

stress: the amount of applied load per unit area

$$\sigma = \frac{F}{A}$$

unit: $\text{MPa} = 10^6 \frac{\text{N}}{\text{m}^2} = 1 \frac{\text{N}}{\text{mm}^2}$

engineering (nominal) stress

$$\sigma = \frac{P}{A_0}$$

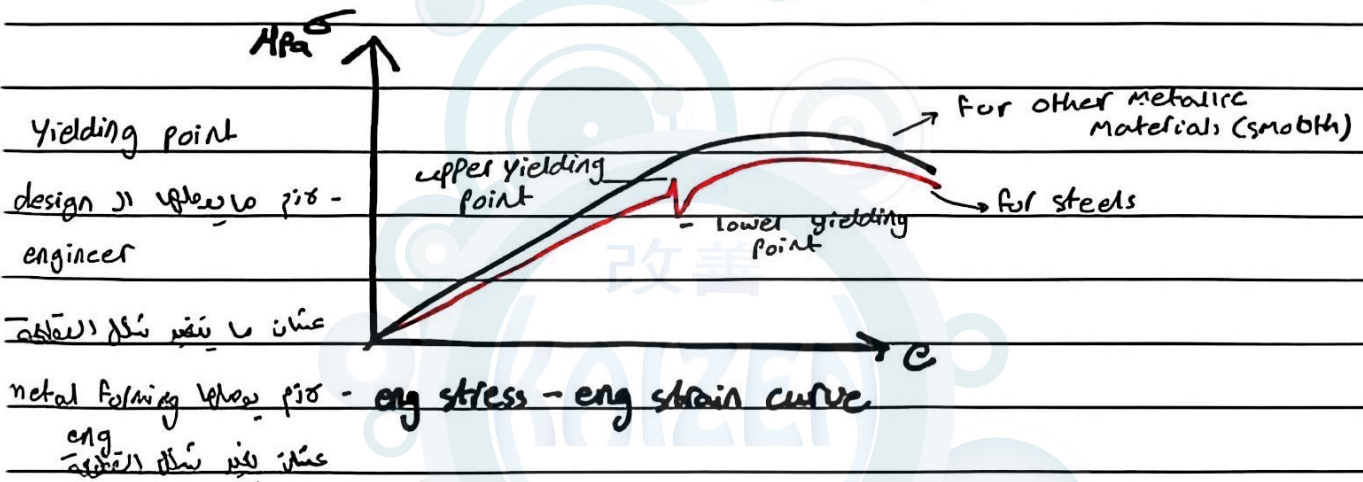
A_0 initial cross sectional area m^2

strain: relative change in dimensions

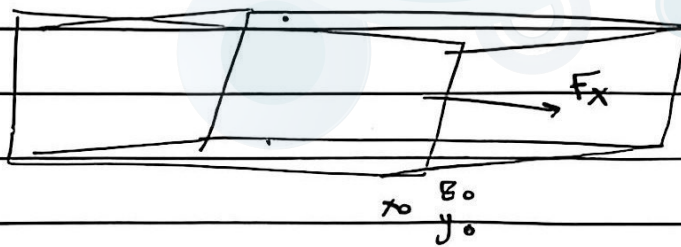
$$\frac{\Delta L}{L} \rightarrow \text{unitless}$$

engineering (nominal) strain

$$e = \frac{\Delta L}{L_0} = \frac{L_f - L_0}{L_0}$$



Poisson's ratio: the ratio of lateral strains (e_y & e_z) to longitudinal strain (e_x)



$$e_x = \frac{\Delta x}{x_0}$$

$$e_z = -\nu e_x$$

$$e_y = -\nu e_x$$

$$\nu = (0.2 - 0.35)$$

in elastic range $\rightarrow$ volume changes

$$\epsilon_z = \epsilon_y = -\nu \epsilon_x$$

example: $x_0 = 100 \text{ mm}$ $y_0 = 20 \text{ mm}$ $z_0 = 50 \text{ mm}$

$$x_f = 101 \text{ mm} \quad \nu = 0.3$$

what's the volume under loading?

Note: volume if released = V_{initial}

$\downarrow$
we calculate final (x_f, y_f, z_f)

$$= 100000 \text{ mm}^3$$

$$\epsilon_y = \epsilon_z = -\nu \epsilon_x$$

$$\epsilon_x = \frac{x_f - x_0}{x_0}, \quad \epsilon_x = 0.01$$

$$\epsilon_y = \epsilon_z = -0.003$$

$$\frac{y_f - y_0}{y_0} = -0.003 \quad y_f = 19.94 \text{ mm}$$

$$\frac{z_f - z_0}{z_0} = -0.003 \quad z_f = 49.85 \text{ mm}$$

$$V_f = x_f * y_f * z_f = 100394.909 \text{ mm}^3$$

initial volume is 100000, final volume is 100394.909

elastic region

modulus of resilience

MOR: energy per unit volume the material can absorb elastically -

$\downarrow$
MPa

'area under the curve of elastic region'

$$= \frac{1}{2} \epsilon_y \sigma_y$$

$$\sigma = E \epsilon$$

$$= \frac{1}{2} \frac{\sigma^2}{E} \approx \frac{\text{energy}}{\text{volume}}$$

manu lecture 4

UTS $\leadsto$ maximum stress $UTS = \frac{P_{max}}{A_0}$

up to UTS $\leadsto$ uniform elongation $L \uparrow$ $A \downarrow$

at UTS $\leadsto$ necking

$$\text{True stress} = \text{eng stress} = \frac{P}{A}$$

$$\text{True strain} = \ln \left| \frac{A_F}{A_0} \right| = \ln \left| \frac{L_F}{L_0} \right|$$

ductility: the ability of the material to deform plastically before fracture

$$EL\% = \frac{L_F - L_0}{L_0} \times 100\%$$

True until UTS as nonuniform elongation occurs

$$AR\% = \frac{A_F - A_0}{A_0} \times 100\%$$

A_F can't represent the average area

module lecture 5

* eng strain & true strain are almost the same in elastic range

↳ because the change in dimensions is relatively close

* True strain is the only thing valid in the plastic range

so, we will always use the true strain because its a better measure than the eng one.

True stress - True strain curve.

UTS is the point where the material starts to neck

Why? Force is just the same but the true area is decreasing as the material is necking

Mechanical behavior formula (equation)

$$\sigma = K\epsilon^n ; \text{MPa}$$

K: strength coefficient ; MPa

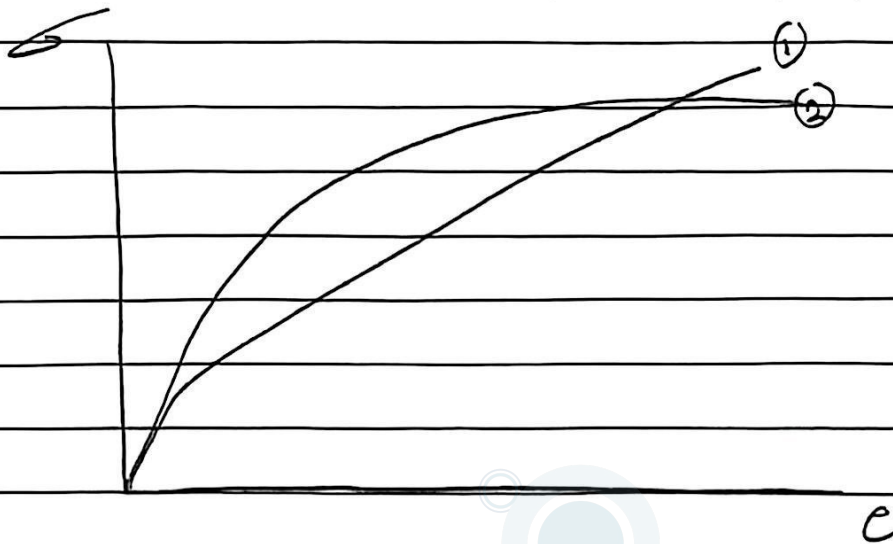
n: strain hardening index

Strain-Hardening: The increase in material's strength and/or hardness as a result of plastic strain (plastic deformation)



plastic deformation

strain hardening is the increase in strength and hardness due to plastic deformation



① low K , high n

② high K , low n

①

$$\sigma = K \epsilon^n$$

$$\log \sigma = \log K + n \log \epsilon$$

$$y = a + bx$$



اگر n و K معلوم شود

Table 2.2 سے

②

$$\sigma = K \epsilon^n$$

$$\text{if } \epsilon = 1$$

$$\sigma = K_1^n$$

$$K = \sigma \text{ when } \epsilon = 1$$

two ways to find K , but we will only use table 2.2

flow stress: the true stress required to continue plastic deformation

average: flow stress

toughness: the amount of energy per unit volume absorbed before fracture

(plastic & elastic isu)

elastic av. is MOR ←

curve is is toughness ←

area is isu
under
the whole curve

$$\text{Toughness} = \int_0^{\epsilon_f} \sigma d\epsilon$$

manu lecture 6

UTS

$$\text{At UTS } \sigma = \frac{P_{\max}}{A_0}$$

$$\epsilon = \ln\left(\frac{A_0}{A}\right) \quad A = A_0 e^{-\epsilon}$$

$$P = \sigma A_0 e^{-\epsilon}$$

$$\text{at UTS } \frac{dP}{d\epsilon} = 0$$

$$\therefore \frac{d\sigma}{d\epsilon} = \sigma$$

$$\text{at UTS in } \sigma = K\epsilon^n \quad \epsilon = n$$

manu lecture 7

question:



$$l_0 = 100 \text{ mm}$$

$$\sigma = K\epsilon^n = 600 \epsilon^{0.5}$$

$$\text{yield} = 200 \text{ MPa}$$

$$E = 200 \text{ GPa}$$

if $\epsilon = 0.2$ while the load still applied

1/ Find length after load has been released

$$\epsilon = \epsilon_{\text{plastic}} + \epsilon_{\text{elastic}}$$

$$0.2 = \epsilon_p + \frac{200 \times 10^6}{200 \times 10^9} \quad 0.2 = \epsilon_p + 0.001$$

$$\epsilon_p = 0.199$$

$$\epsilon_p = \ln\left(\frac{l_f}{l_0}\right) \quad 0.199 = \ln\left(\frac{l_f}{100}\right)$$

$$l_f = 122.02 \text{ mm}$$

2/ Find material UTS

$$n = \epsilon$$

$$\text{UTS true} = 600 (0.5)^{0.5} = 424.26 \text{ MPa}$$

$$\text{eng UTS} = \text{true UTS} \times e^{-\epsilon} = 424.3 \times e^{-0.5}$$

$$= 257.3 \text{ MPa}$$

$$0.199 = \ln\left(\frac{l_f}{l_0}\right)$$

$$\begin{aligned} \epsilon &= \epsilon_{\text{plastic}} + \epsilon_{\text{elastic}} \\ \sigma &= E\epsilon \\ \epsilon &= \ln\left(\frac{l_f}{l_0}\right) \end{aligned}$$

الطول

العرض

main lecture 8

chapter 2 Page 60.

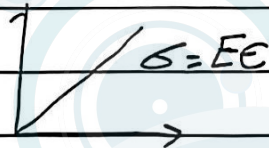
→ perfectly plastic (no strain hardening)

↳ extremely ductile materials: elastic up to
failure

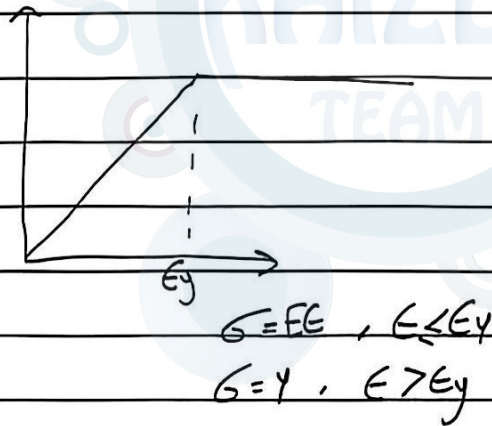
"perfectly plastic"



a/ perfectly elastic



c/ half perfectly elastic and half perfectly plastic



elastic ϵ_s

plastic ϵ_p

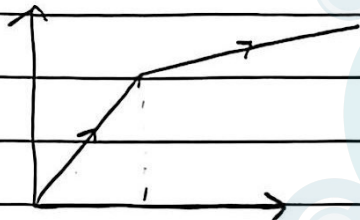
d/ rigid linearly strain hardening



$$\sigma = \gamma + E_p \cdot \epsilon$$

↓
modulus of plasticity

e/ elastic linearly strain hardening



$$\sigma = E \epsilon \quad ; \quad \epsilon \leq \epsilon_y$$

$$\sigma = \gamma + E_p (\epsilon - \epsilon_y) \quad ; \quad \epsilon > \epsilon_y$$



Increasing temperature :

decreases : strength, hardness, E

Increases : ductility (x axis)

toughness is the area under the stress-strain curve up to the point of fracture. It is a measure of the energy absorbed by the material before fracture. Toughness is the area under the stress-strain curve.

table 2.3

strain rate : strain pair unit time

$$\dot{\epsilon} = \frac{d\epsilon}{dt} = \frac{1}{s} = s^{-1}$$

eng strain rate

$$\left(\frac{\Delta L}{L_0} \right) \frac{1}{\text{time}} = \frac{v}{L_0}$$

true strain rate

$$\dot{\epsilon} = \left(\frac{dL}{L} \right) / dt$$

$$\dot{\epsilon} = \frac{v}{L}$$

deformation speed (m/s)

$$= L_0 / \text{time}$$

"سین ثانیه"
از واحد v ثابت

"سین ثانیه" واحد v ثابت

"سین ثانیه" واحد v ثابت

Increasing strain rate:

increases: strength, hardness, σ

* و ductility بتدریج به ازای کان در strain rate قوی و جلی

"سین ثانیه" واحد v ثابت

改善

KAIZEN

TEAM

Revision lecture 1 - lecture 8

$$\sigma = \frac{P}{A}$$

$$\epsilon = \frac{L_f - L_0}{L_0}$$

$$\text{True } \epsilon = \ln \left| \frac{L_f}{L_0} \right|$$

in elastic region $\sigma = E\epsilon$

$$\text{MOR} = \frac{Y^2}{2E}$$

true stress-strain $\sigma = K\epsilon^n$

True UTS $\rightarrow$ ~~also~~ $\sigma = K\epsilon^n$
 $\epsilon = n$

$$\text{eng UTS} = \text{True UTS} \times e^{-\epsilon}$$

$$\text{eng strain rate} = \frac{V}{L_0}$$

$$\text{true strain rate} = \frac{V}{L}$$

manu lecture 9

strain rate : when temperature increase tensile strength become more and more sensitive to strain rate.

$T \propto \frac{1}{C}$: strength $\propto$ $\frac{1}{C}$ temperature rise
strength coefficient $k \rightarrow C$

n : strain rate sensitivity exponent

effects of hydrostatic pressure :

ductility increases largely with the presence of hydrostatic pressure :

deformable $\rightarrow$ is brittle $\rightarrow$ is $\rightarrow$ hydrostatic pressure $\rightarrow$ is $\rightarrow$ *
mainly cast materials materials pressure

compression : $\rightarrow$ is compression all stresses and strain negative

Force : vector

strain : vector

$$\dot{\epsilon} = \frac{-\dot{V}}{V_0} \quad \dot{\epsilon} = \frac{-\dot{V}}{V}$$

yielding criteria

C. Yielding is $\rightarrow$ is $\rightarrow$: $\rightarrow$

when applied stress = yielding stress $\rightarrow$

Manu lecture 10

Volume strain

Volume strain "dilatation" $\Delta = \epsilon_x + \epsilon_y + \epsilon_z$

$$\Delta = \frac{\text{Volume change}}{\text{original volume}} = \frac{1-2\nu}{E} (\sigma_x + \sigma_y + \sigma_z)$$

in elastic range

$$\Delta \neq 0$$

in plastic range

plastic deformation doesn't affect volume

$$\Delta = 0$$

$$\Delta = \epsilon_x + \epsilon_y + \epsilon_z = \frac{1-2\nu}{E} (\sigma_x + \sigma_y + \sigma_z)$$

Volume strain $\Delta = \frac{\Delta V}{V_0} = \ln \left| \frac{V_F}{V_0} \right|$

$$\epsilon_x = \frac{\sigma_x}{E} - \nu \frac{\sigma_y}{E} - \nu \frac{\sigma_z}{E}, \quad \epsilon_y = \frac{\sigma_y}{E} - \nu \frac{\sigma_x}{E} - \nu \frac{\sigma_z}{E}, \quad \epsilon_z = \frac{\sigma_z}{E} - \nu \frac{\sigma_x}{E} - \nu \frac{\sigma_y}{E}$$

Common geometries:-

1/ Solid cube



$$\epsilon_x = \ln \left(\frac{x_F}{x_0} \right), \quad \epsilon_y = \ln \left(\frac{y_F}{y_0} \right), \quad \epsilon_z = \ln \left(\frac{z_F}{z_0} \right)$$

2/ solid cylinder



$$V = \frac{\pi}{4} D^2 L$$

$$\epsilon_x = \epsilon_y = \epsilon_D = \ln \left(\frac{D_F}{D_0} \right)$$

$$\epsilon_z = \epsilon_L = \ln \left(\frac{L_F}{L_0} \right)$$

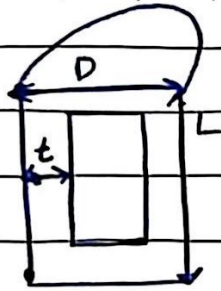
3/ solid sphere



$$V = \frac{\pi}{6} D^3$$

$$\epsilon_x = \epsilon_y = \epsilon_z = \epsilon_D = \ln \left(\frac{D_F}{D_0} \right)$$

4/ cylindrical shell



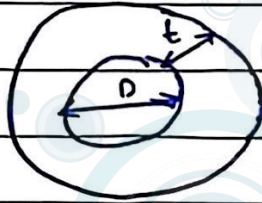
$$V = D L t$$

$$\epsilon_x = \epsilon_D = \ln \left(\frac{D_F}{D_o} \right)$$

$$\epsilon_y = \epsilon_L = \ln \left(\frac{L_F}{L_o} \right)$$

$$\epsilon_z = \epsilon_t = \ln \left(\frac{t_F}{t_o} \right)$$

5/ spherical shell



$$\epsilon_x = \epsilon_y = \epsilon_D = \ln \left(\frac{D_F}{D_o} \right)$$

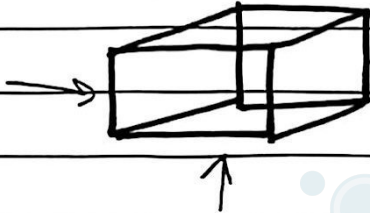
$$\epsilon_z = \epsilon_t = \ln \left(\frac{t_F}{t_o} \right)$$

main lecture II

$$\text{mean stress } \sigma_m = \frac{1}{3} (\sigma_x + \sigma_y + \sigma_z)$$

$$\text{bulk modulus} = \frac{\sigma_m}{\Delta} = \frac{E}{3(1-2\nu)}$$

Quiz question



$$x_0 = 100$$

$$y_0 = 70$$

$$z_0 = 120$$

$$\sigma_x = \sigma_y = \sigma_z = p$$

$$E = 200 \text{ GPa}, \nu = 0.2$$

find final volume under pressure $p = 30 \text{ MPa}$ and dimensions

$$1/ \epsilon_x = \epsilon_y = \epsilon_z$$

$$\epsilon = \frac{1}{E} (\sigma_x - \nu \sigma_y - \nu \sigma_z) = \frac{1}{200 \times 10^3} (-30 - 2 \times 30 \times 0.2) = -9 \times 10^{-5}$$

$$\epsilon_x = \ln \left(\frac{x_f}{x_0} \right) \rightsquigarrow x_f = 99.991 \text{ mm}$$

$$\epsilon_y = \ln \left(\frac{y_f}{y_0} \right) \rightsquigarrow y_f = 69.9937 \text{ mm}$$

$$\epsilon_z = \ln \left(\frac{z_f}{z_0} \right) \rightsquigarrow z_f = 119.99 \text{ mm}$$

$$\Delta = \ln \left(\frac{V_f}{V_0} \right)$$

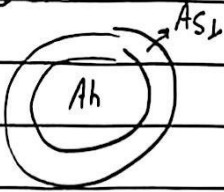
$$\Delta = \frac{1-2\nu}{E} (\sigma_x + \sigma_y + \sigma_z) \rightsquigarrow \Delta = -2.7 \times 10^{-4}$$

$$V_f = e^{\Delta} \times V_0 = 839773.23 \text{ mm}^3$$

hollow cylindrical shell:

manu lecture 12

Q.6L



Ah: hollow area

ASL: solid area normal to "L" direction

$$Force = P \times Ah = P \times \frac{\pi}{4} D^2$$

Force is hollow area
Force is normal to L

$$\sigma_L = \frac{F}{A_S} = \frac{P \times \frac{\pi}{4} D^2}{\pi D t} = \frac{PD}{4t} = \frac{Pr}{2t}$$

radius

W's solid area AS

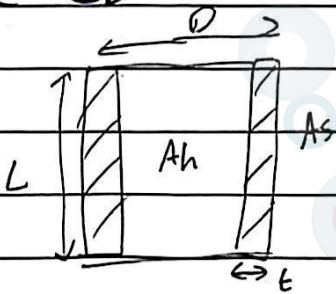
stress is in L

W's stress is

thick cylinder -
Diameter = thickness
2

thick cylinder is the same as the thick cylinder

Q.6D



$$F = PDL$$

$$\sigma_D = \frac{F}{A_S} = \frac{PDL}{2tL} = \frac{PD}{2t} = \frac{Pr}{t}$$

Q.6E



W's AS and Ah

$$\sigma_{thickness} = \frac{-PAE}{AE}$$

$$-P$$

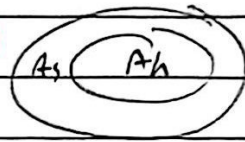
P < < < < < GL and GD

$$\therefore \sigma_t = 0$$

hollow spherical shell $\rightarrow G_D = G_L$

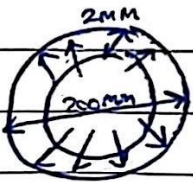
(1) $G_D = G_L$ for hollow cylindrical shell

$$G_D = \frac{F}{A_s} = \frac{PA_h}{A_s} = \frac{P \frac{\pi}{4} D^2}{\pi D t} = \frac{PD}{4t} \quad \left(\frac{Pr}{2t} \right)$$



(2) $G_L = -P \approx 0$

Example:



$E = 200 \text{ GPa}, \nu = 0.25$

$P = 5 \text{ MPa}$

Note: solid shapes $\rightarrow$ external pressure

thin shapes $\rightarrow$ internal pressure

a/ Find G_D, G_L

b/ Final dimensions after pressurizing

a/ $G_D = \frac{PD}{4t} = 125 \text{ MPa}$

$G_L = -P = -5 \text{ MPa}$

which is $\ll 125 \text{ MPa} \approx 0$

b/ Final dimensions

$$\epsilon_D = \frac{1}{E} (G_D - \nu (G_D + G_L)) = \frac{1}{200 \times 10^3} (125 - 0.25 (125 - 5)) = 4.75 \times 10^{-4}$$

$$= \ln \left(\frac{D_F}{D} \right), \quad D_F = 200.095 \text{ mm}$$

$$\epsilon_L = \frac{1}{E} (G_L - \nu (G_D + G_L)) = -3.375 \times 10^{-4} = \ln \left(\frac{L_F}{L} \right)$$

$$L_F = 1.9493 \text{ mm}$$

Main lecture 13

Section 2.11: uni axial & triaxial

Note: as tensile test is uni axial

uniaxial stress system

2.11.1 Maximum shear stress criterion

triaxial as per class

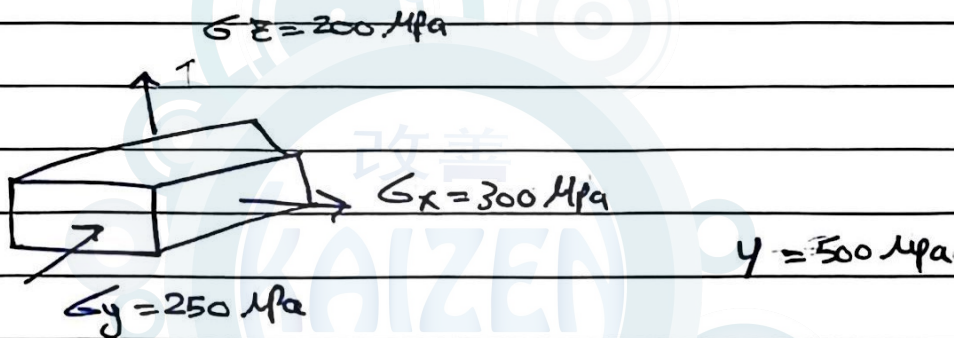
$$K = \frac{\sigma_y}{2}$$

$\sigma_{\max} - \sigma_{\min} = Y$ → for materials that follow maximum shear stress criterion

if $\sigma_1 > \sigma_2 > \sigma_3$ then for yielding to take place:

$$\sigma_1 - \sigma_3 \geq Y$$

example:



does yielding occur given that material follows maximum shear stress criterion -

$$\sigma_{\max} = 300 \text{ MPa}$$

$$\sigma_{\min} = -250 \text{ MPa}$$

because its
compression

$$\sigma_{\max} - \sigma_{\min}$$

$$= 300 + 250 = 550 \text{ MPa} \therefore > Y$$

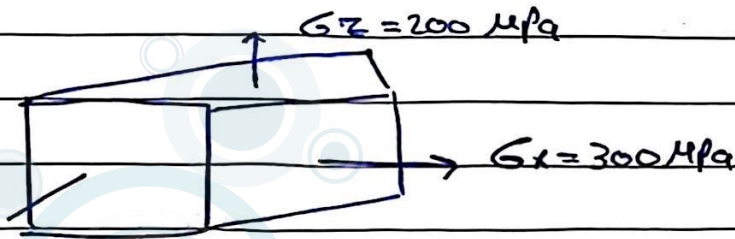
$\therefore$ yielding occurs

→ Notice that in maximum shear stress criteria middle stress (200 MPa in the previous example) is not important

2.11.2 distortion energy criterion

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2\sigma_y^2$$

example:



$$\sigma_y = 500 \text{ MPa}$$

given that the material follows distortion energy criterion, find σ_y needed for yielding

$$\sigma_x = \sigma_1, \sigma_y = \sigma_2, \sigma_z = \sigma_3$$

$$(\sigma_x - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_x)^2 = 2\sigma_y^2$$

$$\sigma_y^2 - 600\sigma_y + 90000 + \sigma_y^2 - 400\sigma_y + 40000 + 10000 = 500000$$

$$2\sigma_y^2 - 1000\sigma_y - 360000 = 0$$

$$\sigma_y = 742 \text{ MPa} \quad \text{or} \quad \sigma_y = -242 \text{ MPa}$$

$$\sigma_y = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

المعادلة العامة :

هنا كيف بدد افتر ان قيمة افتر ؟ و انه القيمة لا مسخر .

2.11.3 plane stress & strain

Prin. str. & strain

Plane stress

$$(\sigma_1, \sigma_2, 0)$$

$$(\sigma_1, 0, \sigma_3)$$

$$(0, \sigma_2, \sigma_3)$$

plane strain

$$(\epsilon_1, \epsilon_2, 0)$$

$$(\epsilon_1, 0, \epsilon_3)$$

$$(0, \epsilon_2, \epsilon_3)$$

Pressure: is a triaxial plane stress whether external or internal

Pressure

في الضغط الداخلي (Mirror)

$$\sigma_1 = -p, \sigma_2 = 0, \sigma_3 = -p$$

$$\therefore \sigma_2 = \max$$

$$\text{if } \sigma_1 > \sigma_3 \therefore \sigma_3 = \min$$

$$\text{MSSC } \sigma_3 = -p$$

$$\text{if } \sigma_3 > \sigma_1 \therefore \sigma_1 = \min$$

$$\sigma_1 = -p$$

في الضغط الخارجي

$$\sigma_1 = +p, \sigma_2 = 0, \sigma_3 = +p$$

$$\therefore \sigma_2 = \min$$

$$\text{if } \sigma_1 > \sigma_3 \therefore \sigma_1 = \max$$

$$\text{MSSC } \sigma_{\max} - \sigma_{\min} = p$$

$$\sigma_1 = p$$

$$\text{if } \sigma_3 > \sigma_1 \therefore \sigma_3 = \max$$

$$\sigma_3 = p$$

في الضغط الداخلي (Mirror)

$$\sigma_1 = +p, \sigma_2 = 0, \sigma_3 = -p$$

$$\sigma_1 - \sigma_3 = p$$

$$\text{if } \sigma_3 = 0 \therefore \sigma_1 = p$$

$$\text{if } \sigma_1 = 0 \therefore \sigma_3 = -p$$

في الضغط الخارجي

$$\sigma_1 = -p, \sigma_2 = 0, \sigma_3 = +p$$

$$\sigma_3 - \sigma_1 = p$$

$$\text{if } \sigma_1 = 0 \therefore \sigma_3 = p$$

$$\text{if } \sigma_3 = 0 \therefore \sigma_1 = -p$$

yielding frame : whether for MSSC or DEC

y = frame yield stress

$y <$ frame yield stress

(where y is the yield stress)

DEC is the yield stress

$$\sigma_1^2 + \sigma_3^2 + (\sigma_3 - \sigma_1)^2 = 2y^2$$

$\sigma_2 = \sigma$ is

$M_1; y_1 \rightarrow$ MSSC

$M_2; y_2 \rightarrow$ DEC

Frame yield stress $y_1 = y_2$ is the same

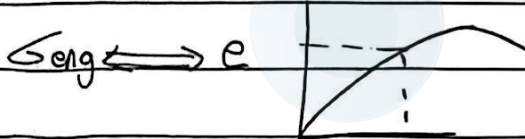
(where y is the yield stress) Frame yield stress y_2 is the same

2.11.6 effective stress & effective strain

representative stress & strain

Let us consider the following:

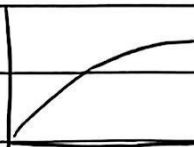
[1]



elastic & plastic

[2]

$\sigma \leftrightarrow \epsilon$



$$\sigma = K\epsilon^n$$

Let us consider the following:

[3]

stress و strain في أكثر من واحد و أكثر من

$$\begin{Bmatrix} \sigma_1 & \epsilon_1 \\ \sigma_2 & \epsilon_2 \\ \sigma_3 & \epsilon_3 \end{Bmatrix}$$

hook's law في elastic range

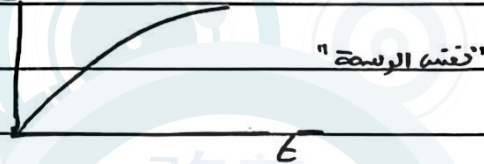
[4]

هذا اننا نريد ك دالة و ϵ دالة representative is an

$$\bar{\sigma} \Leftrightarrow \bar{\epsilon}$$

if $\sigma = k\epsilon^n \rightarrow$ uniaxial

the $\bar{\sigma} = k\bar{\epsilon}^n$



to find $\bar{\sigma}$

→ MSSC $\bar{\sigma} = \sigma_1 - \sigma_3$

→ DEC $\bar{\sigma} = \frac{1}{\sqrt{2}} ((\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2)^{1/2}$

to find $\bar{\epsilon}$

→ MSSC $\bar{\epsilon} = \frac{2}{3} (\epsilon_1 - \epsilon_3)$

→ DEC $\bar{\epsilon} = \frac{\sqrt{2}}{3} ((\epsilon_1 - \epsilon_2)^2 + (\epsilon_2 - \epsilon_3)^2 + (\epsilon_3 - \epsilon_1)^2)^{1/2}$

تغير

Volume constancy principle (plastic deformation)

in plastic range no volume change $\therefore V_0 = V_f$

Volume $\leftarrow \Delta$ in plastic range = 0
strain

$$\Delta = \epsilon_1 + \epsilon_2 + \epsilon_3$$

$\therefore$ in plastic range $\epsilon_1 + \epsilon_2 + \epsilon_3 = 0 \neq$

Subclasses of original energy J

12.12 work of deformation

total work $\leadsto$ photo 1 in 3k

$$W_T = W_I + W_F + W_R$$

W_T : total work of deformation

"plastic work" $\leftarrow W_I$: Ideal " " "

W_F : Frictional " " "

W_R : Redundant " " "

ideal work "plastic work"

المشغل الذي يتسبب في حدوث التشوه البلاستيكي هو العمل البلاستيكي W_I وهو الجزء الأكبر من إجمالي العمل W_T

أما W_F و W_R فهما جزء صغير من إجمالي العمل W_T

W_R & $W_F \leadsto$ we can easily find them

W_T is 15-35% of W_I

specific energy for plastic deformation

المشغل البلاستيكي (area under the curve) toughness $\leftarrow$

Plastic work to fracture $\leftarrow$

$$u = \int_0^{\bar{\epsilon}} \bar{\sigma} d\bar{\epsilon} \quad \text{J/m}^3$$

$$W_I = V \cdot u_I \quad \text{J}$$

heat $\leftarrow$ work $\leftarrow$

heat $\leftarrow$ work $\leftarrow$

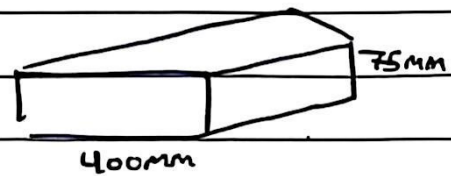
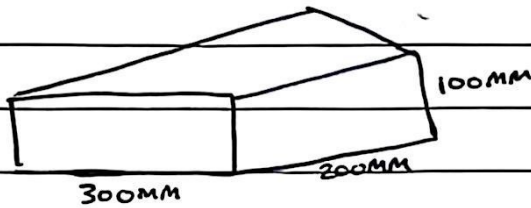
$$\Delta T = \frac{u_{\text{total}}}{\rho C_p} \quad \leftarrow \quad u_T = u_I + u_F + u_R$$

density

kg/m^3

specific heat $\text{J/kg} \cdot \text{K}$

Example:



$$\sigma = 300 \epsilon^{0.5} \text{ MPa}$$

$$W_F + W_R = 30\% \cdot W_T$$

material follows von Mises (DE) criterion

$$\rho = 8 \text{ g/cm}^3, C = 0.5 \text{ kJ/kg} \cdot \text{K}$$

find rise in temp in the

$$\epsilon_1 = \ln \left| \frac{400}{300} \right| = 0.288$$

$$\epsilon_2 = \ln \left| \frac{75}{100} \right| = -0.288$$

to find ϵ_3

$$\epsilon_1 + \epsilon_2 + \epsilon_3 = 0 \Rightarrow \epsilon_3 = 0$$

$$\bar{\epsilon} = \frac{\sqrt{2}}{3} \left[(\epsilon_1 - \epsilon_2)^2 + (\epsilon_2 - \epsilon_3)^2 + (\epsilon_1 - \epsilon_3)^2 \right]^{1/2}$$

$$\bar{\epsilon} = 0.3325$$

$$\Delta T = \frac{U_I}{\rho \cdot C} ; U_I = \frac{W_I}{V} \quad W_T = W_I + W_F + W_R$$

$$W_I = U_I \cdot V$$

$$U_I = \int_0^{\bar{\epsilon}} \sigma \cdot d\bar{\epsilon}$$

$$U_I = \int_0^{0.3325} 300 \epsilon^{0.5} \text{ MPa} \cdot d\epsilon = \left. \frac{300 \epsilon^{1.5}}{1.5} \right|_0^{0.3325} = 38.43 \times 10^3 \text{ kJ/m}^3$$

no need
with this value in
work rise temp

$$V_I = 6 \times 10^{-3} \text{ m}^3$$

$$W_I = 38.43 \times 10^3 \times 6 \times 10^{-3} = 230.58 \text{ kJ}$$

$$W_I = 0.7 W_T$$

$$W_T = 329.4 \text{ kJ}$$

$$U_I = \frac{W_I}{V} = \frac{230.58 \text{ kJ}}{6 \times 10^{-3} \text{ m}^3} = 38.43 \times 10^3 \text{ kJ/m}^3$$

$$\Delta T = \frac{U_I}{\rho \cdot C} = \frac{38.43 \times 10^3}{8 \times 10^3 \times 0.5} = 13.725 \text{ K}$$

$$\rho = \frac{8 \text{ g}}{\text{cm}^3} \times \frac{\text{kg}}{1000 \text{ g}} \times \frac{10^6 \text{ cm}^3}{\text{m}^3} = 8 \times 10^3 \text{ kg/m}^3$$

Five Apple
هون سويت كى هون الفى
زىلى ملى

chapter 6 - bulk deformation processes

Metal forming processes

Classification of metal forming processes

1 according to sequence in processing :-

1/ primary processes: initial processes in preparation for further processes.

2/ secondary processes: intermediate or final processes

2 according to processing temperature :-

1/ homologous temperature $T_h \text{ or } T = \frac{\text{Processing temperature in Kelvin}}{\text{melting temperature in Kelvin}}$

"unitless ratio" fraction of ratio is temp of

if $T_h < 0.5$:: cold forming / cold working

mostly final process

cold & plastic working

because it requires relatively high levels of force and energy

stronger material is

"strain hardening is its"

limited formability / 2

"high strain rate" "low strain" , low ductility is its

good surface finish and dimensional accuracy / 3

high mechanical properties / 4

strain hardening is its

if $T_h > 0.5 \therefore$ hot forming / hot working

hot 11/10/20
working

why?

why?

poor surface finish and dimensional accuracy

Why?

• "no strain hardening" strain hardening is cum. ← why?

why?

in between : ^swerliest

✓ bulk deformation processes:- metal forming processes involving work pieces with relatively low surface area to thickness ratio.

2/ sheet metal forming processes: metal forming processes involving work pieces with relatively high surface area to thickness ratio.

sheets are up to 6mm if $>6\text{mm} \therefore$ plate $\rightarrow$ bulk & sheet & tubes

Table 6.1

Forging = compressive forces

↳ open-die forging = hot working

• high temp & plastic deformation

work piece volume is 1/1 ∴ open-die is always

smaller than die-cavity volume.

used for simple shapes/geometries /2

requires lowest levels of force /3

and energy among forging operations

notably hot-primarily processing /4

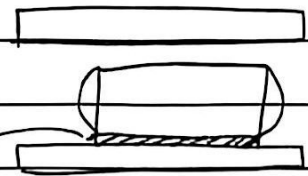
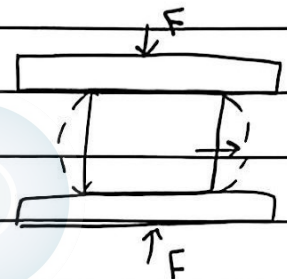
Figure 6.1 (a) ideal forging (no barreling) (cylinder stays cylinder 1.50)

(b) actual forging (barreling)

Friction /1 ∴ barreling

lubrication: reduces friction

Figure 6.2 cooling effect /2



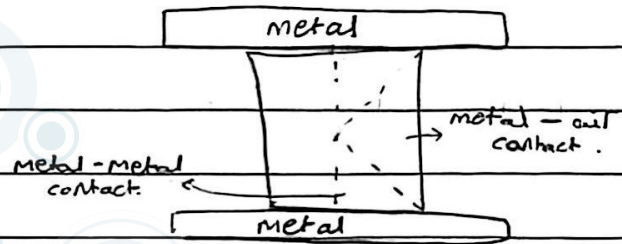
see cold plate at times in hot worked piece

strength & cooling

ductility

• workability

Quiz question: explain the triangular shape of the non-deformed zone in Figure 6.3



في المنطقة المثلثية من المنطقة غير المتغيرة، يتم تبريد المعدن بشكل رئيسي بواسطة المعدن.

في المنطقة المثلثية من المنطقة غير المتغيرة، يتم تبريد المعدن بشكل رئيسي بواسطة المعدن.

في المنطقة المثلثية من المنطقة غير المتغيرة، يتم تبريد المعدن بشكل رئيسي بواسطة المعدن.

Impression die forging

- w/p volume larger than die-cavity volume.
- used for complex shapes with fine details
- normally hot deformation (may be cold forming for soft metals)
- requires largest amounts of force and energy among forging
- only intermediate and/or final processing
- extremely frictional force

figure 6.12

- (a) acts like open die
- (b) - shape is the die details
- (c) details of the metal and friction force cause flash
- (d) Flash - 1/ to force the metal to flow into details of the die-cavity
2/ prevent the two-die halves from contacting each other under high mechanical forces which may lead to deformation and/or fracture of the die itself.

Figure 6.13

- Dies contact work piece - flash begins to form
 - like true stress-strain slope.
- Flash begins to form - forging energy
 - Friction ↑ due to force and high friction coefficient

↳ precision forging

- wip volume = die cavity volume
- soft metals
- no flash is formed

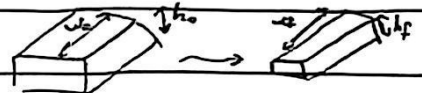
Forging → Press
 ↳ Hammer

6-3 Rolling compressive forces.

Rolling is the process of reducing thickness (Flat rolling)

plane strain

$$w_0 = w_f$$



or change in cross section (shape rolling):



Figure 2-28 & Figure 2-29

R : roll radius (mm/in)

h_0 : initial height

h_f : final height

h : any height between h_0 & h_f $h_f \leq h \leq h_0$

w_0 : initial width

w_f : final width

$$w_0 = w_f$$

V_0 : initial velocity

V_f : final velocity

V : instantaneous velocity

V_r : rollers surface velocity

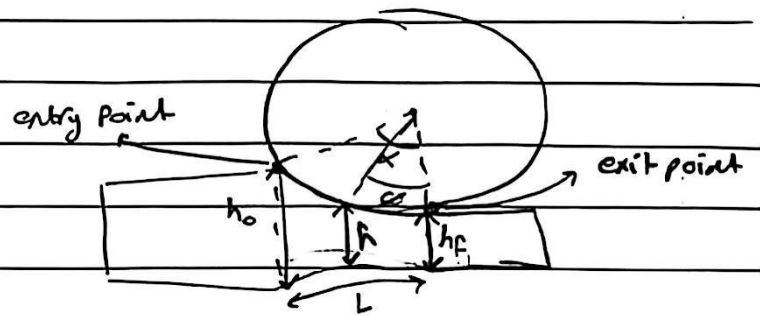
$$V_r > V_0$$

$$N: 60 \text{ rpm}$$

$$V_r = \frac{\pi D N}{60} \text{ m/s}$$

α : entry angle

الزاوية بين الأسطح
roller و workpiece
(surface angle)



L : length (arc) of contact

ϕ : any angle on the arc of contact corresponding to any height "h"

$$0 \leq \phi \leq \alpha$$

N : coefficient of friction between roller & W/P materials

manu lecture 19

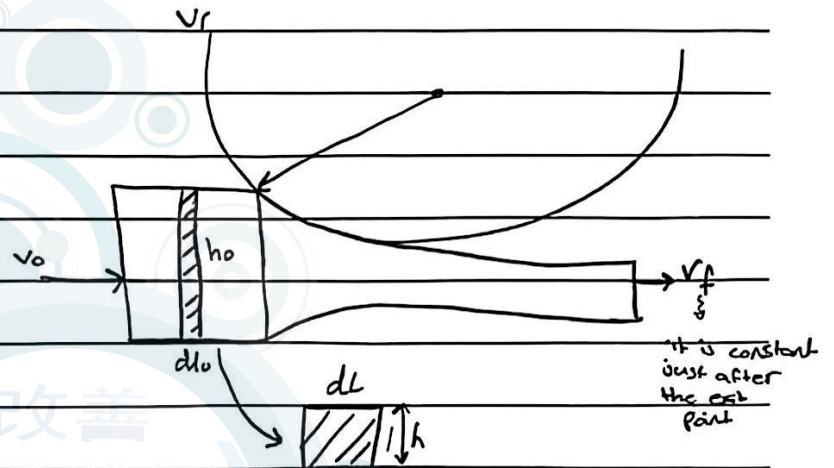
initially the material approaches the rollers at a constant initial velocity (v_0), while the rollers rotate with a constant surface velocity (v_r) and where $v_r > v_0$. This difference in velocity together with frictional forces causes the material to squeeze in between the two rollers with a corresponding reduction in height and increase in velocity (v)

sum up: ω constant $\therefore$

$h \propto \omega$ $\therefore$

$\therefore L \propto$

$\therefore v \propto$



$$\text{volume} = \frac{dl_0 \cdot v_0 \cdot h_0}{dt} = \frac{dl \cdot v \cdot h}{dt} \quad \omega_0 = \omega \quad \text{constant}$$

$$v_0 h_0 = v h$$

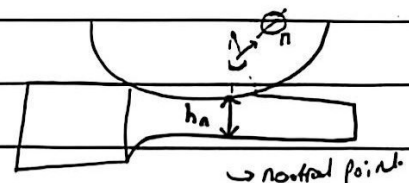
$$\frac{v}{v_0} = \frac{h_0}{h}$$

$$h_0 > h$$

$$\therefore v > v_0$$

the material's velocity continues to increase along the arc of contact until reaching the rollers surface velocity (v_r) at a particular point on the arc of contact known as the neutral point.

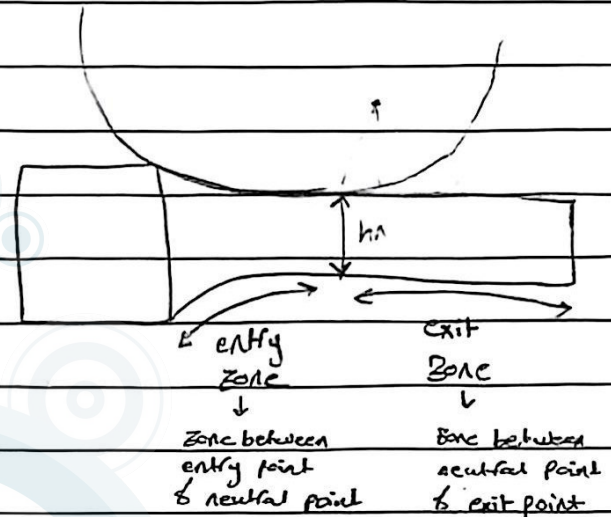
$\therefore$ at neutral point $v = v_r$



Five Apple

after the neutral point the materials velocity V exceeds V_R causing a reverse in the frictional forces associated with a phenomenon known as the forward slip.

Forward slip = sliding of the material on the roller's surface.



Equations:

$$h = h_f + 2R(1 - \cos \phi) \quad \text{in deg or rad}$$

$$h = h_f + R\phi^2 \quad \text{in rad}$$

$$\tilde{H} = 2 \sqrt{\frac{R}{h_f}} \tan^{-1} \left(\sqrt{\frac{R}{h_f}} \phi \right)$$

height ≈ 10

at entry point: $\phi = \pi \therefore H = H_0$, at exit point $\phi = 0 \therefore H = 0$

for entry zone:

$$P = \sigma_f' \frac{h}{h_f} e^{\mu(H_0 - H)}$$

at neutral point

6.32

6.33

$$H_n = \frac{1}{2} \left(H_0 - \frac{1}{\mu} \ln \frac{h_0}{h_f} \right)$$

$$\phi_n = \sqrt{\frac{h_f}{R}} \tan \left(\frac{H_n}{2} \sqrt{\frac{h_f}{R}} \right)$$

for exit zone:

$$P = \sigma_f' \frac{h}{h_f} e^{\mu H}$$

plane strain conditions:

ϵ_3 is

$\sigma_3 = p_3 = 0$

σ_f' = flow stress in plane strain conditions

$$\sigma_f' = \frac{2}{\sqrt{3}} \sigma_f = 1.15 \sigma_f \text{ ; if } \sigma = K \epsilon^n \text{ then } \sigma_f = K \bar{\epsilon}^n$$

example: $h_0 = 100 \text{ mm}$, $h_f = 80 \text{ mm}$, $\mu = 0.5$, $\sigma = 500 \epsilon^{0.5} \text{ MPa}$, $R = 250 \text{ mm}$.

material follows the MSL

find the roll pressure at the neutral point.

$$P_n = \sigma_f' \frac{h_n}{h_f} e^{\mu H_n}$$

$$\sigma_f' = 1.15 \sigma_f \rightarrow \sigma_f = 500 \bar{\epsilon}^{0.5}$$

$$\bar{\epsilon} = \frac{2}{3} (\epsilon_1 - \epsilon_3)$$

$$\epsilon_1 = \epsilon_h = \ln \left(\frac{80}{100} \right) = -0.223$$

$$\epsilon_1 + \epsilon_2 + \epsilon_3 = 0 \rightarrow \text{plastic range}$$

$$\therefore \epsilon_3 = \epsilon_c = 0.223$$

$$\bar{\epsilon} = 0.297$$

$$\sigma_f = 272.6$$

$$\sigma_f' = 313.53 \text{ MPa}$$

$$h_n = h_f + R \phi_n^2$$

∴ example 11 is

$$\sigma_f = 313.64 \text{ MPa}$$

exit zone $\leftarrow$ $P = \sigma_f \frac{h_n}{h_f} e^{u H_n}$ $P = 313.64 \times \frac{82.4}{80} e^{0.5 \times 0.6} = 436.1 \text{ MPa}$

$$h_n = h_f + R \phi_n^2 \quad h_n = 80 + 250 \cdot 0.097^2 = 82.4 \text{ mm}$$

$$\phi_n = \sqrt{\frac{h_f}{R}} \tan\left(\frac{H_n}{2} \sqrt{\frac{h_f}{R}}\right) = \sqrt{\frac{80}{250}} \tan\left(\frac{10.6}{2} \sqrt{\frac{80}{250}}\right) = 0.097 \text{ rad}$$

$$H_n = \frac{1}{2} \left(H_0 - \frac{1}{u} \ln \frac{h_0}{h_f} \right) = \frac{1}{2} (1.645 - 2 \ln(\frac{100}{80})) = 0.6$$

$$H_0 = 2 \sqrt{\frac{R}{h_f}} \tan^{-1}\left(\sqrt{\frac{R}{h_f}} \alpha\right) = 2 \sqrt{\frac{250}{80}} \tan^{-1}\left(\sqrt{\frac{250}{80}} \cdot 0.284\right)$$

$$H_0 = 1.645$$

$$h_0 = h_f + R \alpha^2$$

$$100 = 80 + 250 \alpha^2$$

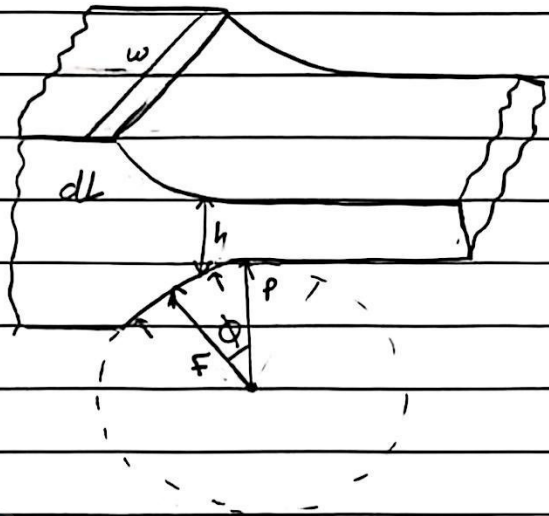
$$\alpha = 0.284 \text{ rad}$$

entry zone $P = \sigma_f \frac{h_n}{h_f} e^{u(H_0 - H_f)}$

$$313.64 \cdot \frac{82.4}{100} \cdot e^{0.5(1.645 - 0.6)} = 435.8 \text{ MPa}$$

$$dF = p dA = p w dL$$

$$dL = R d\phi$$



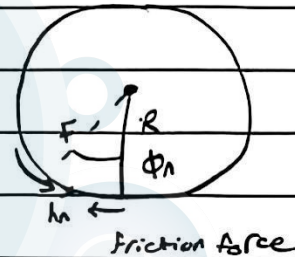
$$\text{flow stress } \sigma_F = K \bar{\epsilon}^n$$

$$\text{average flow stress } \bar{\sigma}_F = \frac{K \bar{\epsilon}^n}{n+1}$$

$$\text{average flow stress in plane strain condition } \bar{\sigma}_F = 1.15 \frac{K \bar{\epsilon}^n}{n+1}$$

$$\text{Torque (T)} = F_f \cdot R$$

$\downarrow$
F.M



$$\therefore \text{Torque (T)} = \frac{FL}{2}$$

$$\text{Power} = T\omega = \frac{FL\omega}{2} = \frac{\pi FLN}{60} \quad \begin{matrix} \text{in rad} & \text{in rpm} \\ \text{rad} \rightarrow \text{rpm} \end{matrix}$$

→ Continue of previous example (last lecture)

assume $w = 400\text{m}$

$$\dot{\sigma}_F = 314 \text{ MPa}$$

$$\bar{\sigma}_F = \frac{\dot{\sigma}_F}{n+1} = \frac{314}{1.5} = 209.3 \approx 210 \text{ MPa}$$

$$L = \sqrt{R \Delta h} = \sqrt{250 \times 20} = 71 \text{ mm}$$

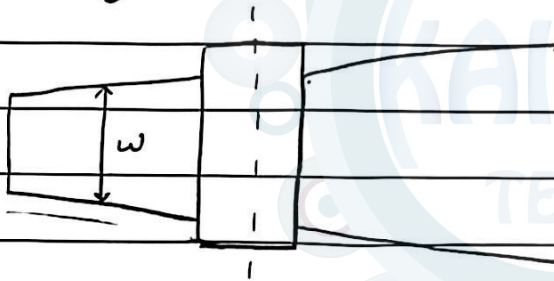
for low friction $F = L w \bar{\sigma}_F = 71 \times 400 \times 210 = 5964 \text{ kN}$

for high friction $F = 5964 \left(1 + \frac{0.5 \times 71}{2 \times 90} \right) = 7140 \text{ kN}$

• example 6.34 -

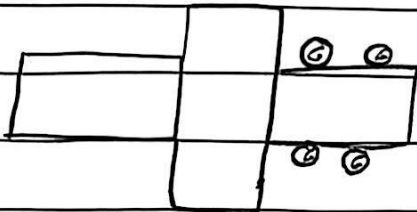
Flat rolling

a) spreading: increase in width in flat rolling figure 6.34



spreading: width زیاد می‌شود

و حالتی defect می‌باشد، زیرا یکنواختی ندارد



2) Figure 6.34 a), b)

camber: Measure to get rid of out surface curviness after rolling

نوع : اذا كان على السطح او width الى 1/2 من قوس الكمالية في rolling

هذا ما يدعى ان يكون already flat في rolling

(camber) rolling في flat السطح

section 6.3.2 self reading.

(6.3.5) rolling في شكل -

thread rolling , shape-rolling , ring-rolling

6.4 Extrusion

mostly a cylindrical billet placed in a container and forced by a stem

→ extrusion is easier than rolling in mass production

types of extrusion figure 6.45 important

1/ Forward extrusion (direct)

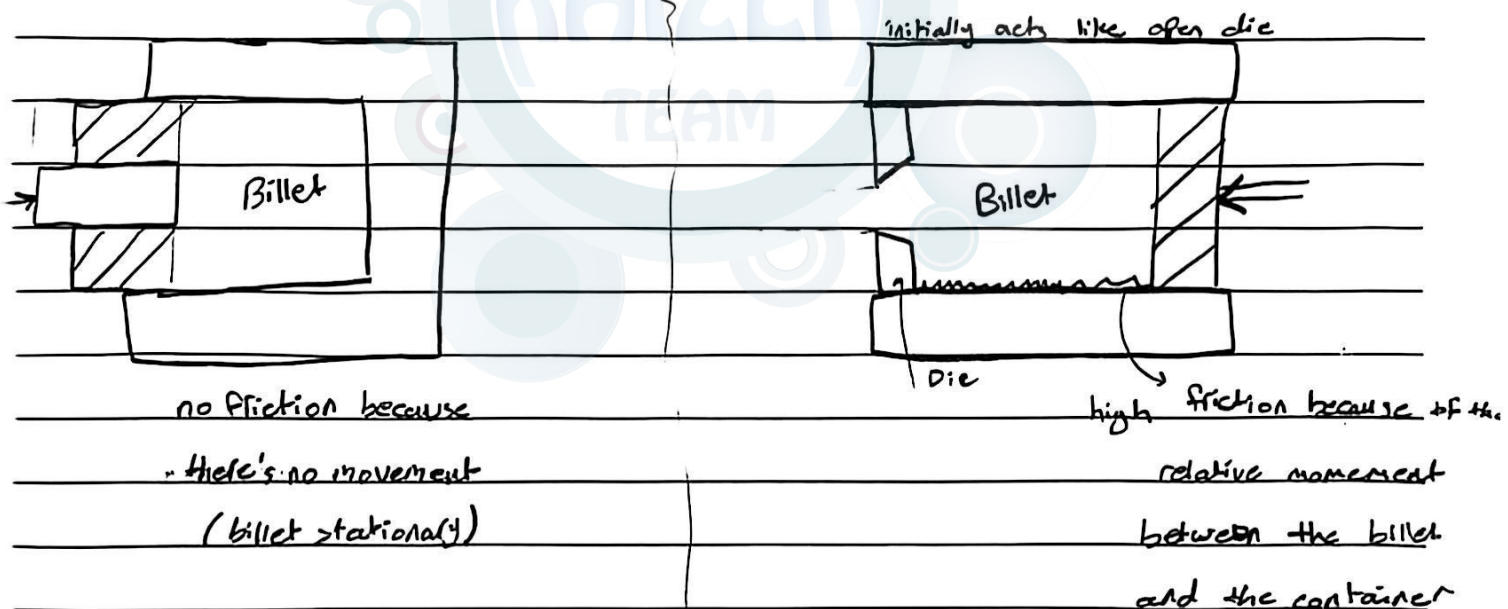
direction of metal flow with direction of stem

2/ inward (inverse) (indirect) extrusion

direction of metal flow opposite of direction of stem

main

→ two differences between direct & indirect



∴ first difference : Friction

second difference:

direct extrusion $\rightarrow$ continuous, ramp & zig. billet casting

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

indirect extrusion $\rightarrow$ continuous one, large to small billet in out

extrusion Upstream

3/ hydrostatic extrusion

in hydrostatic pressure: there's no ~~space~~ ^{gap} between the ramp and the billet, force is ~~trans~~ ^{trans} by fluid.

brittle material N cold work given call is -

4/ impact extrusion

used for extremely ductile metals, suitable for hollow shapes

more details in book!

extrusion ratio

$$R_c = \frac{A_o}{A_f}$$

see book figure 6.47

types of metal flow (mainly depends on friction)
Pattern material at casting site

1/ homogeneous uniform flow pattern 6.47a

in no friction metal acts like fluid and it changes its direction.

∴

2/ 6.47b

Friction 1/1 and 1/2 zones

Friction 1/1 and 1/2 zones, Friction 1/1 and 1/2 zones

1/ easily flowing metal

2/ shear zone (metal flow)

3/ dead metal zone (component of Friction)

metal flow

3/ 6.47a

extreme friction: 1/ shear zone, 2/ dead zone

metal flow

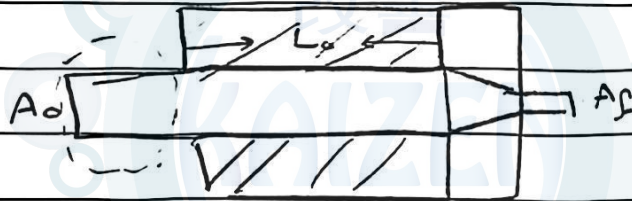
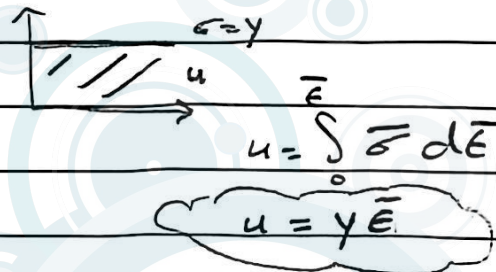
flow

6.4.2 mechanics of extrusion

uniaxial $\sigma = \sigma_x$ stress

$$\epsilon = \ln \frac{l_f}{l_0} = \ln \frac{A_0}{A_f} = \ln R\epsilon$$

super important: for a rigid perfectly plastic material with a yield strength of S_y , the energy dissipated in plastic deformation per unit volume, u , is:



$$W = u \cdot V = \gamma \bar{\epsilon} A_0 L_0$$

$$W = F L_0$$

$$P = u = \gamma \ln \left(\frac{A_0}{A_f} \right) = \gamma \ln R\epsilon$$

(ideal force) $F = P A_0$

important note: for strain-hardening material: γ must be replaced by $\bar{\sigma}_p$ average flow stress

$$\bar{\sigma}_p = \frac{k \epsilon^{n+1}}{n+1}$$

Ideal force, with friction (general)

$$P = \gamma \left(1 + \frac{\tan \alpha}{\mu} \right) \left[R_e^{m \cos \alpha} - 1 \right]$$

die anglecoefficient of friction

special case when $\alpha = 45^\circ$:

$$P = \gamma \left(1.7 \ln R_e + \frac{2L}{D_0} \right)$$

改善

KAIZEN

TEAM

$$x \rightarrow x + \left(\frac{30 - x}{4} \right)$$

main lecture 22

example

a cylindrical billet $M=0.5$ $\alpha=15^\circ$ $D_o=100\text{ mm}$ $D_f=90\text{ mm}$

$$\sigma = 200 \epsilon^{0.5} \text{ MPa}$$

find pressure if there's friction or if there's no friction

$$R_c = \frac{A_o}{A_f} = \frac{D_o^2}{D_f^2} = 1.23$$

$$\epsilon = \ln R_c = 0.21$$

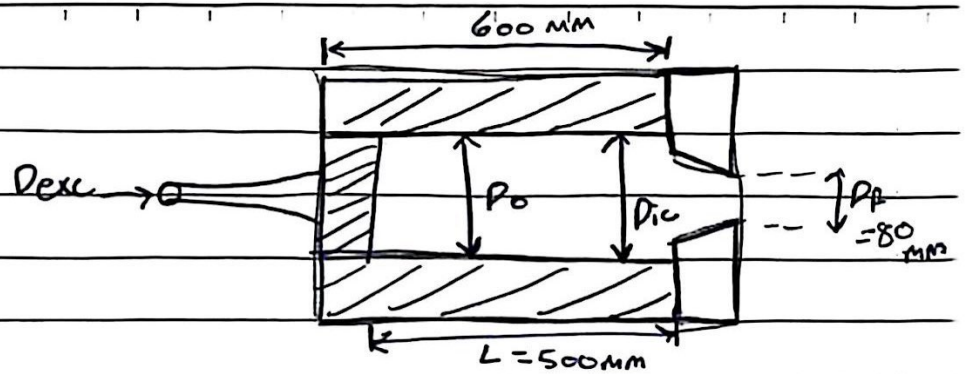
$$\bar{\sigma}_f = \frac{200 \pm 0.21^{0.5}}{1.5} = 61.1 \text{ MPa}$$

if no friction $p = \bar{\sigma}_f \epsilon = 61.1 \pm 0.21 = 12.85 \text{ MPa}$

if friction

$$p = \bar{\sigma}_f \cdot \left(1 + \frac{\tan \alpha}{\mu} \right) / (R_c^{4 \cot \alpha} - 1)$$

$$= 44.32 \text{ MPa}$$



Container material

$$\sigma_y = 250 \text{ MPa}$$

$$\mu = 0.5 \quad \alpha = 15^\circ \quad P_o = 100 \text{ mm}$$

$$E = 250 \text{ GPa}$$

$$\sigma = 200 \epsilon^{0.5} \text{ MPa}$$

for frictional case find P_{ex} so that container can absorb all the required energy without experiencing any plastic deformation.

$$R_c = \frac{D_o^2}{D_i^2} = 1.56, \quad E = \ln R_c = 0.44$$

$$\bar{\sigma}_p = 88.44 \text{ MPa}$$

$$p = \bar{\sigma}_p \left(1 + \frac{\tan \alpha}{\mu} \right) (R_c^{\mu \cot \alpha} - 1) = 175.61 \text{ MPa}$$

$$F = pA = 175.61 \times 10^6 \times \frac{\pi}{4} (100)^2 \times 10^{-6}$$

$$F = 13.8 \text{ kN}$$

$$W = FL = 13.8 \times 10^3 \times 500 \times 10^{-3} = 6900 \text{ J}$$

N.m
↓
المقدار المطلوب
الم
الم

$$\text{using } HCR = \frac{\sigma_y^2}{2E} = 0.5 \times 10^6 \text{ energy/Volume}$$

$$0.5 \times 10^6 = \frac{6900}{\text{Volume}} \quad \text{Volume} = \frac{\pi}{4} (D_{ex}^2 - D_{in}^2) \times 600 \text{ mm}$$

$$0.5 \times 10^6 = \frac{\pi}{4} \times (D_{ex}^2 - 100^2) \times 600 \times 10^{-3}$$

$$D_{ex} = 204.1 \text{ mm}$$

6.5 Rod, Wire, Tube drawing

drawing

is a process of drawing a rod of diameter d_0 into a wire of diameter d_f .

↓ the first operation in bulk deformation processes that we use tensile forces (pulling).
(final dimension of wire is d_f , force is F) tensile stresses

* drawing is similar to extrusion

no pressure in drawing → / / = extrusion

(tensile stress) stress is

ideal deformation $\sigma_d \sim$ similar to p in no friction case in extrusion

$$\sigma_d = Y \ln R_e$$

↳ or $\bar{\sigma}_f$

$$F = \bar{\sigma}_f A_f \ln \left(\frac{A_0}{A_f} \right)$$

A_f is the force in the wire (rod) is A_f

ideal deformation and friction

$$\sigma_d = Y \left(1 + \frac{\tan \alpha}{N} \right) \left(1 - \left(\frac{A_f}{A_0} \right)^{1 + \cot \alpha} \right)$$

relative motion of wire to friction in extrusion is used to draw wire ←

extrusion is better than.

example 6.7

هذا هو المطلوب ←

$$\epsilon = \ln \left(\frac{10^2}{8^2} \right) = 0.446 > \epsilon \text{ at UTS} = 0.3$$

important note :- in wire drawing we have to check if $\epsilon \leq \epsilon_{\text{at UTS}}$

UTS لا يتعدى في هذه المراحل لا نريد أن يحدث necking في المراحل

• بعد أن يحدث necking لا يمكن استخدامه

∴ maximum strain in any stage $\leq$ strain at UTS ∴

∴ Example 11 في

$$\text{First stage: } \epsilon_1 = 0.3 = \ln \left(\frac{A_0}{A_{f1}} \right) = \ln \left(\frac{10^2}{D_{f1}^2} \right)$$

$$D_{f1} = 8.61 \text{ mm}$$

$$\text{Second stage: } \epsilon_2 = \ln \left(\frac{8.61^2}{8^2} \right) = 0.146$$

$$\epsilon = \epsilon_1 + \epsilon_2 = 0.3 + 0.146 = 0.446$$

$$\frac{\epsilon}{\epsilon_{\text{UTS}}} = \frac{0.446}{0.3} = 1.48$$

- stages لا يمكن أن تكون 1.01 ←

$$\bar{\sigma}_p = \frac{1300 (0.446)^{0.3}}{1.3} = 785 \text{ MPa}$$

$$F = \bar{\sigma}_p A_p \ln \left(\frac{A_0}{A_p} \right) = 0.0175 \text{ MN}$$

$$\text{Power} = FV = 8.75 \text{ kW}$$

Maximum reduction per pass

constant die cross section $\rightarrow$ deformation & reduction of

deformation $\rightarrow$ drawing stress $\rightarrow$ σ : $\sigma = \frac{F}{A}$

in the ideal case of a perfectly plastic material :

$\sigma = \sigma_y$ $\rightarrow$ $\sigma = \sigma_y$

$$\sigma_d = \sigma_y \ln \left(\frac{A_0}{A_f} \right) = \sigma_y$$

$$\ln \left(\frac{A_0}{A_f} \right) = 1$$

$$\frac{A_0}{A_f} = e$$

$$\frac{A_0 - A_f}{A_0} = 1 - \frac{1}{e} = 63.7\%$$

deformation $\rightarrow$ $\sigma = \sigma_y$

in strain hardening no friction

$$\sigma_d = \bar{\sigma}_p \ln \left(\frac{A_0}{A_f} \right) = \sigma_y$$

$$= \frac{K \epsilon^n}{n+1} \ln \left(\frac{A_0}{A_f} \right) = \sigma_y \rightarrow \frac{K \epsilon^{n+1}}{n+1}$$

$$\epsilon_1 = n+1$$

$$\text{maximum reduction Area} = 1 - e^{-(n+1)}$$

1 maximum strain $\leq \epsilon_{at UTS}$ in strain hardening

2 maximum reduction in area $= 1 - e^{-(n+1)}$

yield point elongation in low carbon steel sheet metal

chapter 7: sheet metal processes

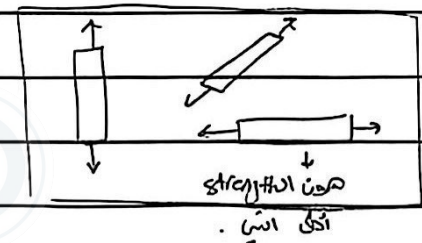
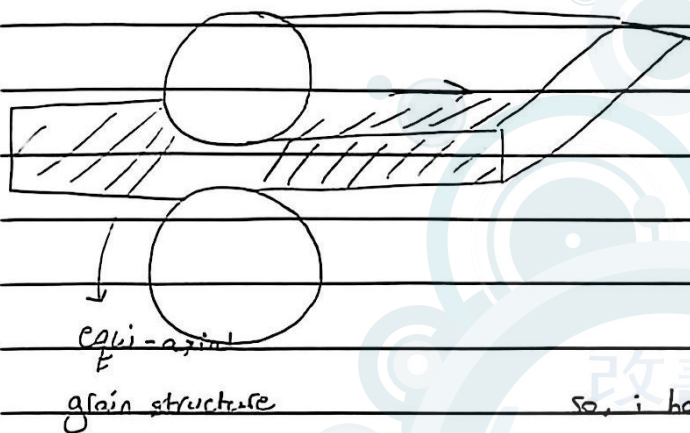
1. yield point elongation

yield point elongation happens in low carbon steel sheet metal

2. Anisotropy: differences in property due to differences in direction

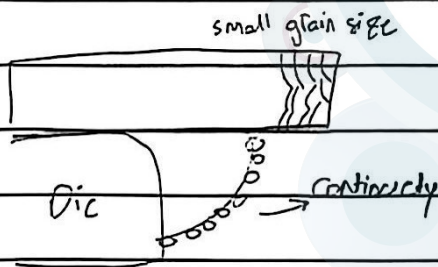
Note:

main process in sheet metal forming: flat rolling.



so, i have to choose the appropriate direction

3. grain size: large grain size: more defects



4. Residual stresses: inner stresses due to nonuniform deformation

(الضغط الداخلي في actual stresses في الأجزاء المتبقية)

5. spring back: elastic recovery in sheet metal.

الانحناء العكسي

bulk deformation: $\frac{\text{elastic strain}}{\text{total strain}} \ll \text{sheet metal} \gg \frac{\text{elastic strain}}{\text{total strain}} \ll$

in bending $\rightarrow$ a lot of elastic deformation that why i will consider springback

6. wrinkling: happens due to unsupported sheet metal parts under compressive stresses.

7. Coated sheet:

الطلاء ← carbon steel

so: we have to choose coating so that it has appropriate properties.

(الطلاء) يجب أن يكون له α 1

Thermal expansion of coat = thermal expansion of sheet / 2

bonding to coat appropriate 1/3

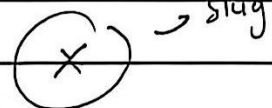
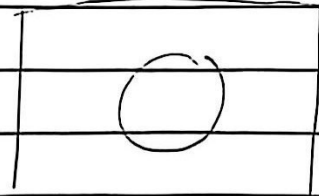
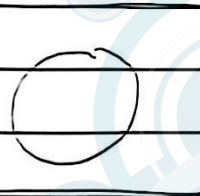
7.3 shearing

figure 7.4 sheet metal die and punch
die punch clearance

figure 7.6 stretching vs. pure shearing
a, b, c stretching

blanking

punching, piercing



sheet metal die and punch

sheet metal die and punch

Blank: sheet metal die and punch

(scrap) slug: sheet metal die and punch

blanking process

punching, piercing process

in slug

buys:

أركان الزاوية إلى بطلان إحدى

rough surface $\rightarrow$ rough surface $\rightarrow$ rough surface

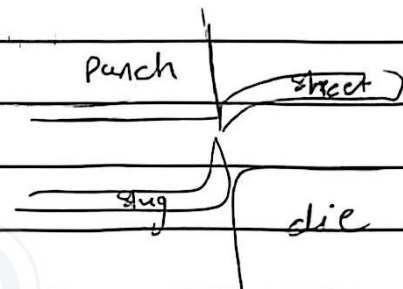
slug is the first all sheet metal 2k. is the one and the only

سؤال : اكتب العنصر من الجدول التالي : sheet metal

call call smooth punch 11 is

الجذ المسد مناد Rubbing slug

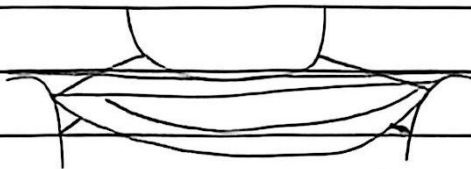
check book - die 11
super important!



super important: the ratio of the burnished to rough areas on the sheared surface
(a) increases with increasing ductility of sheet metal (b) decreases with increasing sheet thickness and clearance.

تفسير : (a) لها تزيه ال stretching ال ductility وبتدق ال punch ال punch
اكتي بال sheet metal و ال slug بتخب ال اكثر بال die فبتدق ال area ال
(amount of travel for punch over sheet and slug over die بتدق)

(b) تَبَيَّنَ أنَّ التَّيْلَانَ clearance و thickness و هو من ٢٠ إلى ٣٠ amount of travel



نسبت در استیکس و زدن در clearance

rubbing is is 21 to can stretching is is 21

the university of Jordan 5 5 record year 5

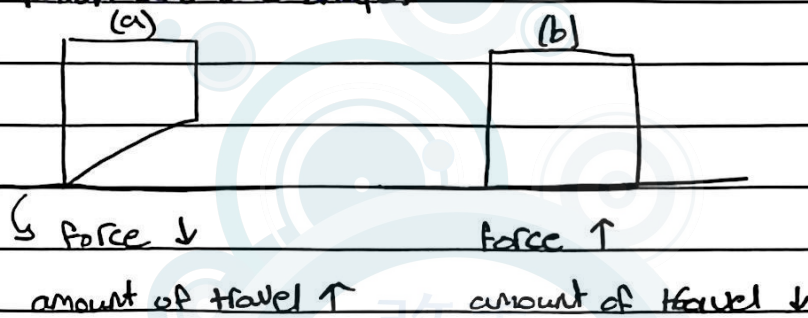
lecture 25

Note 8- Burr height increases with increasing clearance and increasing ductility of the metal

why? because in both cases (increasing ductility or clearance) stretching increases which may allow the material to stretch down

7-3.2 shearing dies

1. punch and die shapes



$$\text{energy} = \text{force} \times \text{distance}$$

∴ same total energy

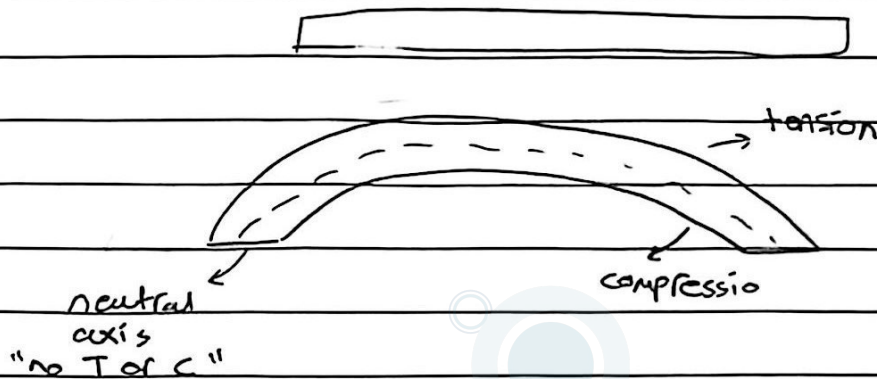
that's why i will use (a) to contain the same energy with less force (less capacity)

Figure 7-11

a, b/c → shaped punch → used in punching → ^{off} punch slug & dies

d → shaped die → used in blanking → ^{off} sheet or disc metal

7.4 bending of sheet metals



$$L_b = \alpha (R + kt)$$

$$K \approx 0.5$$

L_b : bend allowance : neutral axis π idb

α : bend angle

R : bend radius

t : thickness

figure 7.14

$$e_g = e_i = \frac{1}{(2R/t) + 1}$$

fracture) dip maximum strain) is) i) x h) a) k) a) s) l) a) ←

r : reduction in area

$$\frac{R}{t} = \left(\frac{60}{r} \right) - 1$$

minimum $\frac{R}{t} = \frac{50}{r} - 1$ → minimum bend radius

thickness $\frac{R}{t}$ $\frac{50}{r}$

ductility $\frac{R}{t}$ $\frac{50}{r}$

factors affecting bendability

1/ as L increases, the minimum bend radius increases.

(bend length "width" $\propto L$)

2/ Anisotropy of the sheet usually decreases bendability.

ductility $\propto \Delta \sigma_{0.2}$

springback

spring back factor $K_s \rightarrow$ figure 7.17

$$\alpha_f < \alpha_i$$

$$R_f > R_i$$

$$K_s = 0$$

$$K_s = 1$$

$i \rightarrow$ underload

fully springback

no springback

$f \rightarrow$ after releasing load

"complete elastic recovery"

ductile materials

elastic materials

$$K_s = \frac{\alpha_f}{\alpha_i}$$