SUPPLMENTARY MATERIALS FOR DETC2018-85769

ME444 STUDY SURVEYS

1 Demographics Survey

Name:

Batch:

1. "Define Geometric Dimensioning and Tolerencing (GD&T) in your own words."

2. Are you familiar with the basic principles of GD&T?
   - If you have studied about this in a course, please mention the course title and list what concepts were taught.
   - If you have used GD&T principles in any machining/fabricating tasks, please describe what concepts you used briefly.

3. Have you ever used a laser cutter? If yes, why?

4. Have you ever used a 3D printer? If yes, what kind (SLA, FDM, Metal) and where?

5. Do you have any knowledge about GD&T considerations in acrylic laser cutting and/or 3D printing? If yes, briefly summarize your understanding of these concepts.

2 LC Mini Fabrication Survey

Name:

Batch:

1. What was your rationale behind choosing the designs dimensions (also include a hand-drawn sketch to explain your rationale)"

2. If you have studied about this in a course, please mention the course title and list what concepts were taught.

3. Are you happy with your submission? How confident are you about the success of your design?

Take multiple measurements of your laser-cut models and tabulate them below. Specify what you have measured in the first column, eg. gear hole diameter, centre to centre distance, box height, etc.

Measured dimension	Design dimension	Atmpt 1	Atmpt 2	Atmpt 3	Atmpt 4	Atmpt 5	Avg	Deviation

1. Are there any difference in dimension(s) between the design and the fabricated part(s)? If yes, how much? Are they within the specified tolerance?

2. Does the gears mesh as expected? In case, you designed the box, did it assemble as expected? Why/why not?

3. What did you learn through this prototyping experience? If given another chance, how would you change the gear/box designs ?

4. Based on this experience, what precautions will you take in your final toy design project?

3 SLA 3D Printing Mini Fabrication Survey

1. Name and Batch

2. Did the performance of the catapult meet your expectations? Why/Why not?

3. List your observations on what failed/worked after testing the catapult assembly (name the components).

4. Indicate the types of failures observed in the catapult;

   ☐ Did not assemble: wrongly dimensioned parts

   ☐ Did not assemble: clearances specified were insufficient

   ☐ Poor assembly: higher than expected friction as clearances were insufficient

   ☐ Poor assembly: loosely fit parts as clearances specified were excessive

   ☐ Structural failure: excess deformation observed in component(s)

   ☐ Structural failure: breakage/fracture observed in component(s)

   ☐ Structural failure: unable to secure/fasten component(s)

5. Briefly explain what caused the observed failures (if any) in the catapult.

6. What did you learn through this prototyping experience? If given another chance, how would you change the catapult design?

7. Based on this experience, what precautions will you take in your final toy design project?

4 Final Interview and Survey

Interview protocol: Planning

1. Print out student responses to previous surveys and organize them by group
2. Print out the paper survey to distribute to students. Note: The paper survey should identify student with his/her name.
3. Check audio recorders in the conference room. Go in and speak to check the recording volume is adequate.
4. Organize a set of A4 sheets / notebooks to take notes during the survey
5. Have 4-5 pens ready to take to survey so that students can fill out the paper survey
6. Make sure the conference room is booked and you have adequate seating
7. NOTIFY students about the survey procedure
8. Conduct a dry run to CONFIRM all systems are working as planned

Interview protocol: Tasks

1. Welcome team
2. Interviewer says: Thank you for participating in the survey. I would like to remind you that the survey responses will be kept strictly confidential. You response to the survey **will not affect your grade** in any manner
3. Note down group name and time of starting interview on a paper
4. Start the audio recorders (Make sure you have two audio recorders running)

Open ended questions asked to the group

Take down short notes during the questions so that you can match it to the audio recording later.

a. Are you satisfied with the performance of the final toy? Why or why not?

b. What are the kinds of failures that you observed in the final toy *(Note down each type of failure observed on the paper, 1=Observed, 0= Not observed. Also note down what kind of part it was and take pictures if you can)*

   i. Did not assemble due to wrongly dimensioned parts

   ii. Did not assemble as clearances specified were insufficient

   iii. Poor assembly due to higher than expected friction as clearances were insufficient

   iv. Poor assembly due to loosely fit parts as clearances specified were excessive

   v. Structural failure due to excess deformation observed in components

   vi. Structural failure due to breakage/fracture observed in components

   vii. Structural failure due to unable to secure/fasten components

   viii. Any other failures

   Interviewer recaps failures mentioned by the students to them

c. What failures in the final toy can be attributed to limitations/errors in the final design?

d. What failures in the final toy were due to not modifying the design with the method of manufacturing in mind (i.e 3D printing or laser cutting)?

e. What failures in the final toy can be attributed to lack of sufficient time?

f. What failures in the final toy can be attributed to the 3D printer not printing properly?

g. Are there any other significant reasons for the failures you observed?

Interviewer says: Now we will move on to questions about the mini prototyping experiences and hands out students responses the the previous surveys (it will also be great if they can get the actual parts they made). Please go through your responses to the

surveys on the mini prototyping exercises and try to recollect your experiences. Give the students 2-3 minutes to reflect on the feedback they provided earlier.

h. How did the 3D printing mini prototyping exercise help in you in the final toy design project? - What did you print and why?

i. How did the laser cutting mini prototyping exercise help in you in the final toy design project? - What did you laser cut- box or gears? Material? Was the same material used for the final, if not, what changes did you notice in the process?

j. Do you remember making any design changes in the final project specifically because of the mini prototyping experience

k. What would you have changed about the mini prototyping experiences to better assist you in the final toy design project?

Interviewer says: Thank you for answering the questions. The next part of this exercise is for you to fill out a short paper survey. This will be an individual task.

Final Survey

Name and Team:

ME444: CAD and Prototyping Final Survey

1=Strongly disagree 2=Disagree 3=Unsure 4=Agree 5=Strongly agree

a. The 3D printing & laser cutting mini prototyping exercises helped to prevent the following failures in the final toy design project.

   i. Did not assemble due to wrongly dimensioned parts

   1 2 3 4 5

   ii. Did not assemble as clearances specified were insufficient

   1 2 3 4 5

   iii. Poor assembly due to higher than expected friction as clearances were insufficient

   1 2 3 4 5

   iv. Poor assembly due to loosely fit parts as clearances specified were excessive

   1 2 3 4 5

   v. Structural failure due to excess deformation observed in components

   1 2 3 4 5

   vi. Structural failure due to breakage/fracture observed in components

   1 2 3 4 5

vii. Structural failure due to unable to secure/fasten components

1 2 3 4 5

viii. Any other failures **(Name them here)**

b. The mini prototyping exercises helped me learn concepts of tolerancing that were necessary for the final toy design project.

1 2 3 4 5

c. The mini prototyping exercises helped me learn concepts of structural design (shape & stress) that were necessary for the final toy design project.

1 2 3 4 5

d. Having more mini prototyping exercises on 3D printing would have improved the success of the final toy design project.

1 2 3 4 5

e. Having more mini prototyping exercises on laser cutting would have improved the success of the final toy design project.

1 2 3 4 5

f. The mini prototyping exercises were useful for testing out ideas/concepts relevant to the final design.

1 2 3 4 5

g. I would have preferred that designing for laser cutting was taught using a lecture instead of the mini prototyping exercise.

1 2 3 4 5

h. Having more mini prototyping exercises on laser cutting would have improved the success of the final toy design project.

1 2 3 4 5

i. I would support the 3D printing mini prototyping exercise being conducted in future ME444 classes.

1 2 3 4 5

j. I would support the laser cutting mini prototyping exercises being conducted in future ME444 classes

1 2 3 4 5

Rubric for classifying failure modes in final toy designs

Failure modes were evaluated by the authors based on the type of failure reported by the student team in the final survey and the group interviews. The authors also inspected the final toy designs produced by the teams to verify functional failures. The rubric adopted for classifying the failure modes are as follows.

- *Mechanism design failure:* assigned when the group said that their model design itself had flaws or they did not take into account design parameters (e.g., use of fasteners) during their design stage
- *Tolerance failure:* assigned when the group said that they had to drill holes to make them larger, sand down parts for sliding, wobbly fitting due to too much clearance.
- *Physical properties failure:* failures due to material properties like friction and weight
- *Printing failure:* failures experienced due to errors during 3D printing (e.g., flat faces warping during UV curing, non cylindricity of holes due to print orientation
- *Sizing failure:* failures due to not realizing actual dimension of parts while modeling in CAD (e.g., parts modeled too thin causing them to break)
- *CAD modeling failure:* assigned when the students did not model an exact design of their desired toy (e.g., did not consider exact geometry/dimensions of purchase parts)

It was possible for a single toy to consist of more than one failure mode.