

# First-Year Engineering Product Realization

Jeff Ray and John Farris

Padnos School of Engineering  
Grand Valley State University  
Grand Rapids, Michigan

## Abstract

A recognized need for product realization and design topics is occurring throughout engineering curriculums nationwide. Current engineering curriculums demand such activities due to ABET EC 2000 criteria and employer demands. During the past year, a modified course structure was piloted at Grand Valley State University to include the product realization process. In addition, manufacturing principles were included. The new course organization will be fully implemented during the upcoming 2000 – 01 academic year. Entering first-year engineering students from all disciplines offered are the target audience for the course, which is comprised of two lecture and one laboratory sessions per week. Topics covered include 3D solid modeling design techniques and hands-on experiences in computer-numerically controlled (CNC) milling. Students are introduced to both the product realization process and specific manufacturing principles during their first semester of study, as opposed to initial exposure in upper division courses. Discussion of the implementation process and course organization is outlined. Additionally, examples of lecture and laboratory sessions are included.

## 1.0 Introduction

Engineering graphics courses have been a cornerstone of most engineering programs in the United States for several decades. Over the past few years much attention has been focused on the paradigm shift from teaching 2D drafting skills to 3D solid modeling in first-year engineering curriculums<sup>1,2</sup>. With the advent of 3D solid modeling software such as Mechanical Desktop, Pro/E, and Solidworks, more schools are integrating this approach in their engineering graphics courses<sup>3</sup>. Another reason for the transition is the demand from industry that their engineers understand such technology. Such an approach allows schools to integrate engineering design in the first-year engineering curriculum<sup>3-5</sup>.

The inclusion of engineering design at the first-year level is being driven by several factors. First, is the requirement of subsequent courses and employer needs to use the design database and documentation as a tool for developing and implementing faster product development times. Second, is the ABET EC 2000 criteria with a focus on design and product realization<sup>6</sup>, which lists several areas directly connected to first-year engineering courses. These areas include: the ability to design a system or component; communicate effectively; and use of modern engineering tools and techniques. The Padnos School of Engineering (PSE) at Grand Valley

State has additionally included an outcome that all graduates be able to create physical realizations of their designs. The criterion is required based on requests from co-op employers and the regional manufacturing community of West Michigan. Specifically, co-op employers have expressed a concern about engineering students understanding the manufacturing implications of tolerances and dimensions. The methods and skills learned in the course will prepare students for subsequent courses to achieve more mature design and build projects.

In 1997, the Society of Manufacturing Engineers issued the Manufacturing Education Plan (MEP)<sup>7</sup>. The report identified several competency gaps in engineering education, and included the ability to create and document engineering designs, 3D solid modeling skills, and a knowledge of computer-aided manufacturing (CAM). The PSE's response to the above demands is a course in 3D solid modeling and CAM.

This purpose of this paper is to outline the course, and display its role of addressing the described deficiencies in engineering design education. First, the requirements to offer a course in 3D design and CAM are discussed. A brief discussion of the hardware, software, and machinery issues will be presented. Next, a description of the course is discussed along with a presentation of typical design exercises and projects. Finally, future work in the development of the course will be addressed.

## **2.0 Course Objectives and Requirements**

### **2.1 Course Objectives**

Most entry-level courses in computer-aided design focus on technical issues and the skills required to manipulate a software package. Prior to the implementation of the revised course, EGR 101 – Engineering Principles I, the computer was simply used as a direct replacement for the drawing board. The original course did little to introduce students to the design process and assure the ability to understand the manufacturing processes required to produce a physical realization from their design drawings. An added benefit of using a 3D solid modeling approach is students are introduced to the concept of treating their models not as a geometric representation, but as a design database. The methodology implemented allows students to see the benefits of turnkey applications such as toolpath design and finite element analysis.

The greatest concern in restructuring EGR 101 was the course should not be a simple skills course. Several objectives were identified to be implemented, and include:

- Introduce students to 3D modeling techniques and skills
- Treat the model geometry, not as a model, but as a design database
- Produce physical realizations of their designs using CNC mills
- Solve manufacturing process problems
- Experience the iterative design process

In order to meet the above objectives, it was determined to restructure the existing course rather than create a second course. By introducing these concepts in the first-year, students are well prepared to deal with the design and build projects required in subsequent courses. In addition, it

was decided to implement a design conference instead of a final exam at the end of the course. The design conference approach allows the students to engage in a five-week complex design and build project, culminating in an oral presentation of their completed designs.

## **2.2 Requirements**

In implementing any new teaching methodologies, associated startup costs are incurred. Using the available resources and funds allocated for offering pilot sections of the course, it was decided to utilize AutoCAD as the 3D solid modeling software. Although, a parametric, feature-based modeler was preferred, it was determined the core graphics kernel of AutoCAD was acceptable. The existing software was chosen, not for monetary purposes, but for simplification reasons in offering the pilot sections. The CAM software implemented in the course was Surfcam, chosen due to its simple interface, excellent manufacturing details, and the educational pricing structure. All of the utilized software runs on all platforms of the Windows operating system.

Based on all of the requirements for the course, several bench-top CNC mills were reviewed. The mills were selected based on several factors, including 3-axis capabilities, tool sizes to be used, and cost. MAX/NC Series 10, 3-axis CNC milling machines were chosen for use in the course, due to their versatility in handling different engineering materials and their compact size. Three of these mills were purchased to support the pilot course enrollment of approximately 60 students.

## **3.0 Course Description**

The format of EGR 101 is composed of two fifty-minute lecture periods and a three-hour laboratory session. The lecture periods meet in a typical classroom, while the laboratory sessions meet in a computer-aided design studio. The co-requisite for the existing and restructured courses is Calculus I. In implementing the revised course it was decided to let the lecture sessions support the laboratory sessions, rather than the standard format of lab sessions supporting the lectures. Such a format allows students to experience a more hands-on approach to the engineering design process. A course outline is included in Table 1.

The lectures are directed towards supplementing the labs by introducing the theoretical background to the topics. Each lecture is presented using Microsoft PowerPoint with lecture outlines provided for student use before class. Providing outlines prior to the lectures allows time during the lecture sessions for in-class exercises developed to strengthen the students learning of the lecture and lab material. Lecture topics include: the design process, Boolean operations, 2D and 3D design sketching techniques, dimensioning, tolerancing, GD&T, and design documentation. The course design projects are focused on students acquiring the knowledge to implement design and build projects.

Four design projects are assigned during the semester. These projects are structured in a progressive format building on the material introduced each week. All projects require the students produce a physical prototype of the design using the CNC mills. The first project consists of a systematic tutorial to design a keychain, which introduces the complete design and

**Table 1. Topical Outline for EGR 101 - Engineering Principles I**

<b>Session</b>	<b>Topics</b>
1	Design process and design project I
2	3D pictorial sketching techniques, base feature creation, creation of solids by extrusion and revolution
3	2D orthographic sketching techniques and manual G-coding design project
4	Vectors, coordinate systems, and Boolean operations and advanced solid modeling commands
5	Exploiting the CAD design database for detail drawings, mass, toolpath generation, and FEA
6	Dimensioned drawing generation
7	Use of metrology equipment, lifting hook redesign project
8	Fastener types and selection, drill and tap skills
9	Final design project assignment
10	Geometric Dimensioning and Tolerancing
11	Self-directed final project work
12	Design documentation
13	Assembly drawings, bill of materials
14	Complete final project and first-year engineering design conference

manufacturing cycle. In addition, students are exposed to the entire semester in one session, allowing them to experience the complete spectrum of the course during one session. Students are given the dimensions of the part and allowed to create their own design. The next project requires students to manually write the G and M codes to design and build a plastic plate. The approach is used so students learn basic CNC programming to allow them to troubleshoot future CNC programs. Additionally, the project enables students to exploit and query the CAD database to write their CNC programs.

The next two projects are more extensive in nature. Students are assigned to teams to complete these two projects. The third project is to design and build a lifting hook for a fictitious company. Engineering design constraints are placed on this project including geometry, weight and strength requirements. Students are required to analyze an existing hook and redesign it to reduce weight by 20% and maintain strength of the current design. The project's intent is to expose students to aspects of fixturing, tolerancing, inspection, and aspects of manufacturing errors. Additionally, students are expected to use the CAD database to calculate reduced weight of their design.

The final project is introduced and executed during the last five weeks of the course. Student teams are required to propose a conceptual product design for a fictitious capital investment company. A requirement of the project is it must contain a minimum of two mating parts. Typical projects include: handles for medical devices, mating gears, CD cases, desk organizers, and tape dispensers. The project focuses on manufacturing process limitations and the use of tolerances. For all projects, students must include a minimum of three design sketches, the design selection, solid models of their design, and a completed prototype of their design. Final projects are presented at the end of the semester in a first-year Engineering Design Conference (EDC). Faculty of the school ranks each presentation for the best three design projects to receive the EDC award.

In implementing the changes, it was decided to try to maintain as much of the same topical coverage as the original course. Two major difference between the courses concerned coverage of manufacturing and design processes. In the original course, these topics were covered during a two-week period of lecture. The pilot courses presented the material in laboratory sessions where the students were able to gain a more hands-on experience. Coverage of section and auxiliary views were dropped from the original course.

#### **4.0 Future Work**

Three additional items are being considered to improve EGR 101 based on the outcomes of the pilot offerings. The first is to fully integrate the topics throughout the course offerings beginning during the fall semester of 2000. The second item is to add an expanded list of design project ideas. The goal is to have an encompassing list of projects that will appeal to all engineering students, regardless of their discipline choice. Students who have taken the course have proposed additional design projects to include in the list for future course offerings. The second requirement for the project is that it be composed of a minimum of two separate components to strengthen the student's comprehension of the design and build process for assemblies. The third item is to increase the coverage and discussion of Geometric, Dimensioning, and Tolerancing (GD&T) in both the lecture and lab sessions to aid in the students understanding of the topic.

#### **5.0 References**

<sup>1</sup> Ronald E. Barr, *Developing the EDG Curriculum for the 21<sup>st</sup> Century: A Team Effort*, Proceedings of the ASEE

<sup>2</sup> *Making the 2D-to-3D Transition: Rationales and Methodology*, Autodesk white paper, Autodesk, Inc., San Rafael, California.

<sup>3</sup> Condoor, Sridhar S., *Integrating Design in Engineering Graphics Courses Using Feature-based, Parametric Solid Modeling*, Proceedings of the 29<sup>th</sup> ASEE/IEEE Frontiers in Education Conference, 1999.

<sup>4</sup> Newcomer, Jeffrey L. et.al., *Visualization, Freehand Drawing, Solid Modeling, and Design in Introductory Engineering Graphics*, Proceedings of the 29<sup>th</sup> ASEE/IEEE Frontiers in Education Conference, 1999.

<sup>5</sup> Khan, Hamid, *Integration of Robust 3D Modeling Software into the Design Curriculum*, Proceedings of the 29<sup>th</sup> ASEE/IEEE Frontiers in Education Conference, 1999.

<sup>6</sup> *ABET EC2000 Criteria*, ABET

<sup>7</sup> *Manufacturing Education Plan*, Society of Manufacturing Engineers, Dearborn, Michigan, 1997.

## **6.0 Biographical Information**

Jeff Ray, Ph.D., is an Assistant Professor of Engineering in the Padnos School of Engineering at Grand Valley State University. He holds a BS and MS in Mechanical Engineering from Tennessee Technological University and a Ph.D. from Vanderbilt University. His primary teaching responsibilities are First-year engineering courses and coordinating the Senior Capstone Design sequence.

John Farris, Ph.D., is an Assistant Professor of Engineering in the Padnos School of Engineering at Grand Valley State University.