AC 2001-244: The Development of a Combined Materials/Manufacturing Processes Course at Texas A&M University

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Abstract

Mechanical Engineering at Texas A&M University is reducing the required number of undergraduate degree credit hours from 138 to 130 or 132 credit hours. Two long-standing courses, Properties of Materials (4 credit hours) and Manufacturing Processes (3 credit hours), will become one new junior level course (4 credit hours). Both of the predecessor courses had laboratory components as will the new course. This paper describes the process used to develop the course. An outline of the topics covered and the laboratory activities are included in the paper. One thrust of the laboratory portion of the course will allow students to make choices and to plan their laboratory activity rather than following a cookbook recipe for the activity. The paper provides and discusses several examples of this.

Introduction

In an effort to reduce the number of credit hours in mechanical engineering at Texas A&M University, two long-standing courses are to be combined into one new course. The original courses were "Properties of Materials" (4 credits) and "Manufacturing Processes" (3 credits). Both courses had laboratory activities associated with them. The new course is entitled "Materials and Manufacturing in Design," and will be 4-credits including laboratory activities. The faculty thought it possible to combine these courses into one semester and still provide the students a useful background in the properties of materials and in manufacturing processes within a design context. This is possible because of the skills of the undergraduates who spend their first two years within the Foundation Coalition curriculum.[1]

Process

The College of Engineering at A&M has undergone an extensive restructuring of the freshmen and sophomore years during the past 6 years.[1, 2, 3] These changes have improved the skill base of the juniors. The most recent NSF program at Texas A&M University, Foundation Coalition, provided a substantial change in the way faculty teach. Instead of lecturing at students for a class period, the faculty use collaborative learning. The classrooms are places where the students are actively involved in the learning process. As part of the development, several classrooms were made more useful for collaborative learning. Computers installed in the classrooms are available for the students and faculty to use during class. In each of the classrooms a console for the instructors contains a computer, document camera, and VCR. The instructors can combine materials from each source with the teaming assignments. These freshman and sophomore year programs have prepared the junior-level students to continue their education in an active technology enhanced manner.

Another development from the Foundation Coalition was the creation of a sophomore-year engineering-science program. As a result, the prerequisite class, Engineering 213, has undergone substantial changes over its predecessor. Engineering 213 includes information on phase diagrams and strengthening mechanisms, and it has several in-class laboratory activities. Some of the laboratories were presented at previous conferences.[4, 5] Collectively, these factors add up to an opportunity to make significant changes in the way the material and the topics are presented.

New Course Objectives

The new junior level course must combine materials and processing subject matter with a design approach where case studies focus students on the importance of the course content. Accomplishing this requires meeting these objectives:

- combine essential elements of materials and manufacturing processes curricula from two existing courses
- use a design approach in planning the course
- apply case studies to help students connect the diverse subject matter, e.g. photonic materials, nanomaterials, smart materials, and biomimetics, semiconductors, Kevlar fibers to specific designs
- use active learning, teaming, technology, and integration
- integrate software as a systematic approach: solids modeling plus material and process selector plus manufacturing simulation tool plus rapid prototyping
- develop a variety of laboratory activities that relate materials and manufacturing
- allow students choice in the various laboratory activities within a reasonable and safe range

Lecture Topics

From a pedagogical viewpoint, our opinion was that we could combine the courses and satisfy the objectives by covering fewer topics and relating the discussion of materials to relevant manufacturing processes. For example, if you examine Table 1, you can see that lectures on steel include processing by forging, rolling, and sheet metal formation in the discussion. Similarly, discussion of Al alloys includes metal casting and thermal processing. It will not be possible to cover all types of materials and processes in the same detail found in two semesters of coursework. However, we anticipate the material covered by this method will supply the basis for individual learning as the need arises. From the prerequisite course, the students have an understanding of phase diagrams, strengthening mechanisms, and mechanical properties. In addition, they have performed several laboratory activities either within the classroom or in a laboratory.[6] The students also come to this new class with an extensive background in teaming and collaborative learning; and one of goals is to use this expertise the students have to aid in the learning process.

Table 1. The proposed topics for MEEN 360; a 4-credit (3-3) course.

Weeks	Materials	Manufacturing Processes
3	Mechanical Properties	
	Fracture Mechanics	
	(Fatigue)	Cambridge Engineering Selector (CES)- Introduction
	(Creep)	
	Failure	
	Ductile/Brittle	
	Surfaces: hardening, tolerances	Surface Treatments
4	Metals: Steel, Al	Properties and Design
	Types of Steels	Forging, rolling, sheet metal deformation
	Transformation kinetics	
	Quenching and tempering	
	Stainless Steels	
	Cast Iron	Casting
	Precipitation Hardening: 6061	Machining
	Wrought: 5000 series	Effect of Processing On Properties
	Plastics and Polymer Composites	Pultrusion
	Semicrystalline, amorphous, thermosets, elastomers, polymeric composites	RIM
4	Tg,Tm, Mn, Mw-morphology	Lay-ups
	Viscoelastic deformation and superposition	Filament winding
	Time-Temp superposition	
	Characterization and properties	
	Reinforcements: continuous and chopped	
1	Electronic Materials	Semiconductor fabrication
1	EXAMS	
1	Case Study- with industry	
14	**Total**	

Laboratory Activities

Laboratory activities are an important component in the proposed course. Table 2 lists the laboratory activities in the original courses. There is no way to include all of them in one course. More importantly, the previous courses had carefully preplanned laboratory activities that provided little room or time for student input. The laboratories always worked, because the faculty had orchestrated the activities to be useful for demonstrating principles. After many years of teaching a materials laboratory, we believe that this method may not be in the student's best interest. By the junior year, students must begin to gain the independence and judgement they need to make decisions in the workplace. To build this independence and judgement, students must make choices. They need the skills required to search resources and assemble data. For example, previously the laboratory manual provided students with times and temperatures for precipitation hardening the particular alloy being tested. Carefully chosen, those times and temperatures assured that the experiment worked and that the precipitation hardening process occurred just as discussed in lecture. Now, this is not necessarily bad, but it does not require the kind of student input that would enhance their learning.

The laboratory activities proposed for the new course and listed in Table 3 would remedy this situation. The experiments require that students have choices to make in the laboratory activities before they can be conducted. For example, in the above precipitation hardening experiment, the students will have to go to handbooks and select the times and temperatures for their alloys. While the outcome may not be as perfect as before, students' results (effect) will be directly connected to their choices (cause).

Another feature of the new laboratories will directly connect processing and properties. The experiment listed in Table 3 by weeks 3 and 4 will require the students make injection molded thermoplastic tensile specimens one week and then the following week evaluate the mechanical properties of the specimens (perhaps a tensile test). Computer tools and rapid prototyping strengthen the processing/property connection. Rapid prototyping by selective laser sintering (SLS) will provide several levels of comparison of material, design, processing and properties issues. First, the SLS model provides a verification of the solid model that the students design on the personal computer. That physical model is a real component with low strength since it is a sintered polymer part. The verified solid design leads to the fabrication of two parts by casting and by machining. Using the virtual part, students design a mold and core set for the casting laboratory. The SLS machine makes the sand mold and core and the student team casts the part. Finally, toolpaths generated from the virtual part guide a 3-axis CNC system to cut the same design in stock metal. Mechanical tests of the three parts will demonstrate the effect of processing on properties and the failure mode of one part executed in each material.

Conclusion

A combined materials/manufacturing processes course is in development at Texas A&M University. The course builds on the previous sophomore engineering materials course and will use the teaming and active learning methods from the Foundation Coalition curriculum to promote student learning. The combined course attempts to build on the synergy inherent in the material/processing/property relationship. The laboratory portion of the course builds student input into the actual running of experiments. While fewer experiments may be run, the hope is that more learning will take place as the student see the connection between their choices and their results.

Table 2. Laboratory activities used for prior courses.

MEEN 340, Materials Course	**MEEN 310, Manufacturing Processes Course**
1. Tensile Test	1. Casting
2. Hardness	2. NDE
3. Fatigue	3. Rolling – Separation force
4. Charpy Impact	4. Forging – Upset Disk
5. Cold Work & Annealing	5. Polymer Extrusion
6. Metallography	6. Polymer (Injection Mold)
7. Age hardening	7. Lathe
8. Polymer Properties Tensile test, strain rate effects	8. Milling
9. Metallography	9. Composite Manufacturing Lay-up, autoclave, testing
10. Heat Treatment	10. Welding – Actual Weld
11. Creep	
12. Corrosion	

Table 3. Proposed new laboratory activities for the new combined course.

Weeks	**Experiment**
Wk 1	Introduction to Measurements
Wk 2 & 3	Machining (Lathe + Milling Machine)
Wk 4 & 5	Injection Molding & Mechanical Properties
Wk 6 &	7 Rapid Prototyping, Metal Casting + Tensile Test & Metallography
Wk 8 & 9	Cold Rolling vs. *Conventional Extrusion vs. ECAE* & Annealing
Wk 10& 11	Age Hardening (Al) + Heat Treatment (Steel) Fatigue, Impact & Hardness
Wk 12	NDE/Welding/Joining
Wk 13	Material Selection (CES)

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[1] Malave, C.,"Teaming in the Integrated Curriculum of the Foundation Coalition at Texas A&M," ASEE National Conference, Washington, D.C., June 1996.
[2] Malave, C.,"Teaming in the Integrated Curriculum of the Foundation Coalition at Texas A&M," ASEE National Conference, Washington, D.C., June 1996.
[3] Griffin, R. B., Everett, L., and Lagoudas, D., "Development of a Sophomore Year Engineering Program at Texas A&M University," FIE, Pittsburgh, PA, Nov. 1997.
[4] Griffin, R. B., Cornwell, L. R., Yapura, C., Krishnan, S., and Hallford, J., "Use of a Four-Point Bend Apparatus to Determine the Modulus of Elasticity," National Educators Workshop Update 98, Brookhaven, NY, 1-4 November, 1998.
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