AC 2010-1898: RAPID PROTOTYPING AS AN INSTRUCTIONAL TOOL TO ENHANCE LEARNING

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Rapid Prototyping as an Instructional Tool to Enhance Learning

Abstract

It is widely known that students tend to learn best by active participation. The least effective method of learning is listening, with observation falling in-between. When students are exposed to concepts through multiple paths it should enhance their overall learning. Rapid prototyping can be an additional tool for the instructor to enhance student learning.

Traditional methods of instruction in Strength of Materials courses involve explanation of theory and reinforcement of the underlying concepts through laboratory demonstration and homework problems. Some of the other techniques used to supplement these methods typically focus on visualization through computer animation. This paper describes an attempt at integration of these methods with rapid prototyping as an instructional tool for one section of students in order to enhance their understanding of concepts. It is anticipated that future students in all sections of the Strength of Materials course will experience this improvement to their learning process.

Several hands-on experiments were developed to enhance the student's understanding of theory. Students were given problems from their textbooks and then they were asked to created 3-D models. These models were then fabricated on an in-house rapid prototyping machine. Students performed the experiments on their models and compared the results to the calculated results. Initial feedback from the students has revealed that modeling, fabricating, and testing some of the textbook problems enhanced their learning of the concepts. This provided a relevant transfer of skills for the students from solid modeling to physical problem solving. An additional benefit of this technique is exposure of the students to the design process early in their curriculum.

Introduction

There is a large amount of work in the literature addressing different means of effective teaching. Most of the literature that deals with effective teaching indicates that active learning is an acceptable strategy to enhance student learning. In teaching, it is our responsibility to present certain tasks or activities with the intention of inducing learning. In light of this, it is essential to teach the subject matter in a way that maximizes student learning. It is our intention to create this environment by adopting certain instructional strategies to achieve this goal.

Michael Prince[1] et al. has made an extensive review of the literature to address the question: Does Active Learning Work? He has defined Active Learning Terminologies that are used in literature among different authors. In general, Active Learning is defined as any teaching method that engages students in real meaningful learning activities that make them think deeply about what they are doing[2]. Typically, there are several techniques that are adopted to implement active learning in instruction, namely Collaborative, Cooperative, and Problem-Based Learning (PBL).

Among these accepted active learning styles, PBL has been growing in recent years and has become an acceptable instructional strategy in engineering education[3]. This trend is also evident by the large amount of work done by scholars in engineering programs[4-14]. The major benefits of PBL include problem solving skills, relating concepts learned in lectures to real world problems, working in team environments, development of communication skills, and stimulation of critical thinking.

There are number of techniques proposed by educators in order to incorporate PBL into their lectures. Wood and Jensen[14] introduced multimedia-based courseware as an active learning tool to enhance understanding of the fundamental Strength of Materials principles. They have stated that the use of multimedia as part of class instruction was very useful for the students and the data collected from the feedback received indicated that this method was quantitatively shown to enhance student learning. Linsey[15], et al., and co-workers extensively worked to include active learning exercises into a Strength of Materials course. Hadim and Esche[16] reported that they integrated PBL into their revised undergraduate engineering curriculum. They implemented PBL by assigning group design projects in freshman and junior level courses. Other methods used to implement PBL are by applying Photoelasticity and Finite Element Methods[16] and by application of Virtual Reality in Science and Engineering Education[17].

In this paper, we introduce Rapid Prototyping (RP) as an added instructional tool to increase teaching effectiveness. We applied RP in a Strength of Materials course during summer quarter 2009 at The University of Cincinnati. This document details the approach we took to accomplish this task.

Methods

In teaching basic engineering courses such as Statics, Mechanics, and Dynamics, the fundamental concepts have become increasingly challenging for some students entering into engineering programs. Wood[18], et al., and co-workers stated that there is a transformation from theory to a balance between theory and hands-on activities. They claim that most students entering engineering programs today have limited interaction with basic mechanical tools and are more involved with computers and video games. They suggest that, in the past, students entering these programs had more knowledge of how machines or devices worked (tinkering factor). Therefore, there is a real need for more hands-on activities designed to enhance the learning of today's students after they have entered into engineering and engineering technology programs.

In the Mechanical Engineering Technology (MET) department, we put an emphasis on laboratories for most of the courses taught in the core curriculum. This traditional teaching approach has been adopted for many years in our program. We rely on more hands-on activities in our instructional strategies and this is the reason we offer labs as part of most of the core courses in the program. Laboratory experiments are excellent activities for the engineering technology students to participate in and be able to observe the application of theories taught in lectures. However, most of the labs are limited to a specific topic and are mostly conducted by the instructors. The students simply record the data for future analysis and reporting. While these labs are an excellent source for emphasizing concepts, they provide a limited opportunity for the students to be involved (hands-on aspect).

Although the current methods of Active Learning adopted by many have been shown to be an effective means of increasing student learning, we have gone one step further to include RP technology as an instructional tool to actively engage students in the subject materials. The use of RP encourages students to fabricate the problems that are given to them from the lecture and be able to actually apply loads and see the resulting behaviors.

In this document, we have introduced an active learning approach to improve and enhance student learning of the basic concepts that are taught in a Strength of Materials course. To accomplish this, the Dimension 1200es Series 3D Printer from Stratasys Inc. was used with a type of ABS plastic modeling material. It is a thermoplastic material which is durable and provides good strength. The Fused Deposition Modeling (FDM) process produces parts with unique properties. This is due to the fact that the machine deposits materials in a directional way which makes them anisotropic. In order to keep the properties of the parts uniform, all of the parts were generated with materials deposited along the axis of the members.

The intended objectives were:

- Be able to convert engineering principles into student-centered hands-on projects
- Create a collaborative learning experience and encourage team work
- Increase student interest in the course and, in general, engineering technology
- Be able to integrate knowledge gained from prior courses
- Integrate the engineering design process to complete their projects

Implementation of RP tools in Strength of Materials

We introduced RP tools for the first time in a Strength of Materials course in the summer of 2009. The class was designed to have both lecture and lab components. In this course, we teach the basic topics in Strength of Materials and students are usually required to solve problems either from the textbook or problems assigned by the instructor. Generally, students have difficulty in understanding and grasping these basic concepts which are crucial for their future success in the program. In light of this fact, we introduced RP as a teaching tool to actively involve the students in understanding these concepts through direct hands-on experience. This adaptation of RP as a tool to enhance the Strength of Materials course is supported by similar work done by Said Shakerin and Daniel Jenson[16]. They incorporated experiments using Photoelastic stress analysis and finite element analysis to enhance Strength of Materials in their curriculum. They concluded that using this technique positively affected the student learning of the basic concepts in Strength of Materials.

Project Assignment Process

We divided the class into teams of 3-4 students each and each team was given a project that required utilizing RP to complete. The tasks performed by each team were:

- To understand the nature of the given problem
- Determine dimensions: given in the problem or determined by the students
- Divide the tasks among the team members

- Create the 3-D model of the individual parts using SolidWorks software
- If required, create 3-D assemblies with their parts
- Covert the 3-D part files into STL files for fabrication
- Assemble the fabricated parts
- Add supports and apply loads as specified
- Measure their findings experimentally and gather data
- Check their results against calculated results
- Draw conclusions: how well did their model follow the textbook problem

Project #1: ASTM Standard Tensile Test

In this project, students tested the basic tensile properties of the prototyped tensile test sample. The tensile samples tested were fabricated exactly according to the ASTM tensile sample requirements. After fabrication, the samples were tested in a Tinius-Olsen testing machine as shown in Figure (1).

Figure (1) ASTM Tensile Test

Project #2: Direct Shear Test

In this project, students were asked to fabricate an ASTM Shear Test sample according to the standard specifications. These samples were then tested by the students using the shear block made by Tinius-Olsen. Figure (2) shows the sample after failure.

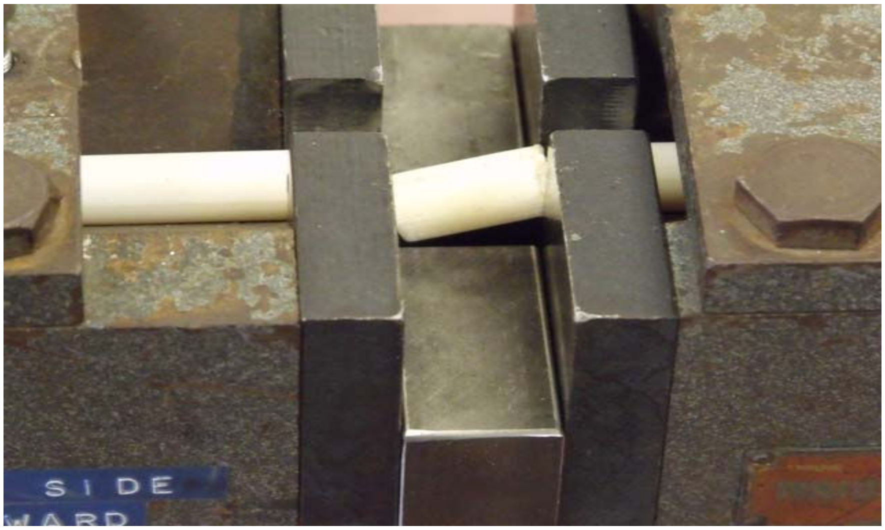

Figure (2) Direct Shear Test

Project #3: Torsion Test

In this project, students were asked to build a torsion sample according to ASTM standards for torsion test. The sample was modeled in Solidworks and then fabricated in our RP machine. Figure (3) shows the sample after failure. The students were directly involved with the testing.

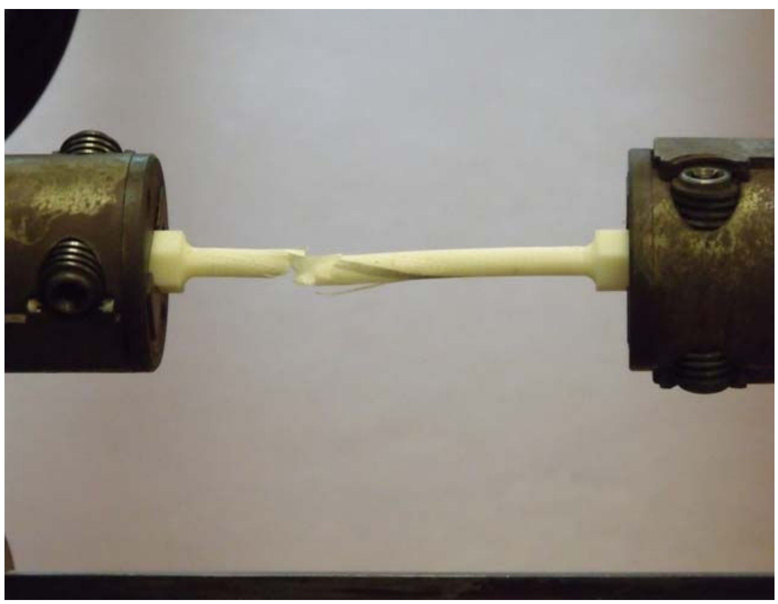
Figure (3) Torsion Test

Project #4: Textbook Problem: Axially Loaded Member

This is a problem from the textbook related to axially loaded members. Figure (4) shows the actual problem taken from the Beer and Johnston textbook. Figure (5) shows the fabricated model that represents the actual problem. We used springs rather than solid (stiff) members so that we could easily see the displacement of the rigid member as it is loaded. This problem was chosen because the center of rotation for the rigid member is not obvious for the students and must be calculated. However, the students can observe this effect by actually applying a load and watching the rigid member as it rotates.

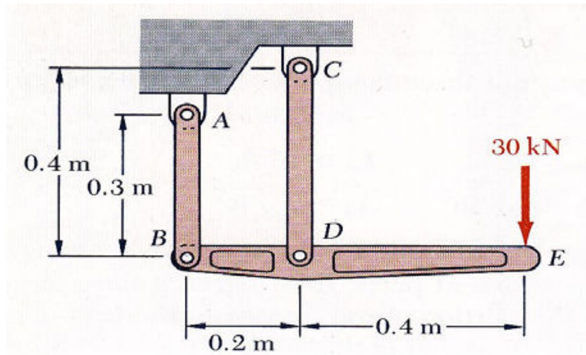

Figure (4) Problem from Beer and Johnston Textbook: Axially Loaded Member

To determine the center of rotation, students were asked to use a still camera to take pictures and then find the center of rotation experimentally. Also, since springs were used as axial members, the students determined member forces by observing their deformations. The springs were also modeled and fabricated by the students in the RP machine. The spring constants were determined by the slope of the force deformation diagram before they were installed and used in the problem. This way we could correlate the force in the spring by measuring their deformations.

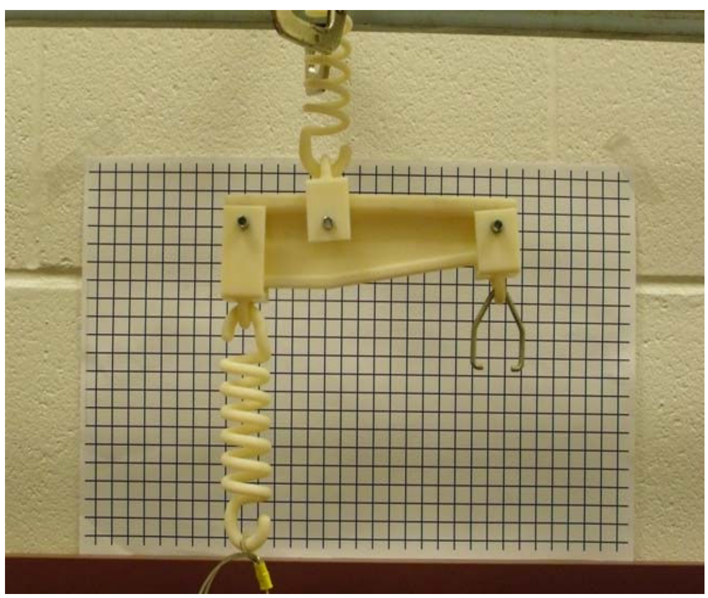
Figure (5) RP Model of the Problem in Figure (4)

Project #5: Textbook Problem: Stresses in Members

This is also a problem that was taken from the textbook which emphasizes the concept of stresses in members and their failures. Figure (6) shows the actual problem taken from the Beer and Johnston textbook. Figure (7) represents the fabricated model of the problem. The students were required to determine the failure in the member BD as shown in the figure (6) and compare their results to the tensile strength which was obtained from an earlier test.

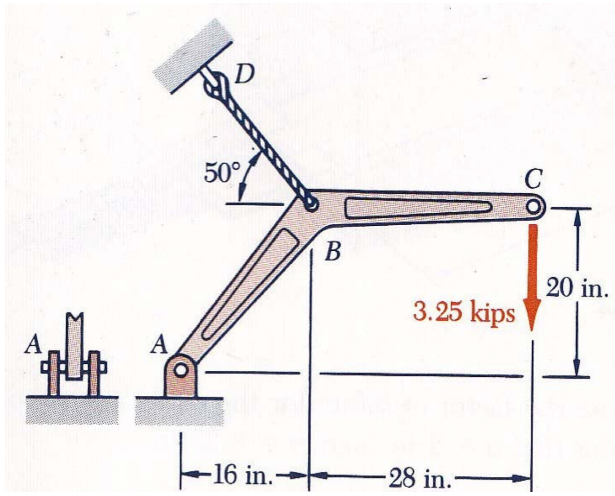

Figure (6) Problem from Beer and Johnston Textbook: Stresses in Members

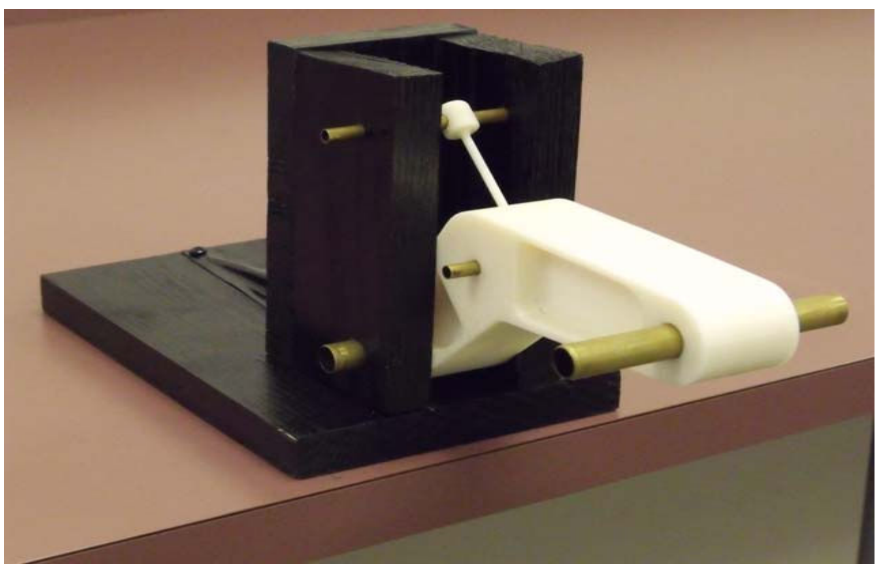
Figure (7) RP Model of the Problem in Figure (6)

Assessment/Conclusions

Application of Rapid Prototyping into Strength of Materials provides an opportunity for students to be directly involved with materials covered in the lecture. Students that enter a MET program expect to have more hands-on learning than theoretical instruction. With these things in mind, we have developed this pilot teaching strategy to help the students become more involved with their learning of the basic concepts of engineering. This pilot study of introducing RP into the Strength of Materials course has many benefits that are summarized here:

- To have students exercise the 3-D solid modeling knowledge learned in a previous course in a meaningful manner

- Be able to work as a team: emphasizing team work and collaboration
- To expose the students to the basic engineering design processes
- Students experience for themselves how the members are loaded and then use their results to calculate the member forces
- Show that concepts that are difficult to understand can be visualized
- Use a active learning technique that requires students to design, build, and test models

In summary, student feedback was very encouraging from this pilot work. The students communicated more frequently with the instructor in order to complete their projects. We observed more interaction between the students themselves in completing each task. A student writes “Overall the project was one of the most interesting parts of the class. It definitely made me understand the issues related to the developing of a project and it made me understand the subject of the class much more clearly.”

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