Ph.D. Qualifying Examination -Manufacturing

The exam is closed books and notes. There are three problems. Attempt all three problems. List all assumptions.

Problem #1

You are given the job of designing an 8,200 kg/hour extruder for high-density polyethylene (HDPE) melt at 230°C to generate 17 MPa head pressure. Assume a constant channel depth extruder with an axial length of 1.5 m. The melt density is 865 kg/m^3, the viscosity is 1000 N-s/m^2, and the specific heat is 3 kJ/kg-K. Assume the flight width is 10% of the barrel diameter. Assume a square pitched screw. The screw spins at 100 revs/min. The helix angle is 17 degrees. The barrel diameter is 254 mm.

(a) Develop algebraic expressions for (i) the optimal channel depth ($H_{optimal}$) and (ii) the channel width (W).
(b) Using the numerical values for the parameters, determine the values of (i) $H_{optimal}$, (ii) W, and (iii) power.

Equations

$$Q_s = \frac{1}{2}\pi N D_b W H cos\theta - \frac{WH^3}{12\mu}\frac{\Delta P_s}{L} sin\theta$$

$$Power = \frac{\mu\pi^2 N^2 D_b^2 W L}{sin\theta}\left(4 - 3\frac{Q_s}{Q_d}cos^2\theta\right)$$

where:

Q_s = volumetric flow rate in the extruder (m^3/s)
Q_d = drag flow component of volumetric flow rate in the extruder (m^3/s)
N = screw rotational frequency (rev/s)
D_b = barrel diameter (m)
θ = screw helix angle (degrees)
μ = viscosity (N-s/m^2)
ΔP_s = pressure drop over the screw from inlet to outlet (Pa)
L = axial length of screw (m)

Problem #2

A mild steel strip of 200 mm wide by 8 mm thick is being cold rolled under plane strain conditions in a 2-high rolling mill with 400 mm diameter steel rolls. A 30% reduction in the cross-sectional area of the strip is desired. Assume the coefficient of friction between the rolls and the steel strip to be 0.1. The flow stress of the strip material is given by $\sigma = 960\varepsilon_t^{0.15}$ MPa.

Answer the following questions:

a. Is the proposed rolling operation feasible? Justify your answer quantitatively.
b. Calculate the roll separating force and the total rolling power of the mill, if the speed of rolling is 20 m/min.
c. Calculate the angular position of the neutral point in the roll gap and comment on the effect any front or back tension will have on its location and the magnitude of the maximum roll pressure. Use an appropriate sketch to explain this.
d. Suggest at least four ways in which the rolling power can be lowered.

Problem #3

A. State whether the following statements are true for orthogonal cutting and justify your answers:

i. For the same shear angle, there are two rake angles that give the same cutting ratio.
ii. For the same depth of cut and rake angle, the type of cutting fluid used has no influence on chip thickness.
iii. If the cutting speed, shear angle, and rake angle are known, then the chip velocity can be calculated.
iv. The chip becomes thinner as the rake angle increases.
v. The function of a chip breaker is to decrease the curvature of the chip.

B. An orthogonal cutting operation is being carried out to machine a piece of steel. The machine has a power of 15 kW. The initial thickness of a piece of steel 50 mm, and the final thickness is 45 mm. The tool is 31 mm wide. The tool can withstand at temperature of 1300°C. Room temperature is 20°C.

- **Determine the cutting speed.**

Properties of Steel
T_m - Melting temperature = 1400°C
ρ - Density = 7000 kg/m^3
c - Specific heat = 475 J/kg-°C
k - Thermal conductivity = 36 W/m-°C
u - Specific cutting energy = 6 W-s/mm^3

Temperature rise

$$\Delta T = \frac{0.4u}{\rho c}\left(\frac{Vt_o}{a}\right)^{\frac{1}{3}}$$

α = thermal diffusivity = k/ρc
V = cutting velocity
t_o = depth of cut for orthogonal cutting
b = width of cut for orthogonal cutting

this equation is valid for $b/t_o > 5$