GRADING AND MOTIVATION OF STUDENT TEAMS WORKING ON INDUSTRY-SPONSORED MECHANICAL DESIGN PROJECTS

David G. Beale
Auburn University
Dept. of Mechanical Engineering
202 Ross Hall
Auburn, Al 36849

P. A. Simionescu
Auburn University
Dept. of Mechanical Engineering
202 Ross Hall
Auburn, Al 36849

David Dyer
Auburn University
Dept. of Mechanical Engineering
202 Ross Hall
Auburn, Al 36849

ABSTRACT

The guiding principles adopted for teaching the Comprehensive Mechanical Design course in the Department of Mechanical Engineering of Auburn University are presented. These were introduced to better serve the need for well-trained engineering personnel, where technical skills must be combined with good communication and management skills.

INTRODUCTION

Comprehensive Mechanical Design courses taught in the Department of Mechanical Engineering of Auburn University are intended to reinforce the concepts previously learned by the students and to expose them to actual problem as they are encountered in industry. The students are required to utilize creative processes to develop, evaluate, and recommend alternative solutions to open-ended design problem under time, cost, and material availability constraints, fundament them with appropriate engineering analysis and provide a working prototype or machine.

COMPREHENSIVE MECHANICAL DESIGN MECH4240-4250 COURSES OVERVIEW

Comprehensive Mechanical Design MECH4240 and MECH4250 are 2 credit-hour per semester, senior level project courses, taught over two consecutive semesters. Groups of students (typically 6 to 10 students) are formed creating different "corporations" working on various projects. In some cases two or more corporations will compete on the same project, either for the conceptual design phase only (after which the corporations will merge, combining the best ideas in the final design) or work independently on separate designs and build the corresponding prototypes.

Each corporation is to provide an engineering design and a construction of a prototype or a machine for a sponsor or industrial client. The faculty members and teaching assistants provide the following services: liaison between the corporate sponsor and student corporations, technical training as needed, and act as observers, graders and facilitators of the process. Lectures and labs are intended to be student project time, but also time for the faculty to discuss issues of importance, lecture on needed topics, address student needs and concerns, and make sure the students are on schedule. As required by university and national advisory and supervisory boards, this class is required to not only develop skills in mechanical design of the individual student, but also develop and assess teamwork and technical communication skills, both verbal and in writing.

MECH4240 is the design phase of the project, and requires a significant individual and teamwork effort. A midterm presentation and a final presentation are given in front of the corporate sponsor and instructor(s) during and at the end of the semester, respectively. Also invited are members on the Department's technical staff aware of the project, other student-colleagues etc.

MECH4250 is a continuation of MECH4240. The corporate assignment is to complete the design, construction of the first prototype and perform at least one cycle of design improvement. It requires at least 6.5 hours/week per student of workshop activities. At the end of semester a prototype presentation will be given, on which the prototype-device or the machine will be introduced to the corporate sponsor, together with the *documentation*, *economic analysis* and *proof of concept* for the respective product. The final prototype must be in working order and demonstrated to the corporate sponsor at the prototype presentation. It should be both improved and tested for reliability, speed, robustness of design, expected working life and accuracy.

GROUP LEADERSHIP REQUIREMENTS

In order to develop and exercise students' leadership skills and technical writing skills, the temporary position of group leader was introduced. The total time of the two consecutive semesters is divided by the number of students; for example, for 32 weeks per two semesters and 8 students per group, this will translates into 4 weeks of leadership per student.

The group leader is the corporate manager and keeper and scriber of a diary of the group activity. Each student (in association with the group leader and team members) prepare short weekly reports and discuss, clarify, and receive approval from the team what he/she intends to do during the coming week and of any technical solutions he/she proposes to be included in the design. These reports are not graded or necessarily viewed by the instructors; they are meant to help in coordinating and planning the activity of the corporation. The group leader will gather the weekly reports from his/her student colleagues, review them and include them in the group diary. Based on these weekly reports, he/she will give to the instructor a verbal report during class-time about: a) what team tasks/plans are for the coming week, and b) the progress the team made during the last week.

At the end of the leadership period, the group leader will write a 1-2 pages report about his/her activity and will hand this report to the instructor. This report will be graded and will count to his/her total grade, and it is due within one week after his/her leadership period. After grading, the leadership reports will also be included in the group diary.

GROUP DIARY

The group diary is maintained and updated by the group leader. On request it should be available for inspection during class, and is always presented to the instructor when submitting the leadership report. It normally includes the followings:

· The leaders' schedule;

· Group-members' weekly reports;

· A list of the drawing-files produced during the current leadership period;

· Quotations received from vendors of the parts intended to be ordered;

· Copies of all the purchase orders that have been placed;

· Copies of the delivery documents of all the parts received;

· Leadership reports from former group leaders;

· Separators between the pages added by each leader.

The group diary helps in organizing the team activity, sharing tasks between students, keeping track of the ordered and manufactured parts and also easing the transition between group leaders.

PEER REVIEW

In order to monitor the student activity, their interaction with the team and contribution towards completing the project, periodic peer-reviews have been introduced. Every 3 weeks the students receive peer-review questionnaires in which they rate his/her colleagues performances based on the following criteria:

· Amount of his/her effort during the past 3 weeks;

· Significance of his/her effort during the past 3 weeks;

· If (s)he satisfactorily completed his/her assignment and/or how significant progress (s)he made toward completion of his/her assignment;

· How well he/she worked with the group (i.e. show up on time, have good attitude, contribute to the meetings, was proactive);

· Mention if he/she had unexcused absences these 3 weeks;

· The activity of the student(s) acting as group leader(s) during the last 3-week period.

The questionnaires remain confidential and the grades count towards the final grade of each individual student.

MIDTERM AND FINAL PRESENTATIONS (MECH4240)

The *midterm presentation* is a conceptual presentation with a hardcopy report, where no dimensioned technical drawings are supposed to be presented, although 3D solid models of the concept are strongly encouraged. During the presentation the students should prove thorough understanding of the problem(s) they are called to solve. This will include a specification sheet that defines the problem and includes design requirements and constraints. The students should refer to and criticize existing machines or processes used at present for solving the same problem (nationwide and internationally), as a proof of their knowledge of the state of the art. If needed, testing can be performed to evaluate feasibility of various solutions. If it is the case, the students should help the industrial sponsor clarify the problem they have, and of all the implications encumbered by their solution(s) so that the best choice can be made. The students should get the approval of the project-sponsor regarding the concepts they are considering, so these do not come as a total surprise to the corporate sponsor during their presentation. Adequate graphic material is required to be used for the presentation i.e. photographs, 3D drawings, charts of estimated parameter improvements etc. Power Point presentations are encouraged, as well as transparencies. A rough cost estimate of the project should also be given.

The *final presentation* is a design presentation, where detailed technical drawings are to be presented together with the necessary engineering analysis, material selection justification, economic analysis, etc. The students should prove thorough understanding of the problem(s) and sub-problems they solved during their work. They should get the approval of the project-sponsor about any revised or modified concepts from the midterm presentation prior to the final presentation. Adequate graphic material is to be used for the presentation i.e. 2D and 3D dimensioned drawings, charts of estimated parameter improvements etc. engineering calculations, materials selection, economic analysis etc. A detailed cost estimate of the project is also required. All these should also be submitted in a final hardcopy report.

Each student is required to participate in these presentations and talk about aspects he/she was in charge of, since this will be graded and include in his/her final grade.

PROTOTYPE PRESENTATION (MECH4250)

At the end of the second semester a working demonstration of the prototype-device or machine will be given to the corporate sponsor. In their presentation the students will briefly summarized the main stages in completing the prototype, will present the performances of the machine, discuss factually future directions of improvement, suggestions for implementation and safety requirements. They are also required to deliver to the corporate sponsor the followings:

· *Documentation*: A complete set of drawings is required that documents the design for future design improvements and modifications, and if it is the case, for patenting and for mass production. Also, instructions, warning labels etc. on use, maintenance and operators' safety must be provided.

· *Economic analysis*: A complete economic analysis of the final design. This should minimally include cost to manufacture and time for the new design to pay out.

· *Proof of concept*: Documented test results of the components under consideration simulating demands that are identical or near identical to those anticipated in the plant environment.

All graphic material (2D and 3D drawings, PowerPoint slides) and engineering analysis files are required in electronic format, either on a zip-disk or on a CD. In particular the technical drawings files should be given in their latest version.

INDIVIDUAL TECHNICAL REPORTS

At the end of the second semester, in preparation for the prototype presentation, every student will write a technical report about a topic in which he was intimately involved. This can include description of a design task (analysis of alternative solution, engineering calculations, materials selection, technical drawings (s)he generated), description of a process, of a mechanism or subassembly etc. Together with the leadership reports, they form the basis for grading the students' technical writing skills. The technical report must be written in accordance with standard professional technical writing practices and format [1][5].

GRADING RULES

For MECH4240 Class the individual grade (IG1) is determined with the following formula:

$$\mathbf{IG_1} = 0.8\left(\frac{\mathbf{CG_m}}{3} + \frac{\mathbf{CG_f}}{3} + \frac{\mathbf{PRF}}{2}\right) + 0.1(\mathbf{LG} + \mathbf{IP})$$

and is based on the followings:

- *Corporate Grades* for the midterm ($\mathbf{CG_m}$) and final presentation ($\mathbf{CG_f}$) are determined by the instructor and influence by the input from corporate sponsor. The corporate sponsor establishes the winning corporation if there are two corporations competing on the same project. The winning corporation (if it is the case) will receive the higher grade for the presentation. The final presentation will count twice as much as the midterm presentation.
- *Peer review factor* (**PRF**) is determined based on the secret peer reviews and is the difference between median grade of the corporation and the student's final peer review average grade.
- *Leadership grade* (**LG**) results from the secret peer reviews plus the leadership report and diary updates.
- *Individual presentation grade* (**IP**): as established by the instructor and corporate sponsor during the midterm and final presentations. This has been introduced to evaluate the verbal communication skills of the student.

For MECH4250 Class the individual grade ($\mathbf{IG_2}$) is determined with the following formula:

$$\mathbf{IG_2} = \frac{0.8\,\mathbf{CG} \times \mathbf{AHW}}{6.5\,\mathbf{PRF}} + 0.1(\mathbf{LG} + \mathbf{ITR})$$

and is based on:

- *Corporate grade* (**CG**): This grade will be determined by the instructor based on the input from corporate sponsor at presentation. The corporate sponsor determines the winning corporation if there are more corporations competing on the same project. The winning corporation (if it is the case) will receive the higher grade for the presentation.
- *Peer review factor* (**PRF**): This will be based on the secret peer reviews and will be determined the same as for MECH4240.
- *Leadership grade* (**LG**): This will be based on the secret peer reviews plus the leadership report and diary updates.
- *Average weekly workshop hours* (**AWH**): It is the average time spent weekly by the student in the workshop.

Individual technical report grade (**ITR**): It is the grade given for the technical report written by the student in preparation for the final presentation.

WEB SUPPORT AND STUDENT MORAL REWARD

Each corporation is assigned a collective e-mail account, so that the students can exchange messages and share information by e-mail between them and with the instructors. The class is also supported by a Web page hosted on the Department's main server.

On this page the students can find downloadable examples of: *midterm presentation* and *final presentation* materials, recommended *drawing formats* (as DXF downloadable files), downloadable *peer-review forms*, examples of good *leadership reports* and *individual technical reports*.

The students are morally rewarded by putting on this Web page the best presentation materials and written reports as examples for future students. The students are also motivated by the fact that *past projects* are exemplified with photographs of the prototypes and of the team members that contributed to the respective projects. The students can therefore highlight

their experience in their resumes with references to this Web page.

CONCLUSIONS

The main ideas adopted in teaching the Comprehensive Mechanical Design course MECH4240 and MECH4250 in the Department of Mechanical Engineering of Auburn University were presented. The way in which technical skills enhancement is combined with practicing communication and managing skills and collaborative teamwork are exemplified. Internet tools are applied to facilitate the quick exchange of information between students, instructor and corporate sponsor, and also in morally rewarding and motivating the students to perform well during the class. Other motivational aspects of the course include competition between teams and student participation in grading through peer review.

REFERENCES

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3. Kitto, K.L., McKell, E.K., *Enabling Collaborative Engineering with Computer Tools*, Proceedings of 2000 DETC Design Automation Conference, Baltimore, MD, 2000.

4. Milne, A.J., Leifer L.J., *Information Handling and Social Interaction of Multi-Disciplinary Design Teams in Conceptual Design: A Classification Scheme Developed from Observed Activity Patterns*, Proceedings of 2000 DETC Design Automation Conference, Baltimore, MD, 2000.

4. Thompson, Brian, S., *Creative Engineering Design*, Okemos Press, 1998.

APPENDIX

Examples of three projects successfully completed during the MECH4240-4240 Comprehensive Design Project are presented in Fig. A1-3. More details about these and other projects can be found on the WWW at:

http://www.eng.auburn.edu/department/me/courses/dbeale/mech4240-50/ME402slb.html

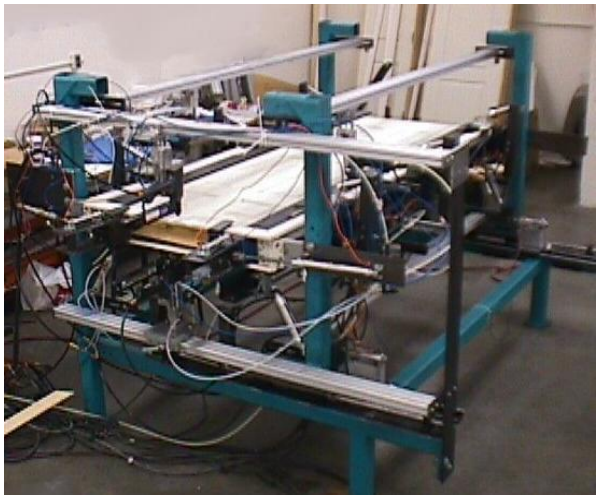

Fig. A1 Automatic door-frame stapling machine (client Auburn Millworks Inc.)

Fig. A2 Vertical axis 7ft radius centrifuge (client Auburn University Solidification Design Center)

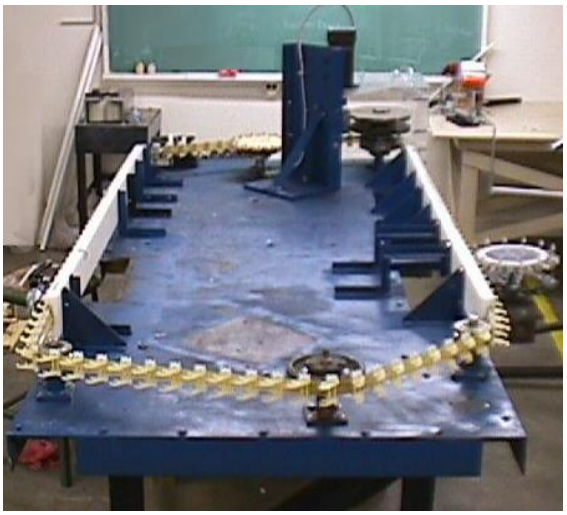

Fig. A3 Automatic tampon-testing machine (client: Kimberly Clark Co.)