Manufacturing Qualifying Exam Spring 2016

All three questions should be answered.

1. A molten metal is being poured into the sprue of a sand mold at a constant flow rate during the time it takes to completely fill the mold. At the end of pouring the sprue is filled and there is negligible metal in the pouring cup. The sprue is 6.0 in long. Its cross-sectional area at the top is 0.8 in^2 and it cross-sectional area at the base is 0.6 in^2. The cross-sectional area of the runner leading from the sprue is also 0.6 in^2 and it is 8.0 in long before leading into the mold cavity, whose volume is 65 in^3. The volume of the cylindrical riser, which is located along the runner, near the mold cavity, is 25 in^3. The time taken to fill the mold (including the cavity, riser, runner, and sprue) is 3.0 seconds. It turns out that this is more than the theoretical mold filling time required, indicating there is a loss of velocity due to friction in the sprue and runner.

Provide a labeled sketch, state all your assumptions, and find:

a. The theoretical velocity and flow rate at the base of the sprue.
b. The actual velocity and flow rate at the base of the sprue.
c. The loss of head (in inches) in the gating system due to friction.
d. The length of the cylindrical riser is to be 1.25 times its diameter. The casting is a rectangular plate 13 in x 5 in x 1 in. Determine the riser dimensions so that it will take the riser 30% longer to solidify than the casting.

2. The turning operation generates a "theoretical" surface finish on the part.

a) Derive the mathematical relationship for this theoretical surface finish, and provide any necessary process parameters. For simplicity please use a feed rate, F, in terms of distance per revolution, and assume that you are using a standard triangular insert (which is an equilateral triangle). Please define all other parameters that you will need for this derivation.

b) Discuss any limitations of the relationship that you have developed. That is to say, your model should work well, but what are the limitations of your model aspects such as process parameters.

3. When used to supply molten plastic for producing fiber from thermoplastics, the output of an extruder is often controlled by a gear pump (figure 1). A gear pump consists of two, intermeshing, counter-rotating spur gears.

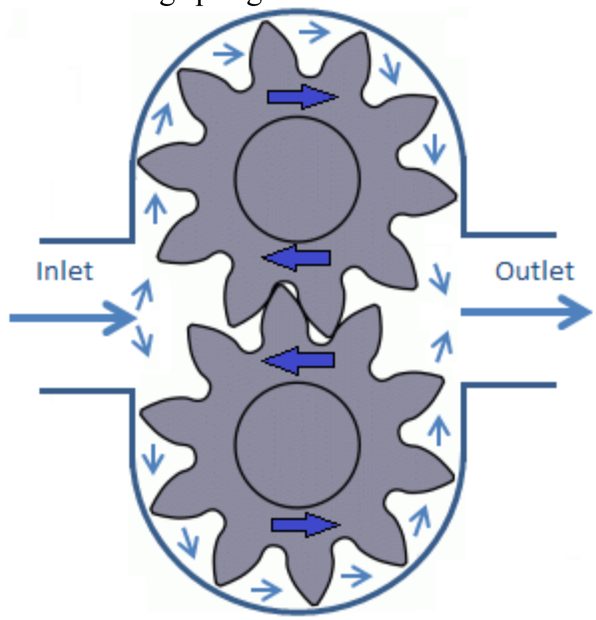

Figure 1 Gear Pump

The gear pump maintains a constant flow rate regardless of the pressure at the input to the gear pump, located just to the right of the "Screen Changer" label and to the left of the "Gear Pump" label in figure 2.

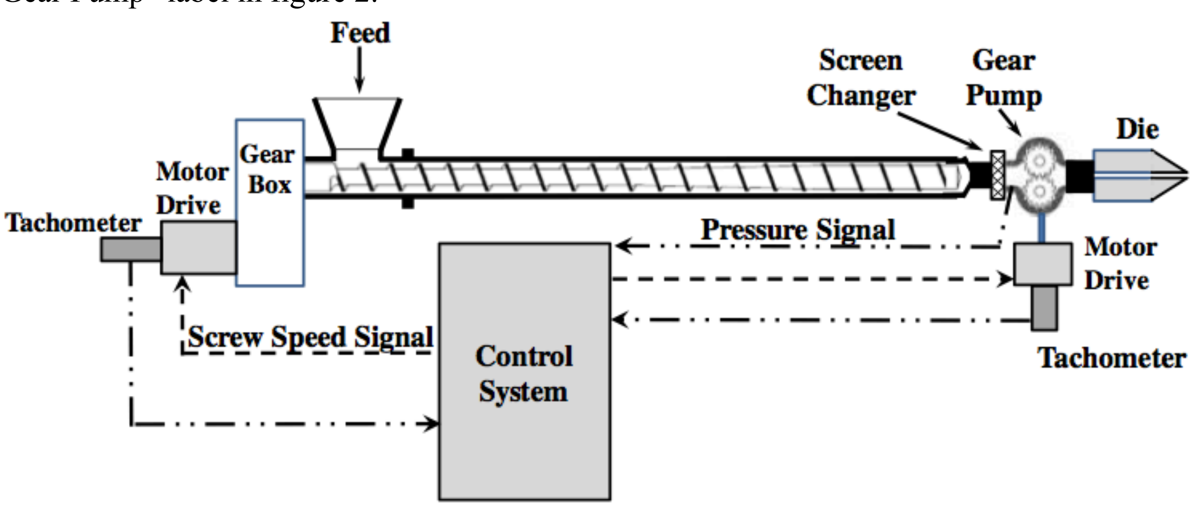

Figure 2 Extruder / Gear pump system

In order to control the pressure at the die, one company uses a controller, as shown in Figure 2, which senses the pressure at the inlet to the gear pump (source of arrow labeled "Pressure Signal" in Figure 2) and controls the screw speed. In addition to this controller, there is a safety device (not shown), which shuts off the whole system if the pressure exceeds a critical value.

You are called in as a consultant because occasionally the safety device shuts down the line. An inquiry shows that there are no blockages or other mechanical failures, and that both the controller and safety device are working properly. The polymer is a Newtonian fluid. You may ignore any effects due to the screen changer. Answer the following two questions:

a) What is causing this problem?
b) What are your recommended solutions?

Be sure to list all of your assumptions. You do need to include in your answers all relevant equations.

Newtonian fluid

$\tau = \mu \cdot \dot{\gamma}$

t = shear stress (N/m^2)

m = viscosity ($N\text{-}s/m^2$)

$\dot{\gamma}$ = shear rate (1/s)

Screw flow equation (drag and pressure flow) (Newtonian)

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

Round channel flow equation (pressure flow) (Newtonian)

$$Q = \frac{\pi R^4}{8\mu}\frac{\Delta p}{L}$$

Rectangular channel flow equation (pressure flow) (Newtonian)

$$Q = \frac{wH^3}{12\mu}\frac{\Delta p}{L}$$

Q = flow rate (m^3/s)

w = width of flight or channel (m)

H = height of flight or channel (m)

R = radius of channel (m)

L = dz = length of channel (m)

Dp or dp = pressure drop (Pa)

v_z = velocity along flight (helix)

z = direction along flight (helix)

θ = helix angle

length along a helix = axial length/sin (θ)

velocity along helix = velocity of barrel * cos (θ)

Gear pump output

$$Q_{gp} = \frac{\pi}{2} \cdot b \cdot \left({d_a}^2 - a^2\right)$$

Q_{gp} = gear pump displacement (m^3/revolution)

b = thickness of gear tooth (m)

d_a = outer diameter of gear (m)

a = center to center distance of gears (m)
