A Coordinated Approach in Design and Manufacturing Activity

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Abstract

This paper describes a concurrent effort in teaching activities undertaken by the Manufacturing, and Mechanical Engineering Technology programs at the University of North Texas. The change is necessitated by a call from industry to prepare students to work in an environment where products are designed and manufactured utilizing concurrent engineering practices. The integrated approach employed helps the students to grasp the discussed subject matter in a consolidated manner and offers them a real world challenge since they need to complete a job within a time constraint, participate in groups, work within limited resources, and produce a useful product for the society. The department for only the cost of materials, tools, coolant, etc. gets high quality test specimens and testing devices.

Introduction

Concurrent Engineering and Management practices are widely prevalent in industry. They utilize the concepts of multifunctional teams and parallel development to reduce the time from concept to market for a product. Rather than developing the product linearly, various tasks are performed simultaneously. Marketers, designers and manufacturers come together to form multifunctional teams. As a unit, they are able to use their varied experiences to anticipate problems and solve them before delays occur in the project. Before concurrent engineering became accepted, many companies used an organizational structure with independent departments. The designers would toss their ideas “over the wall” to manufacturers. The manufacturers would then add ideas and pass the information to another department. Time-consuming disagreements often arose because each department was trying to satisfy different goals. This process proved to be slow, costly and extended the time needed to develop new products. Concurrent practices overcome these difficulties.

At the ASEE 1996 College Industry Education Conference[1] the Aerospace Industry identified three disturbing shortcomings common among new engineering hires which are summarized below:

(1) New hires require excessively long apprenticeships (3-5 years) before becoming productive.
(2) Few engineering graduates know how to work in groups or how to manufacture anything. Even fewer understand the process of large-scale, complex system integration that is so common in industry.
(3) Often the students with the highest GPAs are those that are least prepared to work cooperatively in teams to engineer and integrate complex systems.

As result of these identified shortcomings the Boeing Company proposed a list of attributes they would like to see in engineering graduates[1]. These same attributes are commonly identified throughout industry and also apply to graduates of engineering technology programs. Some of these attributes are: a good grounding in engineering science fundamentals, a good understanding of design and manufacturing processes, possession of a systems perspective, good communication skills, ability to think both critically and creatively and an understanding of and commitment to teamwork.

There have classically been barriers between design and manufacturing that need to be removed if the attributes listed above are to be achieved to the extent required. In the past different education, a different "language", and viewing the product from different perspectives--the design engineer from the performance/aesthetics perspective and the manufacturing engineer from the processing/plant efficiency perspective--have contributed to the barriers. In addition, other barriers often included differing pay scales, a physical separation by being housed in different buildings and budgeting practices which did not fund the manufacturing effort until the design was complete. In a future dominated by customer-driven global competitiveness, concurrent engineering, cross-functional teams, small lot size manufacturing, and rapid turnaround, organizations must abandon the historical "over the wall" relationship between the design and manufacturing functions and adopt organizations and strategies that encourage communications and cooperation[2].

The changes that are taking place within the industry are provoking changes in the engineering and engineering technology programs at our colleges and universities as well. Many programs are being re-engineered to incorporate more multi-disciplinary team activities that encourage concurrent engineering practice. This cross-over between the two disciplines of design and manufacturing would greatly improve the communication between two critical areas that form such an integral part of the process of bringing a product to market. Consequently, there is an effort underway in the Department of Engineering Technology at the University of North Texas to bring the Mechanical Engineering Technology (MEET) and the Manufacturing Engineering Technology (MFET) programs closer together so that the students in either discipline get significant exposure to both design and manufacturing functions. A project to manufacture test equipment for laboratory use was selected as a means of demonstrating the usefulness of concurrent engineering. This selection had some advantages since the fixtures, tools, devices, and test specimens could be used in other labs, thus reducing the laboratory operating costs, and at the same time giving the students realistic problems to solve in the process of learning vital design and manufacturing functions.

Activity

The faculty identified the laboratory needs in terms of fixtures, tooling, devices, and test specimens. They then decided which design and manufacturing courses were appropriate to tackle the problem, which was then incorporated into those classes as a team project. The MEET design students were required at the outset to consider the manufacturing processes available in the manufacturing labs and they communicated with the MFET students on the team so that the design reflected an effort to efficiently use the available processes. The designs were analyzed using appropriate analysis tools including finite element methods in order to give students experience in the full process and in the use of the tools available. The analysis may reveal the need for design changes that can be made directly to the CAD drawings thus producing final drawings ready for the manufacturing members of the team. The tools necessary to implement the project, like CAD software for the design; and lathes, mills, drills, welders, plastics injection molders, metal casting capability etc. for manufacturing; were readily available. Also an industrial flexible manufacturing cell (FMC) capable of "lights out" operation was available. Several CAM software packages were also available for the student to use and those students in the automated manufacturing classes were taught to program the individual machines making up the FMC. Finally, the completed hardware goes to the laboratory that tested it and insured that it functioned as originally specified.

One of the benefits of this program was that it encouraged, even demanded, continuous communication between those involved in the project--the customer that defined the need, the faculty, the members of the design classes, the manufacturing classes, and also within the team. The physical output are the test specimens, fixtures, tooling, devices, etc. defined by the user labs, but the real output is a graduate who has had experience in a team environment, exposure to both design and manufacturing, and extensive experience in communicating both orally and in writing.

This integrated activity not only made it possible to make laboratory specimens for tests such as tensile, compression, impact, fracture toughness, etc. according to the approved standards (ASTM, ISO, etc.), but non-standard specimens can also be easily produced to examine the effect of changes in specimen size and geometry. For example, a recently developed, hand-held fracture toughness tool[3] has been shown to produce good results when used to test high strength metal alloys and it requires test specimens that are quite easy to produce. The same tool and specimen geometry are being used to measure fracture toughness of brittle plastics. In a recent series of tests it was necessary to produce several variations from the standard specimen geometry in order to assess the effect of the specimen shape and notch in order to define the specimen that gives good results and is the easiest to make. This work is now being done in the Department of Engineering Technology at the University of North Texas and the integrated approach discussed above will be used to design, analyze, manufacture, and test the various specimen sizes and notch geometry. The following sections describe how hardware and software have been integrated to facilitate the process of concurrent practice and a demonstration project is described.

Software and Hardware Integration

Under older, more conventional systems, CAD, FEA, and CAM were taught in separate physical locations and any interaction was, at best, accomplished by carrying a floppy disk from one location to another. For many students even this transfer obscured some the connectivity between the different functions. Such a physical transfer also made it much more difficult to do the "what if?" studies that can be critical in helping certain types of learners grasp concepts and interactions. With the current system, which is still being developed, the hardware may still be physically disconnected, but the functions are all electronically connected and can be accessed from one computer lab. It is now much easier to teach the iterative nature of the design process and to illustrate the constraints that manufacturing can place on a design. This clearly demonstrates the validity of concurrent engineering and the need to have cross-functional groups from the very outset of the product design process. It further brings the design and manufacturing functions into a close interactive relationship that they have always needed to have, but lacked until recently. Design, analysis, and manufacturing are now integrated into a seamless instructional whole in both the mechanical and manufacturing engineering technology programs. In fact, students in the two programs have many courses in common and sufficient optional courses so that they can, if desired, complete an engineering technology program that is an intriguing mixture of both. Such a graduate might find a niche in today's team oriented concurrent engineering environment.

The integrated system defined above has an additional benefit-it encourages and even demands that the students learn the technical language of both design and manufacturing. Thus, they are able to communicate with other designers and/or manufacturers. In almost every course they are required to prepare and present oral and written reports. In the senior design projects a mixture of mechanical, manufacturing, and in certain cases electronics engineering technologists will be required so that they get a quasi-real world experience in a cross-functional team environment were they learn to work together. The senior design is not the only exposure to the team environment since it is commonly used in courses from the freshman to the senior year.

Working with a system made up of multiple pieces of hardware and software should also help students understand the importance of the systems approach which must be taken in most industrial environments and flexible manufacturing cells and/or systems. The software for CAD, FEA, and CAM functions, as well as the pertinent computers and peripherals electronically networked to an industrial quality FMC, have the potential to accomplish much of the desired integration between design and manufacturing. Such a system is in place at the University of North Texas and is being used to more closely integrate the mechanical and manufacturing engineering technology programs in an effort to produce graduates with significant understanding of the functions of both disciplines.

Example

During the Fall 1996 Semester a group in the senior design class was asked to prepare a custom injection mold for the departments Arburg Injection Molding Machine. The available machine had only one mold for making 1/8 inch thick Izod impact specimens. A new mold was needed to produce "dogbone" tensile specimens for measuring the tensile strength of plastics. All dimensions of the tensile mold had to be machined within ASTM[4] and ISO 9000 standards. The design and manufacturing activity was fairly complicated and provisions had to be made for cooling fluid flow. Since the students had to work in the department's machine shop, a lot of innovative techniques had to be performed. The overall activity can be summarized as follows:

I . *Scope of the project*: a) design and manufacture "dogbone" tensile specimen for Arburg injection molding machine, b) use the existing runner system for compatibility between molds, c) the design should include cooling lines as they exist and the injector plate that is universal between the molds.

II. *Design Issues*: a) a two mold cavity with truncated gating system, b) test specimens designed around ASTM and ISO standards and c) the mold cavity and runner system should be free of all possible voids.

III. *Mold manufacturing process*: It involved a host of activities like a) drawings using AutoCad R12 to show all visible and hidden lines, b) CNC programming which include the main program and sub-programs for the runner system and tensile bar specimen, c) taking a tool inventory in order to acquire all necessary tools within the required time limit, d) making fixtures for water lines and CNC cylindrical piece, e) working on an aluminum prototype which in turn involved cutting pieces to dimension, milling on the CNC, checking the dimensions, editing the program for cutter radius compensation, feeds and speeds, drilling gate holes etc., f) making the steel mold plate which involved cutting the plate to rough dimensions on a horizontal band saw, milling all sides on the Bridgeport to within 0.010″-0.015″ tolerance, drilling water lines, surface grinding to within 0.001″ tolerance, milling on the CNC, drilling alignment and sprue hole, drilling the gating system and preparing the steel for presentation.

In order to complete the project in one semester the mechanical and manufacturing students had to coordinate their activities. If the traditional approach had been used the time limit constraint could not have been met. The experience the students gained in designing, analyzing, and manufacturing the test specimens was very valuable and illustrated items discussed in a variety of classes.

Conclusions

The demands of today's global economy are motivating many industrial changes and those changes impact the teaching of engineering and engineering technology at colleges and universities. Classical engineering education methods may not be acceptable if we are to meet the demands of industry and do a better job of retaining students who have non-traditional learning styles. In the design and manufacturing environment students must have a good understanding of both functions and must be contributing members of cross-functional teams. They must have good communication skills and be able to see things from a system perspective. These are but a few of the qualities being demanded by the modern industrial community. Concurrent engineering practices are being vigorously pursued by different industries.

In order to prepare students for this changing environment, coordinated projects between mechanical and manufacturing students are being emphasized at the department of Engineering Technology at the University of North Texas. This coordination is being achieved by the students through integration of both their activities and between the hardware and software they are using. The former is being implemented in several courses and specially the senior design class. By learning to look at the entire product life-cycle and the different functions involved, the students take a coordinated approach in order to finish their projects. The difficulty in this time restrictive process is somewhat ameliorated by electronically linking functions that are integral to both design and manufacturing. These include computer-aided design and analysis and automated manufacturing including computer aided manufacturing and flexible manufacturing cells and/or systems. The software for CAD, FEA, and CAM as well as the pertinent computers and peripherals electronically networked to an industrial quality FMC have the potential to accomplish much of the desired integration between design and manufacturing.

References

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