Introducing Design for Manufacturing and Assembly in the Manufacturing Technology Curriculum

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Abstract

This paper presents the introduction of a new course on Manufacturing Process Planning in the manufacturing technology curriculum. The course emphasizes designing for economical manufacture, concurrent engineering, designing for assembly, and other related manufacturing concepts that are used in industry.

Introduction

With much importance being given in industry to concurrent engineering, design for manufacture, and design for assembly, it was felt necessary by the author to include instruction in these concepts to prepare the students for the industry.

A new course titled "Manufacturing Process Planning" has been offered twice – in the Fall semesters of 1994 and 1995. The main thrust of the course is to teach designing for economical production by understanding the capabilities of different manufacturing processes. This course teaches students to determine candidate manufacturing processes for a given part by performing manufacturability evaluation at the design stage. Processes that are considered in the course are primarily metal processes, such as machining, forging, metal casting, fabrication, welding, and assembly. Concepts of concurrent engineering, design for manufacture and design for assembly are introduced using practical examples.

The course content also includes solid modeling concepts and 3-D part representation methods, automated recognition of manufacturing features, effect of tolerances on production cost, group technology, setup reduction techniques, and discussion of STEP (Standard for The Exchange of Product model data) neutral standard. It is a 3-credit course without any laboratory work at this time.

The course is participative in nature. The course content is breed on the industrial experience of the instructor and the students. It includes basic and practical manufacturing knowledge that the students of manufacturing technology should be exposed to in a baccalaureate program. The course also requires each student to write a project report on a relevant topic and present it in the class. This paper describes some of the highlights of the course and shows the way the course content is presented to the students.

Manufacturing Process Planning

This section describes briefly the course catalog description, the course objectives, how the course came into existence and was integrated within the curriculum, and some of the important topics covered in the class with their application.

Description and Objectives

The catalog description of the new course is: the study of design for manufacturability of various manufacturing processes, surface technology, tolerance control, techniques for setup reduction, design for assembly principles, group technology, sequencing of machining operations, chatter theory and control, solid modeling representations, part feature recognition techniques and computer-aided process planning.

The objectives of the course as described in the course outline are: to develop skills in economical part manufacturing and assembly using modern tools and techniques, and to understand and apply principles of design for manufacturability and assembly.

Prerequisites

Before the introduction of IET401 Manufacturing Process Planning, there were only two courses directly related to manufacturing, MET 180 Materials and Processes and MET 335 Basic Machining, taught in that order. With the introduction of IET401 Manufacturing Process Planning, a good sequence of course structure in manufacturing was established as illustrated in Figure 1. The new course is for the junior and senior students of the 4-year degree programs. This revision in the course sequence structure clearly helps to satisfy ABET (Accreditation Board for Engineering and Technology) requirements for the baccalaureate programs.

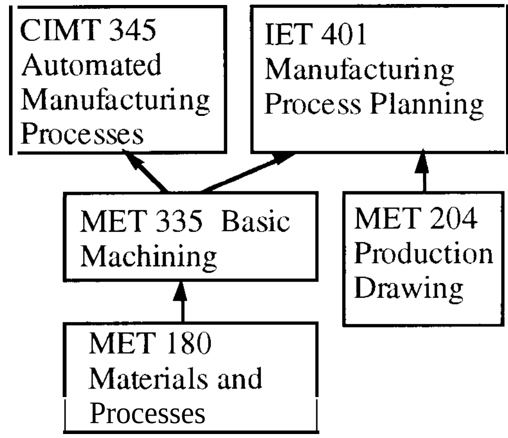

Figure 1 The Course Sequence Structure.

Topics Covered

Some of the major topics covered in the course are described in this section. There are 30 sessions of 75 minutes each in a semester. In the introduction itself, the relationship between design and manufacturing is provided to lay the foundation for the rest of the course. Visual diagrams are used for clear understanding of the concepts. Figure 2 shows one such diagram of CAD/CAM integration. During the semester, the course covers 7 major topics as detailed below:

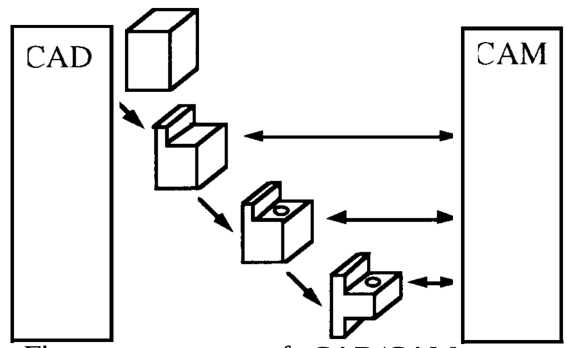

Figure 2 Integration of CAD/CAM

Concurrent Engineering shows the need of design and manufacturing functions to work together. It is the integrated design of both the product and the life-cycle processes to produce and support the product[1]. It is putting together two functions that never should have been separated. It means product design engineering and process design engineering being performed at the same time. An example of concurrent engineering, that shows the effect of change in tolerance specifications and the production and labor rates of different machines on cost. The example clearly brings home the concept of the team approach in design and manufacturing. Also, the following four C's of concurrent engineering are discussed:

Concurrent Product and process design run parallel.

Coordinated: Product and process are closely coordinated to ensure parts that are easy to manufacture, handle, and assemble and to facilitate use of simple, cost effective process, tooling, and material handling solutions.

Constrained: Product and process are virtually constrained to achieve optimal matching of needs and requirements.

Consensual: Product and process decisions involve full team participation and consensus.

Types of Machining Operations session is primarily a review of a prerequisite course on basic machining. A major additional feature is that these operations are linked to the shapes of parts produced, different types of cutting tools, and the types of machines that can do such operations.

Sequencing of Operations is taught in greater detail. Examples of rotational and prismatic parts are used to show the logic involved in process planning[2,3,4]. The steps of process planning function are developed using the tolerance, geometry, and technological constraints among the part surfaces. Figures 3 and 4 illustrate the process planning of a prismatic part. The part drawing in Figure 3 is developed using zero tolerancing concept. The importance of zero tolerancing and its advantages in manufacturing are described since the students already have basic knowledge of geometric dimensioning and tolerancing from MET 204 Production Drawing course. Figure 4 shows the various possible sequencing of operations with letters indicating the surfaces of the part. The number of setup changes required is indicated at the bottom of each sequence. Also, the influence of the type machinery is demonstrated by performing process planning using different types of machines[2,3].

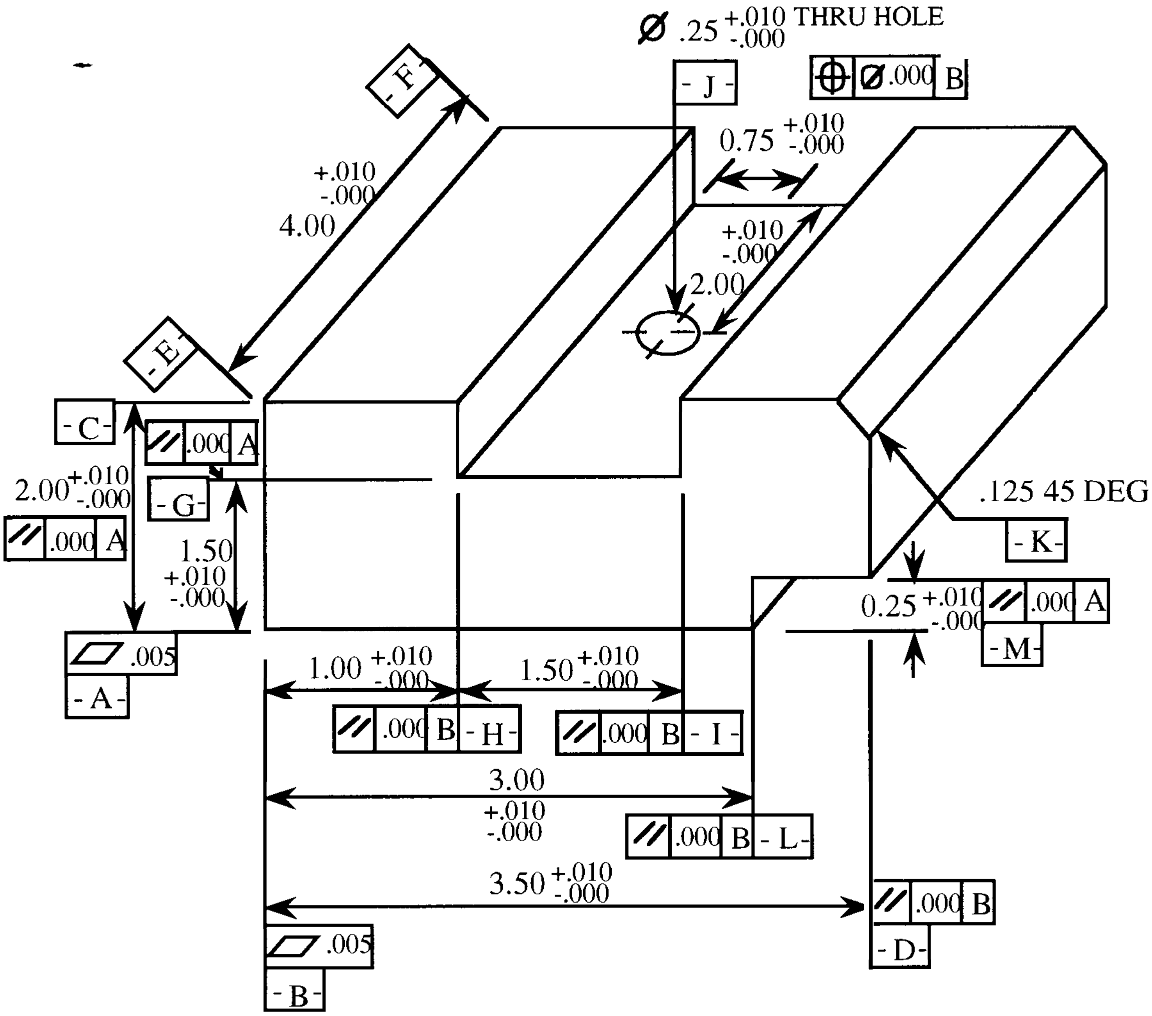

Figure 3 Prismatic Part for Process Planning[5].

Part is Squared -A, C, B, and D

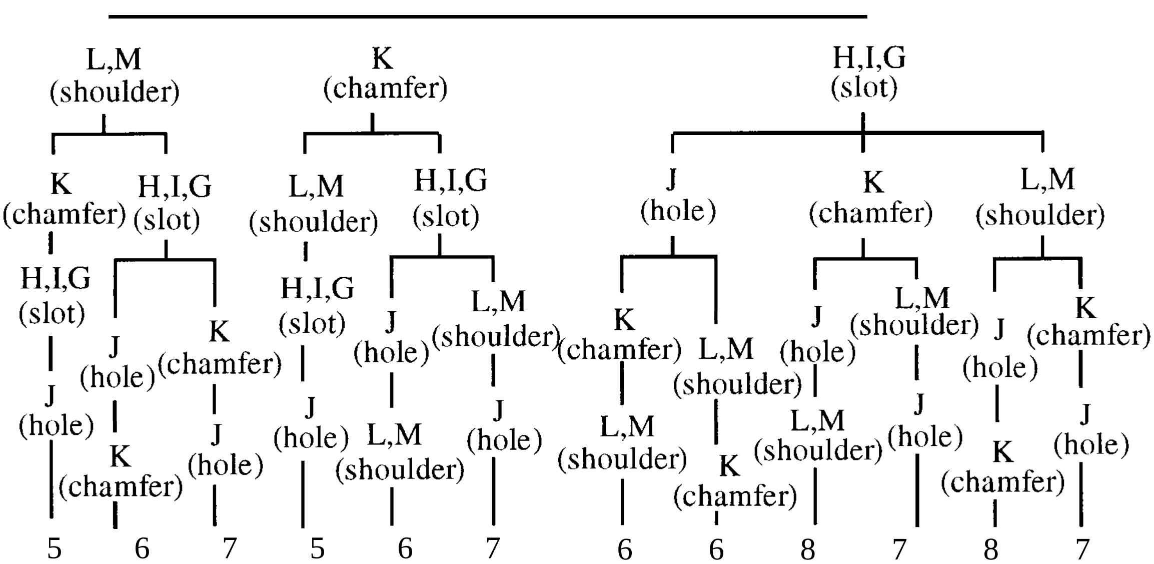

Figure 4 Different Sequence of Operations for the Surfaces of the Prismatic Part.

Economics of Machining has been done in a previous course. Influence of life-cycle quantity on the selection of machines, cutting tools, and fixtures is emphasized here.

Design for Manufacture (DFM) principles are discussed next[4,7]. These are, for instance:

(1) Eliminate parts, processes, operations, tooling, fixtures, adjustments etc.
(2) Simplify processes, operations, tooling, fixturing, material handling, for (a) ease of manufacture and assembly; and (b) to conserve materials and energy.
(3) Standardize, where possible, by use standard interchangeable parts and develop modular design.

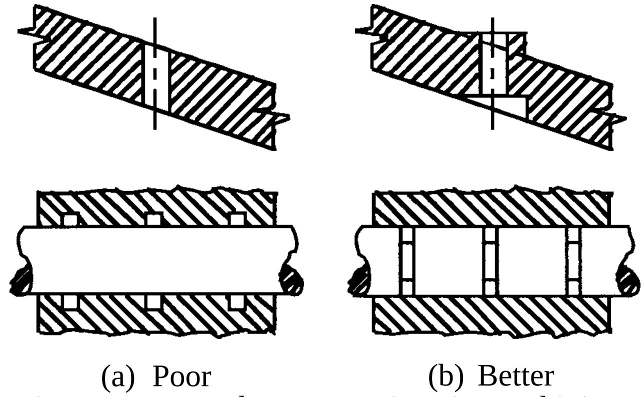

Figure 5 Poor and Better Designs in Machining.

Based on the knowledge of different operations of the machining process, a number of examples of poor and the corresponding better designs are discussed. One such example is shown in Figure 5. In Figure 5(a), the upper design has a drilled hole. A drill attempting to start at an angle will be deflected, with loss of accuracy and possibly breaking the drill. A drill breaking through a slanting underface is subjected to breakage, because the drill point comes through unevenly. Similarly, the bottom part-in Figure 5(a), has grooves that are easier to machine on outside than inside surfaces. At this stage, other manufacturing processes are discussed with a view to understand the important process parameters that affect the quality and cost of the manufactured part. These processes are metal casting[9], metal stamping and forming [10], and welding [11]. Again, a number of examples of poor and the corresponding better designs are discussed in each of these processes.

Chatter Theory and Control gets into prominence because of the recent trends of high power and high speed machining. After a brief discussion of the different types of vibration, primary emphasis is given to stability lobe diagrams. These diagrams show the depth of cut with respect to the cutting speed. Often times as shown by these lobe diagrams, the maximum metal removal rate is not at the maximum cutting speed. This topic ties in well with their background in physics that is taken by them in the first two years of the program.

Design for Assembly (DFA) is another major topic in the course[7]. A sample list of DFA guidelines is given below:

(1) Provide a simple and reliable foundation and fixture for assembly.
(2) Minimize the number of parts:
    (a) Integrate or combine different parts by selecting different process of manufacture.
    (b) Eliminate or minimize different types and sizes of fasteners.
    (c) Design parts to be multifunctional, such as load-bearing member and heat sink.
(3) Facilitate handling of parts:
    (a) Use parts that are easy to grip.
    (b) Avoid flexible or small parts.
    (c) Avoid parts that nest or tangle.
(4) Facilitate orientation of parts:
    (a) Use parts that are easy to orient.
    (b) Provide visual aids for orienting parts.
    (c) Consider feeding parts through magazines, feeders, palletized transportation.
    (d) Avoid parts with hidden features.
(5) Facilitate assembly:
    (a) Use self-locating parts.
    (b) Use compliance to reduce tolerances in part mating.
    (c) Avoid parts that require twisting or bending of fingers or wrist.
    (d) Assemble parts from the same direction.
(6) Consider stability and durability:
    (a) Avoid weak or easily bent parts.
    (b) Use materials that are less likely to crack or chip.

(7) Design for job satisfaction:
   (a) Provide scope to assemble at individual's own pace.
   (b) Provide need for group interaction and cooperation.
   (c) Provide use of individual judgment and decision making.
   (d) Provide potential to learn, develop and try new methods.
(8) Design for automation or robotic assembly.

A flow chart that helps to minimize the number of parts and makes the designer think of the functions of different parts in an assembly is shown in Figure 6. The chart shows that there are three vertical categories, starting from I, II, and III, and three levels in each category. A part in an assembly is an essential part if all answers in the three levels are "yes" in any one of the three categories. An example of a ball point pen is used to illustrate the chart. For example, the cover of a ball-point pen can be of different material than the main body. In such a case, it is difficult to have three "yes" in any one category, and therefore, the cover of a pen is not an essential part.

Other Topics beside the above, have been in (1) STEP (Standard for The Exchange of Product model data) – a neutral format for product definition data, which will eventually enable universal transfer of product data between heterogeneous systems (2) Surface Technology – the capabilities of different manufacturing processes with regards to surface roughness (3) Tolerance Stacking[12] – for a part and assembly to determine the maximum and minimum clearances between parts or features (4) Solid Modeling Representations [1] – the boundary representation and the constructive solid geometry and simple part examples of each representation (5) Computer-Aided Process Planning and Part Feature Recognition Techniques – summarize the need to evaluate part at the design stage. There are two sessions given by a guest speaker on machining and grinding.

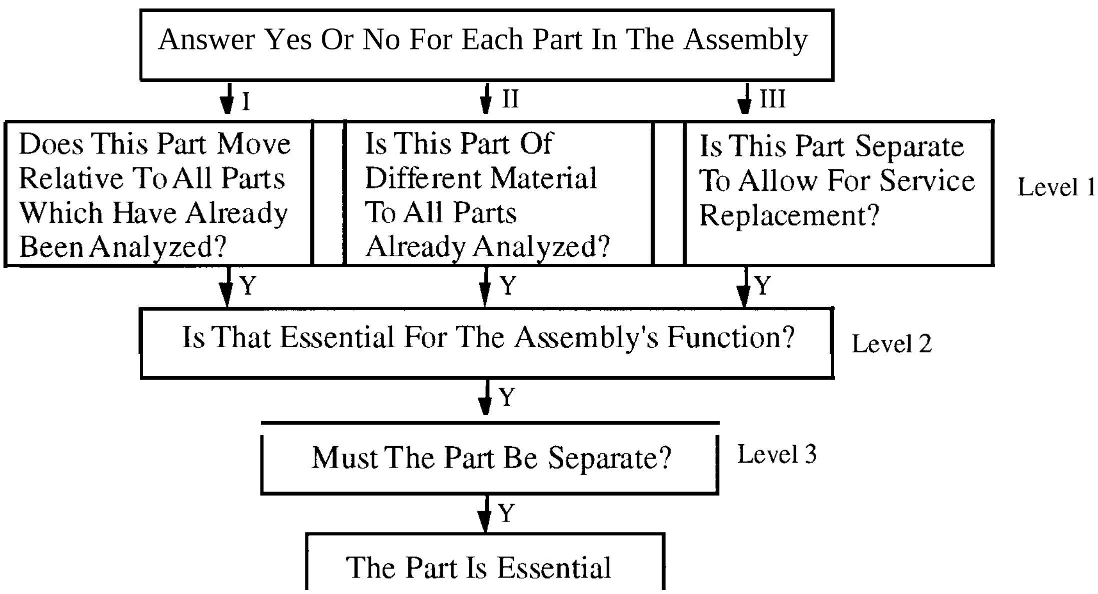

Figure 6 Design For Assembly Flow Chart.

Teaching Aids

Videos have been obtained in some of the topics. These videos are (1) Quick Change Chuck Jaw System from Ingersoll Cutting Tools (2) STEP – A Futurevision... Today from Automotive Industry Action Group (3) Video Cassette Manufacturing & Assembly from Global Zero Inc. (4) Design for Manufacture and Assembly from Boothroyd-Dewhurst, Inc. (5) Corokey from Sandvik Coromant Inc. and (6) Precision Metalforming – A Part of Your Life from Precision Metalforming Association.

Class Project

Each student works on an individual project based on the person's interest and experience. This approach has been greatly beneficial to the students in a number of ways. First, they sharpen their written and oral presentation skills. Second, they learn to use the different facilities and resources available to them such as the library, document delivery services, and the writing center. Third, they get into greater depths in specific areas relevant to them in their profession or of their interest. Finally, because of the project presentations in class, all students get the benefit of the project work done by the others.

Students do not find it difficult to select a topic for the project as most of them have had exposure to industry. Along with the course outline, a list of potential topics for project consideration is given to the students. Some examples of projects done by the students so far have been on: Laser Metalworking, Different Welding Processes, Waterjet Machining, Types of Machine Tools, Process Of Injection Molding Rubber On A Metal Insert, Alternative Joining Processes, Thermoplastic And Thermoset Processing Methods, Pad Printing In Manufacturing, Functional Gaging among others. These projects are professionally typed reports of 8-10 pages in length including figures and references that is turned in for grading. The students spend at least 30 hours on the project work and are ready to start on the project by the fourth week of the semester.

Conclusions

With the type of topics covered and project work, students learn about DFM, DFA, concurrent engineering, and the manufacturing process fundamentals related to part design. Responses of other faculty in the department including visiting faculty from the industry have been extremely positive. To sum it all, a past graduate of this course, who is now employed out-of-state, called the author to specially thank for introducing this new course. The intention of this paper was to provide an impetus to the manufacturing faculty members interested in developing a similar course for their programs. Sufficient information is given here to help take that important first step.

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