ME 355 - Manufacturing Processes

Final Exam - Solutions

Exam guidelines:

1) Do your own work.
2) Do NOT discuss this exam with anyone prior to handing it in.
3) Attempt to do all work in the space provided. The space provided should be sufficient to solve the problem. If it is not, you may be doing too much. However, if you must, attach and clearly label any additional sheets.
4) Open book, open notes.
5) This exam is due at 12:00 pm, Monday, Mar 12, 2001.
6) This exam is OPTIONAL. If you choose to take it, then it will be evaluated as 25% of your total grade for the quarter, (whether it helps or hurts your grade).
7) Good luck.
8) 118 points graded. 120 points possible.

1. (3 points) In 2005, European Union (EU) car manufacturers will be required to receive used cars for recycling. From a design standpoint, what does this mean for the polymers in the vehicle? Specifically: a) What general type of polymers should be used in the vehicle? b) Within that general type of polymer, what should be done to maximize the ability to recycle the materials in the part?

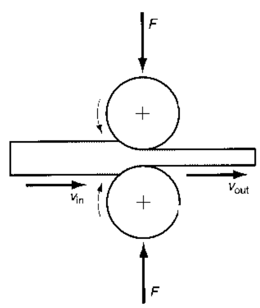
    a) (2 points) Thermoplastics – (Thermosets are not recyclable.)
    b) (1 point) Use thermoplastics from the same family, specifically polyethylene or polypropylene.

2. (3 points) You are the design engineer for a manufacturing firm that produces precision shafting. Recently, you have had a large number of shafts fail in service. The loading conditions for failure are typically a rotating application. List what can be done to a shaft to increase its fatigue life. (List at least three items)

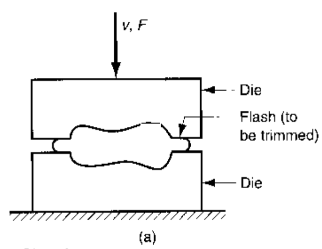
    a) Carburizing, Flame Treatment, Shot Peening, roller burnishing, nitriding, are all acceptable. There are more.

3. (16 points) Identify the following processes:

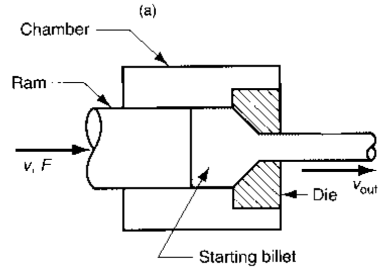
    a) Rolling



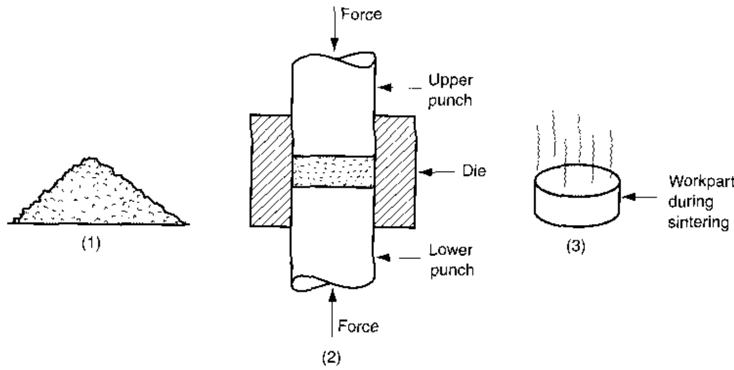
    b) **Forging**



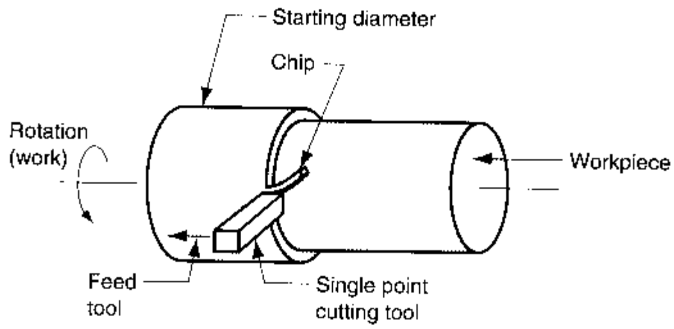
    c) Extrusion



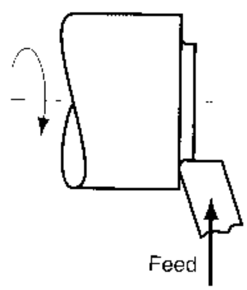
d) **Powder Metallurgy**



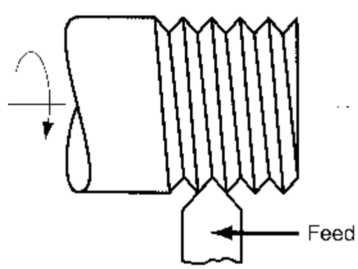
e) **Turning**



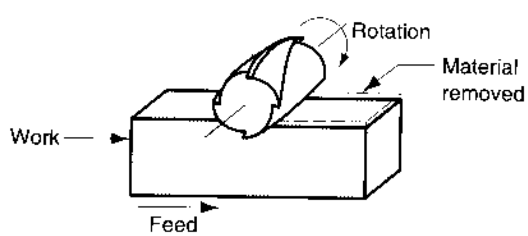
f) **Facing**



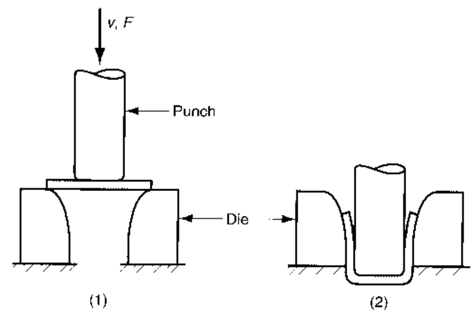
g) **Threading**



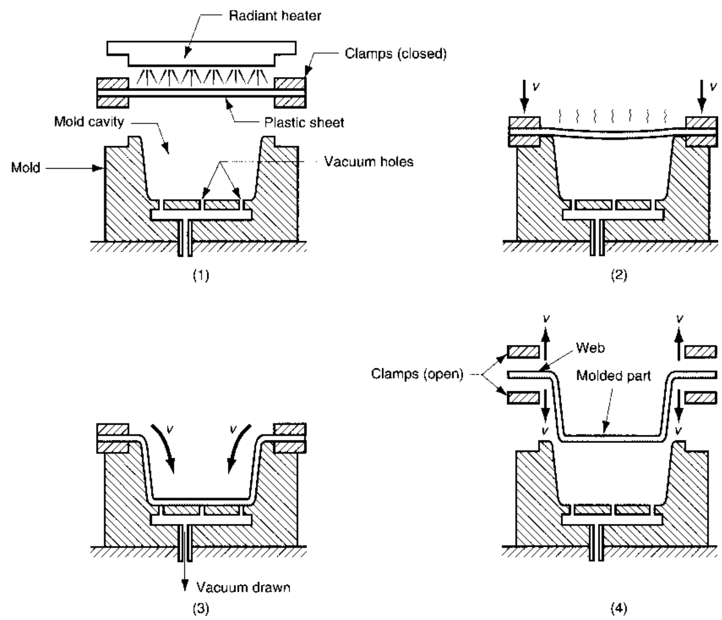
h) **Slab Milling, Specifically, conventional milling.**



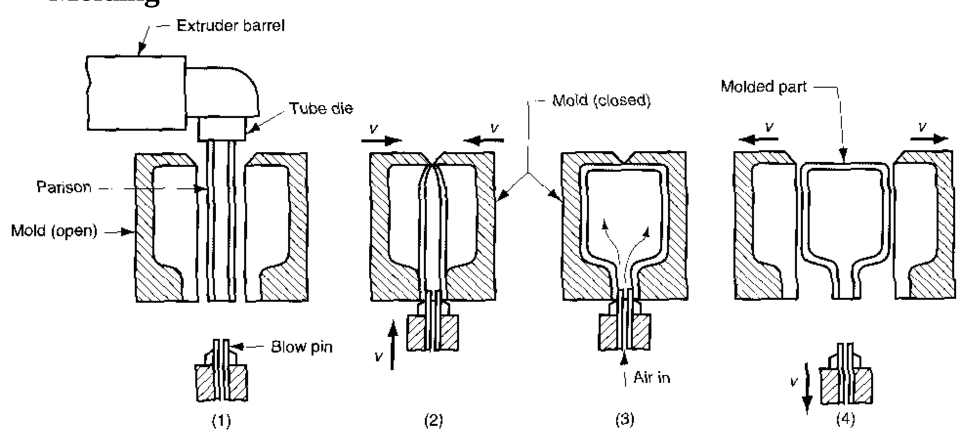
i) Deep Drawing



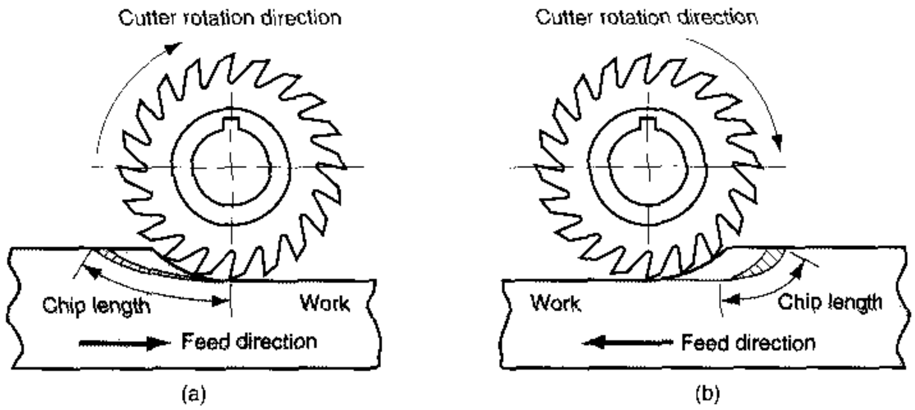
j) Vacuum Forming, (Thermoforming)



k) Blow Molding



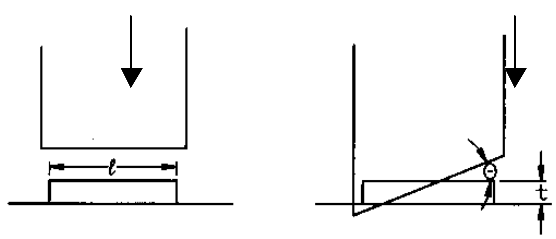
4. (3 points) In the process shown below, identify which process would be better for finishing aluminum. Specifically, what type of operation and what type of cutting is this?



   a) Process (b) is better suited for finishing aluminum. It is a slab milling process, which is specifically called climb milling.

5. (5 points) What are the 5 major steps in a powder metallurgy process?
   a) **Powder Production**
   b) **Mix/Sort Powder**
   c) **Form the part**
   d) **Sinter the part**
   e) **Finishing operations**

6. (6 points) Given a sheet metal shearing operation, as shown below:
   a) (2) Which process will have less force involved?
   b) (4) Given the material will fail in shear at 35,000 psi, and the shown cross-section. Determine the forces required to shear the material using both operations.



Width (labeled l in this picture) = 12 inches.
Thickness (t) = 0.030 inches.
Angle (θ) = 10 degrees.

a) The second process will have less force.

b) $F = \boldsymbol{t} * A_{Shear}$

$$F_{one} = 35{,}000lt = 35{,}000 * 12 * 0.030 = 12600\,pounds$$

$$F_{two} = 35{,}000 * \frac{t}{\tan(q)} * t = 35{,}000 * \frac{0.030^2}{\tan(10)} = 179\,pounds$$

7. (2) Given that a cutting speed of 200 ft/min with a carbide tool will have a tool life of one minute. What is the tool life at 50 ft/min?

   a) **Recall that for a carbide tool, n = 0.25**

$$VT^n = C$$

$$200\ ft/\min * (1\min)^{.25} = 200\ ft/\min$$

$$therefore:$$

$$50\ ft/\min * T^{.25} = 200\ ft/\min$$

$$T = 256\min$$

8. On next two pages.

Given: You need to turn one thousand shafts for an intermediate step in a larger manufacturing process. Each shaft requires thirty minutes of machining time at 50 ft/min, and ten minutes of setup time. Every time a tool is changed, it requires twelve more minutes. The labor cost to run this machine is $100/hr. Overhead cost is 200% of direct labor cost (i.e. overhead cost is $200/hr in addition to the direct $100/hr cost). Material cost per shaft is $50. We will ignore scrap for these calculations. The process has traditionally been done using high speed steel (HSS) tools. You are investigating a change to carbide tools. Determine the following:

Find: a) (2 points) How many HSS tools are required for the job if you can cut for 60 minutes at 50 ft/min? How many Carbide tools if you can cut for 360 minutes at 50 ft/min?

b) (6 points) Assuming the same feed rate as in a) How many tools will you use at 75 ft/min for both the HSS and Carbide tools?

c) (8 points) Calculate the monetary savings to the plant for this batch of shaft by changing to carbide tools when cutting at 50 ft/min. Each HSS tool costs $2/tool and each Carbide tool costs $10/tool. Hint: Cost = labor + material + tools. Labor cost = direct + indirect labor.

d) (2 points) If you increase the cutting speed to 75 ft/min, what will happen to your savings and why? (Do NOT recalculate a value. I just want you to explain what will happen and why. Don't worry about exact numbers.

Solution:

a) HSS: at 30 min/shaft, 60 min/tool, that means you can get two shafts per tool. Therefore, it will take 500 HSS tools.

Carbide: at 30 min/shaft, 360 min/tool, that means you can get twelve shafts per tool. Therefore, it will take 84 Carbide tools.

b) $V \cdot T^n := C$ Taylor tool life equation. $V_{ref} := 50 \frac{ft}{min}$ $V_{new} := 75 \frac{ft}{min}$

HSS Tools: $n_{HSS} := 0.125$ therefore:

$C_{HSS} := 50 \cdot 60^{0.125}$ $C_{HSS} = 83.414 \frac{ft}{min}$

$$T_{HSS} := \left(\frac{C_{HSS}}{V_{new}}\right)^{\frac{1}{n_{HSS}}} \qquad T_{HSS} = 2.341 \frac{min}{tool}$$

Time to machine a shaft:

$$time_{new} := \frac{30}{V_{new}} \cdot V_{ref} \qquad time_{new} = 20 \frac{min}{shaft}$$

Therefore for HSS, it takes $\frac{time_{new}}{T_{HSS}} = 8.543 \frac{tools}{shaft}$ therefore: 8543 tools for HSS

Carbide Tools:

$n_{Carbide} := 0.25$

$C_{Carbide} := 50 \cdot 360^{0.25}$ $C_{Carbide} = 217.794 \frac{ft}{min}$

$$T_{Carbide} := \left(\frac{C_{Carbide}}{V_{new}}\right)^{\frac{1}{n_{Carbide}}} \qquad T_{Carbide} = 71.111 \frac{min}{tool}$$

Therfore for Carbide, it takes $\frac{time_{new}}{T_{Carbide}} = 0.281 \frac{tools}{shaft}$

therefore: 281 tools for Carbide

c) $\text{Cost}_{\text{total}} := \text{Cost}_{\text{labor}} + \text{Cost}_{\text{material}} + \text{Cost}_{\text{tools}}$

$$\text{Cost}_{\text{labor}} := \text{Cost}_{\text{direct}} + \text{Cost}_{\text{overhead}}$$

since overhead cost is directly related to direct cost:

$$\text{Cost}_{\text{labor}} := 300\%\cdot\text{Cost}_{\text{direct}}$$

$$\text{Cost}_{\text{direct}} := \left[\left(\frac{\text{Machinetime}}{\text{shaft}} + \text{SetupTime}\right)\cdot\text{shafts} + \left(\frac{\text{ToolSetupTime}}{\text{tool}}\right)\cdot\frac{\text{shafts}}{\left(\frac{\text{shafts}}{\text{tool}}\right)}\right]\cdot\text{HourlyRate}$$

$$\text{Cost}_{\text{directHSS}} := \left[\left(30\frac{\text{min}}{\text{shaft}} + 10\frac{\text{min}}{\text{shaft}}\right)\cdot(1000\text{shafts}) + \left(12\frac{\text{min}}{\text{tool}}\right)\cdot 1000\frac{\text{shafts}}{\left(2\frac{\text{shafts}}{\text{tool}}\right)}\right]\cdot\frac{100\frac{\text{dollars}}{\text{hour}}}{60\frac{\text{min}}{\text{hour}}}$$

$\text{Cost}_{\text{directHSS}} := \left[(30+10)\cdot 1000 + 12\cdot\frac{1000}{2}\right]\cdot\frac{100}{60}$ $\quad\text{Cost}_{\text{directHSS}} = 7.667\cdot 10^{4}$ dollars

similarly for Carbide: $\text{Cost}_{\text{directCarbide}} := \left[(30+10)\cdot 1000 + 12\cdot\frac{1000}{12}\right]\cdot\frac{100}{60}$

$\text{Cost}_{\text{directCarbide}} = 6.833\cdot 10^{4}$ dollars

$\text{Cost}_{\text{laborHSS}} := 3\cdot\text{Cost}_{\text{directHSS}}$ $\quad\text{Cost}_{\text{laborHSS}} = 2.3\cdot 10^{5}$ dollars

$\text{Cost}_{\text{laborCarbide}} := 3\cdot\text{Cost}_{\text{directCarbide}}$ $\quad\text{Cost}_{\text{laborCarbide}} = 2.05\cdot 10^{5}$ dollars

$\text{Cost}_{\text{material}} := (1000\text{shafts})\cdot\left(50\frac{\text{dollars}}{\text{shaft}}\right)$ $\quad\text{Cost}_{\text{material}} := 50000$ dollars

$$\text{Cost}_{\text{tools}} := (1000\text{shafts})\cdot\left(\frac{\text{tools}}{\text{shaft}}\right)\cdot\left(\frac{\text{dollars}}{\text{tool}}\right)$$

$\text{Cost}_{\text{toolsHSS}} := 1000\frac{1}{2}\cdot 2$ $\quad\text{Cost}_{\text{toolsHSS}} = 1\cdot 10^{3}$ dollars

$\text{Cost}_{\text{toolsCarbide}} := 1000\frac{1}{12}\cdot 10$ $\quad\text{Cost}_{\text{toolsCarbide}} = 833.333$ dollars

$$\text{Cost}_{\text{HSS}} := \text{Cost}_{\text{laborHSS}} + \text{Cost}_{\text{material}} + \text{Cost}_{\text{toolsHSS}}$$

$\text{Cost}_{\text{HSS}} = 2.81\cdot 10^{5}$ dollars

$$\text{Cost}_{\text{Carbide}} := \text{Cost}_{\text{laborCarbide}} + \text{Cost}_{\text{material}} + \text{Cost}_{\text{toolsCarbide}}$$

$\text{Cost}_{\text{Carbide}} = 2.558\cdot 10^{5}$ dollars

d) At 75 ft/min, there will be greater savings by going to carbide tools because the difference in tool life becomes even more substantial. The tool setup cost for HSS will become extremely significant at 75 ft/min, as will the cost of tools.

9. (2 points) When dealing with polymers, what two things combined will tell you nearly all that you need to know?

   a) **Glass transition temperature, (T_g).**
   b) **Molecular Weight.**

10. (3 points) What process is most commonly used to make an injection molding die cavity and why (2 things for why)?

   a) **Electro-Discharge Machining (EDM)**
   b) **Because of the excellent surface finish and good tolerance.**

11. (3 points) Which will have a higher mold temperature when injection molding – Polypropylene or Silicone and why?

   a) **Silicone**
   b) **Because it is a thermoset, PP is a thermoplastic.**
   c) **Thermosets cure faster at elevated temperatures, while thermoplastics need cooler mold temperatures to solidify their shape.**

12. (54 points) How would you make the following and why?:
   a) (2) Metal Matchbox car? **- Die Casting – High volume, precision metal parts.**
   b) (2) Plastic Matchbox car? - **Injection Molding – High volume, precision plastic parts.**
   c) (3) Crank for a bike (the part that the pedals are on). Give two methods and tell which one is superior and why.
      i. **Casting**
      ii. **Forging**
      iii. **Forging is superior due to better mechanical properties**
   d) (2) Prototype gear for a timing mechanism in a car? - **machine it or use rapid prototyping of some sort (i.e. stereolithography) - Low volume, need flexibility of manufacturing.**
   e) (2) Production run gear for a timing mechanism in a car? – **Die Cast, or possibly metal injection molding – High volume, good fatigue life, precision part.**
   f) (2) A kid's hollow plastic baseball bat? - **Blow molding – inexpensive, hollow plastic part.**
   g) (2) A plastic drink cup? – **Blow molding or thermoforming – inexpensive, hollow plastic part.**
   h) (2) A metal drink cup? – **Deep drawing – inexpensive, hollow metal part.**
   i) (2) The mold for an injection molded cover for a CD player? Be very specific (a particular type of this process) **- Die sinker EDM – three**

dimensional geometry, precision tolerance, with great surface finish.

j) (2) How would you cut angel food cake on a production scale, other than with a knife? - **Water jet – cuts well, little or no deformation, clean.**

k) (2) How would you cut the extrusion die for a cooling fin cover on an amplifier? Be very specific (a particular type of this process) – **Wire EDM – precision, two dimensions, great surface finish.**

l) (2) High power electrical transmission lines **- Drawing – high strength wire.**

m) (2) The rubber gasket that seals your car door – **Polymer Extrusion, two dimensional shape, polymer.**

n) (2) Plastic sheet to be made into plastic signs – **Sheet Extrusion, two dimensional plastic sheet.**

o) (2) The metal tips in a fine ball point pen that will have 2,000,000 total units? **- Metal Injection Molding or Powder Metallurgy, precision, high volume.**

p) (2) Plastic gears in your computer printer? **- Injection Molding – precision, high volume.**

q) (2) The free weights in the gym? **- Sand Casting – big, three dimensional, loose finish requirements.**

r) (2) Nails (after the blanks have been made)? **Forging – fast, inexpensive.**

s) (2) Cam shaft in your car? **Die Casting – good fatigue life, precision, high volume. Could be forged – precision, high volume, good material properties.**

t) (2) The plastic cover on your TV? **Thermoforming – inexpensive, three dimensional, polymer.**

u) (2) The plastic milk jug in your fridge? **Blow molding – inexpensive, high volume, hollow three dimensional polymer part.**

v) (2) The lid to the milk jug in your fridge? **Injection molding – three dimensional polymer part.**

13. (Extra Credit – 2 points) What two things will you take away from this course?