Implementing A Sophomore-Level Materials, Manufacturing & Design Laboratory

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ABSTRACT

A one-credit hour, sophomore-level laboratory course was implemented in Fall Quarter, 1995 to integrate materials, manufacturing and design. The course meets once a week for three hours, and is team-taught by two faculty members, one with background in materials science and the other with background in manufacturing and design. Course activities aim to create a discovery-oriented learning environment, and the weekly activities are geared towards helping students to successfully carry out a design project involving press-forming/press-shaping. Students engage in hands-on activities to investigate the relationship between structure, properties and processing of materials. They apply some general concepts of manufacturing to design the dies for press-forming/press-shaping, and use AutoCAD and a model computer-aided milling machine to cut a prototype die. They use statistics for product description, tolerance, and properties. Students also make final design project presentation. Details of the course and results of student evaluation are described in the paper.

INTRODUCTION

The faculty of the Mechanical Engineering (ME) Department at the University of South Alabama (USA) began, in Fall 1993, an evaluation of the undergraduate program to meet the challenge of engineering education for the 21st Century. Restructuring of the mechanical engineering curriculum at USA is also prompted by the changing ABET (Accreditation Board for Engineering and Technology) requirements for design. Under the current criteria, design is defined as "an experience that must grow with the student's development," and "the design experience is developed and integrated throughout the curriculum"[1]. In addition to the development of student creativity, formulation of design problem statements and specifications, consideration of alternative solutions, and feasibility considerations, ABET suggests that design should also include "production processes and concurrent engineering design."

A new curriculum, which provides greater flexibility to upper division students to meet their diverse interests and which enhances the design experience for lower division students, was implemented in Fall, 1995 as a result of that effort. A new, one-credit hour, laboratory course, ME211 "Materials, Manufacturing and Design," was implemented in Fall Quarter, 1995 to introduce students to production processes and to provide continuity in design experience in the sophomore year, and is the subject of this paper. Other lower-division curriculum enhancements include the following three, new courses: (a) a 4-credit hour "Introduction to Mechanical Engineering," which replaces a one-credit hour course to provide substantial design experience in the freshman year, was implemented in Winter Quarter, 1996; (b) a 2-

credit hour, sophomore-level course employing writing to explore the social impacts of technology and engineering ethics will be implemented in Spring Quarter, 1996; and (c) a 2-credit hour, sophomore-level "Introduction to Design" will also be implemented in Spring Quarter, 1996.

METHODS

1. Curriculum Design

Course development is guided by the ideas outlined by Stice on teaching problem-solving skills[2]. According to Stice, "Learning theories tell us that the best way...is to give students the opportunity to analyze, synthesize, or evaluate on their own. Then they must be given rapid, accurate feedback on their performance. Finally, they need lots of practice to develop their skills." Course activities are constructed with the goal of creating a discovery-oriented learning environment so students can discover for themselves through guided, hands-on activities the engineering principles and relationships they will need in order to carry out the design project.

The laboratory period normally begins with a 20-minute presentation on the relevance of each week's activities and their relation to the design project, and on the tools that will be used for the period. It is followed by one-and-a-half to two hours of hands-on investigations by the students, including data collection and analysis, synthesize of ideas and concepts, and report writing. Finally, there is a 20-minute wrap-up by a faculty to give students feedback on their work for the session and the relationship to the design project. Homework assignments are constructed to give students the opportunities to discuss and reflect on the results of laboratory investigations and their relevance to the design project.

Mechanical forming is chosen as the theme for the design project because it addresses the educational objectives outlined by the National Research Council (NRC) on educating mechanical engineering undergraduates[3]. A 1989 NRC report recommends "that, regardless their institutional location and organization, undergraduate courses and programs in materials science and engineering be centered on the four basic elements of materials science and engineering, which are synthesis and processing, structure, properties, and performance. For ME undergraduates, the report recommends the joint teaching of subjects by faculty with materials and non-materials science expertise, and a sequence of two courses with one focusing on the elastic and plastic properties of materials. Mechanical forming is chosen as the theme for ME211 because a teaching lab about the relationships between materials, manufacturing and design is relatively inexpensive to equip.

2. The Design Project

Students design and produce a Mardi Gras medallion. The Mardi Gras festival originated in Mobile though its celebration is popularly associated with New Orleans, and Mardi Gras medallions are chosen as the product to give the design project a local tie-in. For the 1995 academic year, the material chosen for the medallions is 260 Brass to take advantage of the equipment on hand. For the design project, students are provided with size and hardness specifications. Weekly activities aim towards helping students gain a feel for the relationships between structure, properties, and processing so they can carry out their design. Students use AutoCAD for solid modeling of the dies for the forming processes, and to create the visual design of the Mardi Gras medallion and the tool paths for a model computer-aided milling machine to cut a prototype die. They can get a feel of the visual design by setting pen size to match the size of milling and drilling bits and printing a hard copy.

3. Equipment for the Materials, Manufacturing & Design Lab

Laboratory exercises are supported by six, networked computer stations (90 MHz Pentium with AutoCAD and Microsoft Office); a Roland Digital Group CAMM-3 Model PNC-3000 computer-aided milling machine; two metallography stations for sample preparation (two Handimet grinders and two polishing stations), two Rockwell hardness testers; two manual rolling mills, a 30-ton and a 60-ton Enerpac press; a Tinus Olsen Tension Testing Machine instrumented for automated data collection, 4 Borsch & Lomb microscopes, and one Nikon microscope equipped with a video camera and Noesis image analysis software run on a 90 MHz Pentium PC.

4. Results of Course Evaluation

Students are surveyed retrospectively on the last day of class to assess their opinions about ME211 on their ability to do design. In the survey, students are requested to pick one of five categories (strongly disagree, disagree, not applicable, agree, strongly agree) that best represents their answers to six questions. They are also requested to provide written comments about course activities.

The results of the survey for the 1995-96 academic year are as follows:

a) 19 respondents "agree" with the statement "I gain confidence in using a computer as an analytical tool as a result of ME211," 4 replied "strongly agree," and 4 replied "not applicable."

b) 21 respondents "agree" with the statement "I gain confidence in using spreadsheet to perform engineering analysis as a result of ME211," 5 replied "strongly agree," and 1 replied "not applicable."

c) 20 respondents "agree" with the statement "I gain new understanding about the design process as a result of ME211," 6 replied "strongly agree," and one replied "not applicable."

d) 21 respondents "agree" with the statement "I gain confidence in my ability to do engineering design as a result of ME211," 4 "strongly agree," and 2 "not applicable."

e) 21 respondents "agree" with the statement "I am satisfied with the overall format of the course," 4 "strongly agree," and one "disagree." 2 replied "not applicable."

f) Students wrote these comments to the question, "Identify the activity(ies) in ME211 that helps you gain a new insight about engineering and/or a new skill. Why?" --
• "I feel that I learned more [about] designing than in any other lab"
• "probably the step by step process and achieving the goal at the end of the quarter using engineering methods"
• "Yes, industrial applications helped me put the course curriculum in focus. By applying the theoretical knowledge we have learned to the design/manufacturing process, it has given me new insight into the usefulness of engineering studies and applications"
• "I think learning how to dimension shafts and holes for different type fits was valuable. Also, the experience in cold-working and annealing, sample preparation, hardness testing was beneficial as well as the milling activity"
• "All the activities were interesting. The hands-on approach is much more fun than the typical book learning. Also, you cover a little bit from some upper-level courses. The class also helps you develop your confidence with computers"
• "I learned several new AutoCAD commands"

- "The lab on microstructure and photographing the microstructure was very insightful."
- "Using Excel and AutoCAD really helps me in improving my skills in using these programs, and I understand that we will use a lot of them when we are seniors. New skills learned -- knowledge about manufacturing."
- "Really gain a feel for it."
- "Now I know the meaning and the use of standard deviation. In designing the coin, we were allowed to work on it on our own, and it let us recall things we learned and to apply it."
- "The use of the Excel package has helped me organize data more efficiently."

g) Students have the following comments to the question, "Identify the activity(ies) that you think is(are) redundant? Why?"
- "I did not find any of the activities redundant"
- "Not much of the information was redundant, but I think that the two labs we did on metallic crystalline structure took away from the main idea of the course, while not going deep enough into the usefulness of such studies. Internal structure analysis perhaps should be part of another class with a larger scope than this design & manufacturing class"
- "None of ME211 is very redundant. The only thing I can think to change would be to make it worth 2 or 3 credit hours. It seemed to involve a tremendous lot of work for a 1-hour class."
- "I believe most of the class was important, however, I thought the emphasis on AutoCAd R13 was a bit unnecessary in light of the program."

5. Description of Weekly Activities for ME211, "Materials, Manufacturing & Design."

Week One

Lab period begins with a 5-minute presentation and discussion of course objectives, grading and lab policies. It is followed by a 20 minute presentation on the design process. Next, students will be given a 15 minute presentation on mean, standard deviation, and an example illustrating their application. Students then spend the next hour measuring the thickness of a brass blank with a micrometer, tabulating the data using Excel, calculating the mean and standard deviation, and completing a memo to report the results to the instructor. A final wrap-up of 20 minutes focuses on the application of statistics for product description. The design project is also presented together with information about the material that will be used. The homework assignment consists of a one-page report about the Mardi Gras tradition, including the medallions thrown by revelers during the parade.

Week Two

Laboratory activities focus on the mechanical properties and their relationship to the design project. Lab period begins with a 30-minute presentation on stress-strain relationship and Hooke's law. The instructor then performs a tensile test at the end of which data will be given to the students in the form of a floppy disk containing the test data; this activity takes about 45 minutes. For the next hour, students use Excel to reduce the data, plot the stress-strain curve, and determine Young's modulus, yield and tensile strengths, percent elongation, and toughness. Then they write a memo to report the results to the instructor. The final wrap-up concerns the accuracy of the mechanical properties determined, and their relationship to mechanical forming. The homework assignment is a free-hand sketch of the visual design for the Mardi Gras medallion.

Week Three

Laboratory activities focus on the relationship between processing and properties. Lab period begins with a 15-minute presentation on the rolling process, including the equation for percent cold work. Students then roll the brass blank with the different groups performing various amounts of percent cold work. They then measure the thickness with a micrometer, and determine its hardness -- these activities take approximately 1 hour. They spend the next 45 minutes using Excel to determine the mean and standard deviation of thickness and hardness. Using the results of all the groups, they plot hardness versus the actual percent cold work performed. Final wrap up consists of a discussion of relationship between the results of the day's activities and the design project.

Week Four

Lab period begins with a 20 minute presentation on design for manufacturability and tolerance. Students refresh their AutoCAD skills by completing four exercises in the book, "Learning AutoCAD." Exercise One covers drawing circles and lines and trimming lines; Exercise Two covers drawing on different layers, applying hatch patterns and mirroring objects. Exercise Three covers creating a solid model and viewing the model. Exercise Four covers linear dimensioning, and dimensioning filleted edges and a radius. Students use the rest of the period to begin work on a fully dimensioned drawing of the Mardi Gras coin in AutoCAD, which will be completed as a homework assignment and turned in next week.

Week Five

Laboratory activities focus on the relationship between structure and processing. Lab period begins with a 15 minute presentation on microstructure and a 15 minute demonstration on metallography techniques. Students then spend the next hour-and-a-half preparing their cold-rolled blanks for examination of the microstructure, and record an image of the microstructure. At the same time, students will perform annealing of their cold-rolled blanks. (The blank receiving the highest degree of cold roll will be cut into smaller pieces so the groups will be able to anneal the pieces for 30 minutes and 1 hour, respectively, at various annealing temperatures.) Lab period concludes with a 20 minute wrap-up comparing the microstructures of the blanks with different amounts of cold work, and synthesizing a relationship between structure, property and processing based on the results of lab activities. Homework assignment consists of a memo to the instructor reporting the results of lab investigations and the relationship between cold rolling, hardness, and microstructure.

Week Six

Laboratory activities focus on the effect of annealing on hardness and microstructure. Lab period begins with a 15 minute presentation on the annealing process. Students then spend the next 90 minutes performing hardness tests, metallography preparation, and recording of the microstructures of the annealed samples prepared the previous week. Using data from all the groups, students spend the next 30 minutes calculating the mean and standard deviation of the hardness of the annealed samples, and plot hardness versus annealing temperatures (and times). Final wrap-up consists of a discussion on processing, properties and structure, and their relationship to the design project. The homework assignment consists of a memo to the instructor reporting the results of lab investigations and the relationship between annealing and properties and microstructure.

Week Seven

This session focuses on the design of die fixture. Lab period begins with a 45-minute presentation on fixture design and solid modeling using AutoCAD. Following a short break, students spend 30 minutes design the dies, and 45 minutes using AutoCAD to make drawings for the dies. The homework assignment consists of a memo to the instructor describing the design process for rolling to meet the design specifications of thickness and hardness.

Week Eight

This session focuses on machining a prototype die for pressing the visual design. Lab period begin with a 30 minute presentation on tool size, tool speed, and tool path. Students will spend the next hour-and-a-half using AutoCAD to convert the codes of their visual design into codes for the tool path of a model computer-aided milling machine. For the remaining of the lab, students will cut prototype dies.

Week Nine

Week Nine is devoted to pressing the Mardi Gras medallions. Instructions for the final project report and presentation will also be given at the lab period.

Final Exam

Students make oral presentation of their design project.

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