ME 5990
Machining Dynamics
Homework Assignment 1

Problem 1

Consider the orthogonal machining with a 0.25 mm uncut thickness, a 2.5 mm uncut width, a 200 m/min cutting speed, and a 10° rake angle. The shear angle and rake face coefficient of friction have been determined to be 30° and 0.50, respectively. The shear-zone tensile yield strength under these conditions is estimated to be 750 MPa.

a) If the specific shear energy u_s is the shear strain energy per unit volume of material sheared on the shear plane, and the material is assumed to exhibit elastic-perfectly plastic behavior, what is u_s in N/mm^2?

b) What is the in-plane shear force P_ϕ in N?

For the remainder of the problem, assume the answer to part (b) is P_ϕ = 470 N.

c) Using **equations** provided in class, or any others you can **derive** from the FCD geometry, calculate the in-plane rake face force component P_γ in Newtons. **Hint:** Deriving FCD relations is computationally the easiest, but if you wish to use equations from class, get N_γ and P_γ in terms of P_ϕ (known) then solve for N_ϕ knowing μ, and substitute N_ϕ back to find P_γ.

Problem 2

Consider the orthogonal machining of 4140 steel with a high speed steel tool of 20° rake angle at a 0.30 mm uncut thickness and a 1.0 mm width of cut. The machining force components in the cutting and thrust directions are measured to be F_C = 900 N and F_T = 300 N. Assume the Ernst and Merchant shear angle model is valid for this material.

a) What is the average effective coefficient of friction on the rake face μ?

b) What is the shear strain seen by the work material as it traverses the shear plane?

For the remainder of the problem, assume the answer to part (b) is γ= 1.70 and that the corresponding shear angle is ϕ_o = 35°.

c) What is the specific cutting energy in N/mm^2?

d) What are the specific shear and friction energies in N/mm^2?

e) Estimate the shear yield strength of the shear-zone material in MPa.

Problem 3

Consider the orthogonal machining of A-2 tool steel with a 10° rake angle tool. The coefficient of friction is estimated to be 0.75. The shear yield strength of the shear-zone material is estimated as a function of shear plane size, l_ϕ in mm, to be $400 \cdot l_\phi^{-0.25}$ MPa. It should be assumed that the Lee & Shaffer shear angle model is valid for this material.

a) The term used to describe the fact that the shear yield strength shows dependence on the shear plane length, via its dependence on uncut chip thickness, is called size effect. **Briefly** describe the multiple contributors to the size effect and when, in terms of process variables, they are predominant. The following are some of the process variables to consider: uncut chip thickness, rake angle, cutting speed, width of cut.

b) What is the specific shear energy u_s in N/mm^2 as a function of uncut chip thickness, h in mm?

For the remainder of the problem, assume the answer to part (c) is $u_s = 950 \cdot h^{-0.25}$ N/mm^2 for h in mm.

c) An experiment is conducted at V = 50 m/min, an uncut thickness of h = 0.20 mm and a width of cut of w = 2.0 mm. What is the shearing power $\mathcal{P}_s$ in Watts?

d) From the information accumulated so far (S_{sy}, a, V, γ_o, ϕ_o and μ), can the FCD be drawn? Why/how or why not? Sketching (or attempting to sketch) the FBD may help, but is not necessary.