Session 3568

Incorporating Design in an Introduction to Dynamics Course

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Abstract

Prompted by EC2000, a contest to design a spring-powered catapult was incorporated into the Dynamics course at Grand Valley State University. The catapult was required to launch a projectile to clear an obstacle and strike a target while not exceeding a specified ceiling. Students brain stormed design concepts, completed their design calculations, including analysis of the rigid body motion of the catapult and the motion of the projectile, and created component and assembly drawings prior to constructing their catapults. They then constructed prototypes of their designs, tested them, revised them as needed with complete documentation of changes and competed in the contest.

Evaluation of the project was based upon the accuracy of the analysis of the mechanism, the consistency between the calculations and the completed mechanism, the engineering drawings of the mechanism and the conclusions drawn from the experience.

This project gave students the opportunity to apply the concepts learned in a normally purely theoretical course to the design and implementation of a real, open-ended, design problem. In addition, it emphasized good design practices by encouraging students to design their catapult completely prior to building it, build, test, and modify the prototype and prove they met the design requirements.

Students learned that design is an iterative process, that successful design requires careful planning and that there are many ways to solve any problem. In addition, this project offered the students a junior level, guided design experience.

Introduction

Design and build projects are incorporated in many of Grand Valley State University's (GVSU) courses to present a more applied approach to engineering, while maintaining the rigor expected of engineering curricula. From these projects, students learn design procedures, reinforce their learning of design tools such as mathematical modeling programs, mechanical drawing programs and physical modeling programs, learn the value of carefully planning projects, and learn that design is an iterative process even when calculations are carefully performed.

In order to enhance the mission of the GVSU curriculum and to further pursue the intent goals of ABET 2000, a project was implemented in the Dynamics course at GVSU. For this project, students designed and built catapults to compete in a contest which tested the accuracy of their designs.

The "Program Outcomes and Assessment"[1] section of the ABET evaluation criteria for 2001-2002 strongly encourage design in the curriculum. This project addresses several of the ABET program objectives, specifically a, c, e and g. The objectives met include:

(a) an ability to apply knowledge of mathematics, science, and engineering . . .
(c) an ability to design a system, component, or process to meet desired needs . . .
(e) an ability to identify, formulate, and solve engineering problems . . .
(g) an ability to communicate effectively . . .

This project is quite unusual as most engineering curricula do not include design and build projects in dynamics courses. Design is generally relegated to more traditional courses such as early level design courses and capstone project courses. Students completing this project have an additional design opportunity in a carefully mentored atmosphere. This allows them to develop their design skills, reinforce their understanding of dynamics and gain an appreciation of the subject's usefulness in their future careers.

As this project was to design and build, students learned that creating a product that fulfills strict requirements often requires multiple iterations. Students built and tested their prototypes. Often upon testing, they discovered their design did not achieve the desired results. Students then troubleshot their designs to determine the cause of the poor results and design modifications were implemented and explained.

Methods

Students were introduced to the project with one month remaining in the semester, immediately following the instruction on rigid body dynamics. This allowed them sufficient time to complete the project without introducing it prior to the course material necessary to complete the design.

The main goal of the project was to design a spring-powered catapult that would propel an object over a 5 ft high wall located 10 ft from the launch point. In addition to clearing this obstacle, the projectile was required to stay below an 8 ft ceiling and to land on a target 20 ft from the base of the catapult. In addition, students were required to use a release mechanism to ensure that last minute (during the competition) adjustments were not made.

Students were required to brainstorm ideas for their design and perform necessary calculations to design their mechanism--both rigid body analyses of the catapult and projectile motion calculations of the clay ball were required. In addition, they modeled their mechanism in Working Model 2-D. If the design calculations and the Working Model correlated, they created engineering drawings of the components of their mechanisms and an assembly drawing using the CAD program of their choice. The instructor reviewed the calculations and drawings for accuracy, feasibility of implementation, and completeness.

Once approved by the instructor, students constructed their mechanisms to their engineering drawings using materials available in the engineering laboratory facilities. They tested their mechanisms for accuracy and troubleshot any problems that occurred during testing. Modifications were made to the mechanisms and documented. Full documentation of changes including the reason for the change was required.

Evaluation of the project was based primarily on the accuracy of the design calculations, the correlation between the design calculations and the final physical trials, the accuracy and completeness of the engineering drawings and the conclusions drawn from the experience.

Results and Discussion

This project accomplished all of its intended goals. Students were given an opportunity to solve an open-ended design problem. Brainstorming and creativity were encouraged to determine the optimal solution to the problem. In addition, through the use of engineering drawings and documented design changes, students were introduced to two of the most common forms of engineering communication. The final project report provided an opportunity to evaluate the students' writing skills and to provide feedback to help them improve their technical writing skills.

Examples of the finished projects are shown on the next page in Figures 1 & 2. Although the general concept is consistent throughout the examples, there were many variations on the theme. Figure 1 is a compression spring driven catapult. The compression springs were especially vulnerable to spring buckling. Therefore, students needed to devise a means of preventing the buckling. Figure 2 illustrates a tension spring powered catapult. The main design issue for these was providing a mounting platform for the spring.

Students were required to use Working Model 2-D to verify their design calculations. This exposed them to the value of using engineering modeling tools to verify their work. In addition, in some cases, students used Working Model to optimize their design prior to performing the calculations. They then performed the calculations and verified that Working Model was accurate. In either case, students were using an engineering modeling program to enable them to create a better design.

One improvement to be made to the project is to introduce it earlier in the semester. Since particle dynamics is covered in Physics, rigid body dynamics could be moved earlier in the semester, allowing the project to be introduced sooner.

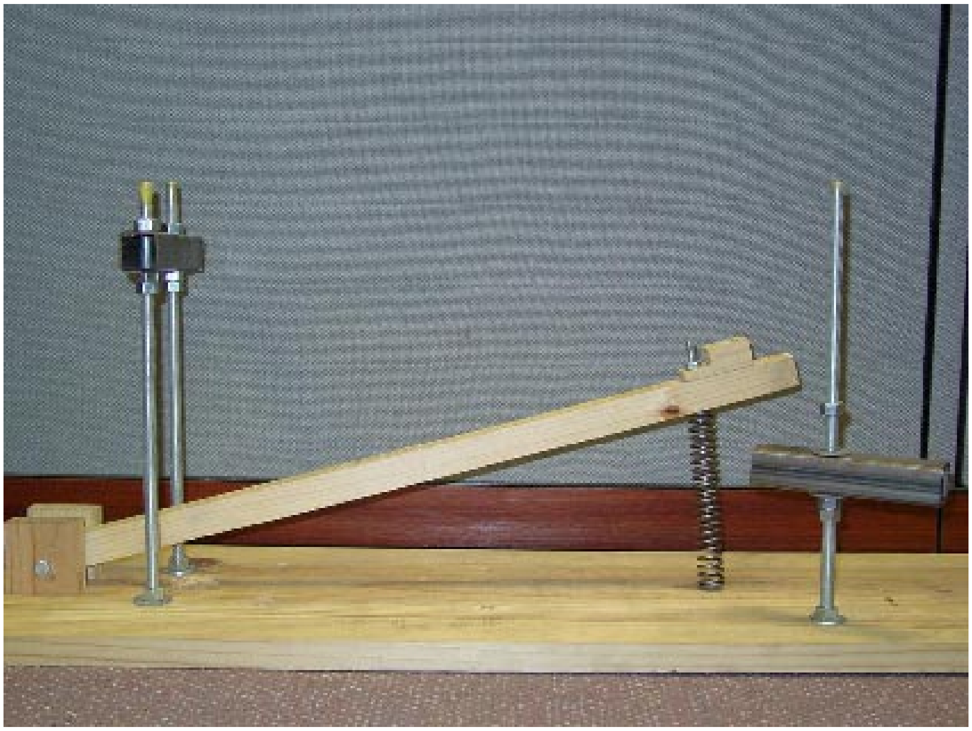

Figure 1--Compression Spring Driven Catapult

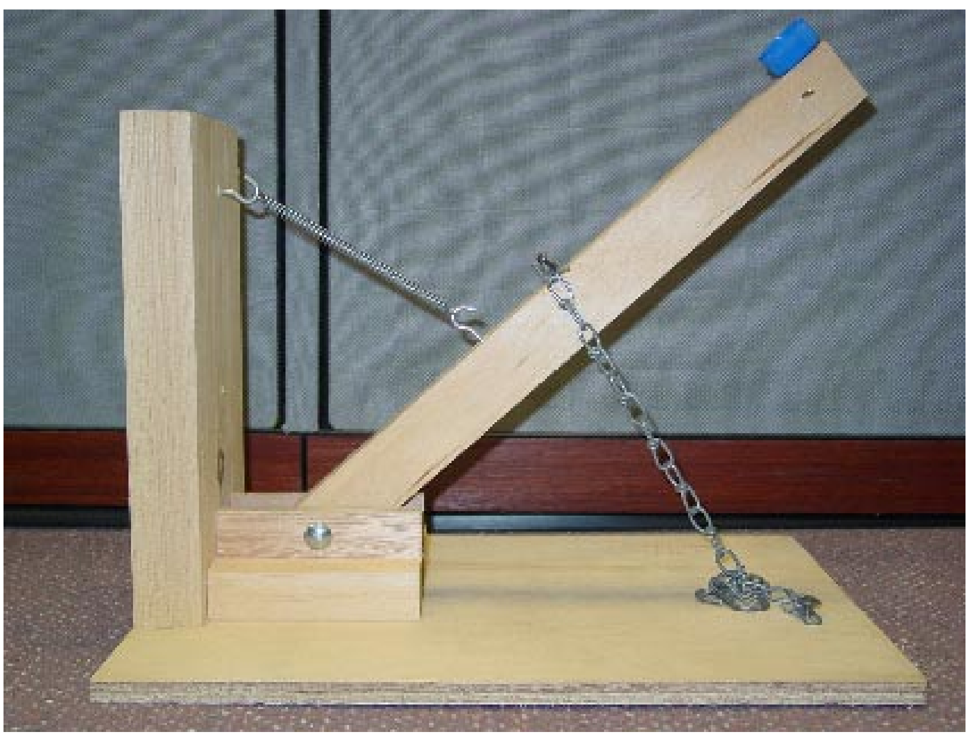

Figure 2--Tensile Spring Driven Catapult

Conclusions

Overall, the catapult design project in dynamics had very positive results. Students were given an open-ended design problem and successfully solved it. There were two main design types: compression spring powered and tension spring powered.

In addition to successfully designing and building a catapult, students verified their designs using Working Model 2-D and completed engineering drawings of their designs.

Future iterations of the project will incorporate beginning the process earlier in the semester and more careful monitoring of the design process.

Bibliography

1) ABET Board of Directors (Ed.). (2000). *Criteria for Accrediting Engineering Programs--Effective for Evaluations During the 2001-2002 Accreditation Cycle*. Baltimore, MD: Engineering Accreditation Commission.

Biographical Information

Wendy Reffeor, Ph.D. is an Assistant Professor of Engineering in the Padnos School of Engineering at Grand Valley State University. She holds a BS in Mechanical Engineering from GMI Engineering & Management Institute, an MS in Mechanical Engineering from Purdue University and a Ph.D. from Michigan State University. Since joining GVSU, she has focused on introducing design in traditionally analytical courses in the Mechanics sequence.