Back to the Future Manufacturing Engineering at Stout

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Abstract

Manufacturing engineering education at the University of Wisconsin-Stout has gone back to the future. Today's undergraduate manufacturing engineering program utilizes laboratory- and industrial project-based instruction throughout the professional component of the curriculum. The century old Stout tradition of hands-on, minds-on instruction emphasizes engineering and industrial applications balanced with a strong basis of engineering sciences. In today's global marketplace, manufacturers wishing to remain competitive must employ pragmatic engineers with a solid foundation in the engineering sciences, engineering practice, and industrial applications. Stout's newly accredited undergraduate manufacturing engineering program develops these pragmatic engineers in an environment rich in applications and engineering science. In addition to the extensive lab-based methods, real undergraduate industrial projects are funneled to the program through an outstanding technology transfer outreach program. This paper presents the past and present environment that has created this back to the future manufacturing engineering program. Both the methods in which the laboratory based learning environment is utilized and the industrial partnerships that create project opportunities will be presented in this paper. Laboratory innovation and development along with real industrial projects are the keys to the current manufacturing engineering program's success.

UW-Stout's Rich History

James Huff Stout, lumber baron, civic leader, and state legislator, founded the Stout Manual Training Schools in 1891. These original training schools were merged into the Stout Institute in 1908. The institute was designed to "*provide facilities in the way of buildings, equipment, and teachers, through which young people of both sexes may secure such instruction and training in industrial and related lines of educational effort as will enable them to become efficient industrial, social, and economic units within their environment*." Engraved in the arch over the entry to Bowman Hall are the words "Industry, Skill, Trade, and Honor." The original mission of the Stout Institute and these four core values are still practiced in this unique University of Wisconsin Institution. The University of Wisconsin-Stout, the only system institution bearing an individuals name, serves a unique role within the state of Wisconsin. UW-Stout prepares individuals for professional careers in business, industry, and education. James Huff Stout believed every individual was entitled to an education, and the manual training schools were developed with the intent to actively train individuals in the manual arts and domestic sciences, thereby allowing individuals to succeed and prosper in society.

Today, UW-Stout calls this approach "hands-on, minds-on," and this applied philosophy is practiced in all of its thirty-six undergraduate and twenty-six graduate programs. While this philosophy is not a unique method of education, Stout has not wavered in this methodology since the institution came into being under the direction of James Huff Stout. The "hands-on, minds-on" philosophy of undergraduate education is unique in the field of engineering education. This is truly a back to the future approach to engineering education.

The Manufacturing Engineering Program

In August 1994, a new and unique program within the University of Wisconsin System began at UW-Stout. This ABET accredited program is fulfilling the needs of regional as well as national manufacturers in their quest to maintain competitiveness in today's global marketplace. The mission of the undergraduate manufacturing engineering program at UW-Stout is to "*prepare pragmatic manufacturing engineers who will respond aggressively to the changing needs of the global marketplace, apply research and theory in the development of marketable products and efficient processes, and design with an awareness of the realities of manufacturing and the needs of society. This preparation is enhanced through extensive hands-on laboratory learning experiences*." Pragmatic, as defined by Merriam-Webster[1], is in the practical sense, or "*being disposed to action as opposed to speculation or abstraction*." Pragmatic also encompasses several other definitions of practical: "*qualified by practice or practical training, designed to supplement theoretical training by experience*," and "*concerned with voluntary action and ethical decisions*."

UW-Stout's manufacturing engineering program is referred to as a back to the future approach to engineering education for several reasons. First, engineering education of the late 1800's utilized a laboratory approach that was focused on the study of fundamental principles[2]. This laboratory approach was not just laboratory demonstrations, but truly hands-on application in the understanding of the principles. UW-Stout's manufacturing engineering program incorporates this same hands-on application throughout the curriculum. Most courses within the curriculum's professional studies area have lab-based instruction ranging from lab experimentation, in the application of engineering science and theory, to the self-directed individual or team projects, in the extensive utilization of the lab equipment by the undergraduates. Second, the curriculum at UW-Stout incorporates real industrial applications in the lab settings. The incorporation of real industrial techniques mirrors the development in engineering education during the time period between World War I and World War II[2]. Third, the curriculum includes a strong study of the engineering sciences as evidenced by the core engineering concepts of analytic reasoning, physics based mechanics and thermodynamics, and chemistry based materials science. This basis of the study of engineering science has a strong footing in the evolution of engineering education after World War II and during the space race[2]. Finally, the UW-Stout curriculum builds a technical toolbox that emphasizes engineering practice in industrial applications, thereby allowing the graduates to maintain manufacturers' competitiveness in today's global marketplace. Again, this emphasis is supportive of the current shift in engineering education as described by Grayson[2] in *The Making of an Engineer*.

The manufacturing engineering curriculum is structured around the creation of a student's technical toolbox. This technical toolbox supports the four professional components required for undergraduate manufacturing engineering ABET accreditation. The four professional studies components are: *materials and manufacturing processes*; *process, assembly, and product engineering*; *manufacturing competitiveness*; and *manufacturing integration methods and systems design*. In addition to meeting accreditation requirements, this extensive technical toolbox prepares the manufacturing engineers to fulfill the roles of the 21st century manufacturing engineer[3]. The three roles are: *technical specialist*, *manufacturing strategist*, and *operations integrator*. The following lists define the individual courses within the professional studies curriculum and the associated credit hours.

Materials and Manufacturing Processes
- Material Removal Processes (3)
- Polymer Processes (3)
- Casting, Ceramics, & Powder Metal Processes (3)
- Bulk/Sheet Forming Processes (3)
- Joining and Fastening (4)
- Coating, Finishing, and Packaging (3)

Manufacturing Competitiveness
- Production & Operations Management (3)
- Engineering Economy (2)
- Quality Engineering (3)
- Facilities & Material Handling Systems Design (2)
- Principles of Occupational Safety & Loss (2)

Process, Assembly, and Product Engineering
- Engineering Drawing (5)
- Design of Jigs, Fixtures, & Tooling (3)
- Capstone I: Product Design (3)

Manufacturing Integration Methods and System Design
- Computer Aided Manufacturing (3)
- Controls & Instrumentation (4)
- Fluid Mechanics (2)
- Flexible Manufacturing Systems (4)
- Design & Simulation of Manufacturing Systems (3)
- Capstone II: Manufacturing System Design (3)

As can be imagined when examining this list of technical topics, there is a diversified group of faculty required to teach such a program. Backgrounds vary from many different engineering disciplines including mechanical engineering, materials science engineering, electrical engineering, and industrial engineering. The common thread within the faculty is a distinct array of manufacturing experiences. These experiences allow for the integration of current industrial applications into the technical topics. Faculty supports the “hands-on, minds-on” philosophy within the curriculum.

There is an extensive array of physical laboratory space and associated equipment required to support this manufacturing engineering program as well. The fifteen laboratories have over 35,000 square feet of dedicated lab space utilized. The individual lab facilities are:

- Metal Casting
- Joining and Fastening
- Plastics Processing
- Material Removal
- Flexible Manufacturing
- Robotics
- Computer Integrated Manufacturing
- Materials Testing
- Metrology
- Sheet Metal Forming
- Ceramics/Powder Metallurgy
- Computer Aided Design
- Electronics

- Control and Instrumentation
- Fluid Mechanics

Within these extensive laboratory facilities, there are many dedicated pieces of high-end manufacturing equipment, specifically utilized within the undergraduate manufacturing engineering program. Much of this equipment was purchased as a result of a $13 million capital campaign. Most of the above listed lab facilities are within Fryklund Hall, remodeled for $5.6 million in 1993.

A final activity in support of the manufacturing engineering program is its association with the Northwest Wisconsin Manufacturing Outreach Center (NWMOC). This federally funded Manufacturing Extension Partnership (MEP) is mandated to provide technology transfer to manufacturers allowing them to prosper and contribute to economic development within the region. Projects are often filtered through the NWMOC to the manufacturing engineering program as part of their MEP efforts. Many of these projects lend themselves to capstone manufacturing system design or facilities layout team-based projects.

As outlined, the program practices the "hands-on, minds-on" philosophy for manufacturing engineering education. Guided by a visionary industrial advisory committee, the program incorporates real industrial projects into the curriculum in support of the development of the in-depth technical toolbox. There is an extensive array of laboratory facilities and high-end manufacturing equipment required to maintain this approach to manufacturing engineering education.

Developing Pragmatic Manufacturing Engineers

It takes a wide array of activities to develop a pragmatic manufacturing engineer, or one that is well rounded in their abilities to fulfill the different manufacturing engineer roles of the 21st century. UW-Stout's undergraduate manufacturing engineering program utilizes extensive lab-based instruction, two capstone experiences, and industry sponsored projects to develop pragmatic engineers. These engineers, as supported by follow-up comments from employers, hit the ground running, are qualified with practical experience, are disposed to action, and do not need to be retrained.

Extensive Lab-Based Instruction

As previously described, there is extensive depth in technical topics throughout the professional component area of the curriculum. This technical depth is developed through a variety of methods, most of which is lab-based. Several lab activities will be described for a clear definition of what truly is "hands-on." The following lab activities will be described: powder compaction and sintering of ceramics; machining force measurement and process control; extrusion metal flow analysis; and weld failure and analysis.

As part of the course *Metal Casting, Ceramics & Powder Metal Processes*, a lab project dealing with powder compaction and sintering of ceramics is performed. Student teams on a two-week rotation basis do this project. The density and porosity of green aluminum oxide pellets, pressed from powders using a hydraulic press and a set of dies and punches, are measured as a function of the compaction pressure. The threshold pressure to achieve a constant density is identified, and additional samples are pressed at this pressure for subsequent sintering at different temperatures and times. The project goal is to understand the influence of key process variables (pressure, temperature, and time) on the kinetics of densification during part manufacture by powder metallurgy. These technical inferences are determined through experiment and analysis of the data generated.

As part of the course *Material Removal Processes*, machining forces are measured either in drilling, milling or turning. The machining forces are measured through the use of a Kistler force dynamometer. Process variables are determined by developing a theoretical understanding of the material removal process. Student groups develop the statistically designed experimental setup and execute the experiment, utilizing a data acquisition program to capture the machining forces. Technical inferences are made in analyzing the data to determine key process control variables and in verifying the theoretical power consumption values for different material types.

As part of the course *Bulk & Sheet Forming Processes*, a lab experiment is utilized to validate metal flow characteristics in an extrusion process. Originally developed by Professor Marvin DeVries at the University of Wisconsin-Madison, the experiment uses lead as the extrusion metal. The extrusion product is easily split in half lengthwise to analyze the metal flow characteristics, validating theoretical metal flow models. The extrusion force is also compared to predicted force values for the extrusion process as well.

As a part of the course *Joining and Fastening*, welding projects are taken to failure and analyzed for root cause. Students individually create welded samples and machine them into a tensile coupon. These samples are taken to failure utilizing a tensile tester. Upon failure, students are required to analyze the weld failure for root cause. In addition, the theoretical force the weld could actually carry is compared to the actual load value.

The above described lab activities, as well as many others too numerous to mention here, develop an extensive technical toolbox for students in Stout's manufacturing engineering program. The "hands-on, minds-on" philosophy necessitates in-depth lab activities that go well beyond the typical lab demonstration methodologies. Students in Stout's engineering program often set up the equipment themselves, determining appropriate process settings, and then perform much of the lab activity as well. In addition, an extensive comparative analysis is performed with theoretical values to actual values. The tying of theoretical to actual values is an essential element in today's engineering curricula. The determination of industrial process settings along with actually performing the process is also a key element.

Capstone Culmination

To facilitate the integration of the technical tools and manufacturing strategies, two capstone experiences are required within Stout's manufacturing engineering program. Capstone, as defined by Merriam-Webster[1], is the "*high point*" or "*crowning achievement*." Both capstone experiences are self-directed, team-based projects. Instructors provide very limited instruction and serve as project consultants, conducting design and resource reviews throughout the semester. If needed, the instructors help facilitate team difficulties and provide suggestions for project management by the teams. Examples of both capstone experiences will be provided in the next subsection.

The first capstone course, *Capstone I: Product Design*, puts the manufacturing engineer in a setting of developing product designs. Students in Cap I are teamed with product design students from the mechanical design concentration of the industrial technology program. This teaming produces a cross mingling of design and manufacturing experience between team members. Teams work on a variety of product designs, from actual industry products to ones that will carry over to Cap II as a family of products. The manufacturing engineering students gain significant insights into the product design process from these team based projects, and the mechanical design students gain significant insights of actual manufacturing capabilities.

The second capstone course, *Capstone II: Manufacturing System Design*, focuses on the design, build, and operation of a manufacturing system capable of producing a family of parts. The manufacturing engineering students are teamed together with the sole purpose of designing and building an automated manufacturing system. The teams coordinate all aspects of the project. The project requirements include system design, procurement, part production (in the actual labs), control strategy development, electrical system design, sensor integration, system assembly, and operation debug. The students leave this capstone experience with the experience and confidence necessary to become pragmatic engineers.

Industry-Sponsored Projects

Developing industry partnerships has been a focused topic of discussion within the engineering education community in recent years. Stout's manufacturing engineering program brings real industry projects and problems into the curriculum through a variety of courses. In addition to projects developed through outside coordination by program faculty, the NWMOC is able to funnel projects to the program through technology transfer projects. Industry-sponsored projects are an excellent methodology for industry/university partnerships. The sponsoring industry gains an "outsiders" eyes on a project, observes potential employee abilities, brings new manufacturing methodologies to their organization, and establishes company awareness for recruiting purposes with graduating students. The gain for the university is a never-ending stream of real industrial applications that create up-to-date learning opportunities for students and faculty. The diversity of four recent industry projects highlights Stout manufacturing engineering students' industrial applications.

The first example of an industry-sponsored project is a facilities design project within the course *Facilities and Material Handling System Design*. SIG Pack, Doboy Division of New Richmond, WI is a producer of packaging equipment. The management team wanted to make systems improvements to decrease throughput time for assembly of one of their key machines in their product line. The Stout facilities design group analyzed the problem of throughput and developed suggested layout changes to three subassembly areas, and one main assembly area. The changes suggested by the team allowed for assembly of four machines simultaneously, in various stages of completion, in the main assembly area. The use of the suggested facility layout made it possible for smoother material flow, increased productivity, and increased work area and manpower utilization. Doboy initially implemented some of the team's recommendations and will use the overall layout and some of the data presentation techniques for upcoming changes to the machine build area.

The second example of an industry-sponsored project is a controls design project within the course *Controls and Instrumentation*. Northland Electric is a supplier of the Allen Bradley family of programmable logic controllers. The project scope was to design and build a self-contained simulator that utilized a SLC 500 processor. The simulator enables Northland Electric to demonstrate the capabilities of the SLC 500. The developed simulator consisted of a SLC 500 mounted inside a portable enclosure. It was connected to individual pieces of hardware that serve as inputs and outputs of the simulated process/operation. In addition to designing the enclosure wiring and mounting hardware for the devices, the overall class team developed six different ladder logic programs performing the simulated operations within the six processes. The programs were permanently stored on the SLC 500, reducing the need for an external pc to drive program download. Northern Electric is currently having more of these simulators built for in the field demonstration and sales.

The third example of an industry-sponsored project is a product design project within the course *Capstone I: Product Design*. David White, L.L.C., of Berlin, WI, is a producer of laser surveying and leveling equipment. The company needed design assistance in redesigning their existing wall/ceiling mount bracket utilized by their leveling lasers. The key point of the project was to increase the innovation of the design and reduce the cost. The design team developed a laser wall/ceiling mount bracket made of a lighter, more cost-effective material, retaining the overall shape of the existing design to fit the leveling laser carrying case currently used. The design significantly reduced the overall cost of the bracket and David White is currently implementing this new design.

The final example of an industry-sponsored project is a manufacturing system design project within the course *Capstone II: Manufacturing System Design*. In conjunction with L&G Steel of Fond du Lac, WI and Curt Manufacturing of Altoona, WI, an automated part shuttling system used in conjunction with a robotic welder was designed and fabricated. The system was PLC controlled and included electrical, pneumatic, and positioning devices. The major issues addressed during this project were accurate and repeatable placement of palletized fixtures, a reduction or elimination of robot non-value added time, and a reduction of set-up time. This set-up time reduction was achieved by incorporating quick-change fixturing methods, enabling off-line fixture design, build, and maintenance. This successful project proved that an automated part shuttling system could be safe and efficient in achieving the goals for the industry sponsors.

In all of these cited examples, the self-directed, student project teams developed a close working relationship with the industry sponsor. The success of these and other industry-sponsored projects provides real industrial applications of problem solving and solution generation using engineering science and design concepts. Other examples of student project work can be viewed at the manufacturing engineering program website at: www.uwstout.edu/programs/bsmfe/.

The Future of Manufacturing Engineering at Stout

The University of Wisconsin-Stout undergraduate manufacturing engineering program is currently one of the largest in the United States and Canada. It will remain so in the future and will continue to graduate forty to fifty students per academic year. After receiving the ABET accreditation in undergraduate manufacturing engineering in 1999, UW-Stout immediately began development of a masters of science in manufacturing engineering. An initial needs survey identified an urgent need for continuing education opportunities for practicing manufacturing engineers. The M.S. program is currently in the curriculum planning stage with a projected initial program offering in the fall of 2002. This masters program will provide several additional avenues of applied research for program faculty and students. In addition, the masters program will provide opportunities to increase the scope of selective course offerings, especially in the realm of maintaining global competitiveness through applied manufacturing philosophies. Future plans will also strengthen the industry partnerships that funnel real industrial applications back to the classroom and lab. The masters program will significantly strengthen these partnerships as many of the survey respondents indicated a willingness to sponsor projects for either their own engineers or other graduate students. The University of Wisconsin-Stout is a leader in utilizing a “hands-on, minds-on” educational philosophy within all manufacturing engineering curricula. Stout will continue to be an engineering educational leader as new engineering and engineering technology programs are developed.

References

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Biography

DANNY J. BEE is an Assistant Professor of Manufacturing Engineering since 1995 and is currently Program Director for Manufacturing Engineering at the University of Wisconsin-Stout. He earned a B.S. in Mechanical Engineering at the University of Wisconsin-Madison in 1988 and a M.S. in Manufacturing Systems Engineering at the University of Wisconsin-Madison in 1992. He has design/manufacturing experience in the aerospace and computer industries. In addition, he worked as a Quality Specialist in the Janesville/Beloit, WI region at Blackhawk Technical College.