ME 230
Mechanical Processing of Materials
HW#3

Instructor: Ramesh Singh
Assigned Date: March 27, 2026
Due Date: April 3, 2026

Sheet Metal Forming

1. Why is the bending force in $P_{max} = \frac{kYLT^2}{W} \approx k\frac{(UTS)LT^2}{W}$ proportional to T^2. Show from bending stress equations.
2. A cylindrical cup is drawn from the sheet metal that has a normal anisotropy of 3. Estimate the maximum ratio of cup height to cup diameter that can be successfully drawn in single draw. Assume that the thickness of the sheet throughout the cup remains the same as the original blank thickness.
3. Find the maximum bending force required for a 1/8" thick and 12" wide Ti-5Al-2.5Sn Titanium alloy in a V-die with a width of 6".
4. For the material mentioned problem 3, estimate the force required for deep drawing with a blank diameter of 10" and a punch diameter of 9".

Machining

1. Consider the Merchant's Cutting Force diagram and tool-chip interface presented in the lecture notes. Consider the directions of the cutting force and the thrust force. Will the Fc, cutting force, be always positive and why? Is the thrust force, Ft, also positive at all times? If not, explain why. Show from force expressions how you can make Ft = 0 for a given friction coefficient between the tool and the work piece. Please provide physical explanations of your suggestions/recommendations.

2. Assume that in orthogonal cutting operation the frictional force, F, is given by $F = K\tau_s A_0$ where K is a constant, τ_s is the material shear strength and A_0 can be either (a) uncut chip area; (b) cut chip area. If the rake angle is α and the shear angle is ϕ, prove that the average coefficient of friction, μ, for :
   a) If A_0= uncut chip area: $\mu = \frac{K \sin \emptyset . \cos(\emptyset - \alpha)}{1 + K \sin \emptyset . \sin(\emptyset - \alpha)}$
   b) If A_0= cut chip area: $\mu = \frac{K \cos^2(\emptyset - \alpha)}{1 + K \cos(\emptyset - \alpha) . \sin(\emptyset - \alpha)}$
3. For the orthogonal cutting of a particular work material with zero rake angle, it has been found that the tool-chip contact length is always equal to the chip thickness (t_c) and the mean shear stress (τ_f) at the tool-chip interface is a proportion k of the mean shear stress on the shear plane (τ), i.e., τ_f=k τ . Find the cutting forces in terms of t_0, w, k and ϕ.

4. The top view of as tube being turned orthogonally is shown in the Figure 1. Rake angle is + 10° and the dynamometer shows Fx = 1259 N, Fy = 0 and Fz = 1601 N. The axial feed is 100

mm/min and the rotational speed of the spindle is 1000 rpm. The chip thickness is 0.28 mm. Estimate the shear strength of the workpiece material and list the assumptions underlying the theory you are using.

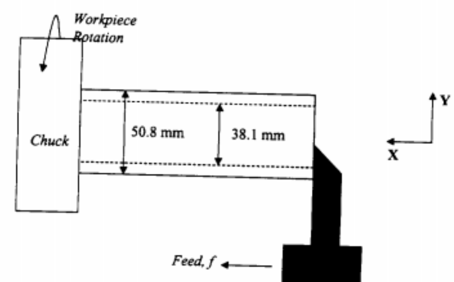

Figure. Top view of cutting process

5. Plot the parametric effect of change in coefficient of friction (or friction angle) on cutting and thrust forces for unit width.
   a) Assume that μ lies between 0.3 and 1 and the shear stress of the material is 400 MPa and rake angle is 10 deg and uncut chip thickness is 0.1 mm. Use Merchant's shear angle relationship. Explain the physical significance of your findings.

   b) Now alter the depth of cut 0.1 mm to 0.01 mm and plot the specific cutting energy vs. uncut chip thickness.

   (Use Mathematica, Matlab or excel to plot. No messy hand plots please)

6. You are planing a part with a tool that takes a cut that is 0.1 mm deep. In a planer, the tool stays still and the workpiece moves orthogonally to the tool, cutting only on the forward stroke; it then indexes over for the next cut. The workpiece has specific heat (c) = 500 J/kg-K, thermal conductivity (k) = 35 W/m-K, and density (ρ) = 3500 kg/m^3. The specific cutting energy (u) for this tool-workpiece combination is 3.5 W-s/mm^3. The melting point of the material is 2200°C, and room temperature = 20°C. The cutting tool can be used up to 1800°C. The tool has an 11 kW motor.
   <u>Determine the maximum feed rate in mm/stroke.</u>

$$\theta = 0.4\left(\frac{u}{\rho c}\right)\left(\frac{Vt_o}{\alpha}\right)^{\frac{1}{3}}$$

θ = temperature <u>change</u>
u = specific cutting energy
ρ = density
c = specific heat
α = thermal diffusivity = k/ρc
V = cutting speed
t_o = depth of cut (orthogonal cutting) or feed (turning on a lathe)
Power = u x MRR