Abstract

The manufacturing laboratory of mechanical engineering (ME) department at Christian Brothers University provides students with an environment of complete product design process. The manufacturing laboratory consists of all kinds of hand tools, power tools, traditional machining tools, and advanced computer numerical control (CNC) machining tools. In conjunction with the computer-aided engineering (CAE) laboratory and rapid prototyping (RP) Laboratory, a complete design through manufacturing and product realization process has been established.

Undergraduate student instruction is enhanced in a number of ways. Modern engineering graphics, including 3-D solid modeling, is now introduced in the freshman year using Pro/ENGINEER™. Hands-on experience with traditional and CNC machining is still included in the Manufacturing Processes class in the sophomore year. After exposure to CAD drafting techniques, solid modeling and familiarization with different machining tools, students can apply enhanced skills to projects in higher-level classes. With the support from Assisi Foundation, ME department has acquired a new rapid prototyping machine, CNC lathe (in 2004), 4th & 5th-axis for current Fadal vertical machining center, injection molding machine (in 2005), and other equipments.

The newly renovated Benilde Hall and new equipment enhance the undergraduate manufacturing curriculum by providing substantial improvements in graphical, computational, and manufacturing capability including hands-on experience. It creates a laboratory environment that reinforces and integrates undergraduate instruction in modern design methods, agile manufacturing, and product design process.

Introduction

Design begins with a need. The need is either requested by end user or created by the provider. During the design process, creativity and imagination play an important role in the success of the final product. How do you put you ideas into reality becomes a part of product design process. A complete product design process includes design, manufacturing, prototyping, and testing.
In 1995, Christian Brothers University (CBU) received a grant from the National Science Foundation (NSF) through the Instrumentation for Laboratory Improvement Program (ILI) [ ]. The objective of this project was to develop an integrated laboratory to facilitate undergraduate instruction in the complete design through manufacturing process. The laboratory consists of three subsystems. The design subsystem is composed of workstations and software that support Computer-Aided Design and Manufacturing (CADM) instruction at the advanced undergraduate level. The manufacturing subsystem includes computer numerical control (CNC) machining and robotic assembly stations. The integration subsystem consists of a workstation server with network connection to the design and manufacturing subsystems as well as to existing Computer-Aided Engineering (CAE) and Controls laboratory resources. The Integrated Curriculum for Undergraduate Manufacturing Education (ICUME) has pushed the leading edge technology to the early stage of higher education. With the recent upgrades supported by the Assisi Foundation, a new rapid prototyping (RP) machine (Dimension 3D Printer) was added in Fall 2003. 4th & 5th axes was added to the existing Fadal vertical machining center plus a new ROMI M17 CNC lathe was installed in Spring 2004. An injection molding machine and a universal tensile tester will be added to the manufacturing lab in 2005. The design subsystem was also upgraded by adding a new CAD/CAM laboratory with 20 Premium 4 3.06GHz computers.

Combining the existing and the new acquired equipment, a complete product design environment was established. Undergraduate instructions become more challenging and interesting. Students are able to turn their idea into solid model and quickly obtain a prototype through the Dimension 3D Printer. The prototype can be used for testing, concept exchange, product visualization. Final design can be produced by using all machining tools in the manufacturing lab.

**Product Development Process**

In order to put your imagination into reality, sufficient hardware and software are keys to the success of the process. The computer-aided-design/computer-aided-manufacturing (CAD/CAM) is accomplished by using Pro/ENGINEER Wildfire. It is a feature-based parametric design and solid modeling tool with manufacturing and other modules. Combining with Pro/MECHANICA, stress and thermal analysis can be performed as part of finite element analysis. Mechanism design and motion simulation can be done under the Mechanism Design Module or Pro/MECHANICA Motion. Traditional design process adopts a top-down process as shown in Figure 1. This approach shows shorter design time. However, manufacturing/prototyping and modification takes longer time to accomplish. Also, the after market service costs are higher. Therefore, more and more companies/organizations are adopting the concept of concurrent engineering. Figure 2 shows a structure of concurrent engineering. This approach involve personnel in different disciplines/departments in the overall development process such as marketing, financial, manufacturing, design engineer, testing, vendors, and upper management. The concurrent engineering approach has proved to a better process for product development because it reduce the over development cycle. Also, it reduces the after market service costs.
In order to simulate a complete product development process, the Mechanical Engineering (ME) at CBU offers a series of courses in its area of disciplines. The integrated curriculum for manufacturing education within the ME curriculum plays an
important role in product development. It provides a complete concept of product development from design through manufacturing, prototyping, and testing. On top of other mechanical engineering courses, figure 3 shows some main courses in manufacturing education.

![Integration of Curriculum](image)

**Figure 3: Integration of Manufacturing Engineering Education**

**Freshman Year**
The Solid Modeling (ME 121) class is a requirement class for both ME and Electrical Engineering departments. It is also the prerequisite for Manufacturing Processes (ME 201). This class utilizes the CAD/CAM capability of Pro/ENGINEER Wildfire. Students learn the basic parametric design of 3-D objects and produce 2-D drawings with dimensioning along with producing rapid prototype using the Dimension 3D Printer. This class builds up the ability of design from imagination and reproduction. Figure 4 shows some student project in ME121.

**Sophomore Year**
All ME Students are required to take Manufacturing Processes (ME 201). This class includes four parts: concepts and theory, field trips, hands-on projects, and knowledge bowl. In the concepts and theory portion, different manufacturing processes and material properties are introduced. Students learn to use different kinds of traditional machining tools such as lathe, mill, drill, bend saw, power shear, etc. Oxyfuel and MIG welding are also a part of practice projects.
In the second half of the semester, CNC machining is introduced to students as well as NC programming and robotic assembly. Students learn to write NC code manually and machine parts on the CNC machine. In addition, approximately six field trips to local industry are taken. Students learn from engineers in industry and actually view machining processes. Other manufacturing processes that have not been introduced during field trips will be introduced via videotapes of different manufacturing processes. Projects corresponding to course material utilize machine tools in the ME Development Shop at CBU. Some projects utilize the VMC-15 vertical machining center shown in Figures 5, 6, 7, 8, and 9. With the new 4th and 5th axes add-on and the new ROMI M17 CNC lathe, students will have more flexibility of producing complex components. The manufacturing module of Pro/ENGINEER is also introduced with NC programming. After having the background of using Pro/ENGINEER™ to create parts, Pro/PROENGINEER can also be used to create manufacturing model as well as tool path and cutting simulations.

The highlight of the course is the Manufacturing Bowl at the end of the semester. Students are divided into four groups for competition in general knowledge in manufacturing. The competition is conducted with multimedia presentation using Microsoft PowerPoint. The instructor will serve as the judge of this competition and adopt the method of double elimination match. This class provides general knowledge of manufacturing processes and prepares students with enough skills in manufacturing for other projects and experiments in higher level classes and advanced manufacturing electives.
Junior and Senior Year
In the junior and senior years, students will continuously utilize the Pro/ENGINEER™ in several classes. Evidence of the impact on these classes can be seen in the Reference 1. The major changes in manufacturing education are the two courses that introduced in 1996 as below.
ME 435 (Intermediate Manufacturing) -- Students utilize the parametric design methodology including part and assembly creation and parameterization using Pro/ENGINEER™. The manufacturing module introduced in ME 201 where students create manufacturing models, build operation sequences, and manufacture complex parts are again utilized. Sheetmetal design is also introduced in the class. Students learn how to perform structure, thermal, and motion analysis using Pro/MECHANICA™. Design for manufacturability is also included in the syllabus. Design projects are assigned to student groups in different stages of the class. A final project allows students to apply all techniques including design, analysis, manufacturing, and machining codes. Figure 10 shows an example gear-type part. Figure 11 shows the cutting simulation of the manufacturing model that shows tool path, and Figure 12 shows the actual machined gear-type part [3].

ME 445 (Concurrent Engineering) -- The concept of concurrent engineering are introduced to students. Students are divided into groups to complete the same project. The design group develops an idea for a part and utilizes Pro/ENGINEER™ to design the part. The analysis group utilizes Pro/MECHANICA™ to perform stress and thermal analysis on the part. The manufacturing group creates a manufacturing model of the part and NC sequences as well as on screen simulation of cutting sequences. After manufacturing of the part, all groups discuss the outcome of the manufactured part and test it. During the process of design, analysis, and manufacturing, all groups meet constantly to discuss the progress of the project. Figure 13 shows a heat sink design, Figure 14 shows a Stirling engine design, and Figure 15 is the design of an air cylinder actuator. An example thermal analysis is also shown in Figure 16 and an example of assemble is shown in Figure 17.
**Equipment and Facility**

The CAD/CAM lab is equipped with 20 Pentium 4 3.06GHz PCs in the. All machines are loaded with Pro/ENGINEER Wildfire. There are 18 PCs in the existing CAE lab which will be upgraded to the Pentium 4 3.06GHz in summer 2004. The manufacturing lab is equipped with all kinds of hand tools and power tools. Traditional machining tools include manual lathes, mills, grinders, shears, bend saws, drill presses, sand blaster, and welding devices. Advanced machining tools include Fadal VMC-15 vertical machining center with 5 axes capability and ROMI M17 CNC lathe. On top of these machining tools, a rapid prototyping machine (Dimension 3D Printer) was added to the program. There will be a new injection molding machine and a universal tensile tester in 2005. Testing equipment includes impact tester, tensile/compression tester, Rockwell hardness tester, torsional and vibration tests.

With these equipment, a complete environment of product development is established. Student can turn their imagination/ideas into reality. Figure 18 shows some equipment in the manufacturing lab. Figure 19 shows the rapid prototyping machine and its sample parts.
Figure 18: Equipment in manufacturing lab
Summary

A complete product development environment has been established in the Mechanical Engineering Department at Christian Brothers University. Students can turn their imagination and ideas into 3D models using Pro/ENGINEER. Utilizing rapid prototyping machine, concept proofing and discussion are easily carried out.
Manufacturing can be accomplished by using different kinds of machining tools in the manufacturing lab. Stress analysis can be simulated on the computer using Pro/MECHANICA along with the actual test in the lab.

The integrated curriculum of manufacturing education trains students to have a solid understanding of product development process from design through manufacturing, prototyping, and testing. The manufacturing laboratory also supports other departments for all necessary maintenance and fabrication works.

As a result, the design through manufacturing and product realization processes give students a simulated environment of industry product development. It prepares students to face more challenging real world engineering design and problem solving.