PhD Qualifying Exam - Manufacturing
Fall 2016

Answer all problems. Clearly show all of your work. List all relevant assumptions.

1. A solid round bar of steel has a diameter of 1 inch. When drawn to 0.57 inch in one pass using 20,000 lb of measured drawing force, the bar cracks. As an alternative to drawing, it is planned that the 1 inch bar shall be extruded to avoid cracking. If the available extruding machine offers a maximum extrusion force of 20,000 lb, what is the smallest possible final diameter in one pass of extrusion?
2. A medium carbon steel bar 100 mm in diameter is to be turned down on a lathe to 70 mm in diameter over 50 mm of its length. It is known that the specific cutting energy of the workpiece material is 2 GJ/m^3 and the lathe has a 3 kW spindle motor that is 80% efficient. The entire operation is divided into two consecutive steps: first, a roughing cut with 12 mm depth of cut that utilizes the maximum available power of the lathe and second, a finishing cut at a feed of 0.1 mm and an average cutting speed of 1.5 m/s. Estimate the following quantities:
    a. The machining time required for the roughing cut.
    b. The machining time required for the finishing cut.
    c. The total production time for each part if the load and unload time is 20 s and it takes 30 s to set the cutting conditions, set the tool at the beginning of each cut, and engage the feed.
    d. The average cutting forces generated in the roughing and finishing cuts. Assume the feed in the roughing cut to be the same as specified above for the finishing cut.
    e. Briefly discuss at least two ways by which you can reduce the cutting force in the roughing operation without compromising the productivity of the operation.
3. An extruder has a barrel diameter of 75 mm and rotates at 100 rpm. The screw has a channel depth of 6 mm, a channel width of 35 mm, and a flight angle of 17.5 degrees. The pumping section of the screw is 3 m long and is used to extrude a rod polyethylene rod. When melted, the polyethylene has a viscosity of 80 N-s/m^2. The die has a diameter of 5 mm and is 10 mm long.
    a. Determine the flow rate through the die.
    b. With the aid of a graph of the specific volume versus temperature, explain the importance of the injection pressure or extrusion pressure during polymer processing.

<u>Die flow equations based on geometry</u>

Rectangular $Q = \frac{wH^3}{12\mu}\frac{\Delta p}{L}$ **Cylindrical** $Q = \frac{\pi R^4}{8\mu}\frac{\Delta p}{L}$

Screw flow equation

$$Q = w\left[\frac{v_z H}{2} - \frac{H^3}{12\mu}\frac{dp}{dz}\right]$$

Nomenclature:

Q = flow rate (m^3/s)
w = width of flight or channel (m)
H = height of flight or channel (m)
μ = viscosity ($N\text{-}s/m^2$)
R = radius of channel (m)
L = dz = length of channel (m)
Δp or dp = pressure drop or back pressure (Pa)
v_z = velocity along flight (helix)
z = direction along flight (helix)
ρ = density
r = radius