

AC 2008-721: LET'S ROCK THE BOAT: EVALUATING THE CONCEPT OF STABILITY IN FLUID MECHANICS

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Let's Rock the Boat: Evaluating the Concept of Stability in Fluid Mechanics

Abstract

As an upper level civil engineering course, Fluid Mechanics often presents concepts that are unfamiliar to engineering students, at least to the level of understanding expected in the course. Many of these fundamental concepts are critical to success in the course, but are frequently difficult to visualize simply with figures and equations. Additionally, many laboratory exercises for students involve a “cookbook” type approach – which increases the chance of the attainment of reliable results, but inhibits curiosity and decreases the development of an independent engineering formation of ideas associated with problem solving. A possible solution to both issues is the incorporation of in class activities which illustrate fundamental concepts, engage students in an active learning environment, and allow for the students themselves to create a testing program.

The complication lies in determining a suitable topic and in creating an activity broad enough to allow for creative testing development but narrow enough to insure at least a marginal level of reliable results. The topic chosen by the authors was that of stability – one of the basic fundamental concepts in fluid mechanics. Working in groups of four to five students, the class was asked to develop an independent testing program that addressed the qualitative effects of adjusting weight in any one, or a combination of multiple, different directions (i.e. adjustments in the x, y, and / or z plane) on a floating object. Students were given supplies to create a model barge: a Styrofoam brick, cardboard sticks, modeling clay and containers sufficiently large to allow for floatation and movement when the barge was placed inside. No restrictions were placed on the direction in which the brick was to be placed in the water, the number and location of masts, or the number, magnitude and location of weight(s). Students were told the activity was to be summarized in a one-page paper, including testing procedure, results, and conclusions and were allowed thirty minutes for experimental setup, testing, and clean-up. Determination of student comprehension was assessed through both the summary paper, as well as an exam question. Results showed a high level of understanding, both in the short term, as concluded with the paper outcomes, as well as long term retention, validated with testing results. Quantitative analysis can easily be incorporated into the program by providing measuring instruments (rulers, calipers, and a balance) if a more robust study is desired.

Introduction

Florida Gulf Coast University (FGCU) is the newest public university in Florida. Established in 1997, FGCU attracts thousands of students from a growing, younger regional population. The mission of both FGCU and the Whitaker School of Engineering (WSOE) is to foster excellence in education by structuring innovative, integrated lecture-lab classes. As one of the earlier upper engineering courses, Fluid Mechanics often confronts students with new concepts and forces them to take a more in depth view on topics that they may or may not have previously considered. When confronted with new ideas, many individuals find that a hands-on approach, which allows for experimentation, trial and error, and independent testing, is more effective in

solidifying the concept over the more traditional lecture presentation approach. Therefore, the University's mission of integrated lab-lecture teaching is a perfect fit for this more challenging class and will affect better student learning. The challenge arises in determining classroom activities that address these novel topics in a manner that is simple to comprehend, yet not so simplistic as to be ignored by the students.

Materials and Methods

The idea for this lab was based on a video available from the online resources associated with the book used in the course, *A Brief Introduction to Fluid Mechanics* (1). The video, available to both students and instructors, showed a large model barge with a single mast floating in a bathtub. The entire device was constructed of metal, and the loading weight was able to be adjusted to four heights on the central mast. The video showed the results of horizontal displacement of the top of the mast with the weight at different heights. The initial idea with this lab was to allow students to recreate the video, and test for themselves the results. Upon further consideration, the experiment was enlarged (as discussed below) to broaden creativity and engage students in testing development. The class was broken into groups of 4 – 5 students each and groups functioned independently from each other.

One of the primary advantages of this activity, from the perspective of the instructor, is the relative ease and minimal expense associated with the procurement of materials for this lab. Figure 1 illustrates the supplies provided to each group and consists of a Styrofoam brick, cardboard sticks, modeling clay, and a container sufficiently large to allow for floatation and movement of the manufactured barge.



Figure 1: Supplies Utilized in Stability Experiment

As an additional note: the test presented herein consisted of only qualitative results, quantitative analysis can easily be incorporated into the program by providing measuring instruments (rulers, calipers, and a balance) if a more robust study is desired. The use of Styrofoam as the barge material allows students the flexibility of inserting “masts” in virtually any location with minimal complications. The cardboard sticks were easy to bend and cut, but sturdy enough to insert into the Styrofoam block. Modeling clay was an ideal weight because of its ability to “stick” to both the barge and at various heights on the masts, as well as the simple means of adjusting weight with the addition or removal of small or large portions. Although access to water in the classroom is ideal, containers of water can be provided without undue hardship. In retrospect the use of cardboard, rather than another material, in the masts did have the disadvantage of dissolving after extensive exposure to water. Their sturdiness was adequate for a relatively short lab time, but would probably not be sufficient for an extended lab.

Higher level engineering courses often have laboratory components with fairly rigorous standards of practice that result in “cookbook” laboratory activities. Although this typically increases the chance of the attainment of reliable results, it often inhibits curiosity and decreases the development of an independent engineering formation of ideas associated with problem solving. This experiment presents a possible solution to both issues by illustrating fundamental concepts, engaging students in an active learning environment, and allowing for the students themselves to create a testing program. Students were told the activity was to be summarized in a one-page paper, including testing procedure, results, and conclusions and were allowed thirty minutes for experimental setup, testing, and clean-up. No restrictions were placed on the direction in which the brick was to be placed in the water, the number and location of masts, or the number, magnitude and location of weight(s). In this manner the students themselves controlled the magnitude and type of data collected and were able to test a variety of different theories. This test development process is similar to what would occur in a research environment when asked to formulate an innovative testing procedure or in a consulting environment when asked to devise a potential solution to a client’s problem.

The required paper submission not only ensures that students participate in the group activity, but necessitates a clear and concise summary of work performed and professional analysis of results, which evaluates their technical writing skills. A purely qualitative approach results in sufficient data for a one-page single spaced paper; the inclusion of a more quantitative approach could easily result in a two to three page report.

Results and Assessment

The primary goal for this activity was to increase student comprehension of the concept of stability, with secondary goals of cultivating experimental development skills and improving technical communication ability. Assessment of primary and secondary goals was accomplished by means of a paper submission due one week after activity completion. Additional assessment of the primary goal of stability comprehension was performed by means of exam questions two weeks and three months after activity completion.

Initially students were a bit hesitant, and somewhat skeptical, about the idea of creating their own testing program, but after the initial reservations wore off, all groups initiated innovative and relatively extended testing programs – all of which were more complicated than the basic analysis from the online video. In addition to the basic barge with a single mast and varying height to the weight, students also performed the following tests for stability analysis:

- Analyzed stability of the barge itself, placing the block on all three different faces to determine minimum and maximum stability
- Multiple mast locations: not only the more “tradition” two or three masts in a single line, but also mast extending out at various angles from multiple sides of the barge
- Various weight locations: not only at different heights on the mast, but different locations on the barge (without the use of a mast) including placing the weight below the waterline
- Multiple weight locations: multiple weights on a single mast, on multiple masts, and at multiple sites on the barge
- Various weight magnitudes including smaller versus larger weight in the same location, uneven weight distribution across the barge, uneven weight distribution at various heights on single and multiple masts
- Modification of barge shape to maximize stability

Timing for the activity ran roughly 45 minutes – somewhat longer than initially anticipated, mainly due to cleanup time. Groups ran between four and six tests each. Many of these tests were similar across the class; however a majority of the groups developed at least one test unique to their group. The most distinctive of these tests was the modification of the barge shape to test for stability. Although no restrictions were made on changing the shape of the Styrofoam block, no tools were provided to do so. One group utilized personal items to carve the block of Styrofoam and, combined with the cardboard sticks, created a catamaran, which is shown in Figure 2. This design was tested in the same manner as their other setups, and determined by the group to be the superior design with maximum stability.

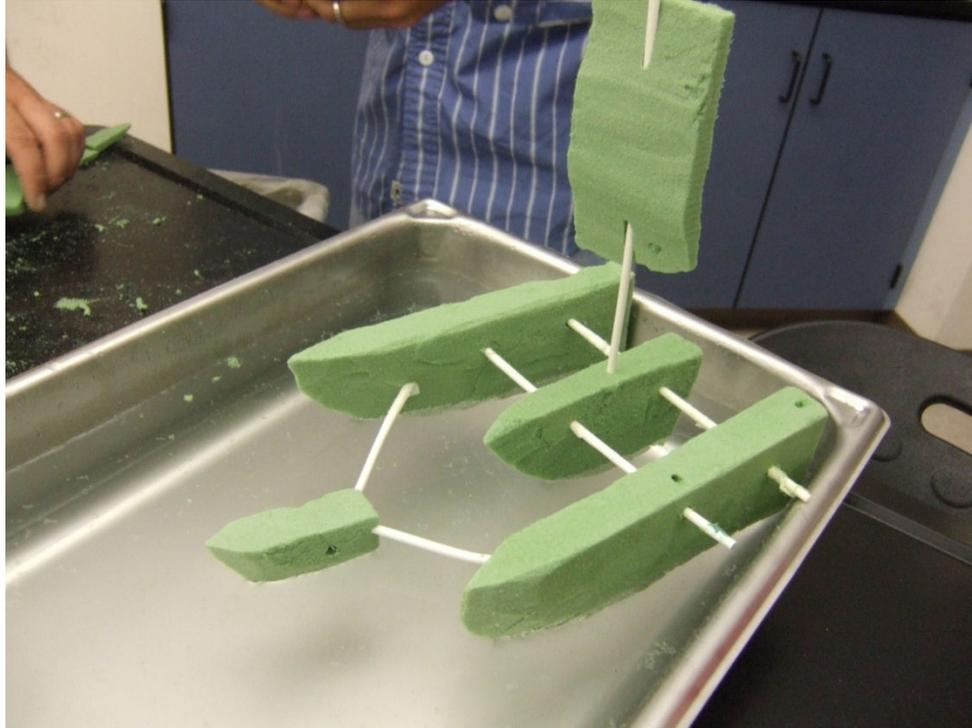


Figure 2: Barge modified into catamaran design for stability analysis

Student Comments on Activity

The following excerpts were taken from papers written by the students and help confirm the instructors thought of the value of this class activity. Comments on the value of the lab were not solicited in the assignment, inclusion of these comments were independent choices made by the students themselves.

- In summary this was a good learning experience in buoyancy and stability. We were able to see the effect of shifting masses on stability of an object.
- The stability experiment we did was very interesting. It was a very good way to visually demonstrate the physical property of stability.
- Overall, this may have begun to seem like a silly task, but we as a group soon realized that the demonstrative models could yield very different results in the same situation, with only one or two minor changes to the load placement.
- In conclusion, this experiment was very simple but great in understanding how loads and different mass amounts can affect the stability of an object in water.
- In conclusion, this activity allowed us to learn how the distribution and size of weights, which correlate to the center of gravity, affect the stability of an object.
- I believe we learned quite a bit about stability and what will make something more stable.
- Overall, the experiment was very successful and a lot was learned about stability and how it depends on the location of the center of gravity with reference to the center of buoyancy.

One of the students even commented that “after leaving the class, I actually thought of how we could have inverted the boat (mast under water, and mass as deep as possible). I believe that this set up would have produced a greater stability.” Overall the students appeared to feel that the activity was a success and was of value to their learning. Based on the responses, it is likely that the instructors will include this activity in future sections of the course.

Short and Long Term Assessment of Student Comprehension

The primary goal of student comprehension of the concept of stability was analyzed by means of a written paper due one week after the activity, an exam question asked roughly two weeks after completion of the activity, and a final exam question asked over three months after completion of the activity. Results from the paper showed a high level of student understanding with regards to stability analysis, with the average on the paper of 96. Students mentioned some or all of the following concepts when discussing the results of testing:

- Barge physical properties: size, shape, density
- Location and magnitude of load(s)
- Centers of buoyancy and gravity
- Restoring and overturning couples
- Stable and unstable equilibrium

The second evaluation occurred by means of an exam question. With reference to Figure 3, students were asked the following question: “Based on the co-ordinate system presented below, in which direction would the smallest adjustment in weight result in the greatest instability of the loaded barge. Justify your answer.”

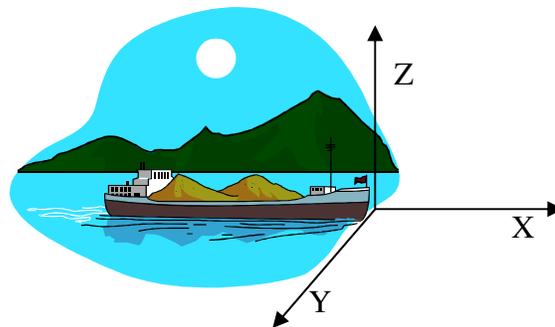


Figure 3: Illustration that accompanied first exam question

Full credit was given for the correct direction and reasoning including mention of barge physical properties and loading and either centers of buoyancy and gravity or restoring and overturning couples. The average score on the question was an 85, with almost 70% of the students earning a perfect score.

The final assessment of student retention was addressed in the extra credit portion of the final exam. The format was short answer and the students were asked: “What are the main factors

that affect stability?” All but two students in the class attempted the question, and 45% gave answers worthy of full credit. Eighty six percent of the students received at least partial credit for their answers. Although these values are somewhat lower than desired, it must be taken into consideration the fact that this question was placed in the extra credit portion of the final exam, rather than in the main exam itself, and possibly received less attention due to the location.

Because this was the first time the course was offered at this institution, it is not possible to compare comprehension and retention of the concept of stability for students having performed the activity with those who have not performed the exercise.

Summary and Conclusions

Integration of in-class activities into engineering courses, especially at the higher levels, is a challenging, but valuable endeavor. The exercise described in this paper introduces the concept of stability to students in a junior level fluid mechanics course. In addition to providing an active learning activity, the open-ended nature of the experiment allowed for students to develop their own testing program; a skill that is often difficult to address due to the need to follow established standards for many traditional laboratory tests. The general nature of the instructions initially concerned many of the students, but with a little encouragement the groups ultimately developed and executed effective testing programs. Assessment indicated a high level of initial comprehension and short term retention of the concept, and a moderate level of long term retention of stability. The required equipment is easy to find and relatively inexpensive, and the activity can easily be adjusted from the qualitative nature presented herein, to a more qualitative analysis if so desired.

References

- (1) Young, Munson, Okiishi, and Huebsch (2007). *A Brief Introduction to Fluid Mechanics* (4th edition). New Jersey: John Wiley and Sons.