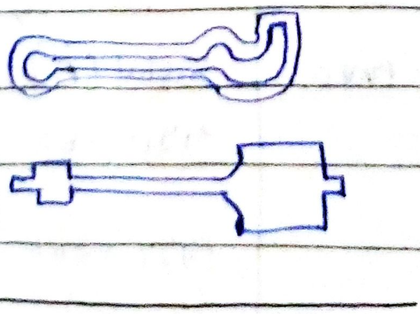
1) Layout plan, elevation & sectional views on a suitable scale.



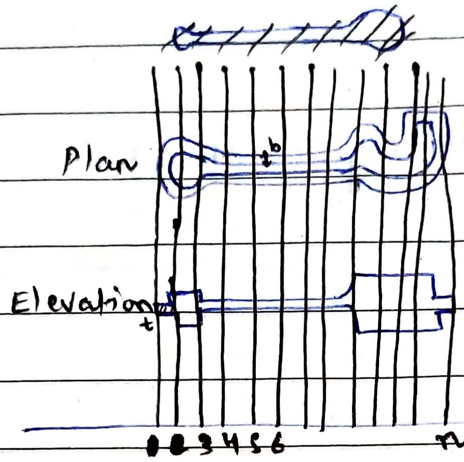
2) Draw flash dimensions on above views



3) Take a horizontal base line



4) Project vertical lines / sections / passing through above views



x (flash width b)

y (flash thick t)

Area $= xy$

$x_6 y_6$

$x_9 y_9$

(Req. area of flash $= 2b \cdot t$)

5) Measure dimension cut on plan (x) & elevation (y)

6) Multiply $x \cdot y$ $\Rightarrow$ Area of cross section at this section

7) Flash Area $= 2b \cdot t$ $\rightarrow$ for all sections

8) Find total area at each section

Area

At 9 $\Rightarrow$ $x_9 y_9 + 2bt$

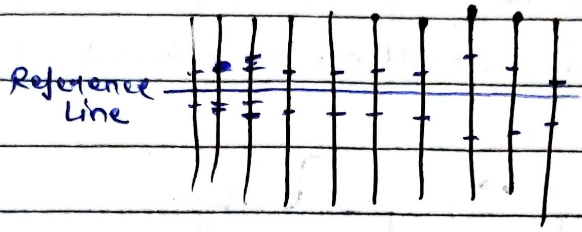
At 6 $\Rightarrow$ $x_6 y_6 + 2bt$

Section	Area	Flash Area	Total (A)
1	$x_1 y_1$	$2bt$	$x_1 y_1 + 2bt$
⋮			
9	$x_9 y_9$	$2bt$	$x_9 y_9 + 2bt$
⋮			

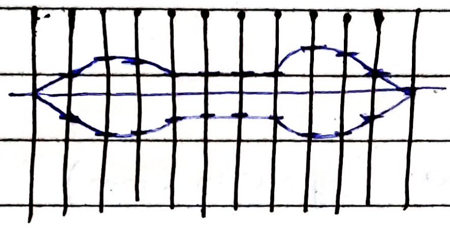
9) Find equivalent diameter for all sections $\rightarrow \frac{\pi}{4} d^2$

Section	Area	Flash Area	Total (A)	Equivalent diameter
1	$x_1 y_1$	$2bt$	$x_1 y_1 + 2bt$	d_1
⋮				⋮
9	$x_9 y_9$	$2bt$	$x_9 y_9 + 2bt$	d_9
⋮				

10) Mark $\frac{1}{2}$ diameter above and below a reference line for each section.



11) Join all marked points with smooth curve



12) This gives preform shape.

Blocker Design Consideration

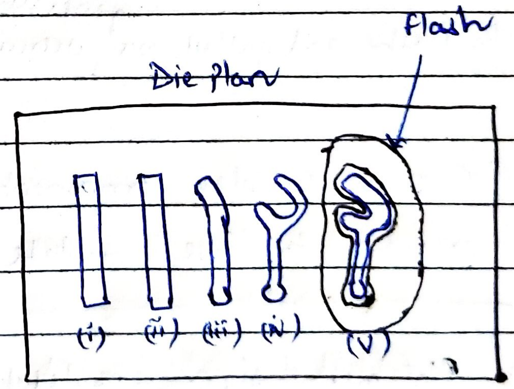
Blocker - just before finisher

Objective of Blocker (Benefits) - It reduces severe deformation

- It increases die life of finisher

- It helps in ensuring complete die filling.

(i) Fuller
(ii) Edger
(iii) Bender
(iv) Blocker
(v) Finisher



- By use of Blocker; yield is improved.

Yield = $\frac{\text{Output}}{\text{Input}}$

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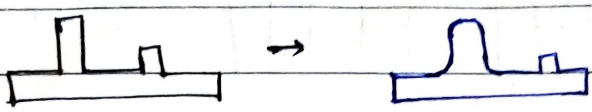
Note: R, M ↓ reduced to 50% by use

Blocker design Considerations :-

- Volume of Blocker is more as compared to finisher.
- Rapid change in dimensions should not be allowed.



overlap defect

- Thinner section with larger surface area be avoided as it chills faster.
- Blocker width is narrow (by 0.5 to 1 mm).
- Blocker depth is more (by 1.5 to 0.5 mm)
- Draft angle remains similar.
- No flash and gutter are generally required in blocker.
- For more complex components, more than one blocker is provided to have complete filling.

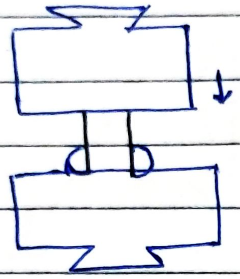
- Finisher design considerations :-

(Vice-versa of Blocker design consideration)

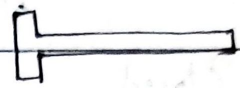
Flash and gutter are required in finisher.

Upsetting

- increase in area of cross-section



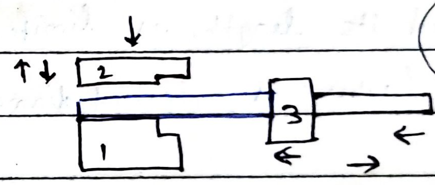
Rear Axle



Valve

How it works?

Upsetting Machine - Working

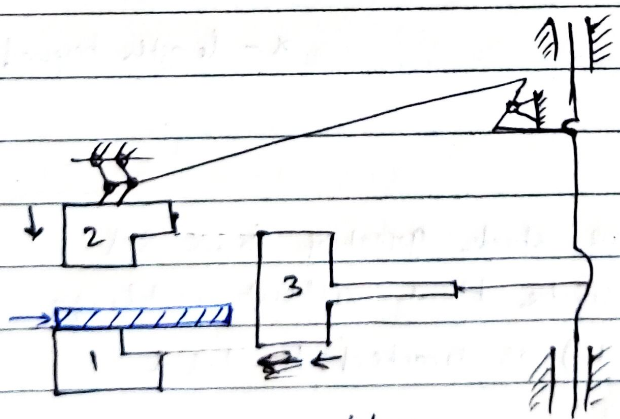


Double stroke

(1) & (2) are gripper dies

(2) & (3) are movable

die (1) is fixed

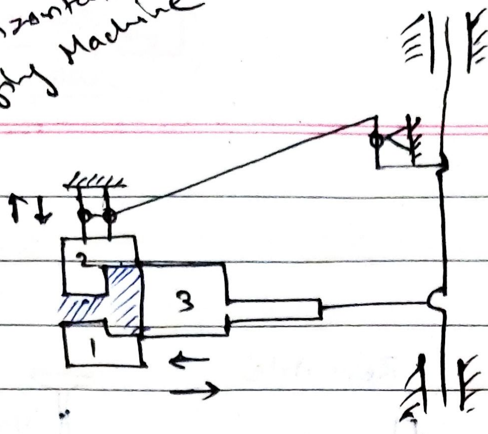


Open

Die Diagram

Line Diagram

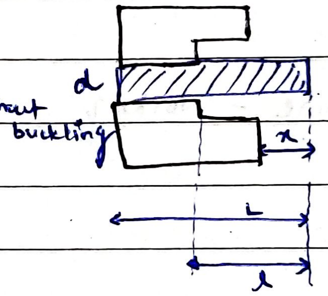
Horizontal Forging Machine



Closed

Upsetting Rule

1) Unsupported length of a bar stock may be upset in a single blow without buckling provided its length is limited to 3d (where d - initial diameter).



$$\frac{l}{d} = 3 \text{ (max.)}$$

L – Total length of bar stock

But in practice, $\frac{l}{d} = 2.5$ taken

l – length to be deformed

x – length beyond die face

2) Unsupported length of a bar stock greater than 3d may be upset in a single blow without buckling provided upset dia (d_1) is limited to 1.5d

If, $l > 3d$

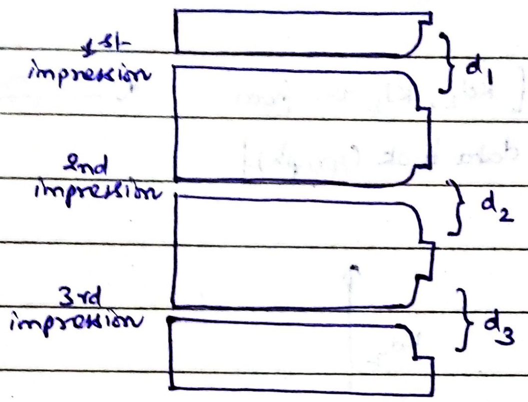
Then, $d_1 = 1.5d$ (max)

In practice, $d_1 = 1.3d$ taken

3) The above condition is possible only when length beyond die face is limited to d.

$$x = d$$

* **Coning Tool Method:**



$d_1 = 1.3d$

$d_2 = 1.3 d_1$

$= 1.3 \times 1.3d$

$= 1.69d$

$d_3 = 1.3 \times 1.7d$

$= 2.2d$

Benefits – ① fast gathering

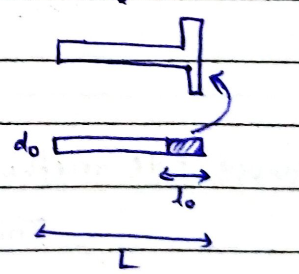
② Reduces no. of impressions

Steps:

1. Select a proper diameter of bar stock (d_o).

Calculate the volume to be gathered (drawing)

$$V = \frac{\pi}{4} d_o^2 \cdot l_o$$



• Check $\frac{l_o}{d_o}$ ratio

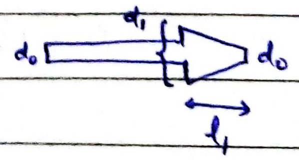
If $\frac{l_o}{d_o} < 3$, there is no need for cone design

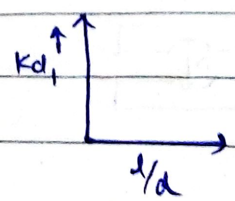
$\frac{l_o}{d_o} > 3$, then design 1st cone.

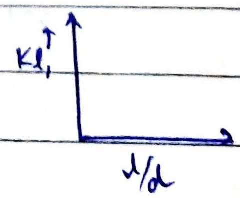
$d_1 = kd_1 * d_o$

$l_1 = kl_1 * d_o$

[Value of kd_1, kl_1 are from data book (graph)]







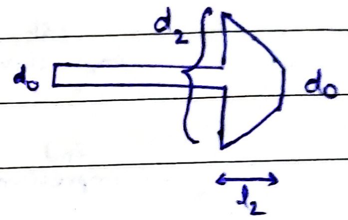
- Check $\dfrac{l_1}{\left(\frac{d_1+d_0}{2}\right)} \le 3$, there is no need for 2nd cone

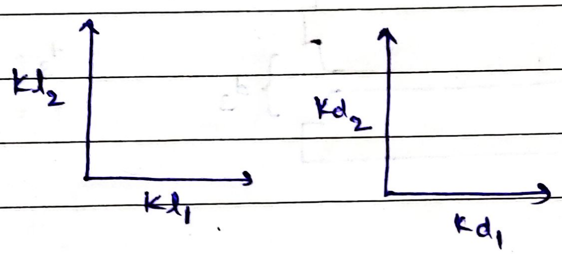
$\dfrac{l_2}{\left(\frac{d_1+d_0}{2}\right)} > 3$, then design 2nd cone.

$d_2 = Kd_2 \times d_0$

$l_2 = Kl_2 \times d_0$

[Kd_2, Kl_2 are from data book (graph)]





- check $\dfrac{l_2}{\left(\frac{d_2+d_0}{2}\right)} \le 3$, no need for 3rd cone (no. of stages – 3)

> 3, design 3rd cone

Square hole method

Initial bar stock dia $= d$

side of square $s = 1.5d$

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

$D = 1.5 \times 1.4 \times 1.5d$