Manufacturing Qualifier

Closed books
Closed notes

Work only three (3) of the questions

List and justify all of your assumptions

Show all work

Question #1: Metal Machining

A HSS single-point cutter is used to turn a cylindrical aluminum alloy work piece under a feed of 1/16” and a depth of cut of 1/8”. From experiments it has been found that the cutter lasts for 187 minutes (before the cutting edge wears out) under a cutting speed of 50 fpm, and seven minutes under 100 fpm. Each piece of cutter costs $20 and can be re-sharpened five times before disposal. It is estimated that a skilled worker, for an hourly rate of $80, takes two minutes to change the tool and five minutes to sharpen the tool.

(1) What is the maximum achievable productivity (in terms of material removal rate, in^3/min) over one entire course of a tool life cycle?
(2) What is the tool life (in minutes) under this maximum productivity condition?
(3) What is the cutting speed (in inch/min) to reach that maximum productivity?
(4) Suppose a less skilled worker is hired at an hourly rate of $58, and he takes five minutes to change the tool and ten minutes to sharpen the tool, how would this change your choice of the cutting speed (for (3), that is)? Why?

List all assumptions used in your analysis.

Question #2: Polymer Extrusion

While on a top secret assignment, you are responsible for conducting several research projects under very strict guidelines provided by the project managers. P-FX is contained inside an environmental chamber, because the specimens are sensitive to ambient conditions, i.e., 25°C and 50% relative humidity.
There has been a major accident that resulted in irreversible damage to the locking mechanism of the environmental chamber, which contains P-FX. Although there is no replacement available, you have access to two extruder machines (1 and 2) and two materials (A and B), as listed in the table below.

(a) You must choose the best machine and material combination to fabricate your part. Your choice must be fully justified.
(b) Explain why you have chosen this combination and the reasonableness of your solution.

Material A	**Material B**
Thermal conductivity = 0.24 W/m-K	Thermal conductivity = 0.12 W/m-K
Density = 980 kg/m^3	Density = 1040 kg/m^3
Specific heat = 2200 J/kg-K	Specific heat = 2100 J/kg-K
Viscosity = 440 Pa-s	Viscosity = 200 Pa-s
Screw rotates at 75 rpm	Screw rotates at 60 rpm
Extruder 1 - Screw and Die Properties	**Extruder 2** - Screw and Die Properties
Barrel diameter = 42 mm	Barrel diameter = 42 mm
Screw flight depth = 3 mm	Screw flight depth = 3 mm
Screw channel width (normal) = 36 mm	Screw channel width (normal) = 36 mm
Screw helix angle = 20 degrees	Screw helix angle = 20 degrees
Screw axial length = 1.2 m	Screw axial length = 0.8 m
Die diameter = 20 mm	Die diameter = 10 mm
Die length = 50 mm	Die length = 25 mm

Die flow equations based on geometry

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

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

Cooling time based on geometry

Slab $$t_c = \frac{4l^2}{\pi^2\alpha}\ln\left|\frac{4}{\pi}\left(\frac{T_M - T_W}{T_E - T_W}\right)\right|$$

rod $$t_c = \frac{1.7r^2}{\pi^2\alpha}\cdot\ln\left|1.7\cdot\left(\frac{T_M - T_W}{T_E - T_W}\right)\right|$$

<u>Nomenclature:</u>

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)
α = thermal diffusivity = k/ρc
k = thermal conductivity
ρ = density
c = specific heat
2l = thickness
r = radius
T_M = injection temperature
T_E = ejection temperature
T_W = mold temperature

Question #3: Metal Rolling

You are designing a large cold rolling mill. The intended application is flat rolling of a 1045 steel strip of 1.5 m width, from 3 mm to 1.8 mm thickness in a single pass. The roll diameter is fixed at 0.25 m and the lubrication system available yields a friction coefficient of 0.12. The flow stress of the steel is given by $\sigma = 950\varepsilon^{0.12}$ MPa.

(a) Is the specified thickness reduction feasible? Justify your answer through appropriate calculations.

(b) If the peripheral velocity of the rolls is 4 m/s, what is the mill motor power required for the stated thickness reduction?

(c) Discuss three ways to lower the rolling mill power requirement for this problem and explain clearly why the proposed methods will do so.

Question #4: Sand Casting

A casting is being produced out of pure aluminum metal in a sand mold. The metal level in the pouring basin is 254 mm above the level of metal in the mold, and the runner is circular with a 10 mm diameter. Pure aluminum has a density of 2700 kg/m^3 and a viscosity of approximately 0.0015 $N\text{-}s/m^2$ around 700°C.

First, determine the following:

1. The velocity and rate of the flow of the metal into the mold
2. Whether the flow is turbulent or laminar
3. What, if any, corrective action is required

Next, for the sprue described above, determine the following:

4. The runner diameter needed to ensure a Reynolds number of 2000
5. The time it will take for such a runner to fill a $2.5\text{x}10^6$ mm^3 casting

Now, provide your analysis (quantitative and qualitative) on the impact of this filling time on the castability of the component.

6. Is the casting process expected to proceed flawlessly or are some difficulties or concerns expected? Explain.

Next, assume that the mold is bottom-gated. The casting has a square cross-section of 150 mm per side and a height of 100 mm.

7. Derive the equation for the mold filling time and use it to determine the filling time for this mold using the original runner diameter. Assume the sprue is frictionless.

Finally, you are to estimate the time for the casting to solidify. The constant "C" in Chvorinov's rule for this situation is given as 3 s/mm^2. The mold can be broken safely and the casting retrieved when its solidified shell is at least 25 mm thick. You should assume that the casting cools evenly.

8. Determine the time that must transpire after pouring the molten metal before the mold can be broken. Provide justification for your analysis.