
AC 2012-4654: SYNCHRONIZING THE TEACHING OF CAPSTONE DESIGN COURSE IN TWO COUNTRIES

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Synchronizing the Teaching of Capstone Design Course in Two Countries

ABSTRACT

In a globalization environment, the sharing of teaching and learning experiences among different educational systems and countries is an important educational exercise for cultivating the next generation of engineers, who will be more likely to work in international companies or in different countries. Capstone design is a good starting place for faculty collaboration and synchronization, because it reflects and assembles all the features of the curricula in different educational systems across a large number of countries.

The authors have many years of combined teaching experience in two different educational systems and have launched collaborative and synchronous teaching of a capstone design course in the United States and China since 2010. The same design topics have been offered to student teams in the two collaborating schools. Based on the students' learning experience and performance in the finished projects, the major differences in the two systems are significant. For example, American students put more effort into creativity, team work, project planning and management. The American system contains a series of software applications including calculation, presentation software for CAD and analysis, such as MATLAB, MS Office, SolidWorks, Algor, etc. Chinese students emphasize individual design performance and one-on-one meetings with their faculty adviser. The Chinese system requires more detailed analyses and review of specific calculations, such as gear tooth strength verification, bearing life calculations, and other specific calculations.

With all these recognized differences, a few commonly agreed upon objectives are clear. For the benefit of training global engineers, and for the efficient teaching of the senior capstone design course, it is desirable to develop a common set of lecture notes and teaching materials, with minor variations that fit the needs of the outcome-based evaluation systems in different countries. We would also like to use the same electronic tools such as Blackboard, Camtasia or Adobe Presenter for online delivery and distance teaching. To facilitate collaborative work, it is desirable that faculty members and

students become proficient in both languages to create future design project teams that are truly multinational.

1 Introduction

Faculty members at the University of Missouri-Columbia (MU) in the US and Shandong University of Technology (SDUT) in China have launched the collaborative and synchronous teaching of the capstone design course in their respective mechanical engineering departments. The same design topics have been offered to both student teams. Some differences in objectives in the capstone design course in the two schools are listed in Tab.1. MU will follow ABET requirements, while SDUT will have requirements set by the Ministry of Education of China.

Tab.1 Objectives of capstone design course at MU and SDUT

Objectives of capstone design course	MU	SDUT
Use computer to analyze kinematic and dynamic properties of machines	Yes	Yes
Use CAD software to make quality design drawing	Yes	Yes
Apply national standards and ISO standards in design	Yes	Yes
Write design project proposal and final project report	Yes	Yes
Make presentation to a large audience, based on the design project	Yes	Yes
Explain engineering ethics, impact of engineering design on society	More	Less
Explain the need for lifelong learning	More	Less
Describe and follow a common mechanical design process	Yes	No
Use foreign language for literature search and report (Chinese/English)	No	Yes

At the present time, the senior capstone design course in the two schools is taught as follows: MU organizes a four-to-six student team with topics coming from companies, alumni, hospital or other branches of the university. Although students can also propose topics for design, the topics must be approved by the faculty instructor of the course. The Senior Capstone Design is a one-semester, three-credit hour course with about a one-hour lecture per week. SDUT organizes a four-to-seven student team and uses a one-semester five-credit hour approach with about five one-hour lectures per week. We will compare a few design topics simultaneously completed at MU and SDUT, and then summarize the common strengths and weaknesses from the student teams in each school. Finally, we will make recommendations for improvement in future collaborations.

In this paper, three design topics, worked on by student teams in both schools, will be presented. The topics were initiated from the MU side, but each topic has been worked on by one student team in each school. Students on the SDUT teams also listened to lectures by the MU course instructor using SKYPE software. However, student teams did not discuss or collaborate on their design activities for these same design topics. By comparing the design reports and other outcomes, observations and comments will be provided regarding these results. Finally, recommendations for future work will be presented.

2 Capstone Design Case Studies

CASE 1—Improving Personal Energy Transportation (PET) Vehicle Design

Background and motivation—A Personal Energy Transportation Vehicle (PET), launched by the non-for-profit organization PET International^[1], is an all-terrain wheel chair for individuals in third-world countries who have lost mobility. Currently, PET vehicles consist of three solid rubber wheels and a simple gear assembly connected to hand cranks to propel the vehicle forward or backward. PET International consulted MU^[2] to help improve the current PET vehicle about the following issues: reduction of the manufacturing cost and the shipping box size; simplification of the assembly process; and improvement of the structural design.

Ideas and approach—Due to design constraints in cost, shipping volume, and ease of assembly, the MU team concentrated on redesigning the frame, seat, backrest and brake of PET, while the SDUT team focused on finding out some alternatives for the weld-on gooseneck, rear axles and brake.

Results—The MU team redesigned a new frame with a detachable gooseneck, attachable wheel axles, and a new seat and backrest allowing the user to change positions both vertically and horizontally. A new brake functions for both braking and parking. A proof-of-concept PET prototype was successfully constructed, as shown in Fig.1. The SDUT team changed the welding gooseneck to one that is bolted on, used movable rear axles, and combined the hand brake with the parking brake. They demonstrated the assembly and collapsing process through SolidWorks simulation, as shown in Fig.2. Both teams have decreased shipping volume more than 20% and costs, more than 10%.

CASE 2—Improving the Design for a Commercial Wood Chipper

Background and motivation—The design objectives^[3,4] were to maximize the mass moment of inertia of the cutting flywheel in a commercial wood chipper, and to improve the cutting efficiency while constraining the mass of the flywheel to be the same weight as in the original design. Improving the kinetic-energy storage capacity can reduce the deceleration during cutting, allowing the flywheel to undergo heavier cutting tasks.



Fig.1 Seat & backrest decision matrix and PET prototype (MU)

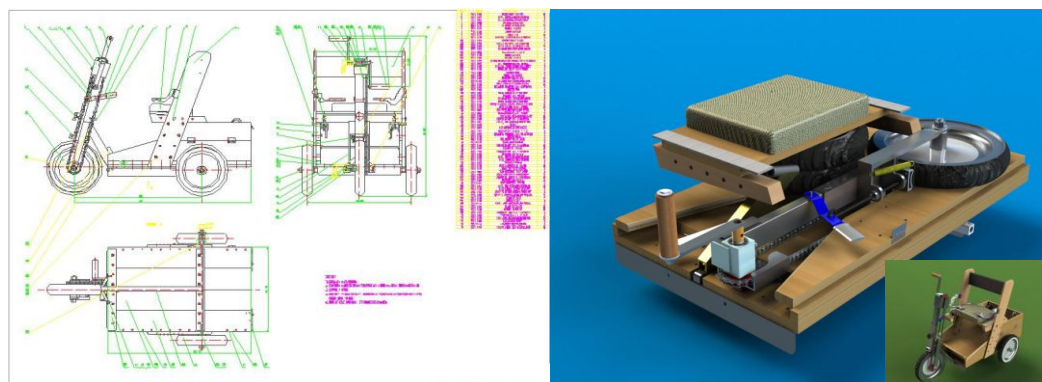


Fig.2 PET assembly drawing and solid model (SDUT)

Ideas and approach—Based on a well-known commercial wood chipper, which claims to have a heavier flywheel and better performance than competing products, the MU team used design optimization tools to increase the mass moment of inertia without increasing the weight of the flywheel, while the SDUT team focused on redesigning the cutter structure and improving the cutter^[5] design.

Results—The MU team designed a new flywheel, increasing moment of inertia by 60% while maintaining the flywheel weight at 34 lbs. A prototype chipper was made for testing (as shown in Fig.3). The SDUT team completed two, detailed designs of wood chippers: one with a single long cutter similar to the commercial design, and the other featuring multiple short cutters. A computer solid model was used for these two chippers (as shown in Fig.4). The teams, utilizing their knowledge and skills in

mechanical design, manufacturing, and engineering computation, made significant improvements to current commercial chipper design.

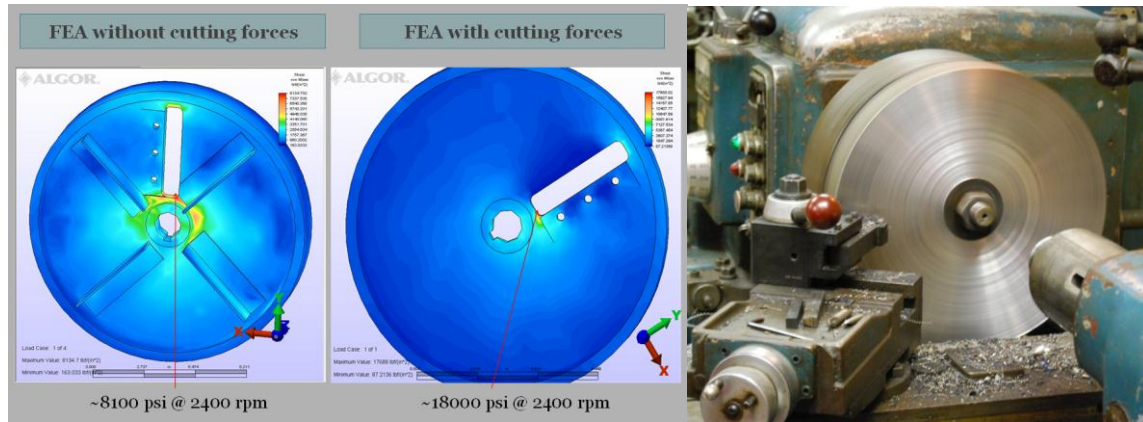


Fig.3 FEA on flywheel and prototype manufacturing (MU)

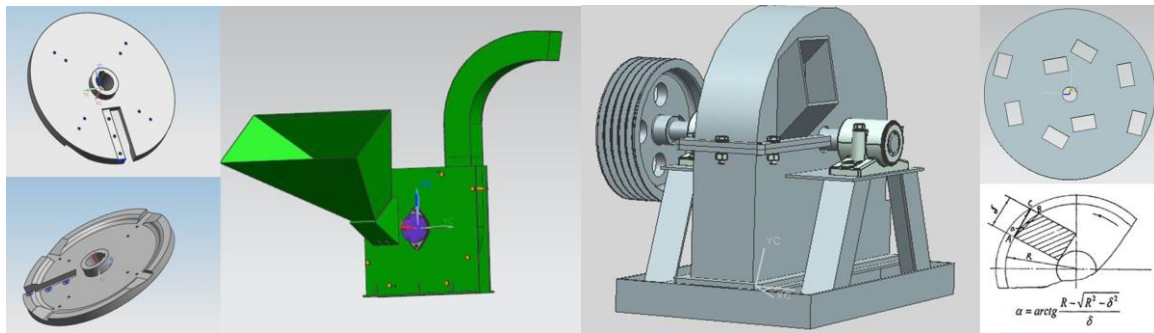


Fig.4 Two designs of wood chipper, one with single long cutter and the other with multiple short cutters (SDUT)

CASE 3—Adsorbent Natural Gas Tank Design

Background and motivation—Compressed Natural Gas (CNG) has been used in commercial passenger cars. Adsorbent Natural Gas (ANG) is a developing technology which shows promise in replacing CNG in small size vehicle applications. Compared to the CNG vehicle^[6], existing tests of ANG vehicles use only 1/7 of the pressure (2.5 MPa vs 22 MPa) in the storage tank. Advances in increasing volumetric capacity of an ANG tank have been made by the Alliance for Collaborative Research in Alternate Fuel Technology^[7] (ALL CRAFT group at MU) through filling the tank with a patented activated carbon. The increase in stored natural gas allows lower pressure with a lighter tank. The purpose of this project is to design a cylindrical ANG Tank and to explore its advantages by testing adsorbent effectiveness and comparing CNG storage capacity^[8].

Ideas and approach—Both teams design an ANG tank with 500 psi rated, with the MU

team mainly concentrating on testing adsorbent effectiveness and comparing storage capability, while the SDUT team mainly focuses on analyzing and reducing the weight of the tank.

Results—Both teams used a traditional cylindrical tank design. The MU student team designed and constructed a tank in a traditional cylindrical shape, using FEA analysis and an ASME pressure vessel code. After filling with activated carbon, this ANG tank offered a 52% increase in stored natural volume over a tank with the same pressure but without the adsorbent (as shown in Fig.5). SDUT students performed admirably in searching the Chinese and English literature. The cylindrical ANG tank conceptual design was analyzed using SolidWorks and FEA (as shown in Fig.6). Improvements in specific details were proposed in the design.

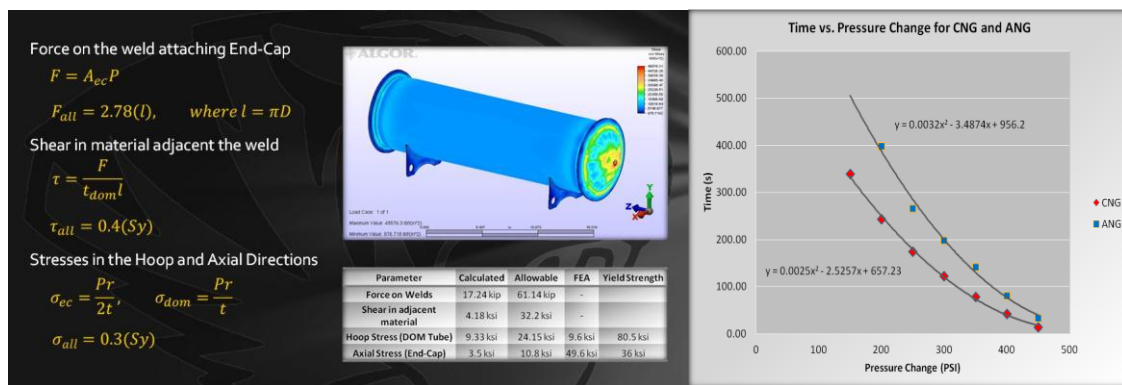


Fig.5 Final design and adsorbent effectiveness testing (MU)

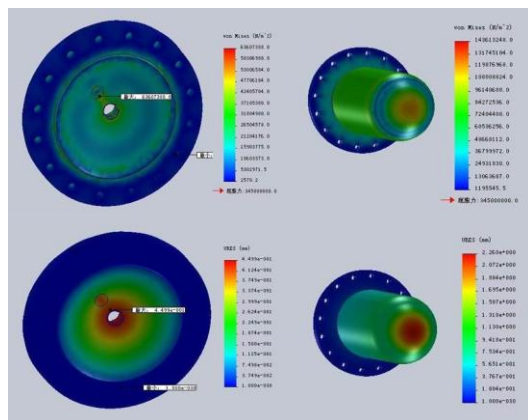


Fig.6 Design model and FEA on cover & tube (SDUT)

3 Summary of the Students Performance from the Two Schools

Through the simultaneous teaching presentations and the implementation of the above

three capstone design projects completed by six student teams, we summarize the strengths and weaknesses from the student teams in each school as follows:

- 1) Student teams in both universities did well using computer aided design (CAD) tools for solid modeling and calculations. Student teams also used, to some extent, national standards and codes to make quality design drawings. The teams wrote design project proposals and final project reports, and presented their design projects to a large audience.
- 2) Almost all teams came across some difficulties, more or less, in designing and implementing electronic or control subsystems involved in their projects. Since most modern designs, even those small and simple, rely on integrated knowledge of multiple engineering disciplines, a consideration for future capstone design projects is to organize design teams with students from different engineering departments.
- 3) The MU teams do well in dealing with design constraints, design objectives, QFD, creativity (new design concepts), decision matrix, testing and cost estimation, because they have been trained to consider mechanical design project as a process. In each stage of the process, they are prepared for relevant software tools for calculation, presentation to CAD and analysis, such as MATLAB, MS Office, SolidWorks, Algor, etc.
- 4) The MU teams do well in teamwork, project planning and management. All of the designs are social instead of individual activities. Modern design has become more and more a collaborative effort. It is very important to cultivate teamwork through senior capstone design.
- 5) The MU teams do well in cost estimating and prototyping. It is recognized by faculty members and school leaders from both schools that prototyping the design is a worthy and important part of the design process. However, prototyping has also become more expensive. Student engineers are capable of designing complex designs for which they may not have time or sufficient resources to complete a working prototype. While encouraging and helping student teams construct a prototype, if at all possible, an early decision should be made between the student team and the instructor about the decision to produce a working prototype or not.
- 6) The SDUT teams do well in undertaking whole design projects and carrying out

individual designs. Their tradition is to work independently, with different design topics for each student for the senior capstone design, although they do at times discuss issues with their faculty advisers and classmates. This current practice emulates the conditions faced by many small companies in China which may not have a team of engineers.

- 7) The SDUT teams do well in the detailed calculations, analysis and process, such as gear tooth strength verification, bearing life calculation, shaft design in detail through analysis to production quality drawing. They have the ability to do good quality work in most design and manufacturing projects without the assistance of advanced computer tools, considered to be important in the basic training of an engineer.
- 8) The SDUT teams did better in using the English language to write their project reports. Not all teams in all projects and not all SDUT students are sufficiently proficient in communicating in the English language (listening to lectures in English, asking questions in and out of classroom). However, SDUT students are better trained in using the English language as a professional tool than the MU students in using Chinese as a second language. It is not a requirement for MU students to use a second language to communicate professionally. However, this is obviously a desirable ability in a globalized environment.

4 Conclusions and Recommendations

In a globalized environment, sharing the teaching and learning experiences of capstone design courses among students and faculty members in different educational systems and countries is an important educational practice for cultivating global engineers. The capstone design course integrates knowledge from previous courses, thus reflecting the effectiveness of the whole curricula. It also introduces students to the real world experience of solving open-ended problems as an engineer. We started this synchronized, collaborative effort using the capstone design course, because it is, nominally, the most identifiable, equivalent course in the two curricula. There are not too many courses in the curricula that closely correspond by merely comparing the titles of the courses. Therefore, there is much work to be done in the effort to synchronize courses.

For MU student teams, it is desirable to enhance the student's ability in the finer details, such as producing quality drawings, analyzing components, and using a second language in professional work. For SDUT student teams, besides adopting the teamwork approach from MU teams, it is desirable to enhance the student's ability to plan and

manage a project within budget and time considerations, to understand mechanical design as a process, to develop measurable design objectives using QFD, and to consider a wide range of design constraints. The authors also recommended that SDUT adopt a suitable textbook that covers most of these new elements for the capstone design course.

This is just the beginning of an ongoing project. More data on the student learning experience and performance in the finished projects will be collected each semester. Based on the collected data, the course content, delivery methods, including language and electronic media, will be adjusted and improved. It is desirable to develop a common set of lecture notes and teaching materials, mixed in English and Chinese, which can feature minor variations to fit the needs of the outcome-based evaluation systems in the different countries. We would also like to share the same electronic tools such as Blackboard, Camtasia or Adobe Presenter for online delivery and distance teaching. It is also desirable that through cooperative work, faculty members and students become proficient in both languages so that future design project teams can collaborate and the learning experience can become truly multinational.

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