Session 1463

INDUSTRY-UNIVERSITY PARTNERSHIPS IN MECHANICAL AND MANUFATURING ENGINEERING AT TUFTS UNIVERSITY

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Abstract

The Department of Mechanical Engineering at Tufts University has a long history of industry-university partnerships. Up until the late 1960's, these interactions focused on education programs such as apprenticeships leading to associates degrees. Growing emphasis on government-sponsored research and full-time undergraduate study directly after high school reduced the organization and substance of industrial interactions during the 1970's and the early 1980's. This paradigm began to change around 1985 and new partnerships have continued to expand to this day. One major influence that stimulated this reengagement was the growth and integration of manufacturing engineering within the mechanical engineering curriculum, instigated by renewed industrial interest in sponsoring employees for continuing education to keep current with changing technology. The need for practical relevancy led to the establishment of our Industrial Advisory Council with members from several companies and the US government. New programs emerged such as the Certificate Program in Manufacturing Engineering and a part-time Masters of Engineering degree program with a project focus. Other collaborative activities include joint responsibility for the Annual Thermal Manufacturing Workshop, industrial sponsorship of senior design projects and providing outside feedback as part of our ABET EC2000 continuous improvement process. The current level of collaboration is good but can be improved. For a university in which most of the students attend classes full-time during the day, meeting the needs of the students from industry and part-time students requires not only additional commitment of resources but also fundamental infrastructure changes. Finally, on the research side, the differing time scales and priorities of academe and industry always pose a challenge.

Background And Current Status

The Department of Mechanical Engineering at Tufts University has a long history of industry-university partnership. Up until the mid-1960's, companies such as General Electric had apprentice programs in which the students worked full-time during the day and took classes in the evenings and on Saturdays at Tufts University. The students were typically from middle-class backgrounds with good hands-on skills. They had an acquired intuition about how products worked and how they were manufactured but lacked a strong analytical knowledge base. The post-Sputnik engineering science "revolution" that fostered a focus on science over application led to a period of increased emphasis on government sponsorship of engineering science research. The apprentice programs were discontinued and many of the hands-on laboratories of the "old" curriculum were replaced with applied science and mathematics courses. Industry connections with Tufts became less organized. Undergraduate admission decisions relied more heavily on standardized tests such as the SAT. Tufts, as many other private universities, centered its student recruitment on full-time students coming directly out of high school. Further, engineering graduate students, especially those from the United States, typically entered graduate studies with little practical experience. This led to a dramatic change in the demographics / socio-economic background of the student population.

The decline in the competitive advantage of the United States in the areas of manufactured goods and product quality in the early 1980's triggered a call for revamping of engineering education with a re-emergence of the industry-university linkages. Our experience at Tufts is a microcosm of the transition across the country. The challenge of the recent evolution was and is to develop symbiotic relationships that are quite distinct from the government research grant model at one extreme to product development consultation at the other.

Four overlapping areas characterize current interactions at Tufts. First, the development, growth and integration of manufacturing engineering within the mechanical engineering curriculum instigated a renewed industrial interest in sponsoring employee-students to take courses and keep current with changing technology. In 1988, Tufts University started the post-baccalaureate Certificate Programs. Presently there are nine programs in areas such as manufacturing engineering, biotechnology, microwave and wireless engineering, etc. In order to get a Certificate, a student typically has to take four or five courses. These courses are typically more applied in nature, focusing on process and production topics. Within the Department of Mechanical Engineering, most part-time, post-baccalaureate students start in the Certificate Program in Manufacturing Engineering (see Table 1). Many of these students continue on for their Master's degree as all the courses taken as part of the Certificate program can be used to satisfy the requirements for the graduate degree. The certificate program is open to students with a bachelor's degree and a background in engineering, science, or mathematics. The program is especially useful to professionals who want to enhance their understanding of quality, manufacturing processes, automation, CAD and controls. The core certificate courses are taught in the evenings, often once or twice per week. The courses are taught by either full-time faculty or outside lecturers if the topic is specialized (e.g. Injection Molding). The student population is a mix of senior undergraduates, full-time graduate students and part-time graduate students. This mix provides a fertile learning environment for these courses because the various groups complement each other with the students from industry bringing practical problems to the classroom.

Presently, half of our graduate students are part-time students (numbering approximately 30 at this time) who work full-time in industry and/or government. In 1998, we instituted a project-based Masters of Engineering (MEng) as an alternative to the traditional research thesis-based MS as a vehicle for this part-time population. This degree program is more structured in its coursework requirements, emphasizing technical breadth to enhance the student's knowledge basis, and a project, that is not constrained by a requirement to include publishable, research quality outcomes. We encourage MEng students to use current challenges in their workplace as the basis for their project.

The success of part-time programs at Tufts is based on a strategic decision to emphasize quality and personal mentorship rather than volume. The principal consumer population is local companies within a reasonable commuting distance to the campus. The school's suburban location has some advantage over more densely populated urban schools. A representative sample includes PRI Automation, Gillette, Teradyne, Foster Miller, C.S. Baird and Raytheon. A special relationship has been developed with GE Aircraft Engines (GEAE). GEAE is one of the largest employers of Mechanical / Manufacturing Engineers locally. Engineers (typically with a BSME), who participate in GEAE's internal "A-course" program, are admitted to our masters programs (either MS or MEng) with credit for 2 of the 10 course credits required. Typically, MEng projects count for 1 course credit while MS projects vary from 2-3 course credits depending upon work scope (see Table 2). The GEAE-Tufts partnership is also interesting from an historical perspective given that General Electric was the largest participant in the old apprentice program.

The second interaction arena is our Industrial Advisory Council (IAC) with members from several companies and the US government. This group was convened in the early 1990's to advise our manufacturing engineering activities, especially those related to Tufts' focus in Thermal Manufacturing. The mission of Thermal Manufacturing activities is to "develop a critical mass of faculty in the department working and collaborating on manufacturing problems, which are recognized to be important to industry. The focus of the fundamental research will be 'thermal manufacturing' area where materials are 'transformed' by the application of thermal and mechanical energy to other states and geometry's whereby the end product and properties are dependent on process parameters and fundamental phenomena, which occur during processing. Thus, this area is characterized by fundamental research relating to materials structure, materials' characterization (such as constitutive behavior), applied mechanics (both solid and thermal-fluids), computational modeling of processes, process control and sensing, and product design." Details about the Thermal Manufacturing program can be found at [1].

In 1999, the department decided to use the new ABET EC2000 criteria for accreditation of the BSME program. Accordingly, it is required that the BSME program constituencies not only include faculty, students, staff and administrators but also alumni and industrial advisors. The role of IAC was then expanded to include advising the department across all programs, participating in our ABET EC2000 continuous improvement process, and helping organize and execute other outreach activities. Current members of IAC are from government and small and large industries such as the US Army Research Laboratory, GE Aircraft Engines, Lucent Technologies, Corning-Lasertron and Cambridge Applied Systems.

These outreach activities define the third and fourth areas of university-industry collaboration - co-organizing our annual Thermal Manufacturing Workshop and sponsorship of design projects. As part of the outreach activities and in order to involve the local engineering communities, Tufts University started hosting the Annual Thermal Manufacturing Workshop. The Fifth Thermal Manufacturing Workshop was hosted on June 21, 2001. The goals of the workshop are to "highlight relevant problems in the manufacturing arena; to provide opportunities for collaboration among engineers and academics through student projects; and to offer practicing engineers a means to stay current in this constantly changing field. The workshop structure is designed to provide a more fluid and productive atmosphere than the typical technical society meeting. Everyone participates in all activities. There are no parallel sessions and ample time is scheduled for discussion and brainstorming." In order to emphasize 'relevant problems' each session of the workshop is jointly organized by a faculty member and a member from the IAC. It now boasts participation by 30-40 engineers from outside of Tufts representing 20-30 companies. It is recognized as an important forum for exploring areas of future collaborations. Table 3 lists the sessions organized as part of the most recent workshop.

Besides presenting state-of-the-art on a given technology, one of the main goals of the workshop is to present the challenges and issues that need to be addressed. For example, at the June 2000 workshop one of the sessions dealt with 'Clean Dry-Coating Technology for ID Chrome Replacement.' Beside talking about the technology, the speaker presented the following problem: Since coating structure depends on geometry, can we coat a flat or sample outside tube under same gun parameters as would coat ID – or do we have to simulate the in-tube conditions [2]? These types of problems / issues have led to several MS and Ph.D. theses that have their roots in this workshop series. Finally, all of the above activities have led of new and focused collaboration with industry on various projects. Nearly three-quarters of our seniors design projects now involve industry sponsors (compared to less than 10% five years ago), who provide a combination of direct support, in-kind support and mentorship. Recently sponsored senior design projects include surgical robotic fixturing (Brock Rogers), biomedical product prototyping (Nova Biomedical), electronics thermal management (Sun Microsystems), in-situ process measurement system for chemical mechanical planarization (Intel and Cabot Microelectronic Corps.), semiconductor manufacturing automation systems and fixturing (Brooks Automation, PRI Automation), and test fixtures for in-flight microgravity experiments (NASA).

Future Directions

During the past few years, most of the growth in the graduate program in the Mechanical Engineering has been due to part-time students and students enrolled in the Master of Engineering program. We see this trend continuing in the foreseeable future. The current level of collaboration is good but can be improved. The strategic questions revolve around balancing the core, traditional full-time engineering programs and these new directions. In particular for a modest size, private university like Tufts, in which most of the students attend classes full-time during the weekday, meeting the needs of the students from industry needs additional commitments related to teaching and one-on-one advising. Tufts University's successful Master of Science in Engineering Management program (Gordon Institute) is based on the various Executive programs around the country where most of the students work full-time in industry and take courses on Fridays and Saturdays. Perhaps, the MEng program will experiment with such a structure. On the research side, the differing time scales and the priorities of academe and industry always pose a continuing challenge. It is very important to define the scope of the project upfront and have a mentor from the industry on joint university-industry projects. In addition, for the industry-university collaboration to succeed, the project should satisfy a specific industry need, should not be proprietary and should not be a short-term 'fire-fighting' project. Similar criteria have been developed and reported in the literature by others [3].

Conclusions

The demographics / socio-economic background of the student population is constantly changing. At Tufts, most of the growth in the graduate program in the Mechanical Engineering has been due to increase in enrollment of part-time students. Industry Advisory Councils can and should be used to develop stronger industry-university collaborations and as a source of 'relevant' undergraduate and graduate projects.

Bibliography

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Table 1 – Requirements for Certificate in Manufacturing Engineering

Required Courses (2)	Manufacturing Processes Robotics or Automation
Elective Courses (2)	Statistical Quality Control Finite Element Methods in Engineering Analysis Computer Integrated Engineering Composites Materials Biomaterials Manufacturing Process Automation Computer Control Systems Thermal Manufacturing Processes

Table 2 – Requirements for MS and MEng Degrees in Mechanical Engineering

MS Degree	
Required Course (1)	Numerical Methods or Advanced Math. for Engineers
Core Courses (2) (Should be from different categories)	Advanced: Strength of Materials or Vibrations or Dynamics Manufacturing Processes or Computer Control Systems or Electromechanical Systems Design Advanced: Heat Transfer or Thermodynamics or Fluid Mechanics or Mass Transfer
Electives (4-5)	
Thesis (2-3)	
MEng Degree	
Required Course (1)	Numerical Methods or Advanced Math. for Engineers
Core Courses (4)	One course each in the area of: Applied Mechanics Materials and Manufacturing Processes System Control and Design Thermal-Fluid Sciences
Electives (4)	
Project (1)	

Table 3 – Fifth Thermal Manufacturing Engineering Workshop – June 2001

Keynote Talk		
Needs and Benefits of Modeling in Thermal Processes	J. Williams	Ohio State
Session 1 - Thermal Manufacturing Process Simulation	A. Saigal J. Wessels	Tufts GEAE
Utilization of Thermal Manufacturing Process FEA Tools in GE Aircraft Engines	J. Wessels	GEAE
Accelerated Insertion of Forged Disk Superalloys	D. Backman	GEAE
Flow Localization in Airfoil Extrusion Processes & Associated FEA Modeling	A. Majorell	GEAE
Status and Future Directions for Forming Software Development	D. Lambert J. Walters A. Samant Y. Ying	Scientific Forming Technology
Mesh Modification Procedure for Evolving Discretizations	M. Shephard J. Wan & X. Li	RPI
Five Decades of Forging Designs, Dies, Preforms, Process Parameters with Cases of Modeling and Simulation and a Look Ahead	C. Gure	Wyman-Gordon
Session 2–Ongoing Industry-Tufts Collaborations		
On-Going Project Updates (Ion-Beam Surface Processing, CMP)	V. DiFilippo A.Scarfo	Tufts Tufts
Final Projects of the Tufts-Rensselaer Thermal Manufacturing Program	V. Manno R. Smith	Tufts RPI
Review of Sponsored Student Design Projects	J. O'Leary	Tufts
Session 3 – Modeling Thermal Spray & Deposition Coatings	R. Adler C. Doumanidis	ARL Tufts
Real-Time Control for Plasma Deposition	M. Gevelber D Wroblewski J. Fincke W. Swank	BU BU INEEL INEEL
Hard Chrome Alternatives Team - Tri-Service Validation of HVOF Thermal Spray as a Chrome Replacement for Aircraft	J. Sauer K. Legg B. Sartwell	Sauer Engg. Rowan NRL
Rapid Thermal Oxidation of Semiconductors: A Case Study	T. Zeng A. Shajii	Axcelis Technologies
In-Situ Processing of Nickel Aluminide Coatings on Steel Substrates	R. Ranganathan T. Ando O. Vayena C. Blue	NEU NEU Tufts ORNL