2.008

Design & Manufacturing II

The Discrete Parts Manufacturing

Lab IV:
Product Design

Lab V:
Tooling Design

Lab VI:
Tooling Fabrication

Lab VII:
Parts Production

Lab VIII:
Product Inspection: Quality & Variation

Labs IV-VIII

OBJECTIVE

This exercise requires student teams to design and manufacture a three-part, or four-part yo-yo.
The goal is to follow a typical product design/manufacturing sequence. The steps include:

1) Designing a product to be manufactured,
2) Designing the tooling to be used to form the parts for the product,
3) Machining the tooling with computer numerically controlled (CNC) machine tools,
4) Optimizing (tuning) the manufacturing processes,
5) Manufacturing a batch of product, and
6) Characterizing the manufactured products.

These exercises provide an opportunity to apply what you have learned about CAD/CAM, to learn about commonly used manufacturing processes, and to recognize some issues concerning the optimization of a manufacturing process. One of the lessons that can be learned by going through this progression is that the process and the tooling impose limitations on the part design. As an example, whether the part is thermoformed or injection molded, it must be easily removable from the forming tool. Thus, we will see that for best results the product and the process (in this case the tooling) must be considered simultaneously.

INTRODUCTION

Forming processes are used to produce a tremendous variety and quantity of parts. Examples of forming processes for metal include casting and sheet metal forming. Two forming processes for polymeric materials, injection molding and thermoforming, will be the focus of this laboratory sequence. The lessons learned from examining injection molding and thermoforming will be applicable not only to plastic materials, but to metals and ceramics as well.

All forming processes have one essential ingredient in common. They all rely on a tool, die, or mold to create the geometry of the finished part. In general, each new part design demands the creation of a new tool or die. This situation contrasts greatly with machining, where a set of cutting tools can be used to create a wide variety of finished shapes. Thus, we see that forming processes are less flexible to design changes than machining processes. However, forming processes result in net shape or near net shape parts. Thus, the use of forming processes is a balance between the cost and time associated with creating the tool or die and lower cost per part when making a large number of parts.

ORGANIZATION

Since the project will take several weeks to complete, we have broken the exercise into small segments: Labs IV, V, VI, VII, and VIII. During these labs students are organized into groups. Each group will design its product together and should delegate responsibility to specific individuals/teams for the manufacture of each of the component parts you intend to produce.

Lab IV: PRODUCT DESIGN

Each yo-yo group will design a yo-yo that has two, or three injection molded parts, and one, or two thermoformed parts. The designs, which you submit, are required to specify the increment of interference that you intend, and the dimensional tolerance that you anticipate will provide adequate service.
An example of an exploded assembly drawing of a yo-yo can be found in the 'Lab Handouts' folder in the course locker.
Mold blank dimensions can be found in the 'Mill Injection Molding Blanks', and 'Lathe Injection Molding Blanks' folders.
Prints of the 'Punch and Die Set' blanks, as well as a 'Thermoform Mold Blank' are in their respective folders.

Design requirements:

- Yo-Yos should be made of 2-3 injection-molded parts that snap fit together, and at least 1 thermoformed part

- A set of ejector pins can be used if the injection-molded parts are not easily removable from the two-piece molds

- Each injection-molded part cannot exceed 2.7 cubic inches in volume

- The maximum outside diameter of the injection-molded parts cannot exceed 2.5" in diameter

- High impact polystyrene 'HIPS' sheet of .020", .030", and .040" thickness is provided for thermoformed parts

- Polypropylene is provided for the injection-molded parts, various colors are available

- Appropriate spec ranges (tolerances) must be specified for the dimensional features of each part

Lab V: TOOLING DESIGN

Team members will design the molds needed to produce the required parts and use Mastercam to generate "G" code to direct the motion of the machine tools to produce these molds. Team members must confer with teammates to reach agreement on common dimensions and intended interferences to ensure snap-fits. All molds will be machined from aluminum. Ejector pins can be used if the design warrants the need for them. Team members responsible for the thermoformed part will machine their designed shape into a mold blank measuring 3.0" in diameter X .625" thick. They will also have an option to design, and machine a punch-and-die set for trimming the finished part from the material. The punch-and-die set will be made from low carbon steel. Prints for all the blanks, including the punch-and-die blanks are posted in the course locker, as well as a print showing the location and size of the ejector pin holes for the injection-molding blanks.

Be sure, when importing your design to the mold blank templates, that you locate the center of the product in the center of the blanks.

Lab VI: TOOLING FABRICATION

Students will machine their molds using the CNC machine tools in the laboratory.

Lab VII: PARTS PRODUCTION

Students will use the injection molding and the thermoforming machine to produce enough parts for fifty assembled products. Students are expected to optimize the process for the desired quality features and to become proficient in the operation of the injection molding and thermoforming machines before beginning the production run. Student teams will divide responsibilities to permit molding, trimming and sequence numbering for the creation of a run chart. During the production, at about fifty pieces, a process parameter (e.g. cooling time, or sheet thickness) is to be altered to simulate a process disturbance to induce a mean shift of a part feature dimension.

Lab VIII: PRODUCT INSPECTION

Injection molded parts should be allowed to cool for a minimum of 30 minutes before measuring. Select one dimension on each injection molded part and one dimension on each thermoformed part to study the dimensional variation in manufacturing. Preferably the critical feature dimensions involved with the snap-fit aspect of the design.

DELIVERABLES

You are required to submit **4 reports as indicated below** during the Discrete Parts Manufacturing progression. A statement should accompany each report attributing authorship, by section, to an individual student, and a joint evaluation of the relative contribution of each group/team member to the entire Discrete Parts Manufacturing exercise. Each group/team member must sign this statement. Your statement should appear as:

Student A	20%	Student C	25%	Student E 30%
Student B	15%	Student D	10%	

Definitions: A 'Group' is the entire Yo-yo group. A 'Team' is a pair of students within the group responsible for their assigned parts. Grading: The entire 'Group' will receive a common grade on group reports. Each 'Team' will receive a grade on their particular team report.

Do not forget to include the agenda and minutes for each meeting.

Each report should contain the following:

Report 1: (10 points) Group report, due one week after the lab, at the beginning of the next lab session.

1. An outline of the planned division of labor for the complete lab progression (i.e. who's doing what for Labs V, VI, VII, VIII)

2. Fully dimensioned drawings of each of the parts using Mastercam, or Solidworks.

3. An assembly drawing.

4. An explanation of how you incorporated the design requirements into the features of your product design.

Report 2: (10 points) Team report, due one week after the lab, at the beginning of the next lab session.

1. A fully dimensioned Mastercam, or Solidworks drawing of the molds.

2. The complete set of G-code programs for machining the mold component. Send the completed programs to the appropriate folders on crossshop1, or crossshop2, identify by including your Athena username in the file name. Please do not print the code.

3. A justification for the dimensions you have established for your mold contours (i.e. how did you calculate your shrinkage allowances?)

4. Select any 10 blocks of the G-code from one of your programs, the blocks must be in sequence. Print just the 10 blocks and submit an explanation of what the blocks of code are doing. For the lathe select movement blocks since the meaning of some of the lathe code isn't covered in lab.

Report 3: (15 points) Team report, due April 9th by 5PM for all lab groups.

1. Justification and discussion of the process optimization and possible mold redesign.

Report 4: (10 points) Group Report, due April 30th by 5PM for all lab groups.

1. A run chart showing the relevant dimensional features of each component part. (i.e. a run chart for the dimension measured during production. A separate chart for each part.)

2. A histogram of the critical dimensions which you monitored during your production run.

3. Plot a Shewhart X-bar chart. Explain how you chose the size of your "rational subgroup." Where did you place the control limits and why? Can you detect the step change induced by the parameter change you made midway through your production run? Why or why not?

4. What is the process capability, C_p, for your process, given the spec range you indicated in the exercise undertaken in Lab IV?

5. What were the restrictions (number of components, material, process limitation, etc.) on the part design? Suggest an alternative design when there are no restrictions (mechanical drawings are not required).