2006-809: DESIGN AND SPECIFICATION CLASS TEAMING WITH ALCOA IN REAL WORLD DESIGN PROJECT

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DESIGN AND SPECIFICATION CLASS TEAMING WITH ALCOA IN REAL WORLD DESIGN PROJECT

Students in a freshman level product design and specification class were given a project to design a test fixture that would be used to evaluate polymer friction for a bottle-closure system. The product design and specification class is a required class in the Mechanical Engineering Technology curriculum at Purdue University, Columbus, Indiana.

Initially, Alcoa CSI, a local consumer products company that makes plastic bottles and closures, needed a way to measure the polymer friction that occurs between the bottle and closure threads and between the bottle and closure sealing surfaces. The friction measurements from standard polymer friction test methods have not been applicable to the bottle-closure system. Developing a way to measure polymer friction for the bottle-closure system was a technical challenge. The goal of the company was to produce a closure that was easier to apply, easier to remove, and easier to manufacture by improving the molding process. Therefore, in order to address the design part of this challenge, a class project was developed.

The class project allowed the students to demonstrate the following learned skills: design principles, drafting techniques, basic physics, teamwork, written communication skills, technical presentation skills and problem solving skills. The students worked in teams using basic drafting and design skills to create conceptual models and drawings of the test fixture. Students also were required to sketch the free body diagram of their fixture and write a brief paragraph to explain how their design would work. By separating thread friction from sealing friction, students were allowed to concentrate on measuring the friction from one area. To develop their designs, students used Pro/Engineer software.

The students were instructed in filling out a preliminary "pre-patent" form to document their original idea. This was done in order to familiarize students with a very necessary part of the creative design process, formal documentation. The student designs were reviewed by the instructor and constructive feedback was given to the student teams. A final technical presentation was given by the students and their communication and technical skills were assessed.

Background and Description of the Design Problem

Alcoa CSI is recognized as a world leader in closure design and manufacture for the food, beverage, and automotive industries. The engineers and scientists at Alcoa CSI are continually exploring innovative methods for improving the seal between closures and bottle finishes. There have been many improvements made to the closure-bottle system by using innovative materials, original geometries, and improved manufacturing processes. There have been many attempts made to better understand the physics of the sealing areas, specifically, the friction forces of the sealing areas. In the literature, there has been much research and experimentation in the field of Tribology for characterizing polymer-polymer friction. The equipment in many of the previous experiments used to measure the coefficient of friction varied from sled-devices, tilt-tables, pin on disk, or pendulum-disk devices. These devices did not specifically address the unique geometry of the closure-bottle interface. There are also many variables, such as temperature, surface condition, speed of sliding force, geometry, material, percent lubricant of material, and humidity that influence frictional forces between polymers. Alcoa CSI is interested in experimentally determining the friction forces on the closure bottle system and to find out which variables have the greatest influence on the coefficient of friction between polymers at the closure bottle interface. Understanding the mechanism of friction between polymers for a closure bottle system will give designers and analysts a tool which they can use in industrial applications to produce better designs of plastic parts for the closure industry.

The Challenges

The technical challenge was to design a test fixture that would measure the polymer friction that occurs between the threads and sealing surfaces on a bottle closure system. In order to make the project less complicated, students were allowed to separate the friction between the threads and the friction between the sealing surfaces, in order to focus on either area.

The classroom challenge was to incorporate a real world problem into a beginning design class as a class project. There is a great need for bringing real world projects into the classroom setting [1, 2]. The course, MET 102, Production Design and Specification, is required as part of the curriculum for either the A.S.M.E.T. degree or the B.S.M.E.T. degree. This class focuses on production specifications and design drawings for manufacturing applications. A complete list of the core learning objectives was given to students at the beginning of the semester. For this design project, the following general concepts of the core learning objectives were emphasized: teamwork skills, written communication skills, student skills for following ANSI standards with engineering and assembly drawings, and student skills for design verification by using calculations and documentation via standard practices.

The students were given a brief summary of the problem and the project scope. The technical requirements of the project then were discussed. The students were required to:

1.) Use Pro\Engineer for designs
2.) Work in teams
3.) Write a technical report that included a description of the design and a free body diagram
4.) Complete the Alcoa disclosure agreement or "pre-patent" document
5.) Present their design to the class with a power point presentation.

There was no restriction on the type or cost of the equipment that the students used in their designs.

First the students were assigned to one of the three teams. Then the students reviewed previous polymer friction research that was given on handouts provided by the instructor. Next the students examined the sketches and standards of various devices that were used to measure polymer friction taken from the literature, provided by the instructor. The students also conducted their own literature and web site searches to find currently used friction measuring devices.

Student Backgrounds

One quarter of the students was already familiar with Pro\Engineer and most of the students had previous CAD experience. Some students needed several weeks to develop their Pro\Engineer skills so the project was not given until mid semester. Eighty three percent of the students in the class had taken Physics or Statics, so they were able to draw a simple free body diagram. All of the students were working as engineers, engineering technicians, drafting technicians, designers, machinists, or technical personnel at local area manufacturing companies. Also, all of the students were familiar with basic equipment and several students were familiar with experimentation and testing from their jobs.

Course Prerequisites

The prerequisites for this course are a computer graphics technology course (CGT 110) and another mechanical engineering technology course (MET 162). The CGT 110 course is an introduction to the graphic language using CAD and sketching to communicate design ideas. In CGT 110 students learn sketching, multi-view drawings, auxiliary views, pictorial views, working drawings, dimensioning practices, and section views. The MET 162 course is an introduction to analytical and computational problem-solving techniques. Students in MET 162 learn different ways to solve technical problems in mechanical engineering technology by using calculators, the factor-label method of unit conversions, and engineering graphs.

Class Project Assessments

The student's designs were collected and reviewed. The rubrics were taken from some original assessments developed for this class and also some assessments that were used in previous classes [3]. Table 1 shows the rubrics that the instructor used to evaluate the students. The completed projects and the project teams were evaluated in the following categories:

1.) Originality of Design
2.) Teamwork
3.) Oral Communication Skills
4.) Written Communication Skills
5.) Proper Use of Design and Drafting Principles
6.) Technical Accuracy
7.) Practicality/Applicability
8.) Pro\Engineer Skills

Table 1. Rubrics Used by Instructor to Evaluate the Students

ASPECT OF PERFORMANCE	**POINT VALUE**				
Originality of Design	**Never 1**	**Rarely 2**	**Sometimes 3**	**Usually 4**	**Always 5**
Equipment was Original					
Use of Equipment was Original					

Teamwork	**Never 1**	**Rarely 2**	**Sometimes 3**	**Usually 4**	**Always 5**
The team showed evidence of full participation by all members					
The team utilized electronic media to aid in communication and planning					
The team resolved differences without faculty intervention					
The team members demonstrated an understanding of the work/tasks completed by other team members					
The team adjusted its plans as additional information became available or the scheduled required					
The team used faculty consultation appropriately					
The team members appear to respect each others' contributions to the project					

Oral Communication	**Never 1**	**Rarely 2**	**Sometimes 3**	**Usually 4**	**Always 5**
The speaker spoke audibly, clearly, and distinctly					
The speaker maintained eye contact with the audience					
The speaker was prepared and relaxed and did not read the presentation to the listeners					
The language used was appropriate for a technical/professional presentation					
The content of the presentation was correct and the subject well covered					
The speaker answered questions honestly and directly					

Written Communication	**Never 1**	**Rarely 2**	**Sometimes 3**	**Usually 4**	**Always 5**
The writing is concise, accurate, and thorough					
The authors used accepted technical terms					

The writing displays correct spelling, grammar, and syntax					
The report content was correct, complete and not too long or short					
Drawings were used to support text					
The report was presented professionally, clean, covered, typed					
Proper Use of Design and Drafting Principles	**Never 1**	**Rarely 2**	**Sometimes 3**	**Usually 4**	**Always 5**
Parts on sketches and drawings were labeled properly					
Drawing title blocks and bill of materials were labeled properly					
Concept sketches were legible, clear, and concise					
Drawings were legible, clear, and concise					
Technical Accuracy	**Never 1**	**Rarely 2**	**Sometimes 3**	**Usually 4**	**Always 5**
Free Body Diagrams were labeled and components were defined					
Free Body Diagrams were drawn properly					
Concept sketches or design was technically sound					
Practicality/Applicability	**Never 1**	**Rarely 2**	**Sometimes 3**	**Usually 4**	**Always 5**
Design was practical and could be manufactured with existing manufacturing techniques					
Design was applicable to the specific problem (closure-bottle system)					
Pro\Engineer Skills	**Never 1**	**Rarely 2**	**Sometimes 3**	**Usually 4**	**Always 5**
Basic part models, assemblies or drawings were done using Pro\Engineer					
Pro\Engineer design techniques such as extrusion/protrusion/sweeps/etc. were depicted accurately					

Connecting Class Project Assessment Questions to Core Learning Objectives

Several core learning objectives were assessed with the class project assessments outlined in Tables 1 and 2. There is a complete list of the core learning objectives in the Appendix. The main areas of assessment for this project were: the student's technical drawing skills, the student's technical communication skills, and the student's teamwork skills. The class project assessments in Table 2 also list the corresponding core learning objective in parentheses. For example, the assessment questions on communication skills and teamwork measured the eighth core learning objective (CLO #8) which states: "When given a team project, cooperate with all team members to complete the common goals of the team project".

Table 2. Tabulated Results of Student Projects:

Results of Class Project Assessments	Team 1	Team 2	Team 3
Originality of Design	4.00	4.50	4.50
Teamwork (CLO#8)	4.57	4.71	4.86
Oral Communication (CLO#8)	4.83	4.08	4.38
Written Communication (CLO#8)	4.83	4.50	4.17
Proper Use of Design & Drafting Principles (CLO #1, #2, #4, #5, & #7)	5.00	3.67	4.50
Technical Accuracy (CLO #1, #2, #4, #5, & #7)	4.67	4.33	4.33
Practicality/Applicability (CLO #1, #2, #4, #5, & #7)	4.00	5.00	5.00
ProEngineer Skills (CLO #1, #2, #4, #5, & #7)	5.00	5.00	5.00
Overall Totals	4.61	4.47	4.59

All members of the three teams were proficient with Pro\Engineer. The three teams also performed well in teamwork. The students have much experience with both written and oral communications because this is one of our MET program outcomes. Our MET program emphasizes all forms of communication skills in almost every class. Team 1 lacked some originality on their design because it was a slight modification to an existing friction measuring device. Team 1 also scored lower on practicality/applicability because the concept did not show how the modification in the rails would be applicable to a closure bottle system. Team 2 needed more practice with their oral communication skills. Team 2 also needed to label their drawings and free body diagrams better. Their lack of labels on drawings and sketches may lead to misunderstanding of the concepts. Team 3 had a detailed drawing showing the closure test fixture. The drawing was well labeled but they needed to provide a more thorough written explanation of their concept. Figures 1 through 5 show the student's work for the project.

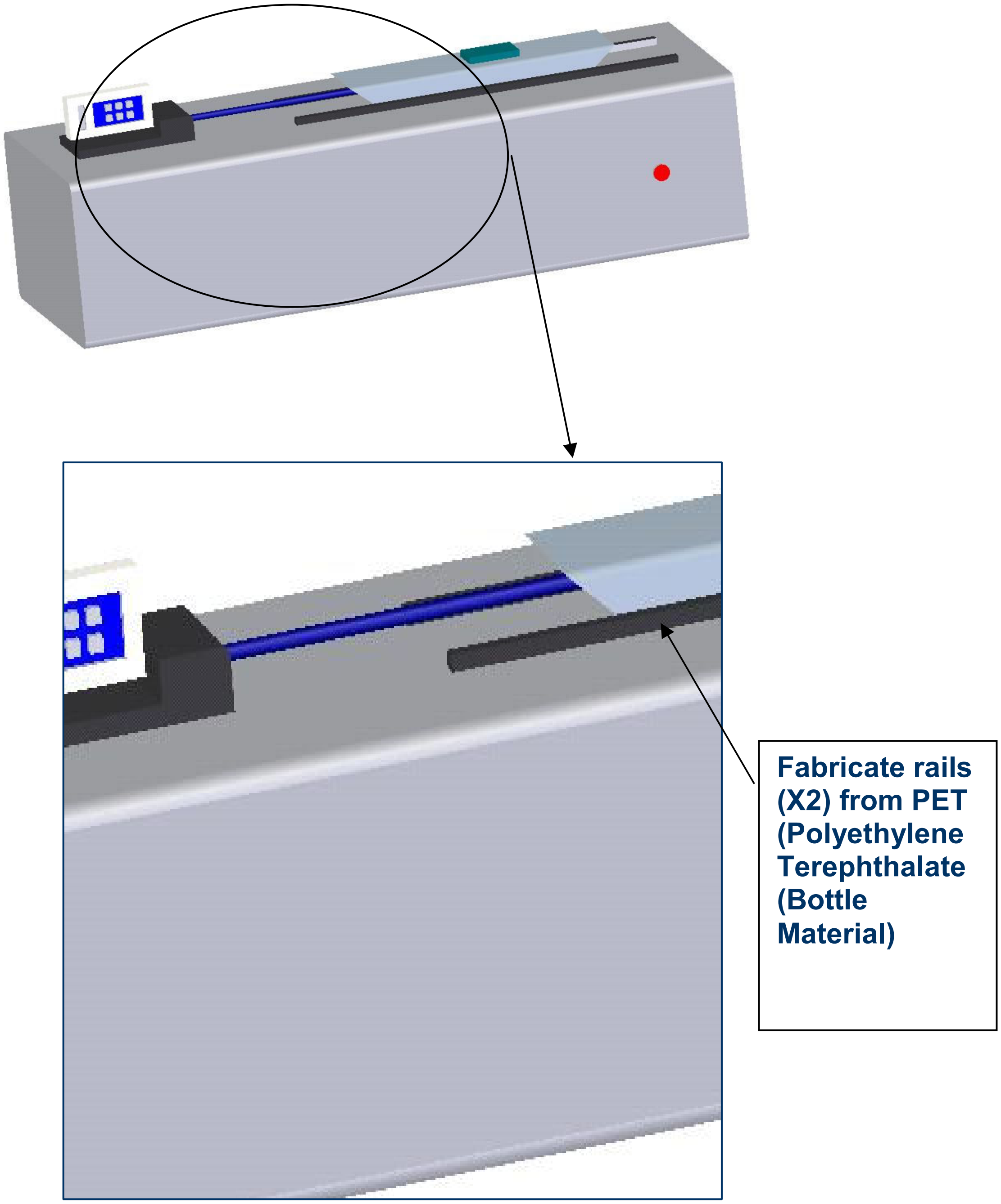


Figure 1. Design by Team 1.

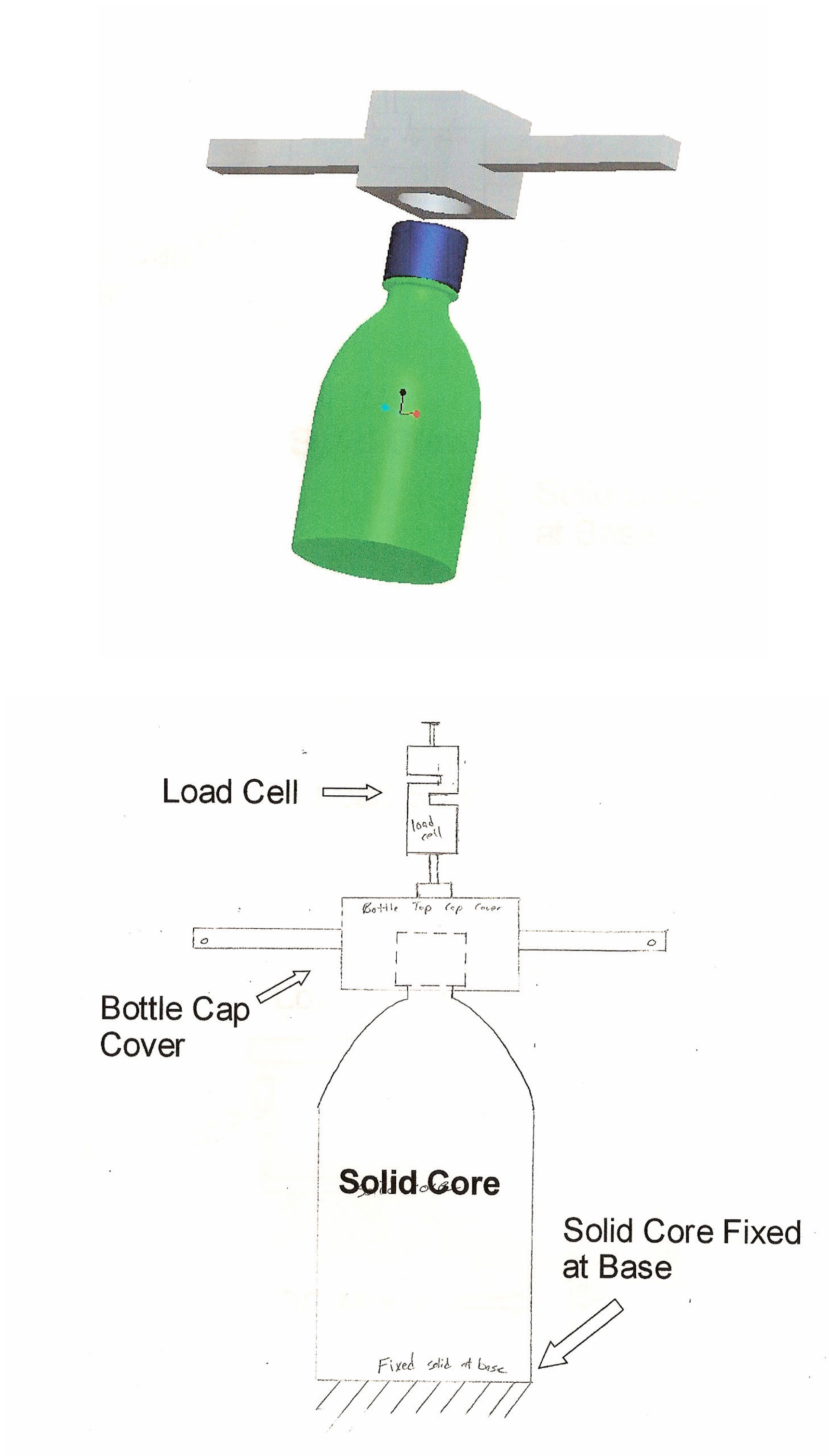


Figure 2. Design by Team 2.

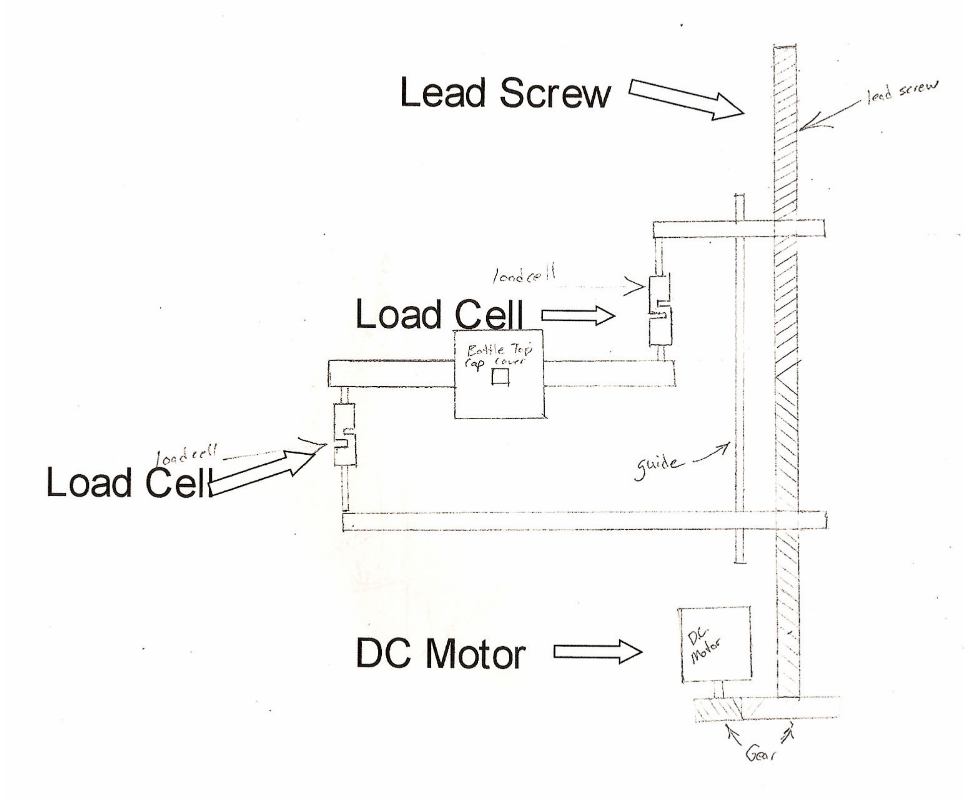
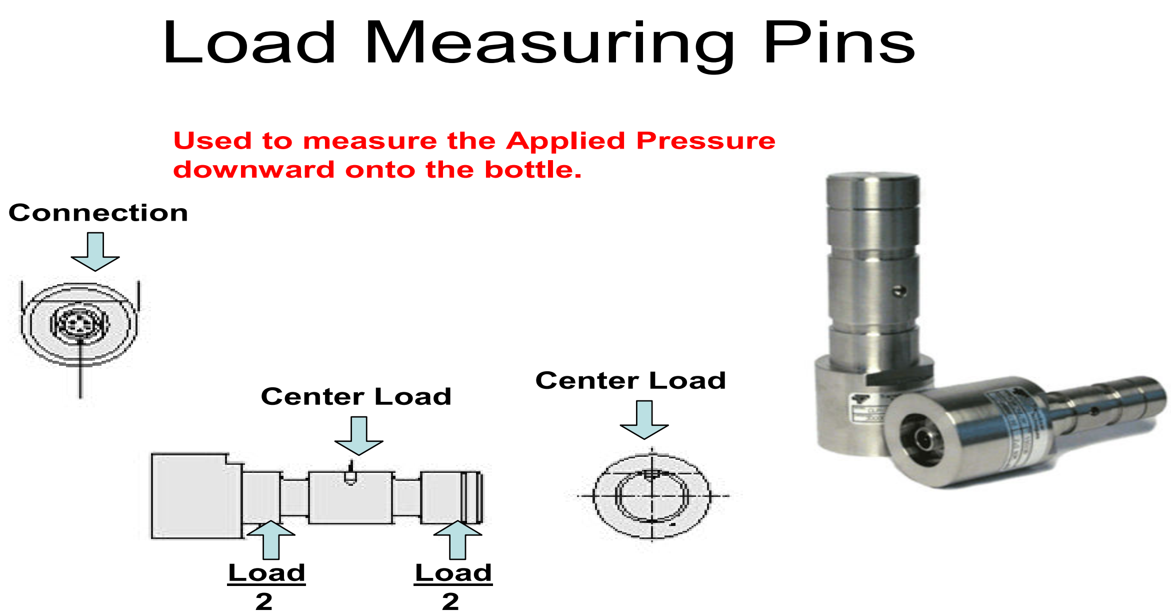


Figure 2. Design by Team 2 (continued).



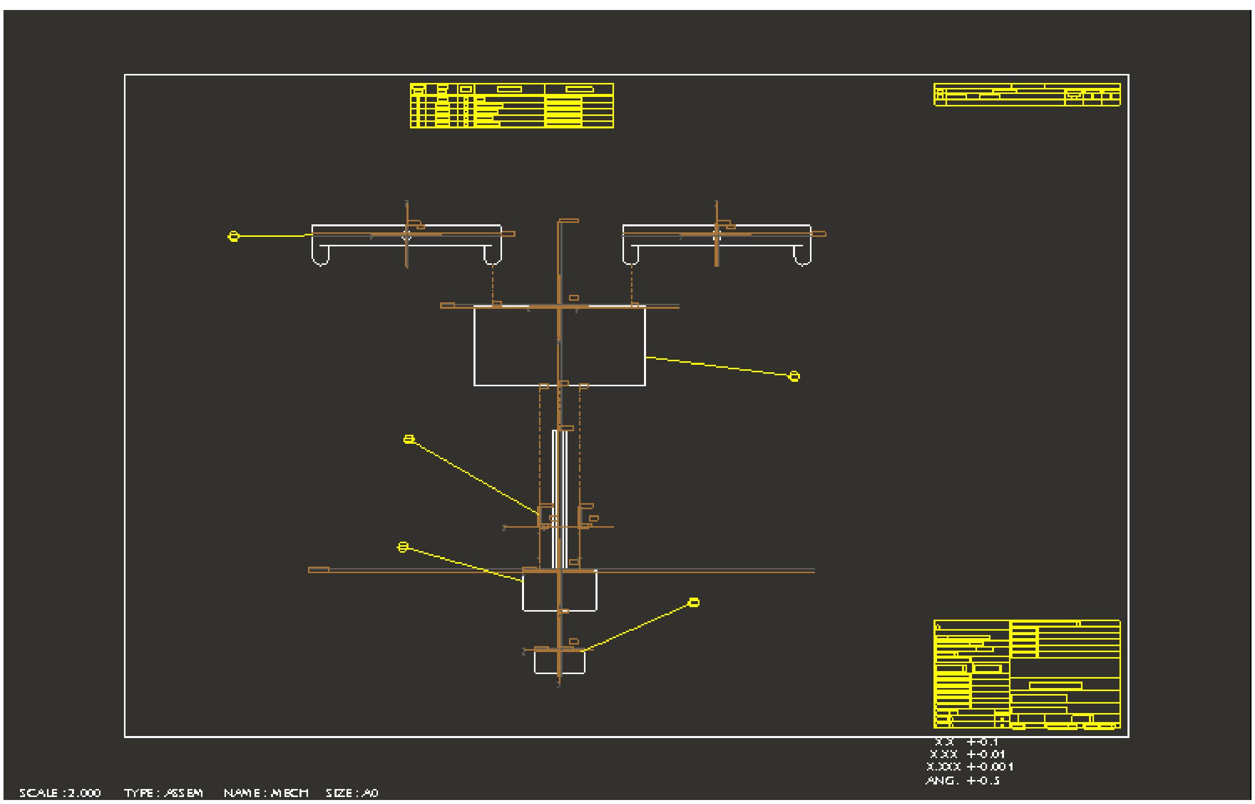
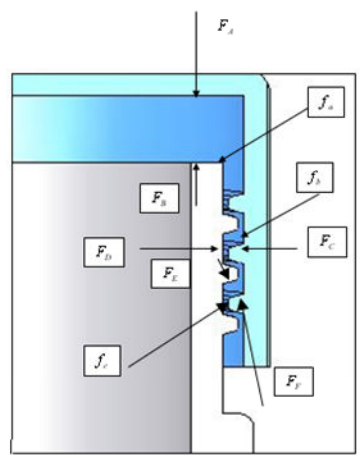


Figure 3. Design by Team 3.

Free Body Diagram (Friction Forces only)

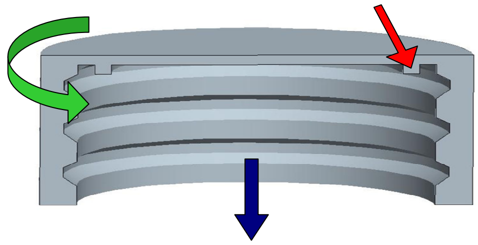


Forces on Cap

- F_A= Weight of cap, pressure inside bottle.
- F_B= Opposing force of F_A.
- f_a= Friction between sealing surface.
- F_C= Force exerted by fingers.
- F_D= Opposing force of F_C.
- f_b= Friction between major dia. of threads.
- F_E= Torsional axial force (Thrust) on threads.
- F_F= Opposing force of F_E.
- f_c= Friction between thread faces.

Figure 4. Free Body Diagrams by Team 1.

Bottle Cap Free Body Diagram



Free Body Equations

- Seal Contact Area $$A_s = \pi\left(R_2^2 - R_1^2\right)$$
- Applied Pressure $$P_1 = \frac{P}{\pi\left(R_2^2 - R_1^2\right)}$$
- Torque $$M = \frac{2}{3}\mu_k P\left(\frac{R_2^3 - R_1^3}{R_2^2 - R_1^2}\right)$$

Coefficient of Friction

From the previous equations we can find the coefficient of friction:

$$\mu_k = \frac{3M}{2P\left(\frac{R_2^3 - R_1^3}{R_2^2 - R_1^2}\right)}$$

Figure 5. Free Body Diagrams and Equations by Team 3.

Conclusions

The introduction of this type of design as part of a class project was successful as a first attempt at giving students real world experience in the classroom. The authors tried to make the project as similar to an actual assignment that would be given on the job. The students took the project seriously and worked harmoniously with their teams in order to create a design that they believed would work for this application. The students also worked very hard to demonstrate their Pro\Engineer skills, their oral and written communication skills and their analytical abilities The students' concepts for the friction measuring devices were good, but were only used for as a learning tool to develop their design project skills. Students were *not* required to sign the pre-patent document but were asked to answer the questions for documentation purposes. The pre-patent document was used strictly for educational purposes.

It is concluded that the students would have had better projects if more time was given to spend on developing their concepts. It is also concluded that this project met several of the course objectives of the class and through this the students were able to have a more diverse experience with design projects.

Bibliography

1. Barrott, James L., "Why Should Cases be Integrated into the Engineering Technology Curriculum?", Proceedings of the 2001 American Society of Engineering Education Annual Conference & Exposition, Session 3650.
2. Tapper, Jerome and Buchanan, Walter W., "Engineering Technology Students Gain Insight into Real-World Engineering Problem Solving by Providing Solutions to Industry Provided Senior Design Projects in Industrial Control Systems", Proceedings of the 2003 American Society of Engineering Education Annual Conference & Exposition, Session 1649.
3. Fuehne, Joe and Lenart, David, "Technology-Hospital Collaboration in Thermodynamics: Experience with Actual Student Projects", Proceedings of the 2005 American Society of Engineering Education Annual Conference & Exposition, Session 2249.

Appendix

List of Core Learning Objectives for MET 102

1. When given various specialty industrial manufacturing processes, apply American National Standard drawing techniques unique to that industry, in the production and interpretation of engineering drawings.

2. When given design intent and a mechanical design, follow current American National Standards practices in generating a complete assembly/detail dimensioned set of drawings.

3. When given an engineering drawing, apply standard rules for numerical significance when performing hard and soft conversions for dimensional specifications to/from metric units.

4. When given an engineering drawing with custom and standard parts, use default specifications, standard documents and/or handbook data to verify design intent by calculating and documenting via standard practices, allowable limits for any dimension or feature on the drawing.

5. When given engineering drawings for an assembly with custom and standard parts, use default specifications, standards documents and/or handbook data to verify design intent by calculating and documenting via standard practices, allowable limits and multi-part fits between parts for any dimension or part on the assembly.

6. When given an engineering drawing set and engineering change authorization, isolate, revise and document the changes via standard practices.

7. When seeking answers to questions on technical specifications, company procedures, products or services, etc., use handbooks, national/international engineering standards, peers, or design engineers, the internet or other references to generate answers via a formal report, critique and/or presentation.

8. When given a team project, cooperate with all team members to complete the common goals of the team project.