An Updated Approach for Preparing Mechanical Engineering Students for the Machine Design Industry

Thong Do[1], Chase Holland[2], Drew Newman[3], Janis Terpenny[4], Richard Goff[5]

Abstract – While design education has improved significantly at Virginia Tech over the last several years, with courses in the first, second, and senior years that challenge student teams to take on realistic (and often real) design problems, the junior level machine design course remains limited in scope and practical use. Recently, a much greater emphasis for the junior and senior years of the Mechanical Engineering (ME) program is placed on fluid sciences, heat transfer and thermodynamics. While this is a strength of the program, there is an opportunity to create a strong mechanical design curriculum for upperclassmen. This paper presents a secondary two-semester machine design class for senior and graduate level students. This class would build on theories introduced during previous engineering courses. A novel approach to machine design education is put forward that combines different methods of solving design problems with various teaching and learning styles. The course will have three distinct sections: advanced mechanics theory, design optimization, and design for manufacturing. The advanced mechanics section will cover situations that are likely to be seen in a real world design problem and focus on developing student knowledge from a theoretical foundation. The design optimization section of the course will focus on how to choose the best design for the situation based on a set of machine design criteria. This section will use various methods including MatLab optimization codes, and will combine theory and practical knowledge of machine design. Finally, the design for manufacturing section will show students how to communicate designs to individuals or companies responsible for manufacturing. This section will focus on the knowledge of standards and manufacturing processes, and will include some hands on and visual learning in a machine shop environment.

Keywords: advanced mechanics theory, design education, machine design, design for manufacturing, machine shop.

INTRODUCTION

There are areas in the current Mechanical Engineering (ME) curriculum at Virginia Tech where there are opportunities for growth in the subjects of design, mechanics of materials, and machine elements. There is a general lack of subject material for students that would like greater depth at the undergraduate level that might aid students wanting to pursue a career in these areas. In addition, many undergraduate ME students graduate from Virginia Tech without critical skills such as a general knowledge of manufacturing techniques and the ability to produce industry quality engineering drawings.

The current curriculum includes introductory courses that focus on "soft design" and cover design methodology and Computer Aided Drafting during the freshman and sophomore years. Mechanical Engineering students are also required to take more technical courses during their sophomore and junior years including Statics, Dynamics, Deformable Bodies, and Mechanical Engineering Design [1]. However, the organization of these courses and their subject matter fail to promote a connection between the design process and the analysis methods and techniques

[1] Mechanical Engineering, Virginia Tech, tqdo@vt.edu

[2] Mechanical Engineering, Virginia Tech, cchollnd@vt.edu

[3] Mechanical Engineering, Virginia Tech, asnew@vt.edu

[4] Engineering Education & Mechanical Engineering, Virginia Tech, terpenny@vt.edu

[5] Engineering Education, Virginia Tech, richgoff@vt.edu

developed in the technical courses. In addition, these courses do not have sufficient material to prepare students for "real world" design problems that have complexities not covered in these basic courses.

In the past, another course titled Mechanical Engineering Design II [2] has been offered, which covered advanced machine elements and loading calculations. This course was intended to follow the Mechanical Engineering Design I course that is currently required for undergraduate Mechanical Engineering students. In recent years, students, both at the undergraduate and graduate level, and engineering faculty have expressed an interest in seeing this course as well as others with similar subject matter offered at Virginia Tech again. This paper introduces a two semester senior/graduate level course that covers the design and mechanics topics that are currently missing from the Virginia Tech curriculum.

PROJECT SCOPE AND ASSUMPTIONS

One of the main purposes of this course is to create a machine design course track for undergraduate and graduate students interested in the design field. The current ME curriculum steers students toward thermal and fluid sciences at the junior and senior level. This course will provide these students with additional classes in the machine design area covering strength analyses of multiple loading conditions, all types of failure modes, and machine elements such as gears, conveyors, and joints. The course will also provide instruction on optimization techniques using MatLab programming and design for manufacturing and assembly. Class work will be aimed towards providing students experience with realistic loading schemes and advanced machine elements. In addition, another course objective is to give students experience working with industry standards for manufacturing processes and drawing, drafting, and tolerancing. The emphasis is on providing students with actual experience in designing a part, performing the appropriate strength analyses, and communicating the design by creating engineering drawings that adhere to industry standards that will be passed on to manufacturing and machine shops. This process will prepare students for real world experiences in industry by allowing them to tackle open-ended design problems similar to what they will find in the workforce while providing constructive feedback.

This course is designed to include two semester-long three credit hour classes. The first class is titled "Advanced Mechanics and Materials (ME Design II)" and the second class is "Advanced Design Methods and Optimization". The entire course is designed such that the first class is the prerequisite for the second class. The first class is meant for senior level students in Mechanical Engineering; it is not intended to replace other classes, rather it will be added as a technical elective for students with interest in this field. The class requires that students have already successfully completed Statics, Dynamics, Deformable Bodies, and most importantly, the first "Machine Design" course in the junior year, ME 3614. Prior experience with solid modeling (CAD) is preferred but not required. The second class is designed for students who took the first class and focuses on understanding additional in-depth methods of design at the graduate level. A basic background in programming with MatLab, and familiarity with Finite Element Analysis (FEA) is preferred for students taking the second class. The first class will be offered in the spring semester of senior year and the second class will be offered in the fall for continuing graduate students.

APPROACH AND METHODOLOGY

It is important to understand that the main impetus for the design of this course is that it is being designed and suggested by current graduate students (also alumni of the undergraduate program) who want to take the course and pursue a career in machine design. The hope is that this will provide for a learner-centered environment in the class. While the course will have a well defined schedule and syllabus, it is important to be able to depart from the schedule to cover topics that students find relevant and interesting. The course is designed to be taken by students at the senior level and above; it is expected that students at this level should have a clear idea of the subjects and areas that they are interested in and would like to gain more knowledge and experience. Therefore, the course will be flexible enough to offer discussions on special topics as requested by the students.

A large component that has helped in the design of this course is the FDI Track G workshop [3], which focuses on developing courses that feature learner centered instruction. The FDI Track G workshop has helped by getting the ideas for this course down on paper in an organized fashion. It has also helped to identify the methods and tools by which the course will be taught.

A major component of this course is the final term project. This project will mirror a typical design project found in industry. In addition, the focus of the project will be selected from graduate research areas at Virginia Tech. It is believed that students will not be able to develop a complete understanding of the subject without a project that ties

together the different aspects of the course. This part of the class ties very closely with the visual components required for teaching the class.

This class will be taught by a team of instructors that will cover the various sections of the class, which is required by the breadth of material and subject matter. Visual and hands on learning techniques will be used wherever possible by the instructors of this course. In many regards, the design of a part requires some innate knowledge. For example, while textbooks and instructor provided presentations and lectures can give you guidance on how to place a bolt hole or feature on a part, these forms of teaching cannot apply to every problem and every part. To help in this regard, instructors will be available for one-on-one office time with students. Students will be able to use class time and available office hours as basis to extrapolate from. Engineering intuition and an ability to visualize three dimensional problems will be very useful in the design of advanced, complicated parts. This course will make efforts to cultivate engineering intuition and visual ability in its students. Descriptions of a proposed course syllabus and an example end-of-the-semester design project follow.

Proposed Class Syllabus

ME 9998 – Advanced Mechanics and Materials

ME 9999 – Advanced Design Methods and Optimization

Course Learning Objectives:

Having successfully completed these courses, the student will be able to:

1. Produce engineering drawings using correct drawing and tolerancing standards (ASME)
2. Analyze complex mechanical systems
3. Apply advanced design methods to evaluate designs
4. Use computer coding to optimize designs based on various constraints
5. Design parts using DFA and DFM techniques
6. Work in teams to complete a design process for a machine part

Required Software: CES 2009 EduPack (Cambridge Engineering Selector) - Granta Design Inc., 2009 Software from VT Software Distribution. More info to be provided in class.

Matlab R2009a with Optimization Toolbox – Mathworks Inc., 2009. Software from VT Software Distribution.

Solidworks 2009 – Dassault Systems Inc., 2009. Software from VT Software Distribution.

Required Text: Mechanical Engineering Design, 7th Ed., Shigley, JE, Mischke, CR, Budynas, RG, McGraw-Hill, 2004.

Y14.5 Standard-2009 Dimensioning and Tolerancing - ASME Product # N00509

Grading for ME 9998:	
Exams (2)	25%
Take Home Final Exam	20%
Homework (approximately 8 – every other week)	30%
Labs/Guest Speakers	20%
Participation	5%
Total	100%

Participation grade is based on class attendance (unscheduled quizzed and roll calls) and participation in class discussion.

Grading for ME 9999:	Exams (2)	25 %
	Final Project	30%
	Homework	30%
	Labs	25%
	Total	100%

Final grades will be calculated according to an absolute scale:

≤59 = F		
60-62 = D-	63-66 = D	67-69 = D+
70-72 = C-	73-76 = C	77-79 = C+
80-82 = B-	83-86 = B	87-89 = B+
90-92 = A-	93-100 = A	

Proposed End of Course Design Project Description

Assignment:

Teams of three or four students will tackle the design of a machine part of their choosing. This part can be selected from graduate research projects or industrial experiences. Student will use their experiences from Advanced Mechanics and Materials as well as Advanced Design Methods and Optimization to define the function and the constraints of the part as well as set and quantify the criteria and objectives. Students will then use the analysis techniques developed in these classes to correctly evaluate the machine part's loading, modes of failure, and critical sections. It is expected that the analysis of the machine part will require multiple iterations.

The second part of this project will focus on the manufacturing of a full working prototype of the machine part. Students will be required to complete a full set of working drawings using ASME Drawing and Dimensioning standards, and work with the Mechanical Engineering Machine Shop to get this part manufactured. It is also expected that students will design the machine part using Design for Manufacture and Design for Assembly methods.

Deliverables:

1) Project Report
    a) Product Function and Background – (5 Points)
    b) Design Criteria, Objectives, and Constraints – (10 Points)
    c) Weighting of Constraints – (5 Points)
    d) Material Selection – (5 Points)
    e) Hand Calculations – (15 Points)
    f) Additional Analysis (FEA or Other) (15 Points)
2) Working Drawings (25 Points)
3) Product Prototype (20 Points)

CONCLUSIONS AND RECOMMENDATIONS

Based on discussions amongst the project team and with two Virginia Tech professors who specialize in this subject the team has come up with an outline for the proposed courses. The course syllabus which includes grading breakdown of the course, the course learning objectives, required course texts, and required course software can be found above in the Approach and Methodology section of this paper.

In making this syllabus, the team used course design techniques as well as techniques familiar to engineering design such as the House of Quality, which the team used to strengthen its learner-centered model by identifying student needs and proposing how to meet those needs. The roof of the House of Quality identifies conflicts between the "hows" which helped the team to limit the scope of the course.

Another method and set of tools utilized for course development included the Track G Analysis module offered by the Faculty Development Institute (FDI) at Virginia Tech [3]. This analysis helped to define the learning goals, nested learning objectives, and type of learning required for the class. The learning goals of the class can be found in the class syllabus. Different objectives defined for the course require different types of learning. This class will incorporate effective communication, complex thinking, information processing, collaboration and cooperation, and habits of mind learning activities. These operations fall under the cognitive, psychomotor and affective learning types.

The team's expectation for the course is that it will include hands on and visual lessons to better help students grasp the concepts being taught. This is written into the course by way of design labs and the final design project. The team felt that the best way to solidify the main ideas of the courses is a design project similar to what students would be tasked with in industry. This design project would follow a part from conception to manufacture and would be based on a need from research projects in the department or partners in industry. A project overview and description can also be found in the syllabus in the previous section.

Additional work remains to fully develop the proposed course at a detailed level. Future work is also needed to ascertain student interest in the course, and to evaluate what other universities are doing to teach these concepts. Once the final syllabus and schedule are complete, they will be presented to students either through email or at a seminar. Surveys will then be distributed to students who have reviewed the syllabus to determine interest level.

REFERENCES

[1] B.S. in Mechanical Engineering Degree Path Sheet, accessed 2009-11-25
http://www.me.vt.edu/academic_programs/undergraduate/Path2009to2012.pdf

[2] ME 4614, Mechanical Design II Syllabus, Mitchell, L. D., Spring 2009

[3] FDI - Creating Learner-Centered Instruction, accessed 2009-11-25
http://www.fdi.vt.edu/summer/2006/TrackG.html

Thong Do

Thong Do received his B.S. in Mechanical Engineering from Virginia Tech. Currently in his first year, he is studying for his M.S. in Mechanical Engineering at Virginia Tech, with focus on Finite Element Analysis, and design optimization techniques. His advisor is Dr. Robert L. West.

Chase Holland

Chase Holland received his B.S. in Mechanical Engineering from Virginia Tech. Currently in his first year, he is studying for his M.S. in Mechanical Engineering at Virginia Tech, with a focus on Finite Element Analysis and Machine Design. His advisor is Dr. Robert L. West.

Drew Newman

Drew Newman received his B.S. in Mechanical Engineering from Virginia Tech. He is currently studying for his M.S. in Mechanical Engineering at Virginia Tech, with a focus on gas turbine heat transfer design.

Richard Goff

Richard Goff is an Associate Professor and Assistant Department Head of the Department of Engineering Education in the College of Engineering at Virginia Tech. He is also the Director of the Frith Freshman Engineering Design Laboratory and the Faculty Advisor of the VT Baja-SAE Team. He is actively involved in bringing joy and adventure to the educational process and is the recipient of numerous University teaching awards.

Janis Terpenny

Janis Terpenny is a Professor in Mechanical Engineering and Engineering Education, and an affiliate faculty of Industrial & Systems Engineering at Virginia Tech. She is Director of the NSF Center for e-Design, a multi-university I/UCRC center. Her research focuses on process, methods, and tools for early design and on engineering design education. She is a member of ASEE, ASME, IIE, and Alpha Pi Mu and is the Design Economics area editor for The Engineering Economist and the Associate Editor for Design Education for the ASME Journal of Mechanical Design.