Manufacturing Engineering Program Overview

Daniel J. Cox(1)

Georgia Southern University
P.O Box 7991
Statesboro, Georgia

dcox@georgiasouthern.edu

ABSTRACT

A program in manufacturing engineering is being established at Georgia Southern University leading to the Bachelor of Science in Manufacturing Engineering degree. The four-year program is currently in its second year with the sophomore cohort concluding their second year. Aspects of the program are described regarding the goal of hands-on experiences in a manufacturing engineering curriculum with significant laboratory and industry-relevant experiences in the program. An overview of the curriculum is provided. The progress to date of the developments of laboratories associated with the courses in the manufacturing engineering curriculum are also discussed in this paper. Several laboratories have been resourced with new equipment acquisitions over the past two years of implementation of the program with additional future acquisitions planned. Many experiments and laboratory exercises in practical aspects of manufacturing can make use of common sets of state-of-the-art, industrial-grade, manufacturing equipment. The equipment includes traditional machine tools, CNC machine tools, other subtractive materials processing equipment, additive manufacturing machines, material handling, robotics and automation, and additional physical equipment. These hardware resources must also be compatible and integrated with software and computing resources including computer-aided design tools, programmable logic controllers, automation software, manufacturing execution systems software, and additional software resources as the courses of the manufacturing engineering curriculum come on-line.

Keywords

Manufacturing Engineering, Robotics and Automation.

1. INTRODUCTION

A newly formed undergraduate manufacturing engineering program requires significant resources to train the modern manufacturing engineer. A new program, in its second year, leverages over forty years of manufacturing and industrial technology programs with the requirements and demands of an engineering program and an increasingly sophisticated manufacturing environment. The four pillars [1] of manufacturing knowledge: materials and manufacturing processes; product tooling and assembly engineering; manufacturing systems and operations; and manufacturing competitiveness provides a framework of educating the next generation manufacturing engineers. Manufacturing engineering at the undergraduate level is often a track or concentration being shared with either mechanical or industrial engineering. In this new program, currently in the second year of existence, the emphasis and degree is solely focused on manufacturing engineering.

Purposes for the new manufacturing engineering program, now with sophomores, are primarily for workforce development, but also include economic development, attracting industry to the region, job creation, and solve industry challenges through applied research and development. The aim is to prepare the manufacturing engineering workforce to be more prepared to hit the ground running, with less supplementary training required of the employers in the faced-paced manufacturing environment.

Like the other engineering programs at the institution, there is a strong emphasis on co-op opportunities and working with industry. This includes hands-on projects with industry driven requirements, and applied research and development opportunities at both the undergraduate and graduate levels. The focus of this paper though, is on the development of the hands-on laboratories of the manufacturing engineering program. Resources for undergraduate research projects are readily available through the realization of the hands-on laboratories for manufacturing engineering. Thus the well-known benefits of student experiential learning that enable students to interact with professionals, gain professional contacts, and gain confidence and experience are realized.

2. CURRICULUM

The strategy with the curriculum is to integrate the hands-on Manufacturing Engineering (MfgE) courses from the onset through the senior year [2]. The degree program results in the bachelor's degree in manufacturing engineering. The program has just completed its second year. There are an abundance on hands-on laboratory experiences creating authentic learning of industry practices. Much of the core engineering requirements are accomplished in the first two years while, as the students' progress through their program of study, they increasingly engage in the MfgE courses and hands-on laboratories. Three thrust areas of the program are supported by authentic industrial grade laboratories. The three thrust areas are: Materials and Processes, Plant Floor Operations, and Advanced Manufacturing.

Materials and Processes

- Traditional Machining and Materials Science
- CNC Machining and Processes
- Additive Manufacturing

Plant Floor Operations

- Statistical Process Control
- Lean Manufacturing
- PLCs, Sensors, and Actuators

Advanced Manufacturing

- Robotics and Automation
- Automated Inspection Systems
- Manufacturing Execution Systems

The general distribution of the curriculum is outlined below (credits).

Basic (61)

- Math (11): Calculus 1&2, Statistics
- Science (12): Physics 1&2, Chemistry
- English (6): Composition 1&2
- General Education (29)
- Economics (3)

General Engineering, Lower Division (10)

- ENGR 1133 Engineering Graphics
- MENG 1310 Manufacturing Process Lab
- MENG 2139 Numerical Methods
- ENGR 2131 Circuits

Manufacturing Engineering, Lower Div. (18)

- MFGE 2531 Material Science for Manufacturing
- MFGE 2142 Fundamentals Engineering Mechanics
- MFGE 2533 Manufacturing Process 2
- MFGE 2534 Applied Computing in Manufacturing
- MFGE 2239 Mfg Engineering Modeling & Analysis
- MFGE 2421 Intro to Additive Manufacturing

Manufacturing Engineering, Upper Div. (31)

- MFGE 3131 Design for Manufacturing
- MFGE 3541 Energy Science
- MFGE 3421 Industrial Controls
- MFGE 3531 Advanced Material Processing
- MFGE 3132 Quality and SPC
- MFGE 3337 Hydraulics and Electromechanical Sys
- MFGE 3423 Facilities Design
- MFGE 4533 Robotics & Automation
- MFGE 4135 Lean Manufacturing
- MFGE 4614 Professional Leadership
- MFGE 4321/22 Senior Capstone 1&2

Manufacturing Engineering, Elective Areas (9)

- SAP
- Lean Manufacturing
- Robotics & Automation
- Materials Processing
- Occupational Health and Safety

3. Laboratories

A hands-on approach to instruction using state-of-the art manufacturing equipment is accomplished with physical resources that can be used in a variety of laboratory sections that are used in courses in manufacturing engineering. Many experiments and laboratory exercises in practical aspects of manufacturing can make use of common sets of state-of-the-art, industrial grade manufacturing equipment. The laboratories described below are currently housed in a newly renovated building. The equipment of the laboratories includes traditional machine tools, Computer Numerical Control (CNC) machine tools, other subtractive materials processing equipment, additive manufacturing, material handling, robotics and automation, and additional physical equipment. These hardware resources must also be compatible and integrated with software and computing resources including computer-aided design tools, PLCs (Programmable Logic Controllers), automation software, MES (Manufacturing Execution Systems) software, and additional software resources.

The development of the laboratories described below has been driven by the design of the curriculum, observation of other manufacturing-related programs, and the existing resources held-over from the former technology program. The new manufacturing engineering program has three thrust areas. The first is materials and processes which includes traditional machining, materials science, CNC machining and processes, and additive manufacturing. The second thrust area is plant floor operations and includes statistical process control, lean manufacturing, PLCs, sensors, and actuators. An additional advanced manufacturing thrust includes robotics and automation, automated inspection systems, and MES. These three thrust areas are correlated to the four pillars of manufacturing knowledge in the following sections.

Most of the laboratories described below support the manufacturing engineering specific curriculum and courses that begin in the freshman year and continue throughout the curriculum. Laboratory and experiment resources must also consist of replicate stations to provide adequate hands-on access for all students in a new and growing manufacturing engineering program. The program is currently in the second year with freshman and sophomore manufacturing engineering student majors. Replications of the various types of physical manufacturing systems contribute to increased student throughput while also keeping the hands-on student group sizes to a minimum, with the goal of a maximum of three to four students per laboratory exercise when hardware resources are used.

Manufacturing in plants and factories has seen dramatic changes over most recent decades compared to the traditional view of manufacturing as a dirty, monotonous, work environment of decades past. Although much of the public perception of manufacturing remains in past misconception, an increased awareness of manufacturing as a profession is driven by a rapid increase and greater awareness of advances in modern manufacturing. A new generation of manufacturing engineers need to be well-trained in areas of computer-based design tools, software and machine programming, CNC machinery, additive manufacturing, plant floor software, automation equipment, and robotics. The laboratories in this section are in various stages of development and will be continuously updated and improved as the new manufacturing engineering program advances and matures.

3.1 Advanced Manufacturing: CNC and Material Processing

The choice of using a single vendor for machine tools is made to keep the maintenance and operational costs of the systems lower than otherwise if multiple vendors are used. By in-large this strategy is used in many other cases regarding equipment selections. It is also important for students to be exposed to, and trained in machinery typical of the industrial environment. Figure 1 partially shows the Advanced Manufacturing Laboratory (AML) - CNC Machining and Materials Processing Laboratory. This laboratory is fairly well developed thus far. Shown in Figure 1 are two CNC mini-milling machines, two CNC lathes, and a 5-axis milling machine. Not shown are industrial grade waterjet, plasma cutter, surface grinder, and band saws. Upcoming acquisitions for this laboratory include Electrical Discharge Machining (EDM) machines and other materials processing equipment. This laboratory is primarily used by students taking courses in manufacturing processes, computing in manufacturing, quality and SPC, and capstone design. This laboratory supports training in all of the four pillars of manufacturing knowledge: materials and manufacturing processes; product tooling and assembly engineering; manufacturing systems and operations; and manufacturing competitiveness.

Figure 1. CNC Machining and Materials Processing Laboratory

The students are trained in engineering graphics and 3D modeling before an applied computing in manufacturing engineering course. The applied computing in manufacturing engineering course trains the students in fundamentals of CNC programming focusing on G and M code programming. An advanced CNC programming course further develops the students' skills in this area. The students are required to learn the programming language of machine tools before using any automatic program generation software tools later in the curriculum. An associated laboratory consisting of multiple small CNC benchtop tools (see Figure 2) is used to train the students in machine programming well in advance of using the industrial grade machine tools shown in Figure 1. The laboratory shown in Figure 2 provides a relatively safe environment for beginning level CNC programming with the benchtop machines running the same software but requiring much less power to produce small, non-ferrous components. This approach is safe both for the students and the more powerful industrial grade equipment shown in Figure 1. The laboratory shown in Figure 2 is primarily used by sophomore students taking introductory computing in manufacturing.

Figure 2. Machine tool programming laboratory benchtop machine tools

Also existing in the machine tool programming laboratory are machine tool simulators. Thus the students learn the requisite programming skills on small, much relatively safe hardware and industrial simulators before any exposure to the much more powerful industry-grade machine tools. Note that all three types of machine tool systems run the same software. The industrial grade machine tools shown in Figure 1 are also used to support senior capstone and undergraduate research.

3.2 Advanced Manufacturing: Additive Manufacturing

Although additive manufacturing has been in existence for many years, it is showing strong gains in use due to advancement in new materials and continuously improving price/performance of the new generation of machines. The ability to rapid prototype as a design tool, the capability to engineer new materials, and quantification certainty in base material content are some of the many reasons why the modern manufacturing engineer must be well versed in this technology that will continue to gain wide acceptance. Courses in introduction to additive manufacturing and advanced additive manufacturing studio directly make use of the AML - Additive Manufacturing Laboratory shown in Figure 3. Senior capstone and undergraduate research will also be supported by this laboratory. This laboratory is fairly well developed thus far. The laboratory consists of a variety of primarily polymer 3D printers at this stage. The polymer printers include four low-cost 3D printers, seven modern industrial grade additive manufacturing machines, and a high fidelity state-of the art industrial grade additive manufacturing machine. Also included are wax and resin printers and a 3D scanner. A metal 3D additive manufacturing machine is under procurement as are additional types of 3D printers and scanners. In addition to the additive manufacturing courses, this laboratory is used for courses in quality and SPC as well as capstone design. This laboratory supports three of the four pillars of manufacturing knowledge: materials and manufacturing processes, manufacturing systems, and manufacturing competitiveness.

Figure 3. AML – Additive Manufacturing Laboratory

3.3 Advanced Manufacturing: Robotics and Automation

A Flexible Manufacturing System (FMS) consists of both hardware and software aspects of the material handling system and six robotics and automation stations of the initial installation. The system is capable of production-like scenarios to highlight hands-on learning experience for the students. The six robotized stations are a machining station, a laser engraving station, a machine vision inspection station, a coordinate measurement station, and two robotic assembly stations, one is a single-arm robot, another featuring a dual-arm robot. Four of the six stations described consist of dockable robot carts that can be separated from the FMS for rapid changeover and standalone use in a laboratory instruction. Quick-connect fixtures allow the robots to then be redeployed back into the FMS. Two more stations are intended for the near-term expansion of the FMS. However, the material handling system and software allow for reconfiguration and expansion for more stations. This will be especially useful when the advanced manufacturing laboratories including the FMS move to new spaces.

The FMS is designed to be used across a variety of courses in the manufacturing engineering curriculum to provide hands-on, industry-relevant training for the students. The system is intended to support hands-on experiential learning in courses including industrial robotics and automation; automation and CIM; PLCs, industrial controls and networking; design for manufacturability, assembly, and sustainability; quality and SPC; applied computing in manufacturing engineering; pneumatic, hydraulic and electro-mechanical systems; plant floor software and MES; systems safety in manufacturing; and senior capstone design. Additional graduate-level and undergraduate technical electives are likely to materialize as the program grows.

The students in the program are currently completing the second year of the four-year degree in manufacturing engineering. The FMS installation is positioned for upcoming junior and senior courses. The RFP was posted in 1Q17 with the award committed in 2Q17. The project is scheduled for completion in 3Q17 and fully functional in the 4Q17.

3.4 Other Laboratories

Manufacturing engineers need an understanding of engineering fundamentals. Calculus, calculus-based physics, and chemistry as in most engineering programs form the basis for courses in fundamentals of engineering mechanics that include statics, dynamics, and strength of materials. Other laboratories in the thermo-fluid and energy sciences exist in the mechanical engineering program to support the manufacturing engineering program and are listed:

- Engineering Mechanics
- Traditional Materials Processing
- PLCs, Industrial Controls, and Networking
- Hydraulics, Pneumatics, and Electromechanical Systems

4. SUMMARY

A summary of the curriculum in a new manufacturing engineering program has been presented. The program is currently in its second year with rising juniors. The inaugural class is scheduled to graduate in spring semester 2019. Laboratory equipment was also discussed. The most recent enhancements to the traditional mechanical technology program that has been enhanced to manufacturing engineering program are CNC lathes, CNC mini-mills a five-axis CNC mill, a waterjet cutter, a TIG welder, a surface grinder, a band saw, and sanding table for the CNC Machining and Material Processing Laboratory. EDM machines are also in the process of acquisition for this laboratory. A high-end polymer additive manufacturing machine, midrange additive manufacturing machines, and wax printer have been acquired to expand the Additive Manufacturing Laboratory. An additional polyjet additive manufacturing machine and metal additive manufacturing machine are under acquisition for this laboratory. A coordinate measuring machine and universal testers add to other laboratories and use in the program. Procurement of an industry-grade Flexible Manufacturing System (FMS) consisting of a material handling system, industrial robots, a Manufacturing Execution System (MES), integrated with processing and inspection tools at stations within the system for the Robotics and Automation Laboratory is underway. These resources provide hands-on, authentic, industrial grade experiences for the manufacturing engineering students.

ACKNOWLEDGMENTS

The author would like to acknowledge the support and commitment of Georgia Southern University to the Manufacturing Engineering Program. The author also gratefully acknowledges colleagues, faculty, and staff of Georgia Southern University.

REFERENCES

[1] www.sme.org/fourpillars/

[2] ceit.georgiasouthern.edu/manufacturing-engineering/