# Industrially Supported Projects in a Capstone Design Sequence

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## Abstract

The design experience in the mechanical engineering BS degree program at The University of Texas at San Antonio (UTSA) contains a senior-level capstone design course sequence, providing students an opportunity to apply and integrate the knowledge gained throughout the curriculum to the development of an instructor-approved project. The two-semester course sequence provides sufficient time for students to complete a project involving the design of a relatively complex system. In the last few years, representatives from industry have been invited to sponsor design projects. Several manufacturing companies and consulting firms have responded positively and actively participated in funding and mentoring capstone design projects. Engineers employed by these companies have served as project mentors and participated in evaluating the final reports and oral presentations. Industrial participation in our capstone design sequence has provided our students with a unique design experience opportunity. This paper describes the content of the capstone design sequence, provides short descriptions of industrial projects companies, and includes examples of completed design projects.

## I. Introduction

The mechanical engineering undergraduate curriculum at The University of Texas at San Antonio (UTSA) was recently revised[1]. Design experience is integrated throughout the revised curriculum. Development of open-ended problem solving skills is a part of all mechanical engineering courses. Design projects with formal report writing are included in many of the required courses, including ME 1403–Engineering Graphics and Design, ME 3513–Mechanism Design, ME 4293–Thermodynamic II, ME 4313–Heat Transfer and Rate Processes, and ME 4603–FEA in Mechanical Design. A substantial portion of each technical elective course is devoted to design of systems and components. The design components of these courses assist the development of student creativity, use of open-ended problems, development and use of modern design theory and methodology, formulation of design problem statements and specifications, consideration of alternative solutions, and feasibility considerations. A capstone design sequence at the senior level provides an opportunity to apply and integrate the knowledge gained throughout the curriculum to the development of an instructor-approved project.

Starting in Fall of 1998, ME 4811-ME Design Project Planning was added to the list of required courses, creating a capstone design sequence, thereby providing additional time to be devoted to the senior design project. This course is now a prerequisite for ME 4813-ME Design Project. In

ME 4811, students select a project title, form design teams, conduct preliminary research, investigate the existing designs, write a proposal for the project (including plan for completion of project), and carry the projects through conceptual design. Written formal reports, progress reports, and oral presentations are required at the end of the semester. The course also includes instructions in writing proposals, preparing technical reports, and oral presentations (including visuals). Discussions in engineering ethics and selected case studies are integrated in this course. Students are also introduced to machine shop operation and assignments are given for fabrication of mechanical system components. The selected project itself is then completed in ME 4813-ME Design Project.

The local industry representatives are invited to provide design topics and sponsor projects. Several manufacturing companies and consulting firms have responded positively and actively participated in funding and mentoring several capstone design projects. Engineers employed by these companies have served as project mentors and participated in evaluating the final reports and oral presentations. The industrial participation in our capstone design sequence has provided our students with a great design experience opportunity. This paper describes the content of the capstone design sequence, provides short descriptions of projects proposed by industrial companies, and includes examples of completed design projects.

## II. General Description of Capstone Design Sequence

The content of capstone design course sequence are briefly describe bellow

**<u>ME 4811-Design Project Planning</u>:** This is a one credit hour course, which meets 3 hours per week. It offers students an opportunity to select a meaningful, major engineering design topic that its completion requires utilization and integration of the knowledge acquired in the engineering core curriculum. It provides professional development in: i) technical skills through conceptual design, and project planning; ii) communication skills through written proposals and oral presentations; iii) engineering ethics awareness through selected case studies, and iv) machine shop operation. The educational objectives of the course is to provide an opportunity for the students:

1. To develop alternate conceptual designs
2. To develop skills in project planning
3. To enhance the understanding of design steps
4. To develop skills in working with others in a team project
5. To improve communication skills
6. To develop skills in how to identify and use resources
7. To develop an understanding of practical engineering problems in design
8. To critically evaluate existing designs
9. To improve the awareness of social, professional, and ethical responsibilities of engineers in design

The course uses a number of required[2], and recommended[3] books, various data books, and professional journals. The course includes instruction in preparation of proposal, progress reports, technical reports, and oral presentation. Students are also introduced to machine shop operation and assignments are given for fabrication of mechanical system components. Professional ethics is presented and a number of factual case studies are reviewed and discussed by students.

Students are free to form their design team and select a topic for their project. However, the selected project must meet the objectives of the course. In the last few years, representatives from the local industry have been invited to provide design topics. Students are also encouraged to contact professionals in industry or faculty for advice and mentorship. The mentor may be a faculty member or an engineer/scientist from industry; the later is encouraged. However, selection of proposal topics and design team members must be coordinated and approved by the instructor. The fabrication of the final design is encouraged.

Course work performed in ME 4811 is assessed according to the categories shown below.

A. Participation in class discussions
B. Project proposal
C. Progress Reports (written and oral)
D. Machine Shop Assignments (2)
E. Proposal Presentation
F. Proposal Report

**ME 4813-ME Design Project:** This is a three credit hour course, which meets 5 hours per week. The detail design for topics selected in ME 4811 and carried through conceptual design will be completed in this course. The course requires progress reports, a final written oral report and oral presentations. Representatives from companies sponsoring design projects and engineers from professional societies are also involved in the evaluation of projects. The educational objectives for this course is to provide students an opportunity:

1. To integrate their engineering education into design of a functional system
2. To conduct preliminary design (modeling, analyzing and evaluation of designs) of the conceptual design
3. To refine, optimize, and complete the selected design projects
4. To develop leadership quality
5. To improve skills in working with others in a team project
6. To enhance communication skills
7. To improve skills in identifying and using resources

## III. Industrial Sponsored Projects

Since Fall 2000, we have invited representative from industries to provide design topics and sponsor student projects. Several manufacturing companies and consulting firms have responded positively and actively participated in sponsoring several capstone design projects. Students have selected several project topics proposed by the industrial firms. Engineers working for these companies became project mentors and participate in the evaluation of the final reports and the oral presentations.

We believe that projects sponsored by industry have helped us to provide a better engineering education for our students and hope that the participating industry have also benefited from this partnership.

In the first semester that we attempted to seek industrial sponsorship for our design projects, the following manufacturing and engineering companies responded with design topics for consideration

1. Design Excellence, San Antonio, (3 topics)
2. Goetting and Associates (1 topic)
3. Laredo Proving Grounds (2 topics)
4. SMI-Texas, Seguin (8 topics)
5. Thermon, San Marcos (2 topics)

Each company submitted a short description of their design topics for consideation. For Example, SMI submitted the following description for one of their proposed design project topics.

Project: "Lift 200 Tons From Melt Floor To Casting Tower Without Using An Overhead Crane."

Problem: Our sister mill wants to increase its heat size. The building would have to be redesigned complete with a new crane way and crane support structure. The building itself would also have to be raised.
Background: The obvious solutions are too costly. The challenge is to design a lifting and transfer device to pick up the ladle full of molten steel and raise it 125 feet onto the arms of a turret that will rotate the ladle to the casting position to feed the continues casting machine parameters.

Goals Of Study: This is a machine design project - a large one at that. We are looking for alternatives to handle the ladle. General arrangements and load calculations are expected. Justify your approach with a cost assessment. And, of course, safety is paramount.

SMI Advisor: (an Engineer employee of SMI was identified)

The representatives from each of the companies attended the class and presented the projects to students. In addition SMI provided students with a tour of their facilities.

In the Fall 2001, our industrial sponsorship challenge resulted in over 26 project submissions and/or presentations by the following organizations

1. Sino Swearingen Jet Manufacturer (1)
2. The Center for Ocean Technology (1)
3. Center for the Study of Women and Gender (CSWG) (Open Proposal)
4. ASHRAE Undergraduate Senior Project Grant Program (Open Proposal)

5. Southwest Research Institute (2)
6. UTSA-AFRL Subcontract (1)
7. Inno Tech Engineering Services (6)
8. Marmon Mok (2)
9. Design Excellence (1)
10. SMI-Texas (1)
11. Wide-Lite (1)
12. NASA-TSGC Student Design Challenge
13. UTSA-SAE (2)
14. UTSA-Facilities Services (2)

Student groups selected 7 projects and presented their proposals in December 2001. The projects were completed in May 2002.

## IV. Examples of Completed Projects

Below are few examples of the industrially supported projects completed at UTSA in the last 2 year. The presentation of this paper will provide additional information and figures related to these projects.

**Slag Dust Suppression System:** Structural Metals, Inc. (SMI-Texas), located in Seguin Texas sponsored a review and redesign of a slag dust suppression system for their quench building. SMI-Texas is one of the nations most modern and productive steel mini-mills that specialize in fabricating and distributing structural steel. In the manufacturing process, dust is a major concern when the slag is removed from the melt shop area and dumped into a quench building for cools and subsequent processing. The quench building is equipped with and array of nozzles in the ceiling which generates a fog for dust reduction. The water spray system was effective for the first few weeks after which many of the nozzles clogged. The nozzles can be cleaned but this required excessive maintenance to keep the system in operation. The design team was asked to develop a better understanding of the clogging and redesign the system to reduce maintenance requirements. While studying the problem, the design team found that the system was periodically turned on and off while material was being moved into the building using a front-end loader. While the fog system as operating, the loader operator had minimal visibility. It appears the dust collected near the nozzle tip when the system was off and this accelerated the clogging. A combine air-fog system was proposed where the fog system would be re-installed inside air plenums. The air would be continually supplied to the plenum using a blower located outside the building. This would minimize the build-up and clogging of the nozzles. Laboratory experiments were conducted to select a final plenum design. Fans were selected as well as duct size and layout. The total cost of fans, ducts, plenums and nozzles was estimated to be $25,000.

**Design of Traction Testing Trailer with a Water Delivery System for a Testing Surface Pad:** Laredo Proving Grounds, located in Laredo TX is an independent tire testing company that specializes in braking traction testing. Braking traction is currently being performed using a skid tester capable of braking one wheel of the trailer while measuring friction force, test tire speed, and vertical load. The tests are conducted following American Society for Testing and Materials (ASTM) Method E-274 using ASTM Standard E-501 and F-408. The existing trailer has the capability of vertical loads up to 2-kip and the company desired a new trailer design capable of loads up to 4-kip as well as a thorough review of the current equipment and operations to assure compliance with ASTM standards[4]. The design focused on three areas of compliance review based on the tow vehicle, towed trailer, and instrumentation. When moving to a heavier trailer, the braking force was found to more significantly change the vehicle speed, depending on the trailer to vehicle mass ratio. The final design showed how the mass of the vehicle can be increased to maintain the speed with the 0.5mph limit as required in ASTM F-408 section 6.2.1. Because of the increasing size of tires, especially for off road conditions, the new trailer was designed with the tow hitch increased form 120 to 160 inches. One result of this project is that a member of the design team is now working full-time for Laredo Proving Grounds.

**Design of an Electrical Heating Module for Hopper Heating Application**: Thermon Manufacturing Company located in San Marcos TX produces a line of electric modular heaters predominately used for freeze protection in coal and fly-ash handling equipment. The design team was asked to explore alternative heating technologies and production methods to update this line of heaters while reducing their manufacturing costs. The existing design is labor intensive and required costly materials, so the goal of a redesign is to make it more economical. The new design was to sustain or surpass the performance and reliability of the existing heater. The existing design was reviewed and a cost breakdown performed to identify where savings were possible. The team evaluated a number of heating techniques, but quickly focused on thick film paste on rectangular sections of ladder shapes. The ease and low cost of manufacturing determined the paste type and width. An economic cost breakdown was performed showing a savings that exceeded the design goal. The proposed design allowed a variety of voltages and heat sizes to be derived by cutting a base heater that could be mass-produced. As a result of this project, the design team leader was hired as a full-time design engineer at Thermon Manufacturing.

**Design of Below the Knee Prosthetic Socket:** The University of Texas Health Science Center at San Antonio (UTHSCSA) supported this project. Two students (Diane Higgs and Phanvan Sanders) got part time employment in the Rehabilitation Engineering Laboratory of the UTHSCSA. The project deals with the development of design and optimization of a below the knee prosthetic socket for successful ambulation, comfort, and stability. The design was based on prescribed specifications, which include manufacturing process, material, physical and mechanical constraints, and static loading limited to normal physical activities: standing, walking, and sitting. Data points were acquired from a CT Scan of a residual limb and allowances were made in pressure areas. The point data was transferred electronically from UTHSCSA to the CAD laboratory at UTSA. Using the point data and the capabilities of the CAD software (ProEngineer), a drawing of a socket was created. Twelve areas were defined and a socket-pylon interface was added. The drawing was converted into an IGES file and imported into the finite element analysis program, ANSYS. A finite element mesh was generated using shell and solid elements. All surfaces were meshed with triangular shell elements. Boundary constraints were applied and the socket was analyzed for the extreme load conditions that exist at heel strike. Moment and load vectors [8] were applied at the center of the socket-pylon interface. Elasticity of the tissues was modeled by assigning an elastic foundation stiffness value to the defined pressure relief areas of the socket that contact with the residual limb. Changing the socket wall thickness, introducing gradual and offset tapered regions, and enlarging pressure relief areas created Eight (8) different design models. The areas were created in ProEngineer and thickness and tapers were defined in ANSYS. Gaining useful information on stresses and deflections from the finite element analyses of the socket designs, a final design of a below the knee prosthetic socket was developed. A summary of methodology used in this process is shown in Fig. 1. The final design satisfied the prescribed design specifications. Plots of data points, datum curves, socket surface, line divisions, meshed model of socket, anterior and posterior interfacial pressures, deflections, and stress distributions are provided in Fig. 2.

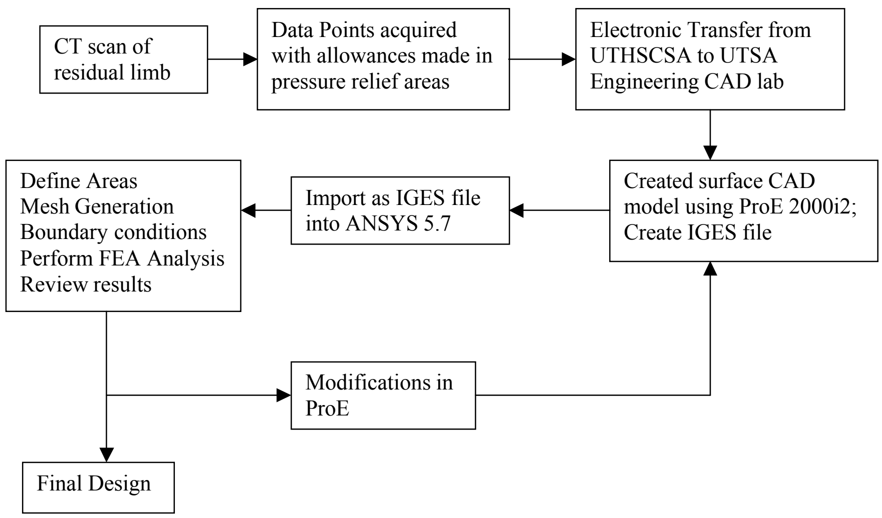
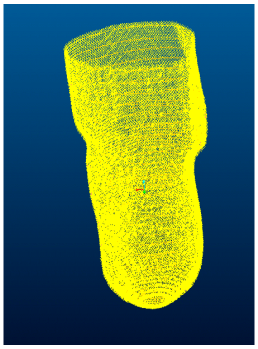


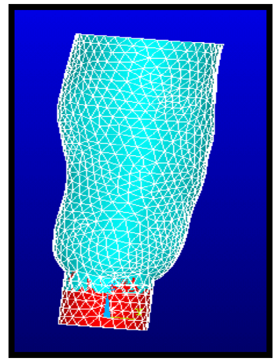

Fig 1. Summary of Methodology

**<u>Design of a Particulate Combustion Shock Tube:</u>** This project was supported by a United States Air Force grant to design and build a shock tube to study shock wave initiated by combustion of particulate laden dust clouds. A shock tube allows engineers and scientists to generate high Mach number flow fields in a laboratory. Shock tubes have become a common aerodynamic testing device due to its simplicity and inexpensiveness.

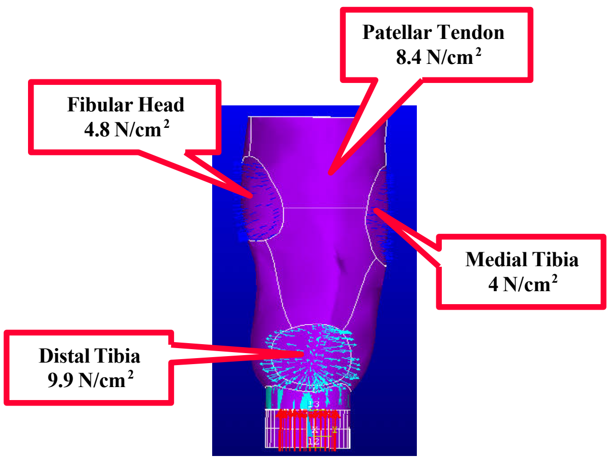
A 76.5" long shock tube with an ID of 2.9", a dual diaphragm initiator and a separate test section with particulate injection capabilities was designed, fabricated, and tested. High-speed pressure transducers and data acquisition equipment were used to collect experimental test results. The dual diaphragm system that was fabricated has been proven to be a reliable method for initiating tests. Design requirements for the injection mechanism were timing, repeatability, and leakage. The self-timing nature of this design allowed the injection of the particulate right before the shock wave.



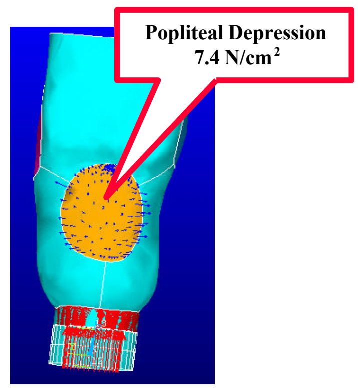
*Socket as Defined by Data points*



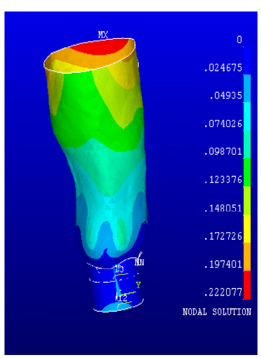
Meshed Model of Socket



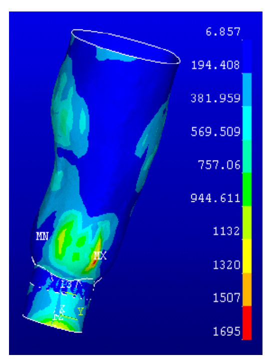

*Anterior Interfacial Pressures*




*Posterior Interfacial Pressures*




*Deflection Plot*




*von Mises Stress Plot*

Fig. 2 Plots of data points, datum curves, socket surface, line divisions, meshed model of socket, anterior and posterior interfacial pressures, deflections, and stress distributions

## V. Current Project Topics

The project topics selected by the students in ME 4811 in Fall 2002 are shown in Table 1. Table

1 also shows the funding sources and the amount for each project. These projects will be completed in Spring 2003 and some of the results will be presented during the annual meeting in June.

Table 1. List topic selected in ME 4811 in Fall 2002, which will be completed in ME 4813 in Spring 2003.

| Project Title | Funding Source | Amount |
|---|---|---|
| Fume Hood Design | UTSA- Facility Services | $4000 |
| Alternative Garbage Truck | Private Investor | $600 |
| Design of Positive Crankcase Ventilation System | BELL Engineering Group | $850 |
| Residential Solar Air Conditioning | Self-Sponsored/Manufacturers | $1,950 |
| Design of a Cooling System for a Cervical Collar | TRAUMATECH | $500 |
| Design of a New Shaft System for the Formula SAE Car | UTSA-SAE | $500 |
| Portable Automated Center of Gravity Measuring Device | INNO TECH | $1,000 |
| Design of a Semi Automatic Meat Cooker | Self-Sponsored/Manufacturers | $3,500 |

## References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3. Harris, C. E., Pritchard, M. S., and Rabins, M. J., ***Engineering Ethics: Concepts and Cases***, **2nd edition**, Wadsworth Publishing Co., Belmont, Calif., 2000.
4. ASTM (American Society for Testing and Materials) Annual Book of ASTM Standards, 1999.


## Biography

**AMIR KARIMI**
Amir Karimi is Professor of Mechanical Engineering at The University of Texas at San Antonio (UTSA). He received his Ph.D. degree in Mechanical Engineering from the University of Kentucky in 1982. His teaching and research interests are in thermal sciences. He has been the chair of mechanical engineering twice: the first time between 1987 and 1992 and again from September 1998 to January of 2003. Dr. Karimi has served on curriculum committees at all university levels and has been a member of the University Core Curriculum (1993-95 and 1999-present). He is the ASEE Campus Representative at UTSA and is the current ASEE-GSW Section Campus Representative. He chaired the ASEE-GSW section during the 1996-97 academic year.

**JAHAN EFTEKHAR**
Dr. Eftekhar joined the mechanical engineering faculty at UTSA in September 1984. He received his Ph.D. in Mechanical Engineering from the University of Texas at Arlington in 1983. Dr. Eftekhar is a Fellow of ASME and has made significant contributions to the development of mechanical engineering program at UTSA. His teaching and research interests are in the area of design, thermal systems, and automotives. He is the next appointed chair of mechanical engineering, effective January 16, 2003. Dr.

Eftekhar is the funding director of the Engineering Machine Shop and has served at that position for 12 years. Dr. Eftekhar also founded the student chapter of the Society of Automotive Engineers (SAE) at UTSA in 1987 and served as the SAE faculty advisor from 1987-2002.

**RANDALL D. MANTEUFEL**
Randall D. Manteufel is Associate Professor of Mechanical Engineering at UTSA. He received his Ph.D. degree in Mechanical Engineering from the Massachusetts Institute of Technology in 1991. His teaching and research interests are in thermal sciences. In 1999 he was awarded the Dow Chemical Outstanding New Faculty Award for ASEE Gulf Coast Southwest section. He is currently the faculty advisor for SAE and ASHRAE at UTSA.

**YESH P. SINGH**
Dr. Singh after 23 years of productive career and "hands-on" broad-based mechanical design experience in industries in India, formal USSR, and USA accepted a position Associate Professor in Mechanical Engineering in Fall Semester, 1985. He has been the chair of Mechanical Engineering at UTSA from 9/93-12/96. He has served as Chair of ME Graduate Study Committee and as ME Graduate Advisor of Records from 9/1998-8/2001. He served as Director of Engineering Machine Shop from 1/1998-3/2002. His teaching and research interests are in Mechanical Design: design of machines and machine elements, design of linkages and mechanisms, design of cams and gears, stress analysis and finite element applications in design of mechanical and structural systems. Professor Singh is a registered professional engineer in the states of Texas and Wisconsin, and is an ASME Fellow.