Motivated Learning through Supersonic Ping Pong Balls

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Abstract

Education of composite materials at the undergraduate (junior year) level requires a different set and knowledge of understanding than is taught at the graduate level. Additionally, undergraduates learn by doing; seeing things and physically understanding how they perform helps to reinforce the different concepts. This paper covers a semester-based project that has students design build and test a composite material that must withstand the impact of a supersonic Ping-Pong ball. This extreme example helps motivate the students in two ways. First it provides a very different type of experiment keeping them motivated. Second it provides an open-ended solution that allows students to think differently and enables creativity in solutions. During the semester students fabricate the materials and test them to get a better understanding of their response and material constants. The final competition is a weight-based solution compared to the other groups in the class. During the impact event high-speed videos of the impact are taken so that students can get a better idea of how their structures withstand the impact. They then perform a post-test analysis of the video to understand the performance of the panel and compare it to other teams.

Keywords

Projects, Supersonic, Composites, Motivation

INTRODUCTION

Class projects put to fruition the theory they are taught in class into a practical application. Providing motivation for project-based activities is always difficult, as it is difficult to find something that will captivate a large portion of the class. Traditional paper-based design projects provide some value, but actually building and testing something that is far different than their everyday experience provides extra motivation for students.

Student competitions and challenges are popular for engaging students outside of the classroom. There has been published work on the educational value of student-based competitions [1] and strategies for structure and scoring [2]. Other fields have used student competitions to enhance certain areas of knowledge retention and to motivate students [3-9]. The American Board of Engineering Technology (ABET) accreditation requires student-learning outcomes related to professionalism and contemporary issues and the competitions can play an important role in achieving these outcomes, as long as they are well scoped.

Wankat [10,11] reviewed several K-12 and undergraduate student competitions and looked for patterns and trends among winners. However, there are several logistical, resource and safety-related challenges to be addressed before holding student competitions. Schuster et al. [12] discussed the relative benefits and challenges of holding student competitions. Jackson and

Popovich [13] discussed the development and implementation of assessment methods for a competition. Engaging freshman undergraduates and younger K-12 students in technical competitions may be more rewarding, and motivate their future career direction. ABET criteria for engineering education also includes the student's ability to function in multi-disciplinary teams preparing them for the future workforce. Rueda and Gilchrist [14] described the significance of student competitions in achieving non-technical skills and multi-disciplinary design experiences. In some cases, the participation in the student design competition counts towards the capstone senior design experience [15].

In this paper, I describe the creation and piloting of a student competition, surrounded on the premise of something silly, a supersonic ping-pong ball. The design, build, test method was used for this work and had students building composite materials for evaluation and testing against a supersonic ping-pong ball projectile. The benefit of this premise is there is no single answer or single solution that performs the best.

MOTIVATION AND OBJECTIVES

The objectives of the student project are as follows:

- *Enhance undergraduate and graduate student awareness of the breadth and opportunities in fields related to composites:* Often the courses focus exclusively on the analysis aspects and due to restrictions on time and context, prevent the students from building and testing. This prevents students from actually seeing the full cycle of what building an actual part would be. The challenge is envisioned as an educational opportunity to apply classroom learning to a practical problem.
- *Motivate innovation of new composites systems and products:* An open competitive environment on a challenging problem may create the necessary learning and sharing environment that fosters innovation.
- *Inspire students to take up careers related to composites in various industry*: The structures curriculum competes with the other focus areas of aerospace engineering. Creative and attractive competition problems can attract students with an aptitude towards careers related to composite materials.

The challenge specifically aims to demonstrate:

a) Innovative designs with composite materials
b) Analysis of complex problems
c) Validation and refinement from results
d) Fun!

In order to achieve these objectives, the challenge was designed allowing a lengthy preparation time that is followed by testing and evaluation before a final report.

CHALLENGE

The project is centered around a central theme of designing and building an object that can stop a supersonic ping-pong ball. The framework is such that the project can be expanded to include new constraints (thickness, size, materials etc) to tailor the challenge to the capabilities of the groups.

Problem Statement: Designing for static loads is something that we can perform easily. It is often the one time loads or dynamic loading events that cause parts to fail. An example of this was the foam impact on the Shuttle Columbia, where something you didn't think would cause damage, did. Your goal is to design a composite structure that can withstand the impact of a supersonic Ping-Pong ball. A standard Ping-Pong ball will be fired at about Mach 1.1 into your structure. Your design will be compared for how well it stops the projectile compared to the weight of the component and the estimated cost. The panel can only be made of materials discussed in this class. This includes composites, honeycombs, Foams, etc. **No Metals, Woods or Ceramic can be used**. Figure 1 shows an example of how a ping-pong paddle cannot stop the supersonic ping-pong ball from penetrating the paddle. The panel is considered to be a success if the projectile is stopped and when the panel is held up to a light you can no see light through it.

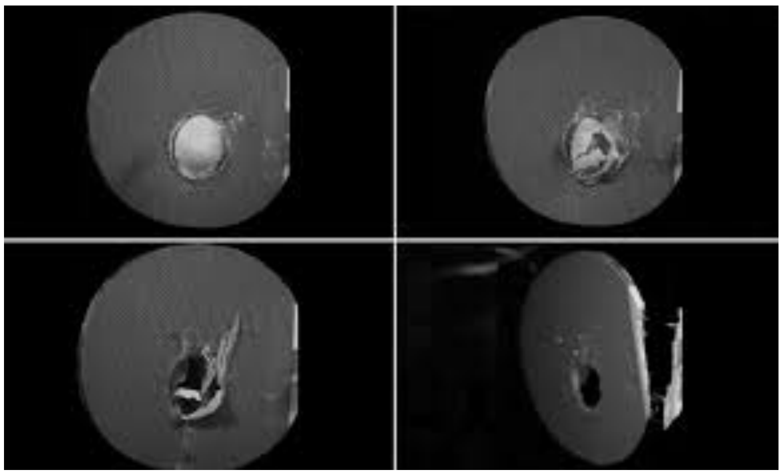

Figure 1 Example of Destruction from Ping-Pong Ball

Students are given over half the semester to complete this project and have preliminary deliverables along the way to keep them on task. This includes preliminary designs, preliminary analysis, preliminary testing etc.

The benefit of this project scope is that there is not a traditional calculation or analysis that can be run to provide the "answer". They have to try many different analysis methods and think about what would be important, and what they can learn from each method of solving the problem.

Sample Student Analysis

Student analysis varied from preliminary hand calculations to detailed finite element model simulations. The difficulty in this project is that there are many unknowns associated with the ping-pong ball. Students don't know the exact properties and when the ball will shatter. This creates an element of unknown where they must use some kind of judgment to understand when failure will occur. Figure 2 shows a sample of a simulations run by one of the student teams. This really shows how far the students can take a project based on the motivation. The results and creativity are quite interesting.

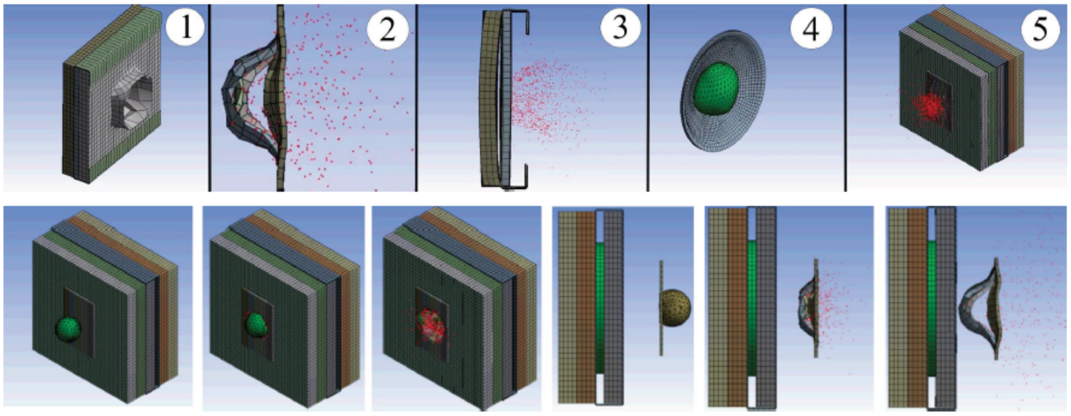

Figure 2 Sample of student simulation data. ANSYS Simulation showing the ping-pong ball hitting their design. The simulation shows that the student spent time learning advanced modeling techniques, such as erosion to understand the performance of their design.

Students fabrication methods varied based on the experience of the students and an example of one of the fabrication methods can be seen in figure 3. This teams performed a multi-step fabrication to create their panel. Each team had their own preferred method although most of the panels ended up being sandwich panels, based on discussion we had in class about the type of loading that was occurring on the panel and the ease of fabrication.

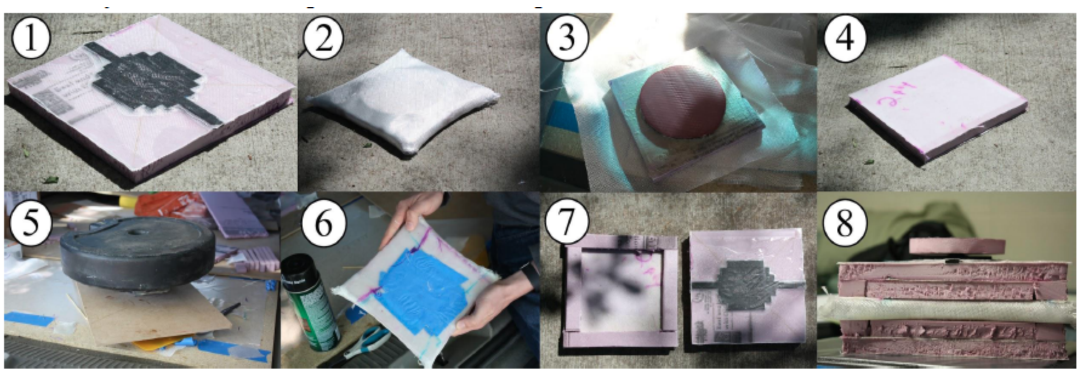

Figure 3 Sample of student fabrication. This process show the steps they performed to fabricate their specimen. The description is detailed enough that one could replicate the entire fabrication process.

Figure 4. shows a couple frames from the high-speed impact of the ping-pong ball against one of the teams' panels. The interesting thing to note is that the ball glows during impact due to the fact that the molecules trapped inside are excited to a higher energy level and then fall back down. It's a side physical phenomenon that many of the teams are able to pick up and discuss based on a class they have taken freshmen year. This also shows knowledge retention.

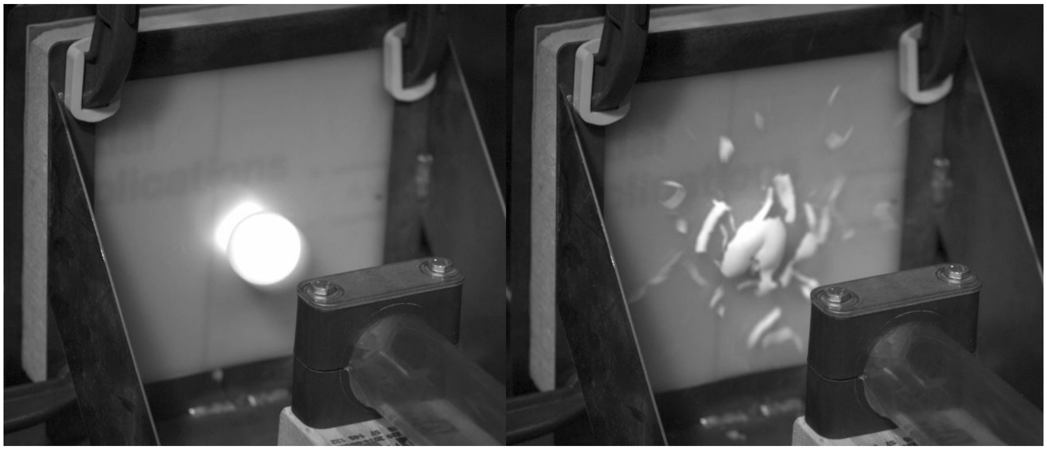

Figure 4 Sample of experimental testing

Table 1 below summarized the results of the weight from each teams' panels. All of the teams were able to successfully stop the projectile; however, most teams completely overdesigned the structure. Only 1 team really pushed the boundary of the design envelope.

Team	Weight (grams)
1	623
2	555
3	465
4	394
5	627
6	454
7	331
8	337
9	595
10	638
11	73

Table 1 Comparison of weights from final designs

Variations to the project are easy, as the constraints can be changed and to affect the response or impose restrictions on certain types of designs. Simple changes like limiting the materials, thickness of the panels, changing the panel size, etc, can make for continued challenges in the class each year. This project has the ability to be drastically changed to provide endless variations on the project so the students can't continually find the best designs from the previous year.

Updated Challenge

In order to change the challenge and keep it relevant to current ideas, a variation on this project was run which featured a Golf ball traveling close to Mach 1. The motivation to this was the following. Due to the prevalence of "Fake News," it has been decided that a wall must be built to keep people out. At this location it has been rumored that someone can hit a golf ball at super sonic speeds, it's big league. In order prevent destruction to the wall, it must be able to withstand a golf ball hit near supersonic speed. Your goal is to design a composite structure that can withstand the impact of a golf ball. A standard golf ball will be fired at around mach 1 into your structure and we will take high speed video to see what happens. Your design will be compared for how well it stops the projectile compared to the weight of the component and the estimated cost. The wall can be no thicker than 20mm.

The challenge in this project is more difficult due to the fact that the golf ball can store more energy and has a high mass, and finally is way less likely to fail on impact. Figure 5 is a series of high-speed images showing the deformation of the golf ball on a panel.

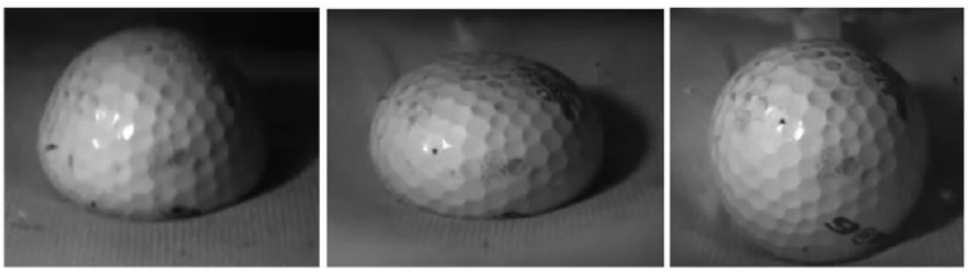

Figure 5 High-speed impact of golf ball on fabricated panel.

CONCLUDING REMARKS

The initial competition ran well as all the teams were able to fabricate panels that were able to survive the impact from the projectiles. Student enjoyed the competition and testing. Based on the results from this year changes will be made to the competition for the following years. This includes a max thickness and maximum weight so that they know their structures are completely overdesigned. Additionally, the projectile will be changed from a ping-pong ball to a golf ball as the added mass will make the problem more complex, but the projectile will hold together better.

REFERENCES

1. Buchal, R. O. (2011). The Educational Value of Student Design Competitions. Proceedings of the Canadian Engineering Education Association.
2. Vasiga, T., Cormack, G., Munro, I., & Kemkes, G. (2006). Structure, scoring and purpose of computing competitions. Informatics in Education-An International Journal, (Vol 5_1), 15-36.
3. Singhose, W., Vaughan, J., & Mayor, R. (2009, April). Use of design competitions in mechatronics education. In Mechatronics, 2009. ICM 2009. IEEE International Conference on (pp. 1-6). IEEE.

4. Green, S. I. (1996). Aircraft design education through student competitions. International Journal of Mechanical Engineering Education, 24(1), 49-57.

5. Murphy, R. R. (2000). Using robot competitions to promote intellectual development. AI magazine, 21(1), 77.

6. Kenderov, P. S. (2006, August). Competitions and Mathematics education. In Marta Sanz-Solé, Javier Soria, Juan Luis Varona y Joan Verdera, Proceedings of the International Congress of Mathematicians Madrid (pp. 1583-1598).

7. Conklin, A. (2006, January). Cyber defense competitions and information security education: An active learning solution for a capstone course. In System Sciences, 2006. HICSS'06. Proceedings of the 39th Annual Hawaii International Conference on (Vol. 9, pp. 220b-220b). IEEE.

8. Russell, R., Atchison, M., & Brooks, R. (2008). Business plan competitions in tertiary institutions: encouraging entrepreneurship education. Journal of Higher Education Policy and Management, 30(2), 123-138.

9. Brusentsev, V., & Miller, J. (2015). The Educational Value of the College Fed Challenge Competition. Eastern Economic Journal.

10. Wankat, P. C. (2005), Undergraduate Student Competitions. Journal of Engineering Education, 94: 343–347

11. Wankat, P. C. (2007). Survey of K-12 Engineering-oriented student competitions. International Journal of Engineering Education, 23(1), 73-83

12. Schuster, P., Davol, A., & Mello, J. (2006). Student competitions-The benefits and challenges. 2006 ASEE Annual Conference Proceedings: Chicago, IL. Jun. 2006. Available at: http://works.bepress.com/pschuste/7

13. Jackson, T. R., & Popovich, N. G. (2003). The development, implementation, and evaluation of a self-assessment instrument for use in a pharmacy student competition. Am J Pharm Educ, 67(2), 57.

14. Rueda, M. A. F., & Gilchrist, M. D. (2010, April). Student Competitions Enhance the Learning of Nontechnical Skills for Large Cohorts of Freshman Engineers. In Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments, 2010 IEEE (pp. 1-15). IEEE.

15. Kaiser, C., & Troxell, W. (2005, October). Student design competitions in undergraduate engineering education. In Frontiers in Education, 2005. FIE'05. Proceedings 35th Annual Conference (pp. S3J-S3J). IEEE.