Indian Institute of Technology, Bombay / Department of Mechanical Engineering
ME 206 – Manufacturing Processes - I

Time:50 mins QUIZ - IV Total Marks: 45 [(3 + 5) + (8 + 8) + (4 x 2) + (5 + 3) + 5]

1. *If the state of stress in an isotropic ductile alloy reaches a limiting condition such as the yield strength of the alloy, it undergoes plastic deformation. The yield condition of the alloy is expressed mathematically by Tresca's criterion and von Mise's criterion. Considering $\sigma_1$, $\sigma_2$ and $\sigma_3$ as the three principal stresses, please write the expression for both Tresca's yield criterion and von Mise's yield criterion and, explain using 2 to 3 bullet points and a simple schematic sketch, how these two yield criteria are different.*

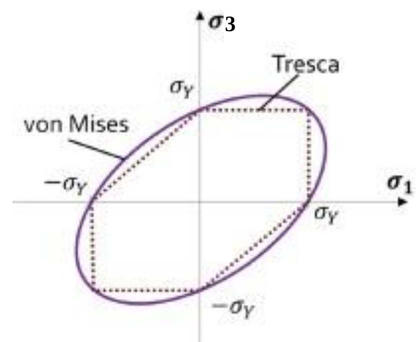
**Ans:**

Tresca's yield criterion: $\sigma_1 - \sigma_3 = Y = 2k,$

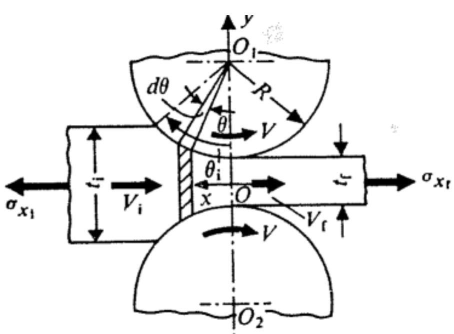
Von Mise's yield criterion: $(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2Y^2 = 6k^2$

(Y is uniaxial yield stress, and k shear yield stress, principal stresses are $\sigma_1 > \sigma_2 > \sigma_3$)

- Tresca: maximum shear stress criterion; von Mises: distortion energy criterion
- Tresca yield criterion is more conservative and mathematically simple.
- Tresca's yield locus is hexagon whereas von Mises's yield locus is elliptical.
- Intermediate principal stress is included in von Mises but not in the Tresca criterion.




2. *Following figure show the typical nomenclature of forces on a strip and its geometry during rolling. The expressions for pressure distributions before and after the neutral (no-slip) point are also given below. For both the front tension and back tension equal to zero, (a) find $\theta_n$ at which the no-slip will occur, and (b) show schematically the likely distribution of roll pressure along the roll - strip contact length from the entry to exit with reasons in 2-3 bulleted points.*




$$\frac{p_i}{2\tau_y} = 1 - \frac{(\sigma_x)_i}{2\tau_y} = \frac{2R}{t_i}\left(1 - \frac{(\sigma_x)_i}{2\tau_y}\right) e^{\mu\left\{2\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\theta_i\right) - 2\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\theta\right)\right\}}$$

$$\frac{p_f}{2\tau_y} = 1 - \frac{(\sigma_x)_f}{2\tau_y} = \frac{2R}{t_f}\left(1 - \frac{(\sigma_x)_f}{2\tau_y}\right) e^{\mu\left\{2\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\theta\right)\right\}}$$

**Ans:**

(a) The neutral point can be determined simply by equating two equations.

$$\left(1 - \frac{(\sigma_x)_i}{2\tau_y}\right) = \left(1 - \frac{(\sigma_x)_f}{2\tau_y}\right)$$

At neutral point

$$\frac{2R}{t_i}\ e^{\mu\left\{2\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\theta_i\right) - 2\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\theta_n\right)\right\}} = \frac{2R}{t_f} \text{-} e^{\mu\left\{2\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\theta_n\right)\right\}}$$

$$\frac{t_i}{t_f} = \frac{e^{\mu\left\{2\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\theta_i\right) - 2\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\theta_n\right)\right\}}}{e^{\mu\left\{2\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\theta_n\right)\right\}}} = e^{\mu\left\{2\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\theta_i\right) - 4\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\theta_n\right)\right\}}$$

$$\ln\frac{t_i}{t_f} = \mu\left\{2\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\,\theta_i\right) - 4\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\,\theta_n\right)\right\}$$

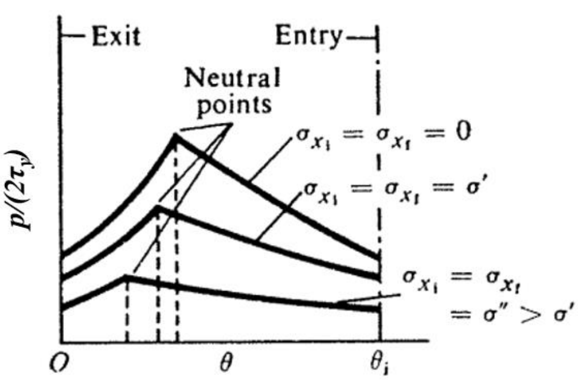
$$4\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\,\theta_n\right) = 2\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\,\theta_i\right) - \frac{1}{\mu}\ln\frac{t_i}{t_f}$$

$$\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\,\theta_n\right) = \sqrt{\frac{t_f}{R}}\frac{1}{2}\left\{\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\,\theta_i\right) - \frac{1}{2\mu}\ln\frac{t_i}{t_f}\right\}$$

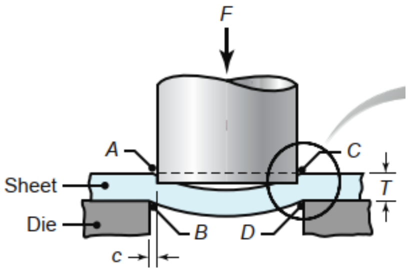
$$\theta_n = \sqrt{\frac{t_f}{R}}\,\tan\left[\sqrt{\frac{t_f}{R}}\frac{1}{2}\left\{\sqrt{\frac{R}{t_f}}\tan^{-1}\left(\sqrt{\frac{R}{t_f}}\,\theta_i\right) - \frac{1}{2\mu}\ln\frac{t_i}{t_f}\right\}\right]$$

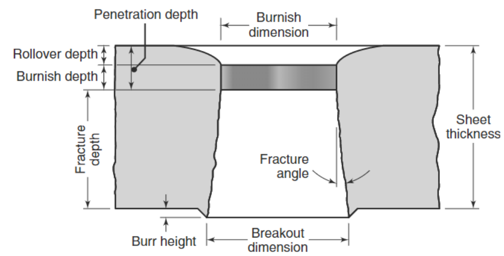
(b) Roll pressure:

- Roll pressure increases continuously from entry to the neutral point, thereafter, decreases continuously.
- Peak pressure at the neutral point (friction hill) increases with $\mu$.
- Roll pressure increases with increasing strength of the material, increasing coefficient of friction, and increasing $\frac{R}{t_f}$ ratio.



3. *Following picture shows shearing of a sheet by a set of punch and die. Please show with a clean figure what will be the typical profile of the sheared edge through the sheet thickness. Show different regions on the sheared edge with two bullet points defending the reason for the formation of each region.*



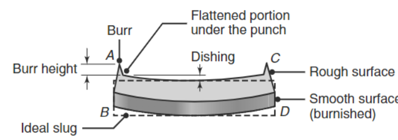

**Ans:**

Rollover
- The initial movement of the punch and sheet into the die

Burnish
- Smooth and shiny surface
- The lower region of sheared edge rubs against the die wall
- The upper region of sheared edge rubs against the punch

Fracture
- Deformation zone
- High shear strain

Burr
- Tooling with dull edges




4. (a) *How would you estimate the force required to punch a 25 diameter hole for a 3 mm thick sheet, which has a room temperature ultimate tensile strength of 600 MPa? (b) State in maximum three bullet points how an increase or decrease in the clearance between die and punch may influence the force and why?*

**Ans:**

(a) Punch force = shear strength x sheared area

An approximate empirical formula for estimating the maximum punch force is $F_{max} = 0.7(UTS)tL$,

$L = \pi D$, $F_{max} = 0.7 \times 600 \times 3 \times \pi \times 25 = 98.96$ kN

(b) If the clearance is optimum, then the two fracture lines meet and a clean edge is obtained with optimum force. The required force varies as the clearance increases or decreases.

- If clearance is too small, then the fracture lines miss each other, and a secondary deformation takes place.
- If clearance increases, the edges become rougher, and the deformation zone becomes larger. The material is pulled into the clearance area.
- If the clearance is too large, the sheet metal is bent and subjected to tensile stresses.

5. *Using maximum four bullet points, state the important differences among a compound die, a progressive die and a transfer die, which are commonly used for shearing / blanking / punching of sheet metals.*

**Ans:**

- Several operations in one stroke in one station, different operations at the same station, and different operations at different stations in case of a compound, progressive, and transfer die respectively.
- Compound dies are limited to simple shearing, a slow process, and more expensive than individual shearing.
- The high production rate in progressive dies due to a series of punches acting on the same station.
- Part is transferred to the next station for subsequent operations in case of transfer dies.