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Integrating Engineering Design into Graphics Courses

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Integrating Engineering Design into Graphics Courses

Abstract

This paper focuses on integrating engineering design into graphics courses in engineering and manufacturing engineering programs. In the past, small deviations like graphical problem solving or simple design knowledge were utilized in engineering graphics courses. However, addition of strong but controlled design content will allow students to get exposed to the design process and its medium (graphics) simultaneously, enforcing better understanding of the purpose of engineering graphics while enhancing the learning process.

In addition to the CAD (Computer-Aided Design) tools, design analysis through CAE (Computer-Aided Engineering) and CAM (Computer-Aided Manufacturing) programming are included within this graphics course. The integrated design approach of parts, tooling, and processing are coupled to introduce consumer product design. Motion studies, thermal and structural analysis are also utilized for representation of mechanical design concepts and their graphics environment.

Adding design components to this graphics course improved student excitement, performance and consequent retention, compared to the other graphics courses taught in a traditional way in the same institution during the same time frame. Examples of each activity employed as well as possible future activities will be included in this paper. The paper will conclude with the assessment process.

Introduction

Replacement of paper-based engineering graphics by its computer-based counterpart expanded the role of engineering graphics into engineering analysis, virtual and physical rapid prototyping, and computer-aided manufacturing.

Graphics instructors have been discussing this evolution and fate of paper based graphics [1] [2] [3]. Another critical discussion has been on replacing introductory graphics education with fundamental design education [4][5] or establishing product design/life-cycle management as the foundation for engineering graphics curriculum [6][7].

This paper presents an effort to help engineering students better understand the implications of what they are learning in their ENGR 2160 Engineering Graphics course by tying engineering graphics to its applications in analysis, prototyping, and manufacturing.

In his graphics course, the author covers basic graphics concepts of: (i) geometry construction, (ii) orthographic, sectional and auxiliary views, (iii) dimensioning and tolerancing, (iv) working drawings, (v) threads and fasteners, and (vi) machine elements. Instruction on 3D modeling, both wire frame and solid, are also provided within the curriculum as well as methods in graphical problem solving in the case of electrical engineering analysis of circuits and mechanical engineering problem solving in mechanism design. However, one of the most critical parts of the course is about teaching students how to associate what they are learning in the course to the very next steps of the engineering design and development process.

Surface modeling is one of the areas utilized in the effort for teaching students applications of engineering graphics. This is similar to an attempt by Hartman [8] where surface modeling was integrated into the graphics curriculum. In this effort, once the students complete their surface modeling study through Mastercam surface creation exercises, they are required to build a 3-D surface model to be employed in computer numerically control (CNC) program generation. The students then have to go through the steps of the computer-aided manufacturing (CAM) process for observing impact of a set of Mastercam NC code operations on the 3-D surface model. Such an activity is important for the students to understand the applications of 3-D surface modeling, especially in effective mold and aerodynamic craft body design and relevant manufacturing processes. Other examples presented or studied in the course include mechanism motion study and finite element analysis (FEA) with SolidWorks, and virtual ergonomics simulation of a human worker through Delmia Human Software as well as Delmia Robotics.

ENGR 2160 - Engineering Graphics

ENGR 2160 - Engineering Graphics course is a mandatory basic engineering course at this ABETS accredited Engineering Department. The department offers two separate undergraduate degrees, B.S. in Manufacturing Engineering and B.S. in Engineering with Biomedical, Industrial, Mechanical, and Software tracks. The course description states the following: “The student is introduced to the fundamentals of engineering drawing. Topics include: three-view drawings, construction methods, CAD applications, graphical methods for engineering problem solving, three-dimensional modeling, and CAD data import/export/exchange.” The course is a 3 credit course with 2 lecture credits and 1 laboratory credit. Students attend two 50 minute lectures and one 2 and 1/2 hour laboratory each week. The prerequisite for the course is ENGR 1010 - Introduction to Engineering. In terms of the course objectives, after completing this course, the students will be able to: (i) understand basic concepts of engineering drawings and role of graphics in problem solving, (ii) develop designs from initial concepts to final working drawings, (iii) effectively utilize computer-aided design (CAD) tools in generating engineering graphics and in problem solving, (iv) understand design, inner-workings, and utilization of various mechanisms and basic machine elements.

The main computer tool used in basic 2-D graphics including drafting is AutoCAD. Within the last few years, AutoCAD had also been utilized in 3-D modeling. James D. Bethune’s

Engineering Graphics with AutoCAD series [9] had been used as a text-book. This book has been recently replaced with James D. Bethune's Engineering Design and Graphics with Solidworks [10] since SolidWorks software is taking a greater role in the course, only to replace AutoCAD within a couple of years. Using books based on software tools may seem like a bad idea, however these books may be more beneficial if they have a strong coverage of the basic graphics subjects complemented by good computer exercises. The 3-D modeling is now based on SolidWorks while Mastercam is also used in a limited sense in 3-D modeling.

The author enforces the following requirements that are critical for an effective learning experience. (i) In order to facilitate the lectures and laboratories, each student is expected to read the textbook and other reading assignments prior to class. (ii) Written works required for this course are home-works and a project report. (iii) Each student must participate in all of the laboratory assignments in a timely manner. Completion of assignments is checked during class and documentation is checked after they are turned in. Completion of a design project for a product with multiple parts is also required. (iv) To successfully complete this course, attendance is required. For each un-excused absence (one in which prior arrangements were not made with the instructor), there is a 30-point deduction from the attendance/participation portion of the grade. Unexcused absence from an examination results in a zero for that requirement. Repeated late-shows to class and labs cause grade loss. Two times tardy is counted as missing a class period. (v) There are four brief examinations and a final examination that pertain to the readings, lectures, and laboratory exercises. As the labs tend to build upon the experience gained in each previous lab, it is extremely important that each student complete the assignments and lab experiments with a full understanding of what is taking place. The instructor reserves the right to not permit a student to take an exam if the student arrives to class after a quiz or test has started.

Helping Engineering Students Understand Applications of Engineering Graphics

This paper presents an approach followed by the author to help students associate graphics concepts, and related tools and exercises with engineering applications for design, development, and prototyping purposes. ENGR 2160 Engineering Graphics course is the medium for the approach. Following section details the major elements of the approach.

From CAD to CAM

After going through basic 2-D drafting and sketching exercises, also including manual sketching and geometry construction, students work on 3-D surface modeling in Mastercam. The objective of this activity is to teach them the basics of surface modeling and associate it with sea or aircraft body or mold design, and CNC programming. Students go through a set of surface modeling exercises including the sweeping exercise shown below (Figure 1). Draft surfaces with or without an angle, revolved, ruled, net, lofted, flat boundary, and fence surfaces are also covered as well as surface fillets, trimmed surfaces, and fillet blends. After completion of these fixed-goal surface exercises, students are asked to complete a 3-D surface model (Figure 2). The model in Figure 2 is used in CNC programming and contains revolved, lofted, and flat boundary surfaces in addition to swept surfaces, surface fillets, and multiple trimming operations. Another CNC programming exercise is also shown (Figure 3) below. This exercise is conducted after completion of the CNC exercise in Figure 2 along with wire-frame based programming.

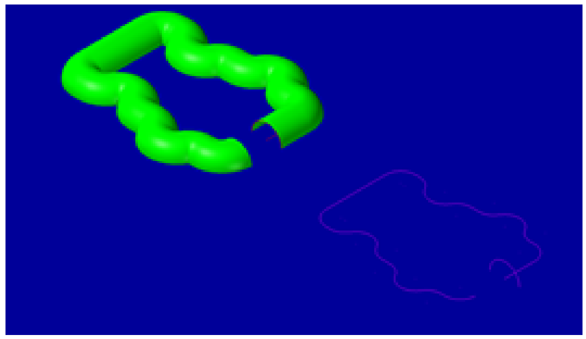

Figure 1 A swept surface example

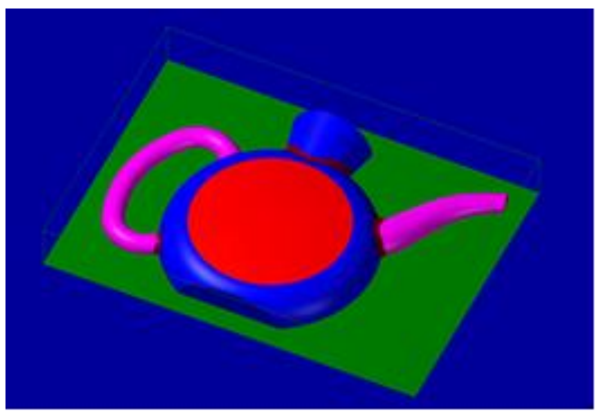

Figure 2 Surface modeling homework for CNC programming

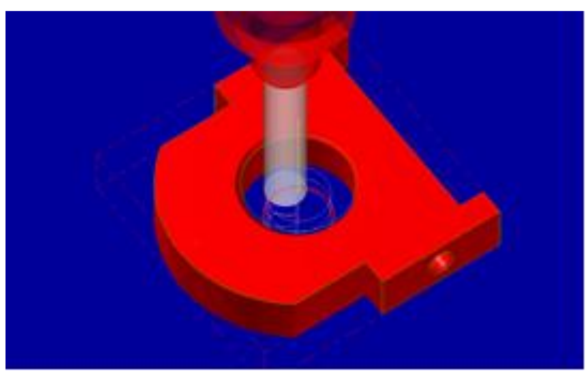

Figure 3 A CNC programming exercise

Computer-Aided Engineering in a Snapshot

After the introduction of 3-D solid modeling, the students are exposed to FEA with an example. The example is taken from the SolidWorks tutorials for the SimulationXpress. Students are given the solid model of a crane hook shown (Figure 4) and they are asked to utilize the SimulationXpress Analysis wizard. They learn about the basic steps of design analysis, assess the safety of the design by calculating the safety factor of the design, and can evaluate the accuracy of their results. The exercise starts with the selection of the hook material, followed by application of a restraint that holds the hook in place. The restraint is also shown in Figure 4. A second boundary condition is also applied in the form of a distributed force representing the weight of an object hanging down the hook as shown in the figure (Figure 5).

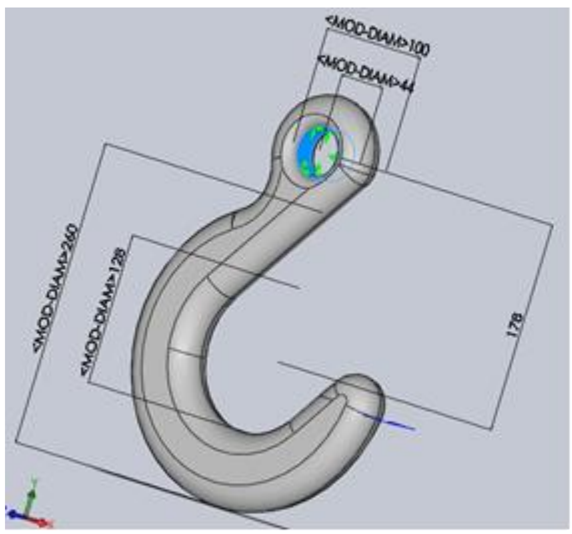

Figure 4 Solid model of the hook and a constraint being applied at the hole

Figure 6 and Figure 7 are presenting the results of the analysis. The lowest factor of safety is given in Figure 6, while Figure 7 is about the stress distribution in Von Mises form. Fundamentals of the numerical simulation are covered simultaneously with this design analysis exercise. Students are exposed to the concepts of finite elements, solid or shell, initial and boundary conditions, as well as simulation parameters including the time step. After the completion of the simulation, there is an in-class discussion where students are engaged in understanding of the results.

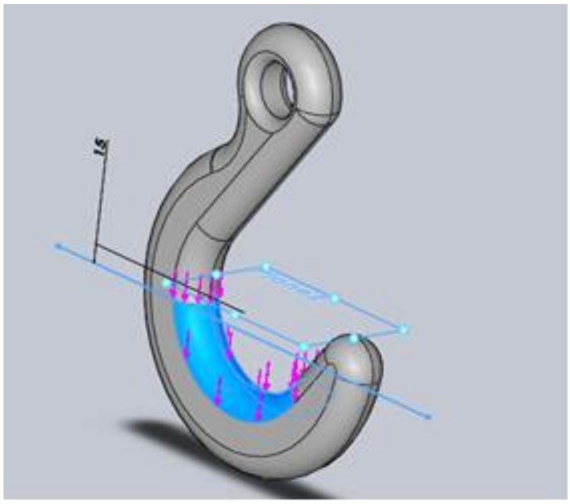

Figure 5 Weight of an object applied as a distributed load

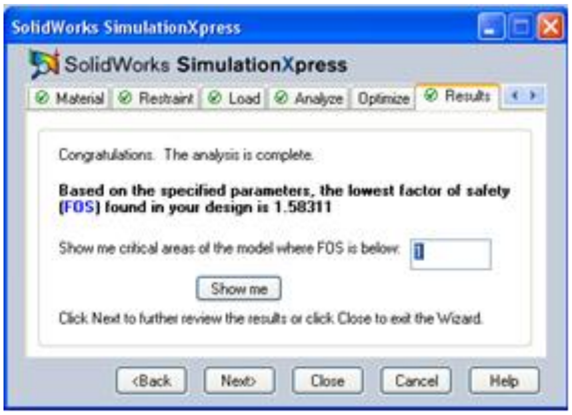

Figure 6 Simulation Xpress wizard indicating the calculated safety factor based on the design

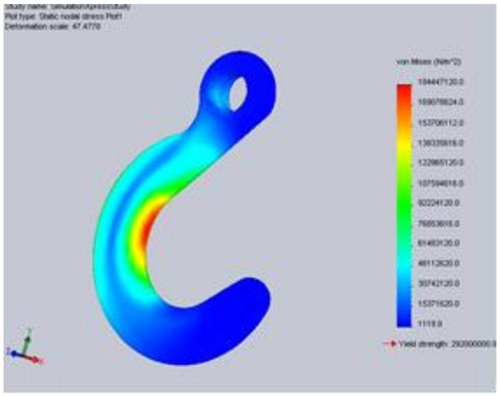

Figure 7 Stress distributions in Von Mises (N/m2) indicating the critical areas of the design

Mechanical System Design with SolidWorks

Machine elements section of the course includes a simple kinematics analysis where students design and build mechanisms to operate them virtually within SolidWorks. This is where they understand the importance of tolerances and clearances in assemblies as well as mechanism design field in general. The students start with studying simple mechanisms such as a 4-bar linkage, oscillating lever with quick return, ordinary crank, crank slider as well as various positive and friction drives, and gear-based systems. They are given wooden and VEX Robotics-based mechanism examples to review for the background study. Figure 8 illustrates a mechanism design for a term project. Figure 9 depicts the motion study for the project shown in Figure 8. The motion study incorporates an actuator, a rotary motor, at the crank handle allowing mechanism to be automatically driven. As the mechanism works, the students can verify their design including the critical clearance and tolerance values from the appropriate operation of the mechanism.

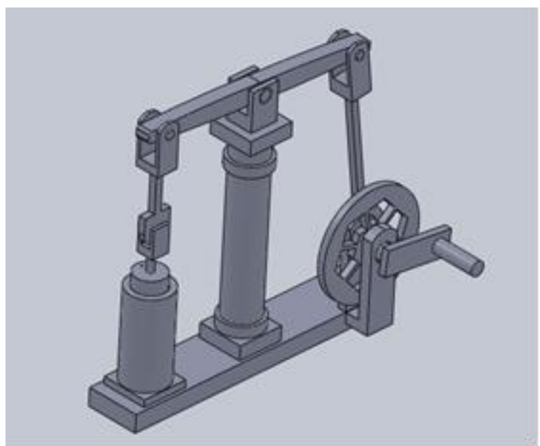

Figure 8 A mechanical system project designed by a student

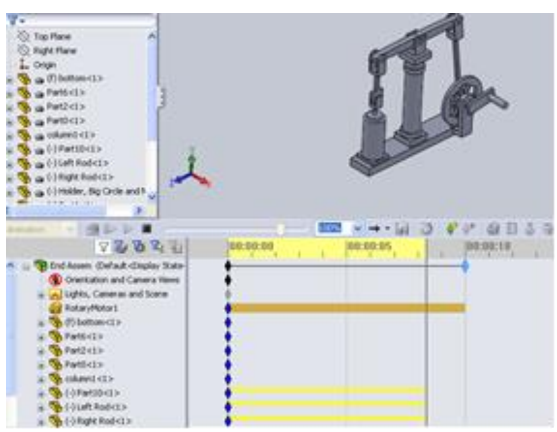

Figure 9 Motion study of a mechanism

Data Exchange and Rapid Prototyping

Data exchange between CAD/CAD, CAD/CAM, CAD/CAE and CAD/rapid prototyping (RP) couplings, are covered with the concepts of direct translators and intermediate data formats like IGES, STEP, and STL. The cricital importance of STL is demonstrated with each student designing a simple chess pawn or a board game pieces to be converted into STL geometry. STL files are then used to print the design via one of the RP systems this Engineering Department

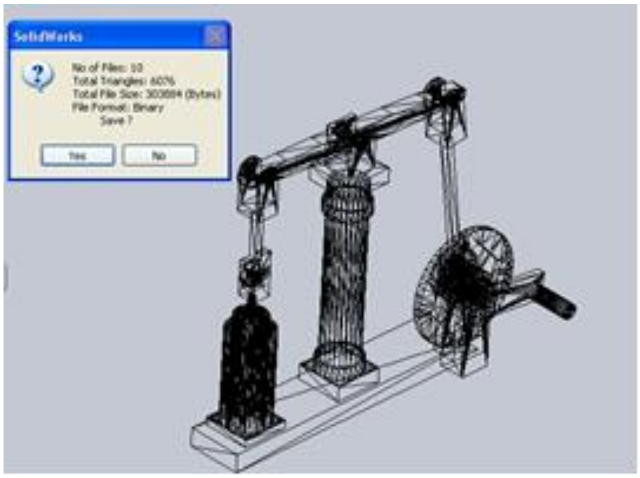

Figure 10 The STL file for a student project

Has .The second practice chance the students have with this application is to print their term projects for extra credit as shown in Figure 11. This exercise allows student to do form, fit, and function check at the freshmen level while seeing their design realized. There have been similar studies in architectural modeling, however this could be one of the original attempts in applying RP technology in engineering graphics and design context [11].

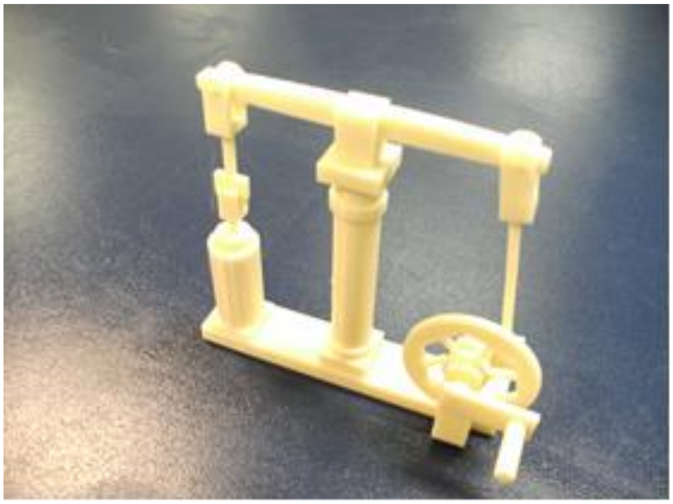

Figure 11 The rapid prototype of the mechanism project

Additional content were conducted in the form of demos with virtual simulation tools of Delmia Human and Robotics.

Conclusions and Future Work

This paper presents an approach to help engineering students associate graphics concepts, and related tools and exercises with engineering applications for design, development, and prototyping purposes. This approached has been followed the last four years with a gradual expansion to different fields. The recent major elements of the effort were 3-D surface modeling in CNC programming, FEA with solid modeling, and mechanism design through a motion study and rapid prototyping. Students were also exposed to virtual simulation of humans and robots with demos. With this approach, students were given an early opportunity to understand the ties between graphics and CAM, CAE, and virtual and physical rapid prototyping. However, the author had to make sure that the students were not overwhelmed with the addition of these elements to the course content. This was accomplished by controlling the detail of the examples and the pressure on the students. Additional help was given throughout the course in the form of coaching. According to the faculty course assessment reports (FCAR), during the last four years more than 80% of the students performed well, 80% being the threshold figure set by the thisrobert Engineering Department for ABET re-accreditation purposes. In the last year, only one engineering student out of the nine demonstrated subpar (below 80% or B letter grade) performance replicating his performances in other courses. Student course evaluations were also in agreement with the author's claims ranging between 4.00-5.00 out of 5.00.

Future work in this effort includes the challenge of applying this approach to a class of more than twenty students, with the actual registration figure standing at 26 for the Spring 2010 term. On the contrary, strong presence of well-set examples and tutorials will help the author to replicate the same impact for a class size greater than any of the classes he has experienced with this course. A buddy system will also be employed during the labs to better help the students. Students finishing their more complicated exercises early will be asked to help the instructor for regular laboratory work and in-class work. This system is close to the pair-programming approach tested by some instructors [12].

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