

# 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  $10^\circ$  rake angle. The shear angle and rake face coefficient of friction have been determined to be  $30^\circ$  and 0.50, respectively. The shear-zone tensile yield strength under these conditions is estimated to be 750 MPa.

- 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  $\text{N/mm}^2$ ?
- What is the in-plane shear force  $P_\phi$  in N?

**For the remainder of the problem, assume the answer to part (b) is  $P_\phi = 470 \text{ N}$ .**

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

#### Problem 2

Consider the orthogonal machining of 4140 steel with a high speed steel tool of  $20^\circ$  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  $F_C = 900 \text{ N}$  and  $F_T = 300 \text{ N}$ . Assume the Ernst and Merchant shear angle model is valid for this material.

- What is the average effective coefficient of friction on the rake face  $\mu$ ?
- 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  $\gamma = 1.70$  and that the corresponding shear angle is  $\phi_o = 35^\circ$ .**

- What is the specific cutting energy in  $\text{N/mm}^2$ ?
- What are the specific shear and friction energies in  $\text{N/mm}^2$ ?
- Estimate the shear yield strength of the shear-zone material in MPa.

## Homework Assignment 1

### Problem 3

Consider the orthogonal machining of A-2 tool steel with a  $10^\circ$  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,  $l_\phi$  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  $\text{N/mm}^2$  as a function of uncut chip thickness,  $h$  in mm?

**For the remainder of the problem, assume the answer to part (c) is**

$$u_s = 950 \cdot h^{-0.25} \text{ N/mm}^2 \text{ for } h \text{ in mm.}$$

- 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 ( $S_{sy}$ ,  $a$ ,  $V$ ,  $\gamma_o$ ,  $\phi_o$  and  $\mu$ ), can the FCD be drawn? Why/how or why not? Sketching (or attempting to sketch) the FBD may help, but is not necessary.