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PRODUCTION TECHNOLOGY

1. EXTRUSION PROCESS
2. ROLLING PROCESS
3. DRAWING PROCESS

EXTRUSION

Forming Concept

It is a Manufacturing process in which the force are applied on the Raw material such that the stress induced in the Material is greater than yeild point stress but below the ultimate stress. After the Material is subjected to plastic deformation.

Advantages

Less wastage, Grain orientation is possible, Material becomes anistropic, strength and hardness increases

dis-advantage

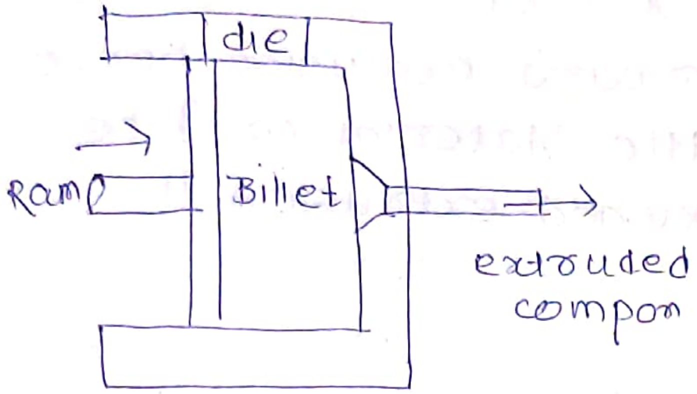
Force and energy Required is very large expect Forging all the operations are used for uniform crossection only.

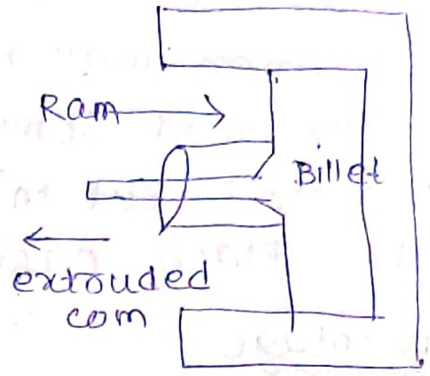
Extrusion

It is the extension of wire drawing operation for reducing the cross-sectional from A_0 to A_1. The Reduction in Area can be obtained by applying a back side Force called extrusion process.

1) BCZ of compressive force it is not neccary to maintain the load for all time
2) due to compressive forces it behaves as fluid
3) Any amount of deformation can be produce

Forward vs Backward extrusion





In the extrusion process the force are applied in the raw material by using a ram in the rigid container such that the stress induced in the Material is greater than or equal to Flow stress due to this it behaves as Fluid and the Material began to Flow through the small opening.

In the Forward extrusion the direction of movement of the Ram and the extruded component will be in the same direction whereas in the backward extrusion the direction of Ram travel and extruded component is oppsite to each other.

higher Friction Result in Forward extrusio But in the backward extrusion the Raw material can directly deform and Flow throu the die to change the shape of the componen Hence the Force Required in Foward extrusion is greater than backward extru

design and manufacturing of Ram and die is eaiser in Forward extrusion where as it is diffcult in backward extrusion.

Due to the presence of friction at the container wall in forward extrusion hence brittle and semi-brittle material can't be machined. But in backward extrusion it takes place easily.

Advantage

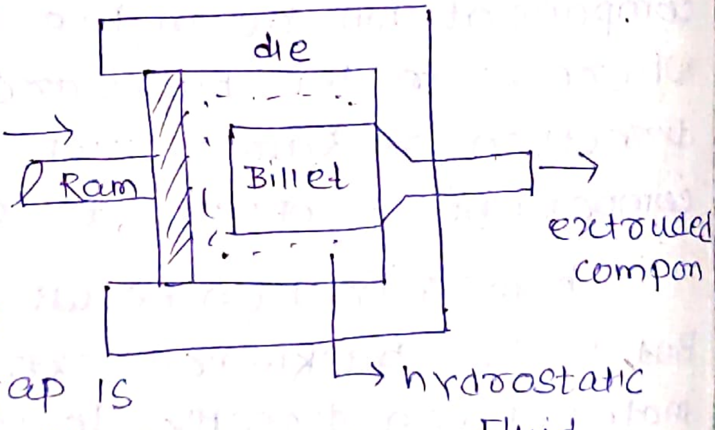
A 25 to 30% Reduction in friction which allows for extruding larger billet, incresed speed, very less chance of cracks, container lining last very long due to no wear

Dis-advantage

Impurities and defects on the surface of the billet affect the surface of the extrusion. To remove it billet may be cleaned, brushed.

Hydrostatic Extrusion

Similar to forward extrusion. size of raw material is less than the size of the container and the gap is filled by hydrostatic fluid.



Now the force applied on the raw material is incresed and uniformly distibuted which is greater than flow stress. bcz of the use of hydrostatic fluid there is no friction. Hence it can be used for all brittle, semi-brittle materials.

Fluid used → Room temp → SAE, glycerin, vegatable

elevated temp → wax, polymer, liquid glass here billet is completely surronded by pressurized liquid expect where it contain die. This process can be used in hot, cold, warm condition. process must be carried out in a sealed cylinder.

constant Rate → Ram/ plunger is used
" pressure → pump is used

Advantages

NO Friction so incresed speed, ductility of Materials increase, even Flow of Metal, NO billet Residue left

dis-advantage

containing Fluid at high pressure is difficult. The billet must be prepared by tapering one side to match die-entry angle.

Impact Extrusion.

It is used to produce thin wall tubes From the solid rods which are very soft Materal using impact load. It is used For producing thin tubes like tooth paste, cosmetic tubes etc.

Stress calculation

$$\sigma_o = \sigma_Y\left(\frac{1+B}{B}\right)\left[1-\left(\frac{A_1}{A_o}\right)^B\right]$$

σ_o ↓ extrusion stress

$B = \mu \cot\alpha$

α = half die angle

extrusion Ratio $= \frac{A_o}{A_1}$

$(E.F)_{Back} = \sigma_o \times A_o$

$(E.F)_{Forward} = (\sigma_o + P_f) \times A_o$

P_f = pressure Required

$$(E.F)_{Min} = \sigma_Y \times A_0$$

$\eta = 0.4$ to 0.5 (F)

$\eta = 0.5$ to 0.6 (B)

$B = 0$

$$(E.F)_{actual} = \frac{(E.F)_{min}}{\eta_{extrusion}}$$

$$\text{The Extrusion Force} = K \cdot A_0 \ln \frac{A_0}{A_1}$$

$$= A_0 \cdot \sigma_Y \ln \frac{A_0}{A_1}$$

(volume before extrusion) = volume After extrusion

$$A_0 \times L_0 = A_1 \times L_1$$

$$\Rightarrow \frac{A_0}{A_1} = \frac{V_1}{V_0}$$

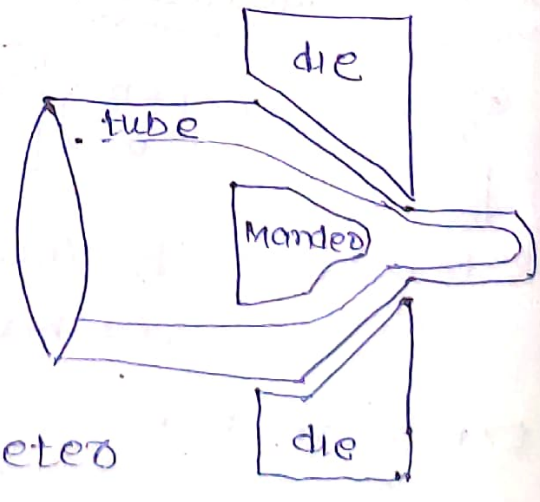
xxx

Tube Drawing

It is a method of reducing wall thickness of already existing tubes by pulling through a stationary die with manderal so that the inside of the tube is Remains same or varying.

Same die as wire drawing and additonaly a manderal is used.

Types of Mandrel



cylindrical → If there is no need of changing the inside diameter of the tube.

conical → If the inside diameter is to be changed.

Classification

Stationary → It is fixed in the tube drawing operation. Frictional forces are acting inside and outside the surface.

$$B = \frac{\mu_1 + \mu_2}{\tan\alpha - \tan\gamma}$$

cylindrical $\gamma = 0$
α = half die
γ = half conical

Movable → It will move in the forward direction along the velocity of the tube. Hence inside friction is zero.

$$B = \frac{\mu_1}{\tan\alpha}$$

Floating → It is moving both in forward as well as backward direction inside the tube. The frictional forces will be in oppsite direction

$$B = \frac{\mu_1 - \mu_2}{\tan\alpha}$$

Drawing stress

$$\sigma_2 = \sigma_r \left[\frac{1+B}{B}\right]\left[1 - \left(\frac{h_1}{h_0}\right)^B\right]$$

$$B = \frac{\mu_1 \pm \mu_2}{\tan\alpha - \tan\gamma}$$

μ_1 = outside surface
μ_2 = inside "

If $\mu_1 = \mu_2$ then floating manderal if used

$B = 0$ $\quad \sigma_2 = 0/0$

we apply L hospital's Rule

$$\sigma_2 = \sigma_r \log_e\left(\frac{h_0}{h_1}\right)$$

For maximum Reduction $\sigma_2 = \sigma_r$

$$\frac{\sigma_2}{\sigma_r} = 1 \Rightarrow \left[\frac{1+B}{B}\right]\left[1 - \left(\frac{h_1}{h_0}\right)^B\right] = 1$$

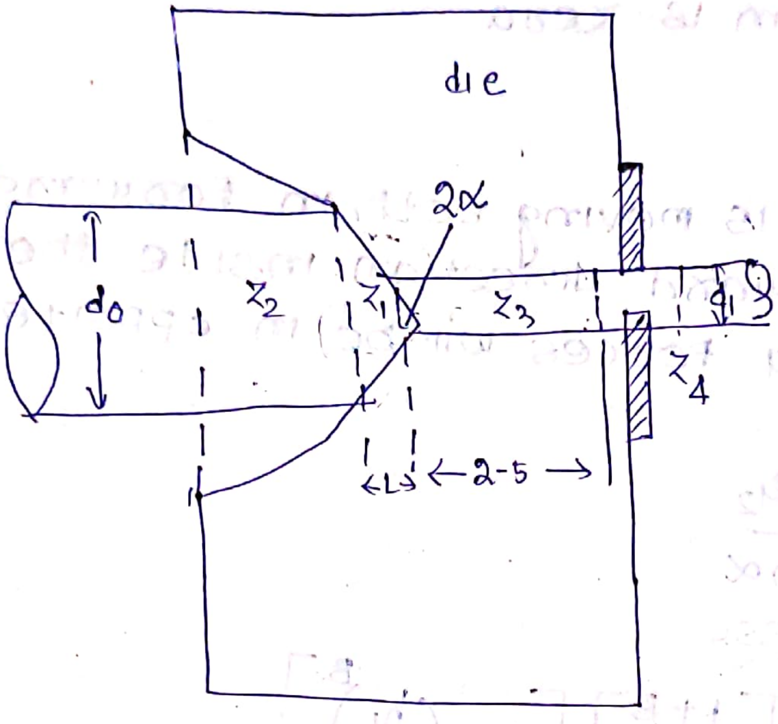
Limitation

(1) As tensile load applied it takes some time to convert E.D to P.D

(2) Reduction possiblity is limited.

(3) To overcome we also use compressive force

Wire Drawing



It is a cold working process in which thin wires can be drawn from solid rods by pulling through stationary die.

d_0 = rod diameter d_1 = wire diameter

Zone-1 (deformation)

whatever the deformation that only occours in the zone-1 so it is called deformation zone.

2α = die angle (12 to 48) hard = 12°

L = Length of deformation Light = 48°

due to the presence of friction of die and the surface of the rods, Frictional force is acting in the backward direction.

Zone-2 (Entry / lubricating)

To minimise the frictional force of the zone-1 lubricating must be supplied so it is called.

Black/burnt colour → No lubrication.
Liquid lubricant → mettalic colour
solid powder → shining/silvery surfac
(powder, glass powder, graphaite)

Liquid Lubricant → (kerosine, mineral, vegetable).

Zone-3 (sizing zone)

constant crossectional Area. conversion of elastic to plastic deformation

Zone-4 (exit zone)

It is also called safety zone used for safeguarding the equipment and manpower from damages due to high pressure and high temperature lubricant

Drawing stress $\sigma_2 = \sigma_y \left(\frac{1+B}{B}\right)\left[\left(1-\left(\frac{A_1}{A_0}\right)^B\right)\right]$

$A_0 = \frac{\pi}{4} d_0^2$ $B = \mu \cot \alpha$

$\alpha = \frac{1}{2}$ die

$A_1 = \frac{\pi}{4} d_1^2$

$K = \frac{A_0}{A_1}$ (draft)   Drawing load $= \sigma_2 \times A_1$

The above σ_2 value is not taken by considering the backward frictional force.

If we consider the horizintal frictional force in the backward direction. is called total drawing stress (σ_t)

$\sigma_t = \sigma_y + (\sigma_2 - \sigma_y) \cdot e^{\frac{-2\mu L}{R_1}}$ R_1 = radius of wire

For Maximum Reduction $\sigma_2 = \sigma_Y$

$\Rightarrow \frac{\sigma_2}{\sigma_Y} = 1$ But $\frac{\sigma_2}{\sigma_Y} = \left(\frac{1+B}{B}\right)\left(1-\left(\frac{A_1}{A_0}\right)^B\right)$

$\therefore \left(\frac{1+B}{B}\right)\left[\left(1-\left(\frac{A_1}{A_0}\right)^B\right)\right] = 1$

For Ideal condition $\mu = 0 \Rightarrow B = 0$

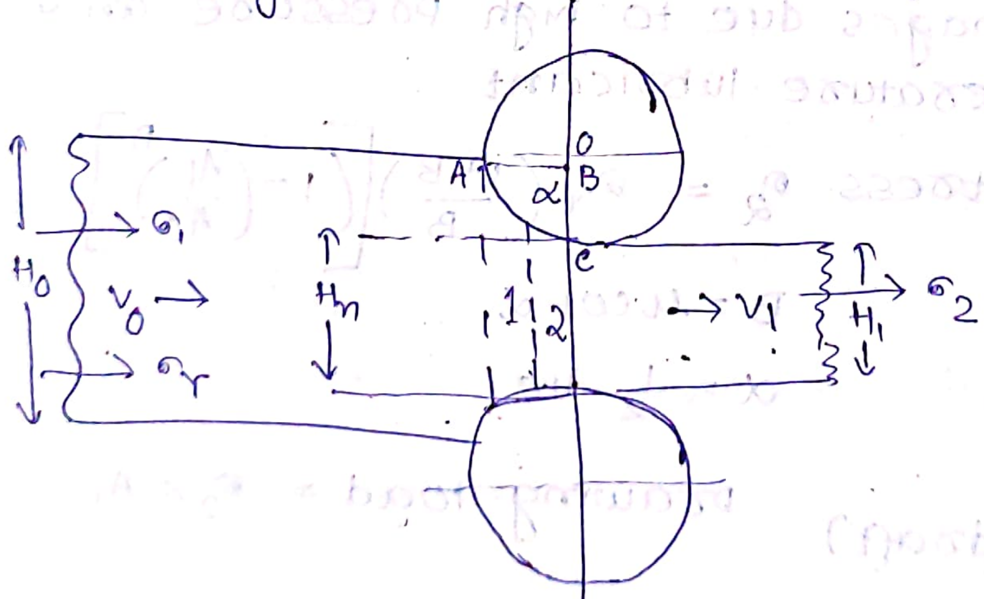
$$\sigma_2 = \sigma_Y \ln\left(\frac{A_0}{A_1}\right)$$

% Reduction in Area = $\frac{A_0 - A_1}{A_0}$

x—x—x

ROLLING

Rolling is a process in which the material is in compression between two rotateing roller such that the thickness of the material is reducing from H_0 to H_1.



1 - Lagging zone H_0 = Intial thickness

2 - Leading zone H_1 = Final thickness

H_n = thickness at Neutral point

V_0 = Intial velocity V_1 = Final velocity

$V_{top\ roller} = V_{bottom\ roller}$

$$\left(\frac{\pi D N}{60}\right)_{top} = \left(\frac{\pi D N}{60}\right)_{bottom} \qquad D_t N_t = D_b N_b$$

to ensure contact Area the diameter of both the rollers are same.

V = Surface velocity R = Radius of Roller

ΔH = Reduction in thickness $(H_0 - H_1)$

B_0, B_1 = width of strip before and after

$\mu = \tan\beta$ β = Friction angle

Assumption

every Material in Forming is considered to be in-compressible. $(\nabla V) = 0$

$H_0 B_0 V_0 = H_1 B_1 V_1 \Rightarrow V_1 > V_0$

in this operation the strip is always pulled into the rollers bcz of the presence of friction between the Rollers and strip. Along the deformation zone the velocity of strip is continously increasing but the surface velocity remains constant. Beyond the Neutral point the velocity of the strip further increases and becomes greater than surface velocity.

α = deformation angle / bite angle

It is the angle made by the deformation zone w.r.to the centre of the rollers.

$$\cos\alpha = \frac{OB}{OA} = \frac{OC - BC}{OA}$$

$$R\cos\alpha = R - \frac{\Delta H}{2}$$

$$\tan\alpha = \sqrt{\frac{\Delta H}{R}} \Rightarrow \alpha = \tan^{-1}\left(\sqrt{\frac{\Delta H}{R}}\right)$$

In a given rolling the $\alpha_{max} \leq \alpha_F$). as the Bite angle increases, the Reduction in thickness of the strip $\Delta H \rightarrow \Delta H_{max}$

If $\alpha = \beta = \alpha_{max}$ $\boxed{\Delta H_{max} = \mu^2 \times R}$

The Neutral point is divide the zone into two parts. The zone between entry and Neutral point is called lagging zone. The zone between Neutral point and exit is called leading zone. At the entry the velocity of the strip is much less than velocity of Roller when we move towards deformation zone because of increase in velocity of the strip their Relative velocity reduces. At the Neutral Point it becomes zero. Beyond the Neutral Point the Relative velocity increases but in oppsite direction and Maximum at exit. So in the deformation zone the Relative velocity reducing first and then increases, but in the lagging zone velocity is reduced and leading zone it increases,

As (slip α Relative velocity)

maximum slip occours in lagging (backward sli
Maximum slip " in leading (Forward slip

Backward $= \frac{V - V_0}{V}$ Forward $= \frac{V_1 - V}{V}$

Pressure is inversly proportional to the slip. In the deformation zone pressure is increasing first and then decreases.

whereas in the lagging zone pressure is decreasing. Let $\eta = \frac{2\mu L}{\Delta H}$

$$(P_x)_{lagging} = \left(\frac{\sigma_r}{n}\right)\left[(n-1)\left(\frac{H_0}{H_x}\right)^n + 1\right] - \left(\frac{H_0}{H_x}\right)^n \sigma_1$$

σ_1 = back tension H_x = thickness in lagging

$$(P_x)_{leading} = \left(\frac{\sigma_r}{n}\right)\left[(n+1)\left[\left(\frac{H_0}{H_x}\right)^n - 1\right]\right] - \left(\frac{H_x}{H_1}\right)^n \sigma_2$$

At Neutral point $(P_n)_{lagg} = (P_n)_{leading}$

$$= \left(\frac{\sigma_r}{n}\right)\left[n-1)\left[\frac{H_n}{H_1}\right]^n - 1\right]$$

Peak pressure is located at the Neutral point.

Friction in Rolling

It depends upon lubrication, work-material and also on temperature. In the cold rolling the $\mu = 0.1$ and warm rolling $\mu = 0.2$ and hot rolling $\mu = 0.4$.

Power Calculation

$P = T \times \omega$ as two rollers

$= 2T\omega$

Torque $= F_{avg} \times R$

$= F_{avg} \times a$ a = arm $= \lambda \times L$

$= F_{avg} \times \lambda \times L$ λ = arm factor $= 0.3$ to 0.4

L = Length of deformation $= \sqrt{R \Delta H}$

$F_{avg} = P_{avg} \times A = P_{avg} \times (b \times L)$

F_{avg} = RSF (Roll separating Force)

$F_{avg} = R.S.F = \frac{2}{\sqrt{3}} \sigma_r \left(1 + \frac{\mu L}{4H}\right)$

where $(H) = \frac{H_0 + H_1}{2}$

∴ The P_{avg} can be decresed by reducing the Maximum pressure which is a Function of contact length. smaller contact length less Friction. so we have to Reduce roll diameter and smaller rollers are used but the smaller rollers are unable to withstand the RSF so back rollers are also Provided. due to increase in Friction also increases the roll separating Force.

Effect of RSF on Rollers

the rolling strips are not uniForm. thickness to make it uniForm we have to use convex Roller. During the rolling operation the R.S.F acting on the Material side the Rollers are deform elastically and becomes straight so that the thickness of the strip in the width direction is uniForm

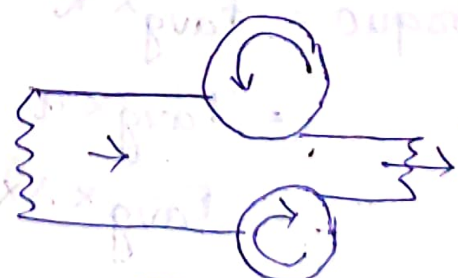
Types of Rolling Mills

1) 2-high Rolling Mills

two rollers

direction are oppsite

Single Reduction



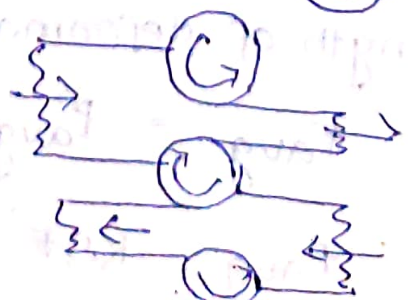
2) 3-high Rolling Mills

3 Rollers

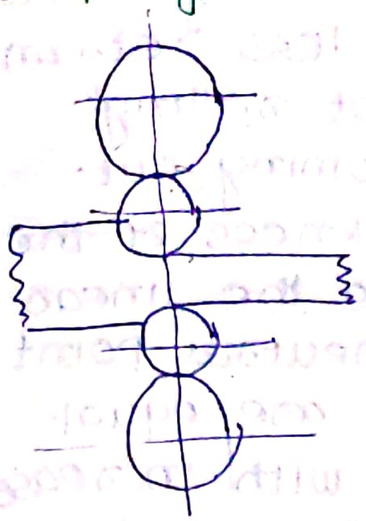
2 Reduction

1, 3 → same

2 → oppsite

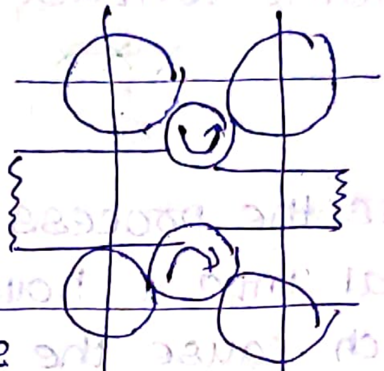


3) 4 high rolling mills →



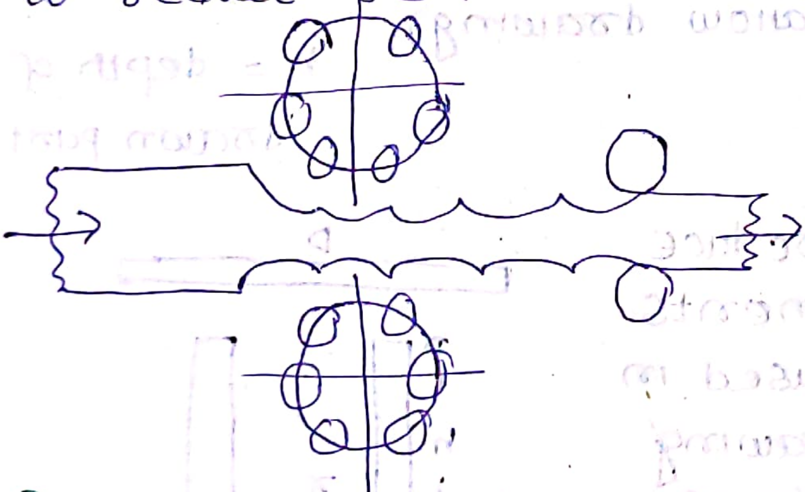
supporting rollers are used to avoid the Failure centere of all rollers lies on a single vertical line.

4) cluster Millers →



5) Planetary rolling Miles →

to Reduce the RSF we have to reduce the radius of the rollers upto a minimum value among all the process this is the best metho to reduce R.S.F.



Points on Rolling

It is the most extensively used Metal Forming process. by means of friction Material are inserted in the gap. The compres. Force applied to the material reduces the thickness of strip. The gemotry of the product depend upon the roll gap. Roll Mater are cast iron, cast steel because of high strength and wear resistance. in the rolling

the crystal get elongated in the rolling direc
in cold rolling crystal more or less retain
the elongated shape but in hot rolling
they start reforming after coming out.
in the deformation zone the thickness of the
strip gets elongated this increase the linear
speed at exit. There exist a neutral point
where roll speed and strip speed are equal.
Roll torque, power etc increases with increase
in roll work contact length or roll radius.

×××

Drawing

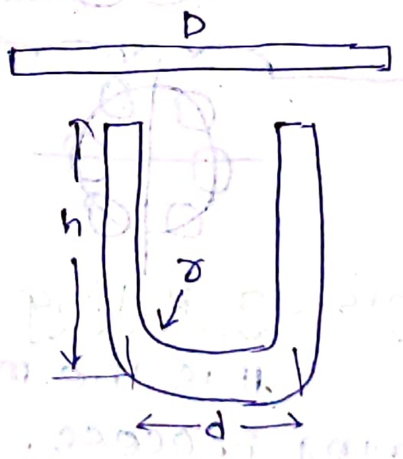
It is the process of forming a flat piece of material into a hollow shape by means of punch which cause the blank to flow into the die cavity.

If $\frac{h}{d} \geq 0.5$ (deep drawing)   d = diameter of blank

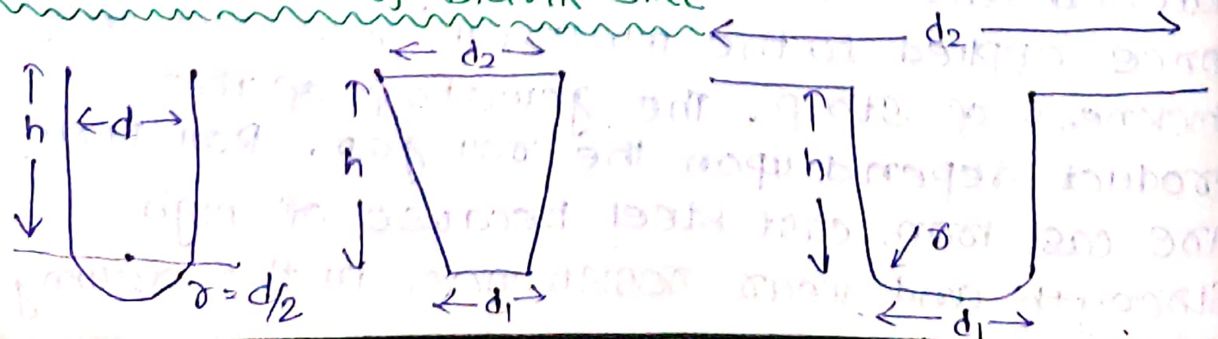
$\frac{h}{d} < 0.5$ (shallow drawing)   h = depth of drawn part

Deep Drawing

It is used to produce cup-shaped components only like utensil used in kitchen. In deep drawing operation, the clearance between punch & die is equal to sheet thickness.



Determination of blank size



r = corner radius of cup used to avoid

$\frac{d}{r} > 20$

when corner radius is neglisible one side surface Area of component will be made equal in one side of surface of blank

if $\frac{\pi}{4} D^2 = \frac{\pi}{4} d^2 + \pi d h$

so $D = \sqrt{d^2 + 4dh}$ if $\frac{d}{r} \geq 20$

$D = \sqrt{d^2 + 4dh} - \frac{r}{2}$ if $\frac{d}{r} = 15$ to 20

$D = \sqrt{d^2 + 4dh} - r$ if $\frac{d}{r} = 10$ to 15

If in case $\frac{d}{r} < 10$ then total surface Area of the component must be equal to the total surface of blank

$\frac{\pi}{4} D^2 = \pi d_1 h + \frac{\pi}{4} d_1^2 + \frac{\pi}{4} [d_2 - d_1]^2$

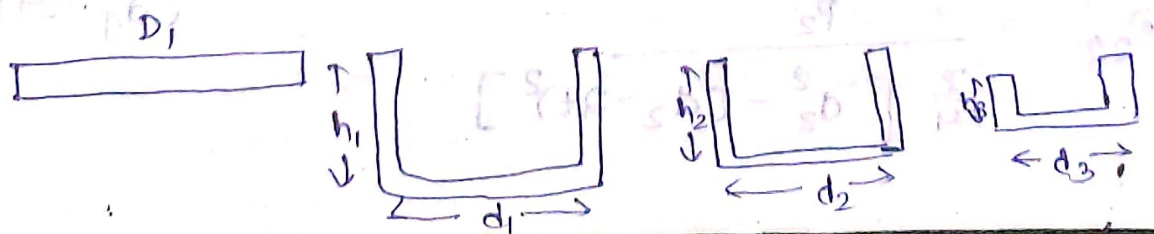
so $D = \sqrt{d_2^2 + 4d_1 h}$ if $\frac{d_1}{r} \geq 20$

$D = \sqrt{d_2^2 + 4d_1 h} - \frac{r}{2}$ if $\frac{d_1}{r} = 15$ to 20

$D = \sqrt{d_2^2 + 4d_1 h} - r$ if $\frac{d_1}{r} = 10$ to 15

and $D = \sqrt{2d^2 + 4dh}$

In this operation also punch and die combination can be used for producing cup shaped component. It is preferable to perform the drawing operation in more than one stages. In each step the combination of punch & die are different.



Load estimation

$$P = \pi d \sigma_y \left(\frac{D}{d} - C\right) \quad \text{(Drawing Force)}$$

$$P_1 = \pi d_1 t \sigma_y \left(\frac{D}{d_1} - C\right)$$

$$P_2 = \pi d_2 t \sigma_y \left(\frac{d_1}{d_2} - C\right) \qquad (C = 0.6 \text{ to } 0.7)$$

$$P_3 = \pi d_3 t \sigma_y \left(\frac{d_2}{d_3} - C\right)$$

D = diameter of blank t = thickness of blank

work done = Force × distance

$$(W.D)_1 = P_1 \times h_1$$

$$(W.D)_2 = P_2 \times (h_2 - h_1)$$

$$(W.D)_3 = P_3 \times (h_3 - h_2)$$

Application of BHF

Spring loaded stripper plate is used for applying BHF in deep drawing operation. The BHF applied by using the spring loaded stripper plate is continued to maintain until the punch is completely withdrawn. The tensile stress induced here is responsible for changing the shape of the component. The stress induced in the deformation zone is greater than yeild point stress but below the ultimate stress.

$$\sigma_{21} = \frac{P_1}{\frac{\pi}{4}\left[d_1^2 - (d_1 - 2t)^2\right]}$$

$$\sigma_{22} = \frac{P_2}{\frac{\pi}{4}\left[d_2^2 - (d_2 - 2t)^2\right]}$$

$$\sigma_{24} = \frac{P_4}{\frac{\pi}{4}\left[d_4^2 - (d_4 - 2t)^2\right]}$$

Draw Ratio

$$D.R = \frac{D}{d} = \frac{\text{diameter of blank}}{\text{diameter of cup component}}$$

This Ratio depend upon many Factor like type of material, amount of friction (1.6 - 2.3) venting is provided to eliminate suction

Draw Ratio Method

(1) Draw Ratio → $D.R = \frac{\text{diameter before}}{\text{Diameter after}}$

$$D.R_1 = \frac{D}{d_1} \qquad D.R_2 = \frac{d_1}{d_2} \qquad D.R_3 = \frac{d_2}{d_3}$$

$$L.D.R = DR_1 = DR_2 = DR_3 = (1.6 - 2.3)$$

(2) Draw Reduction Ratio →

$$D.R.R = \frac{\text{diameter Reduced}}{\text{diameter before}}$$

$$D.R.R_1 = \frac{D - d_1}{D}, \qquad D.R.R_2 = \frac{d_1 - d_2}{d_1}$$

$$D.R.R_3 = \frac{d_2 - d_3}{d_2}$$

Defects in drawing

1) wrinkling → producing wrinkles or foldings in a deep drawing process. It is eliminated by. (I) providing blank holder Force

(II) By using drawbed

(III) the clearance betn the punch and die is slightly less than thickness. due to squezing wrinkles are Removed is called ironing effect

2) Earing → The edge wrinkles or foldings present at the edges of deep drawing compon is called earing. It can be easily eliminated by using drawbed.

Draw bed

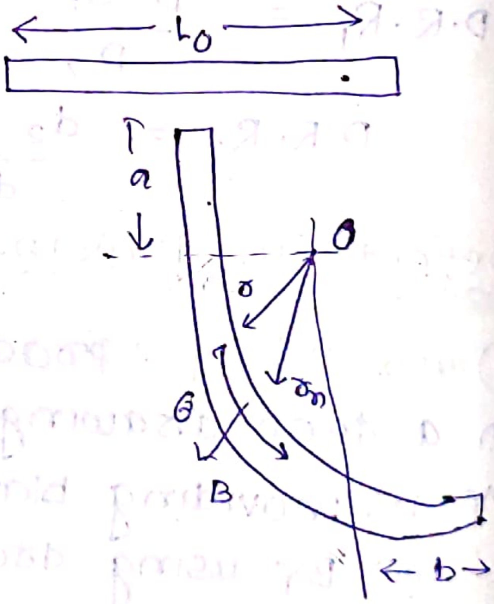
by using it the sheet metal are experiencing diff types of deformation at different location which makes the Material isotropic.

wrinkling defect is eliminated totally
Earing defect is minimized.
Drawing Force increases
bcz the Earing defect is not completely eliminated it can be removed by trimming

$D_{blank} = D + 2 \times$ Trimming Allowance

Bending

It is also a forming operation in which the plastic deformation produced in the sheet will be used for changing the shape of the component. ex → drawing board clip, tubelight Frame



$L_0 = a + b + B$

$B = r_n \times \theta$ bend allowance

r = inside radius

r_n = Neutral Plane radius

$r_n = r + kt$

k = bend Factor $(1/3)$ $r < 2t$

$(1/2)$ $r \geq 2t$

Bending Force

$$F_B = \frac{C b t^2 \sigma_y}{w}$$

C = die opening Factor
$= 1.2t$ if $w = 16t$
$w = 8t/16t$ $= 1.33t$ if $w = 8t$

Spring back

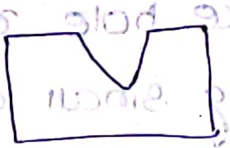
In bending after the bending Force is removed the material tries to regain it's original shape causing decrease in the bend angle such a movement is called spring back phenomenon. It is caused due to the elastic stress Remaining in the bend Area. It is depend upon the Factor like Material, thickness, hardness, Bend Radius. A larger bend radius causes greater springback

Overcome →

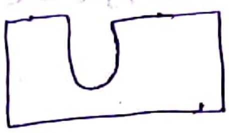
I) over bending to Reduce
II) By squezing at the corner of Material

Methods of Bending

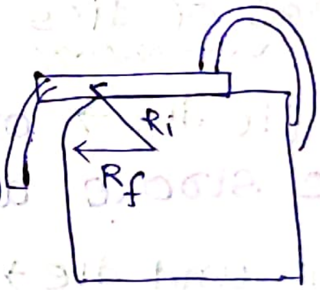
V- Bending →



U Bending →



Edge bending →
↓
Smallest Force (lever effect)



U bending → largest Force

If $\frac{R_f}{R_i} = 1$ S. Back. F = 0

$\frac{R_f}{R_i} > 1$ S. Back. F increases

$$\frac{R_f}{R_i} = 4\left(\frac{R_i \sigma_r}{E.t}\right)^3 - \left(\frac{R_i \sigma_r}{E.t}\right) + 1$$

R_i = initial   E = Young's Modulus

R_f = final R_{min} = minimum radius to which sheet can be bend

$R_{min} = t\left(\frac{50}{a} - 1\right)$ a = % Reduction in Area

a = 50% soft material like Al, Cu,

$R_{min} = t\left(\frac{50}{50} - 1\right) = 0$

they can bent to zero radius without producing any cracks.

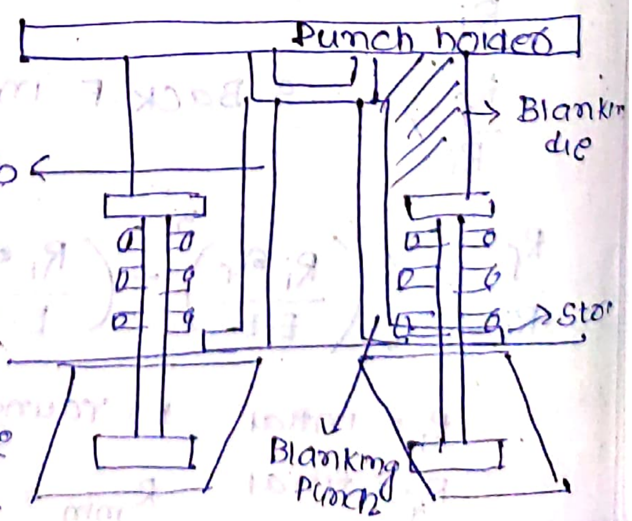
Minor Operation

Perforating → smaller size holes in sheet
Notching → Removing a piece of Material
Lancing → incomplite blank / hole at centre
Slitting → " " " at the edge
Nibbing → large size hole repetative times
Trimming → Removing small amount of Material form complete circumference

Types of dies

Simple die → only operation performed in one stroke at one stage is called simple die

Compound die → two or more cutting operation is performed at one station and at one stroke ex is washer.



Limitation

Both the methods can't be used hence the Force Requred is higher. It is diff to design the Punch & die which produce more than 3 operations.

Progressive die

here also more than one cutting operation can be performed in single stage but in dif stages and blanking will be the last operation. (same production rate)
Manufacturing is easy)

Balancing of force on punch head is diffcult.

Transfer die

more than one cutting operation at single or different stage but blanking will be first operation and afterwards it goes from one stage to another.

combination die

If more than one cutting and forming operations are performed in one stroke at one stage is called combination die.
ex → blanking combined with deep drawing

Multiple Die

to produce more than one component per stroke more than one die are kept in parallel. ex → to produce 10 washers per stroke than 10 compound die are kept.

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