MIT 2.008 Design and Manufacturing II

Quiz 2 - Part A, In-Class Component

Spring 2024
May 8th, 2024

- You will have 80 minutes to complete this portion of the exam
- Closed Book, except that you are allowed one double-sided, hand written 8.5" x 11" notes sheet
- All work for CREDIT must be completed in this quiz document
- Calculators are allowed, and we have provided them in the room. Please return them at the end of the exam.

General Notes

- *For qualitative answers, we're not looking for long essays. Please answer using short (1-2 sentence per answer) bullet points.*
- *For quantitative answers, show your work as clearly as possible. When possible, keep answers in algebraic form until plugging in numbers at the very end; this way, it is much easier for graders to understand where you make mistakes and provide meaningful feedback* ***(and partial credit)****.*

Name: _____

Part A, In-Class Component		
Problem 1		Out of 15 points
Problem 2		Out of 31 points
Problem 3		Out of 24 points
Part B, Take-Home Component		
Problem 4		Out of 30 points
Total		**100 points**

Problem 1 - Short Answers (15 points) **(Est. Time: 15 minutes)**

a) For each of the parts below, indicate the *primary* process used to manufacture the item (do not worry about secondary operations). Provide a brief rationale to justify your choice.

	*Primary manufacturing process* ***(circle one)*** Sand casting Investment (lost wax) casting Die casting Sheet metal bending
	Brief Rationale

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	*Primary manufacturing process* ***(circle one)*** Sand casting Investment (lost wax) casting Die casting Sheet metal bending
	Brief Rationale

b) For the following prompts, indicate the correct choice and provide a brief rationale.

i) A contract manufacturer which primarily engages clients to make parts in prototype quantities is best organized in a (**job shop/transfer line/work cell**) structure.

Brief Rationale

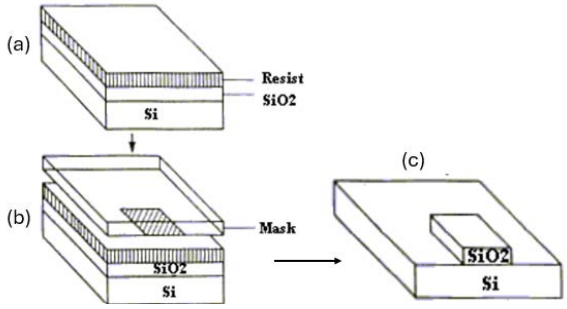
ii) A company will generally consider the rent or mortgage payment on its facility as a (**fixed/variable**) cost of production.

Brief Rationale

iii) A (**chemical vapor deposition/physical vapor deposition**) process is used to add a thin film layer via polymerization to a substrate using a gas as the source material.

Brief Rationale

iv) Based on the mask in step b in the image below, the features produced on the substrate on the right were made with a (**positive/negative**) photoresist



Brief Rationale

v) Aerospace companies are opting to replace metal components with polymer matrix composites for a variety of reasons. One way in which using components from metal is still preferable is (**weight/part strength/stiffness/cycle time**).

Brief Rationale

vi) When making an additively manufactured part, if print time and cost are primary considerations, that favors (**extrusion/photopolymerization**) as the printer choice.

Brief Rationale

Problem 2 - Forming (31 points) (Est. Time: 45 minutes)

Below is a photo of a mounting bracket, primarily sold for as a mount for large motors.

For the questions below, we will ignore the cut holes and focus on the bracket itself, which is made with sheet metal bending. The panel is 4mm thick, and during bending operations, the initial radius of curvature is 10mm.

a) First, let us determine the degree of springback during a bending operation. Assuming that the bracket is made from aluminum (Young's Modulus 70 GPa, yield strength 40 MPa), calculate the radius of curvature after a single operation.

b) Assuming you cannot change the material used, list 1 way you could reduce springback to improve the final part quality.

c) Your engineering team suggests switching to 304 stainless steel (Young's Modulus 200 GPa, yield strength 200 MPa) as a way to reduce cost compared to aluminum. 304 stainless steel is available for $1.25/kg, while it increases to $2.50/kg for aluminum; however, aluminum is much less dense than steel (ρ_{Al} = 2.7 g/cm^3, ρ_{304} = 8.0 g/cm^3).

   i) Your first consideration is that part quality should not be affected by a material change, which means that you want to achieve the same or better degree of springback. Assuming the same initial radius of curvature for the bend, determine the minimum new thickness of the bracket. ***Note: for simplification, you can ignore higher order springback effects.***

ii) Assuming the rest of the part geometry (namely, the area of all surfaces orthogonal to the sheet thickness) is unchanged, determine the ratio of the material cost per part with aluminum compared to 304 stainless steel. Does it appear feasible to make a change in material?

d) The initial mold designs require 7 bending operations to achieve the final shape. However, your engineers come to you with a new set of mold designs, which reduces the process to 5 bends. However, switching to this new tooling requires an additional cost of $25,000, incurred for every 500,000 units produced. Assume the following for a given factory:

Annual demand (parts)	1 million
Labor cost ($/hr)	$20
Average hrs/week/worker	35
Average weeks/yr/worker	48
Cycle time per bending step	6 seconds

i) How many workers do you need to meet production demand, assuming 7 bending steps are needed? How many workers do you need if 5 bending steps are needed?

ii) Will the new tooling pay for itself within one year?

Problem 3 - Casting (24 points) (Est. Time: 20 minutes)

Inspect the glue gun barrel provided with your exam (ignoring the darker polymer section and focusing only on the metal part).

a) Is this part die cast or sand cast? How can you tell?

b) Estimate the cooling time, both for the cases where the part is die cast and sand cast. Assume a coefficient of C = 1,200,000 s/mm^2 for sand casting and C = 80 s/mm for die casting. Assume the volume is 100cm^3 and the surface area is 500cm^2.

c) A critical part of avoiding quality issues during casting is to limit the turbulence of flow when injecting molten aluminum into the mold. Qualitatively (no need to make any calculations), list 2 ways how you can reduce the possibility of short shot without increasing flow velocity.

d) The glue gun manufacturer wants to explore the possibility of making this barrel using powder bed fusion instead of casting. You do not know much about the specific demand or costs of the manufacturer, but you can inform them generally about the tradeoffs between processes. Fill out the table below to qualitatively compare die casting and powder bed fusion to sand casting in terms of quality, cost, rate, and flexibility. We are not looking for very detailed information; just a brief assessment as to whether each process would be better or worse than sand casting with all other factors being equal, and 1 sentence as to why.

Mfg Tenet	**Sand Casting**	**Die Casting**	**Powder Bed Fusion**
Quality	-	*Compare to sand cast* ***(circle one)*** **Better/Worse**	*Compare to sand cast* ***(circle one)*** **Better/Worse**
		Brief Rationale	*Brief Rationale*
Cost	-	*Compare to sand cast* ***(circle one)*** **Better/Worse**	*Compare to sand cast* ***(circle one)*** **Better/Worse**
		Brief Rationale	*Brief Rationale*
Rate	-	*Compare to sand cast* ***(circle one)*** **Better/Worse**	*Compare to sand cast* ***(circle one)*** **Better/Worse**
		Brief Rationale	*Brief Rationale*
Flexibility	-	*Compare to sand cast* ***(circle one)*** **Better/Worse**	*Compare to sand cast* ***(circle one)*** **Better/Worse**
		Brief Rationale	*Brief Rationale*

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