THE CHANGING ROLE OF MECHANICS IN ENGINEERING CURRICULA

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Abstract

Mechanics is the corner stone of the engineering curriculum because it helps to develop essential design skills in engineering students. In the past, the mechanics curriculum was too inflexible with too much attention paid to solving classical problems resulting in unique situation-specific solutions. This rigid approach is now being challenged as the undergraduate curricula go through restructuring to accommodate open-ended problems for students to solve using flexibility and creativity. ABET also has adopted an integrated approach toward design with more flexible definitions. The author examines the subject matters relating to mechanics in the context of recent developments in the field of design teaching. Professional design practice has become interdisciplinary with an emphasis on a team approach leading to *Integrated Product Development* (IPD). This approach offers a competitive edge in the global market place in terms of cost, quality, and reduced lead time in bringing forth a new product.

Introduction

Mechanics plays a significant role in Engineering Design for both structures and machinery. Recently, engineering curricula have exploded so many subjects and all of these courses have been compressed to fit inside a 4-year B.S. degree program. This has created a situation with some subjects demanding innovative approaches to teaching and mechanics is no exception. With renewed emphasis on *Integrated Approach to Design* and *Integrated Product Development,* the teaching of mechanics is receiving considerable attention once more. For example, in the past, educational techniques in mechanics have been too concerned with obtaining unique, deterministic solutions by students, i.e. everyone must get the same answer. With this approach, students often have difficulty in developing realistic models and in exploring the vast arena of possibilities of creative solutions with an open mind. The *open-ended* problems, as recognized by ABET, offers a better understanding of the applications of mechanics to the design of real-life products [1-3].

The availability of sophisticated analytical and graphical tools in the form of commercial software as well as courseware has also added to de-emphasizing the fundamental aspects of mechanics. This has additionally diminished the ability of students to analyze and solve problems on their own. The "black box" approach yields identical output from the input irrespective of the user's knowledge of the fundamentals. Our curriculum must be effective to ensure that students grasp the fundamentals of mechanics and be able to predict ball-park results and provide realistic solutions. However, these computer based tools are essential in our educational arsenal for optimizing solutions as well as reducing the time required to solve realistic problems with various "what-if' scenarios.

Topics in Mechanics

The top of FIGURE 1 shows the typical courses in mechanics as found in Mechanical Engineering and Manufacturing Engineering programs. With the exception of Mechanisms and the emphasis on machine design, these courses are also appropriate for Civil Engineering programs.

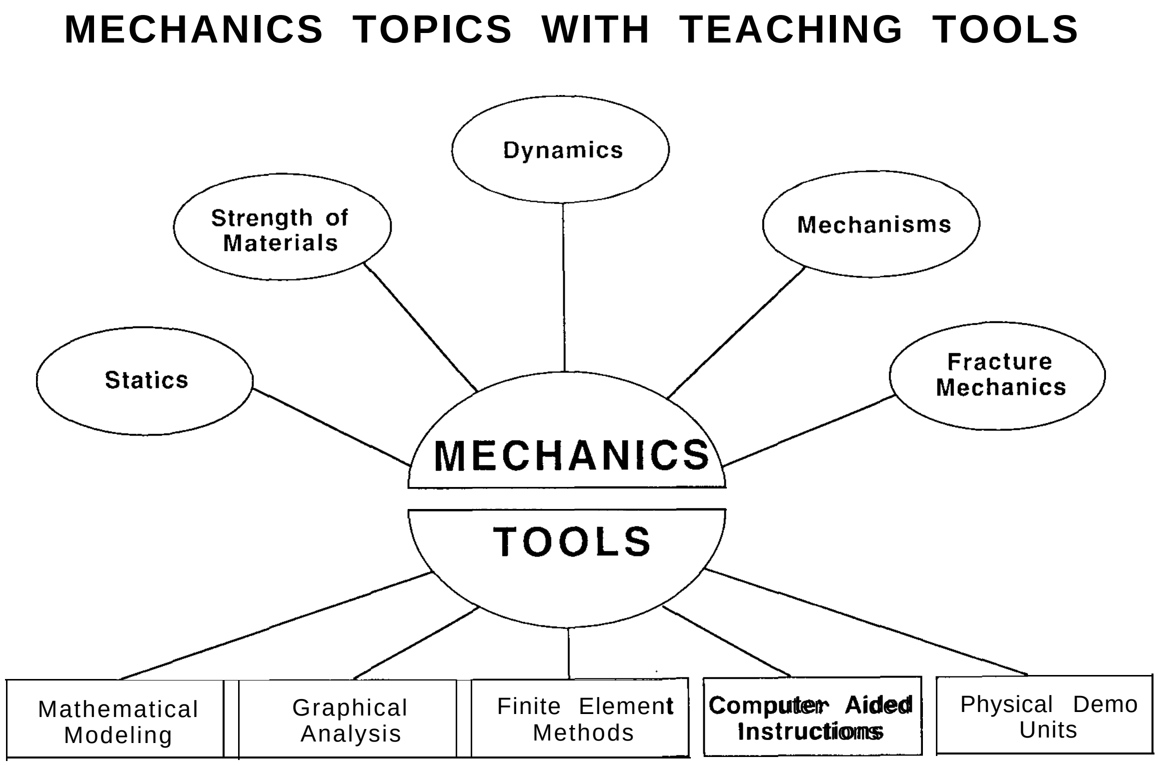

FIGURE 1

Statics is the very first course for students to reemphasize what they learnt in *Physics* and to apply the principle of static equilibrium to simplified problems in Engineering. *Strength of Materials* (also known as *Mechanics of Deformable Bodies) is* a more advanced level course studying stress and strain under various loading conditions and leads to the basic design of simple structural and machine members. *Dynamics* complements *Statics* in its study of the physics of motion; particularly the role of *inertia* forces in the design of moving parts in machinery and structures. *Mechanisms* (more appropriately called *Kinematics and Dynamics of Mechanism*) solely relates to the analysis of various mechanisms (Cams/Gears/4-Bar Linkage, etc.) and teaches the dynamic balancing of forces to avoid or minimize cyclical loading which causes *fatigue* failure. *Fracture Mechanics is* usually a graduate level course but the topic of crack growth leading to fatigue failure are covered, in part, in the *Machine Design* courses.

Teaching Tools

Teaching tools are shown in the bottom part of FIGURE 1 and include the following:

1. Mathematical Modeling
2. Graphical Analysis
3. Finite Element Methods
4. Computer Aided Instructions
5. Physical Demonstration Units

The above mentioned tools do not have to be used in isolation. For example, the results of the mathematical models are often presented in the form of graphical plots. A pure graphical analysis provides a quick approximate answer.

The Finite Element Methods (FEM) have truly grown to be effective as well as user-friendly to provide solutions to both static and dynamic problems. It starts with a solid modeling database which is used for stress analysis and design check. This same database is then further used for manufacturing (NC programming/Rapid Prototyping, etc.).

Computer aided instruction has been with us for a long time as it offers several advantages [4-12]. These high speed solutions have eliminated the tedious hand calculations. "What-if' scenarios are now easy to check with software providing progressive solutions and visualization of motions.

Physical demonstration units are useful tools to visualize concepts associated with some typical problems. They can vary in form and maybe of a throw-away type or one for use in the lab. For example, the strength of a rectangular beam can be demonstrated by tilting the section which provides the larger stiffness (second moment of area) capable of carrying more load with less deflection and stress. The United States Air Force Academy has developed a 2-D *and 3-D Equilibrium Demo Board* to visualize the rigid body equilibrium problems for their Fundamentals of Mechanics course (A combination of Statics and Strength of Materials) [13]. Students learn the effects of geometrical changes (angle, position and length) and load changes (magnitude and point of application) on a rigid body system.

An interesting computer graphics simulation and visualization technique exposes students to the "creative" aspects of engineering by integrating traditional design principles and visual thinking [14]. The success, however, depends on the selection of design problems matching the limited technical knowledge of the participating students.

Design Curricula

FIGURE 2 shows typical mechanics and other courses comprising the typical Design Curricula.

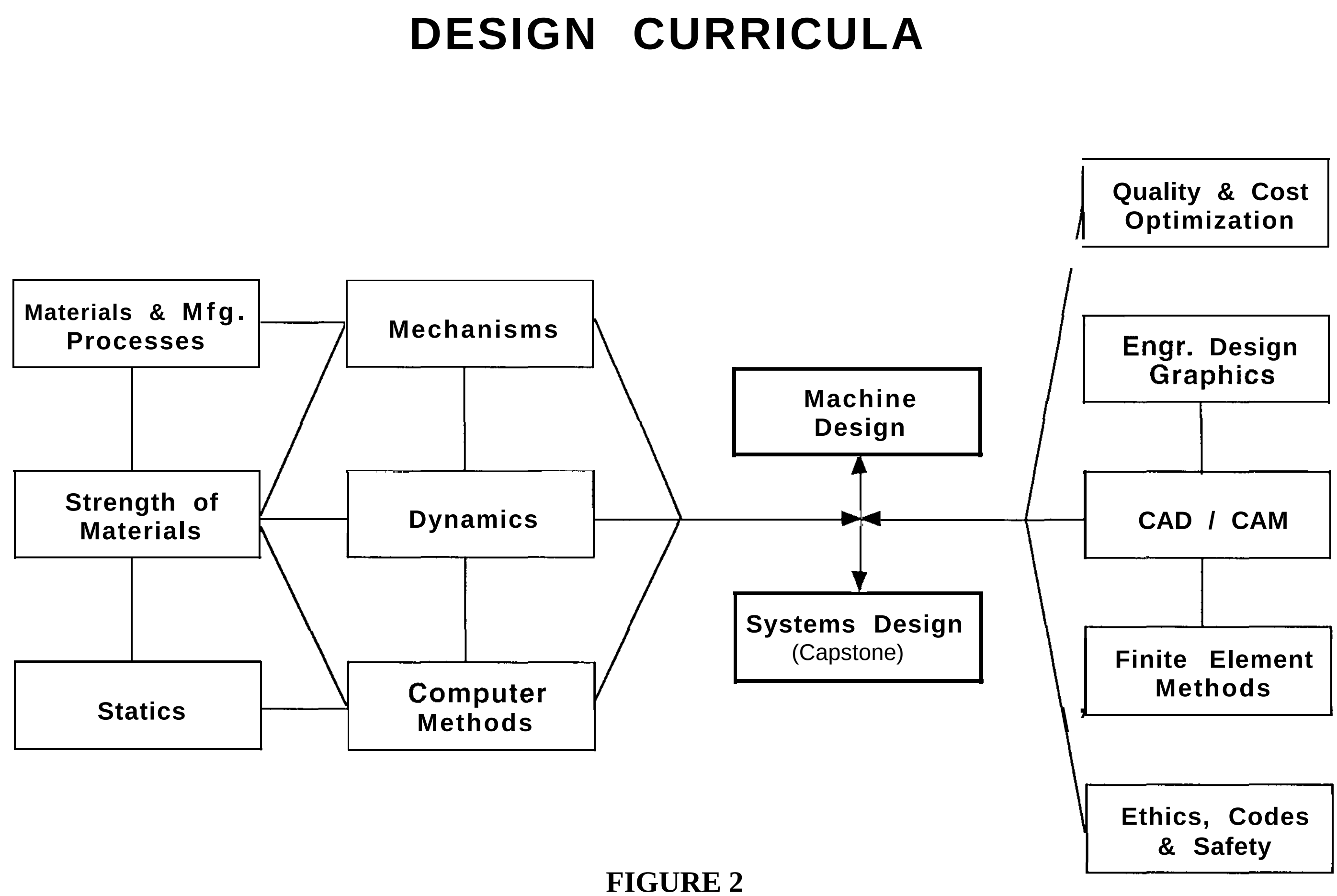

FIGURE 2

Since the students have to perform in a workplace, they must be capable of integrating all information at their command. This realization has renewed interest in curriculum development with emphasis on integration. The professional accreditation bodies are also insisting on an integrated approach. For example, ABET requires that, "The *overall curriculum must provide an integrated educational experience directed toward the development of the ability to apply pertinent knowledge to the identification and solution of practical problems in the designated area of engineering specialization*" [2]. In fact, with reference to Design, ABET requires Design Experience to be integrated throughout the curriculum including lower division courses.

Further analysis of the ABET criteria suggests that the engineering design component of a curriculum must include at least some of the following features:

1. Development of student creativity,
2. Use of open-ended problems,
3. Development and use of design methodology,
4. Formulation of design problem statements and specifications,
5. Consideration of alternative solutions,
6. Feasibility considerations, and
7. Detailed system descriptions.

It is essential to include a variety of realistic constraints such as *economic factors, safety, reliability,* *aesthetics, ethics,* and *social impact.* The above features have been discussed in great detail by Fowler and Bedford [3]. They recognized the excellent opportunities afforded by the open-ended problems for developing and presenting creative solutions by students. According to their observation, many faculty do not use open-ended problems for the following reasons: a) there are multiple correct answers, b) such exercises can be difficult to grade, and c) usually the faculty and not a grader must evaluate the work of the students. Further they made a very pertinent observation -- *Analysis problems do not naturally generate design problems, but each solution of a design problem poses analysis problems.* The author shares the same views and agrees that open-ended problems are helpful for developing design skills of students.

It is evident from FIGURE 2 that mechanics courses form the bulk of the design curricula. In the context of integration, cross-referencing among these courses is very important. Students must have an over-all picture of design every time they embark on an exercise.

Integrated Product Development (IPD)

The *Integrated Product Development* (IPD) process, formally known as *Concurrent Engineering* (CE), helps assure that products are designed, manufactured and delivered to customers with the highest possible first time quality, on schedule and at the lowest possible cost. These are achieved through the use of multi-functional Product Development Teams to identify downstream concerns early in the design process so they can be addressed before they can become problems. FIGURE 3 schematically shows the IPD process. The recognized advantages are: 1) Reduction in lead time to bring forth a new product to the market, 2) Increased market share due to the early introduction of a new product, and 3) A superior product leading to customer satisfaction. The students must be trained to work in a team environment.

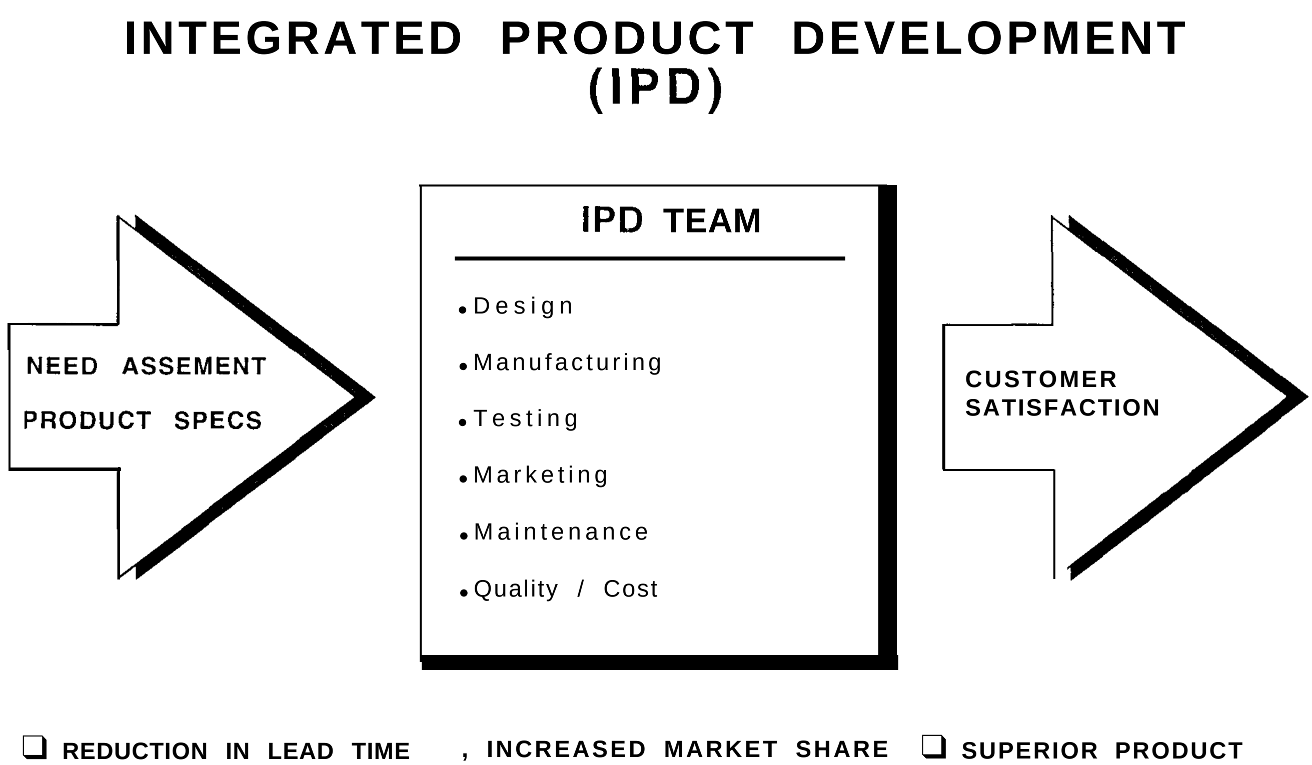

FIGURE 3

Conclusions

The author discussed the mechanics curricula in the context of new and evolving changes in the study and practice of design. In the past, too much attention was paid to solving classical problems resulting in unique solutions within a rigid framework. This approach is now being challenged as the undergraduate curricula are being restructured with an integrated approach utilizing open-ended problems. Recent developments in the field of design teaching, particularly in the mechanics area were examined. The professional design practice is increasingly becoming interdisciplinary with emphasis on a team-approach leading to *Integrated Product Development* (IPD). The IPD approach offers a competitive edge in the global market place in terms of cost, quality, and reduced lead time to bring forth a new product. The students need to be trained to work in a team environment.

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Dr. Mihir K. Das is the Associate Dean for Instruction and Professor of Mechanical Engineering at the California State University, Long Beach (CSULB). He holds a Ph.D. in Mechanical Engineering from the Birmingham University, England. He has published extensively with over 80 papers and several patents to his credit. His current interests are New *Academic Programs, Teaching and Learning Innovations,* and *Total Quality Management* (TQM). Dr. Das also directs the EPSI *(Engineering Problem-Solving Initiative)* program at CSULB, designed to improve student learning through industry defined real-life problem solving.