Curriculum Development in Aerospace Manufacturing

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This paper describes a new course being developed in aerospace manufacturing technology. The course was offered for the first time in the Spring of 1996 as a senior/graduate level elective for Aerospace and Ocean Engineering (AOE), Industrial and Systems Engineering (ISE), and Mechanical Engineering (ME) students. We are developing the course in response to industry requests that aerospace engineering students learn about manufacturing. The purpose of the course is threefold. First, it serves as an introduction to manufacturing for AOE students. Second, it permits ISE students and ME students to extend their knowledge of manufacturing into an industry specific area. Finally, it brings together students with design and manufacturing interests into a common, focused course to discuss interrelated issues.

The course was to begin by focusing on the product -- a design of a specific aircraft. (More will be said about this later.) Next, various manufacturing processes and technologies were introduced and discussed with respect to individual components and subsystems of the aircraft. Industry is helping us to develop case studies illustrating the manufacturing processing sequences associated with particular components. The lectures then focuses on manufacturing cost analysis and cost drivers in aerospace manufacturing. This was followed by a discussion of the manufacturing environment as an integrated system. Finally, concepts in design for producibility were addressed in light of the materials already presented. Laboratory demonstrations, field trips, and a term project served to reinforce class material and provided the students with some hands-on experiences.

Introduction

In the last few years, it has become clear that aerospace engineers need to learn more about manufacturing as part of their formal education. Something vital was lost in the post-Sputnik rush to emphasize science in the engineering curriculum. To accommodate more physics and math, the "shop" courses were eliminated. This was understandable at the time, the aerospace business was performance driven and cost was secondary. We have been told repeatedly that cost was rarely a factor during the Apollo Program. However, the business has changed. Today the aerospace business is market driven, and cost and product design cycle time are critically important.

A government study conducted to understand how to improve US competitiveness concluded that more importance had to be placed on design and manufacturing education. Design had already been identified as a weak part of aerospace engineering education by many engineers working in industry, e.g., McMasters and Ford[2], and Nicolai[3]. Today, the consensus seems to be that design education is improving. However, as "design" improved, it became clear that students needed to understand the cost implications of their designs. They needed to understand that somebody had to build the design! Emerging concurrent engineering processes that promise to drastically shorten product development time and cost[4], make it even more important for aerospace designers to understand manufacturing processes. Remarkably, a long-time CFD researcher has written a paper[5], including a discussion on the dynamics of the competitive marketplace and the importance of reduced product cycle time, even at the expense of performance. Under these circumstances, Virginia Tech is developing the course described in this paper.

Course Description / Objectives

The course introduces students to the principles and practices of modern aerospace manufacturing. It addresses specific manufacturing processes as they relate to the production of major aircraft components and systems. It identifies various manufacturing systems control strategies and techniques that are applied within this manufacturing environment. Emphasis is given to process capabilities and limits, tooling considerations, materials requirements and constraints, economics of production, and design producibility. The course concludes with concepts in producibility/ design for manufacturability and assembly.

For students in aerospace engineering, the course serves as an introduction to manufacturing processes and systems. The intent is not to transform these students into manufacturing engineers, but instead to provide sufficient understanding of the area to ensure meaningful and productive discourse with those who are. For students with prior work in manufacturing, the course provides an insight into the specifics of manufacturing applied to the aerospace industry. It gives them the opportunity to better understand the close relationship that exists between the manufacturing environment and the product domain of the industry being considered.

The Initial Plan

The approach to be taken in the class was to combine lecture material with laboratory demonstrations, field trips, and project work which emphasize specific topics that were being addressed. Being able to see and touch was an important goal. Video tape presentations and slides were to be used to supplement lecture material. Additionally, team term projects and presentations were planned to permit students to have a hands-on experience in a specific facet of the course.

One unique feature of the course that was initially envisioned was that manufacturing processes would be introduced with respect to a specific aircraft. At the beginning of the course, the structural and manufacturing breakdowns of that aircraft would be introduced. As various processes were discussed, they would be related to specific components of that aircraft and consideration of costs, materials and process selection would be highlighted. When appropriate, examples would be given where an original material/ process combination had been modified to a different material or process and the related justification would be presented. This approach should not only provide a solid frame of reference for the students, but should also provide motivation for a more in-depth consideration of the processes.

An underlying theme of the course was to be concurrent engineering. As various material was presented, one topic of discussion was to be design / manufacturing interaction. In addition, specific material was to be presented in the area of concurrent engineering. It was assumed that this course would be taken by students from AOE, ME and ISE. Hence, the term project teams were to be formed to cross disciplinary boundaries.

Current Reality

The course, as offered, has combined a number of different instructional techniques. The bulk of the course was delivered in a standard lecture format. Guest lecturers were used where appropriate to bring specific expertise to the students. Video tapes were used to supplement lecture material when appropriate . examples were found that specifically related to aerospace manufacturing. A laboratory tour was organized of the Manufacturing Processes Laboratory and the Robotics and Automation Laboratory. Here the students saw demonstrations of various manufacturing processes, witnessed a live demonstration of automatic machining and tool changing via a three axis machining center, and watched a robot perform an automatic loading task. A short answer questionnaire was given to the students prior to the laboratory tour to focus attention to specific aspects of the demonstrations. Additionally a field trip was organized to Marion Composites (Marion, VA) where the students saw first hand production processes used in the manufacture of both commercial and military aircraft components. While only a subset of the students were able to make this trip, the remainder viewed a video tape on composite tooling for aerospace manufacturing. A second field trip is being planned, but company commitments have not been fully secured at the time of submission of this paper and had best be left unsaid. Term projects were assigned and will be discussed below.

The concept of relating the entire course to a specific aircraft was not realized in this offering of the course. Sufficient detail was not obtained prior to the beginning of the course on any one aircraft for it to serve as an example throughout the course. Rather, bits and pieces of various aircraft were discussed as processes were introduced. The initial concept is still thought to be desirable and more will be said about this later.

Concurrent engineering and the design/manufacturing interface were constantly addressed throughout the course, but the concepts often lack reality. What was needed were specific examples of product and process improvement that were realized as a result of such interaction. Ironically, as the course developed, these examples became more numerous and subsequent offerings of the course will better emphasize this facet of the course. However, there is still a great need for more real life examples.

General Organization

The initial lectures in the course were introductory in nature. These lectures helped to set the stage and get all of the students thinking in the same direction. There were three primary concerns in this section: 1) an introduction to the course, lecture outline and class projects, 2) an overview of manufacturing processes and process planning for aerospace students, and 3) an overview of aircraft systems analysis and design for non aerospace students.

The next segment of the course focused on manufacturing processes in aerospace production. The focus of this section of the course was on the individual manufacturing processes and technologies that are used to manufacture the various components and subsystems of a modern aircraft. As each process was introduced, specific components of the different aircraft were discussed When appropriate, comparisons to different processes were made. Process limits, economic implications, operation requirements, and materials consideration were addressed. Approximately twelve lectures were planned for this section of the course but it expanded significantly.

Manufacturing cost concepts and analysis were introduced next. This section began by introducing concepts in basic cost estimating. The relationship between materials and cost, tolerances and cost, and production volume and cost were explored. Next, classical cost management system concepts were introduced. Specific emphasis was given to the economics of production systems - fixed versus variable costs, capital versus operation costs, etc. Finally modern concepts in activity based costing were introduced as they relate to aerospace manufacturing.

The manufacturing systems control section attempted to move the student from a process focus to a manufacturing systems focus. Concepts in manufacturing systems management and control were included. Again, these were related to the aerospace manufacturing environment through the use of a number of reference papers. Lecture topics included concepts in 1) basic production planning and control, 2) just-in-time and lean manufacturing, 3) statistical process control, and 4) system simulation and analysis.

The final section of the course interrelated design and manufacturing concepts with a series of presentations on design for producibility. The lectures were based upon both aerospace producibility concepts and current thinking in manufacturing in general. The lectures will include topics in: 1) concurrent/systems engineering and quality function deployment, 2) design for manufacturability and assembly, and 3) CAD/CAM integration and product realization.

Term Projects:

Six project groups were formed prior to the midsemester break. The projects were first presented to the class as a whole and then students were asked to identify the projects that were of most interest to them. Teams were formed wherein most students were assigned to a group that represented one of their strong interest areas. The project topics were chosen to support the interests of the students. Additionally however, some of the project areas were specified in the hopes that the student reports might provide materials suitable for use in subsequent offerings of the course.

The first project team was assigned the task of creating a material selection matrix that interrelates materials, aircraft components, and fictional engineering areas such as design and manufacturing. Next a project team was assigned the task of conducting a rivet study. What types of rivets are being used in current aerospace manufacturing practices and what are the desired applications? This team was asked to create a display board that might be appropriate for lab or class use. The third project assignment actually involved two separate teams. These teams were asked to address the design and manufacturing processes associated with a specific aircraft component. One group was to view the component as an assembly of aluminum components while the other group addressed creation of the component as a single, machined piece of a high strength material. Again, this is to become input for a future class presentation.

The next project group was assigned the task of creating a case study associated with tooling requirements for aircraft assembly. Working with an aerospace manufacturer, this group was to create a realistic case study of the problems, issues, and scope of the assembly task associated with an aircraft subsystem. A similar assignment was given to another project group in the area of manufacturing cost analysis. They were assigned the task of creating a case study on cost drivers for a given component of a specific aircraft. Again, industrial participation in this project was essential. The final term project involved the development of plans to fabricate wings for a wind tunnel model. The group was to design two mating wings that could be machined on the machining center within the laboratory. Complete process plans and NC code were required for this project. Hopefully, the wings will be machined this summer.

During the last three class periods, the student teams will present the results of their term projects. Since different teams will be addressing different components and subsystems of an aircraft, the presentations will provide an opportunity for peer learning.

Continuous Improvements

As indicated in the introduction this is the first time the course has been offered and there are many things that can be done to improve upon this initial attempt. Ideally, we'd like to have five years of aerospace manufacturing experience behind us before we present it again. But that's only a dream. We are grateful for the interaction we have had with industry and hope to not wear out our welcome as we continue to come back with more questions and more requests. We desperately need details that are not always easily forthcoming. We need to find better ways of expressing our needs so that industry can provide the information we want to "pass on" to the students without giving away company secrets.

We need examples of all kinds. Given a manufacturing process - what components are made using that process? Why? What do the parts look like? Can you give me drawings or at least sketches? (We need photographs and video clips that illustrate processes and parts to really make things come alive for the students.) With respect to a part - what are the individual processes necessary to manufacture it? What were alternative processes and why were they not selected? How has the part geometry changed as a result of a redesign and why? And the list goes on. Finally we need details on a specific plane to use throughout the course. Information is forthcoming for next year, but we just did not have the time to really put it all together during this first offering. Each time the course is offered, we'd like to change the aircraft to help us build up a body of knowledge of parts and processes.

References

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