Session 2963

Rebuilding a Manufacturing Processes Laboratory

James B. Higley, P.E.

Purdue University Calumet

Abstract

Manufacturing laboratories always seem to lag behind other laboratories in obtaining new equipment, especially machine tools. Since 1990, Purdue University Calumet totally revamped its manufacturing laboratory from a World War II vintage laboratory to a modern laboratory with both conventional and CNC machine tools. This paper discusses the types of courses that use the manufacturing laboratory, other lab constituents, funding sources, and choosing equipment based on the author's experience of attending seven International Manufacturing Technology Shows (IMTS) and purchasing approximately a quarter-million dollars worth of equipment.

Background

Purdue University Calumet (PUC) is an educationally autonomous regional campus in the Purdue system located in Northwest Indiana just 25 miles from downtown Chicago. Being a regional campus, PUC's mission is, primarily, to serve the needs of local constituents. Northwest Indiana is also home to the nation's largest integrated steel mills, so PUC has served their needs as well. Indeed, the campus was originally started in WWII to provide technical training for the steel mills. While PUC's service base has expanded considerably since then, it still has a strong technical base with well established programs in mechanical engineering (ME) and mechanical and industrial engineering technology (MET and IET), all with a long history of ABET accreditation.

The manufacturing laboratory was originally installed in 1969 with the construction of PUC's Anderson Building. At that time, most engineering programs, including PUC's, had removed manufacturing processes from their curricula as engineering programs became more science based as a result of the space race. Technology programs stepped in and took over most of the application-oriented courses, including manufacturing processes. The MET and IET programs at PUC started in 1969, and they have been the primary users of the manufacturing laboratory ever since. However, industry slowly applied pressure, and in the mid and late 1980's, many engineering programs began adding manufacturing processes courses back into their curricula. PUC followed suite as well. Hence, more technology and engineering students are using manufacturing processes laboratories now than two decades ago, a prime reason to rehabilitate and modernize a laboratory.

When the Anderson Building was initially constructed, funds were included in the original building proposal to equip a modest manufacturing laboratory with a lathe, milling machine, drill press, surface grinder, and horizontal and vertical bandsaws to support the new programs. Equipment was slowly added until the Tools for Schools Program from the Department of Defense (DOD) was instituted. This program loaned machine tools to schools from DOD stores, and eight pieces were loaned to PUC. This program has now been discontinued. That is the state the author found the lab in 1988 when he became responsible for the lab's operation. Any machinist from WWII would have felt very comfortable working with the existing equipment. The remainder of this paper describes the 1988 to 2000 transformation of this lab from WWII vintage to modern. Courses that use the lab, other lab constituents, funding sources, and equipment selection are presented in the following sections.

Courses that use the Manufacturing Laboratory

When planning, designing, or installing a manufacturing laboratory, the laboratory constituents must first be considered. For PUC, the constituents are the MET and IET programs with four courses containing manufacturing components and the ME program with one course with a manufacturing component. Table 1 lists the five current courses that use the manufacturing laboratory. Specific course objectives are available at the MET and ME web sites[1,2]. Based on course objectives, the laboratory provides metal casting, welding and machining experiences for students with a primary emphasis on machining. One could certainly argue that manufacturing processes encompasses much more than metalworking, so additional discussion of other processes is required. Additionally, previous ABET visits and input from alumni suggest that students need considerable practice writing, speaking in front of others, and working in teams. Solutions to all these problems were found by incorporating a team project in MET141 and MET242 which includes researching a manufacturing process other than metalworking, writing a report on the research results, and then presenting the results to the class in a formal presentation.

Table 1. Courses that use the Manufacturing Laboratory

Course	Course Description
MET142	Basic casting, forming, and joining processes are surveyed. The course emphasizes the selection and application of various processes.
MET242	This course surveys the manufacturing processes and tools commonly used to convert cast, forged, molded, and wrought materials into finished products. It includes the basic mechanisms of material removal, measurement, quality control, assembly processes, safety, process planning, and automated manufacturing.
MET461	A combination of lecture and laboratory projects demonstrating the integration of all phases of a product's life cycle from conception through recycling. Laboratory projects include designing parts, graphical finite element analysis, rapid prototyping, computer controlled manufacturing, and testing all using a common, three-dimensional graphical database.
MFET275	A study of the principles, techniques and applications of numerically controlled machine tools. G and M code programming of industry machines, tooling systems, and an introduction to Computer Aided Manufacturing (CAM) systems will be covered.
ME486	Modern manufacturing processes and methods including forming, shaping, machining, and joining. Productivity, quality improvement, material and energy conservation, automatic processing and inspection, process planning, manufacturing control, robotics, CAD, CAM, and computer integrated manufacturing.

Of the courses listed in Table 1, MET242 requires the most equipment and lab space, and it is the most common course taught in the lab. Students in this course manufacture the small (approximately 2" wide jaws) bench vise shown in Figure 1. This project provides lab experiences in most common machining operations including turning, milling, drilling, tapping, counterboring, single-point threading, surface preparation, and finishing. Other courses provide lab experiences in individual processes such as welding, casting, and CNC programming. The students appreciate lab experiences that yield functional products.

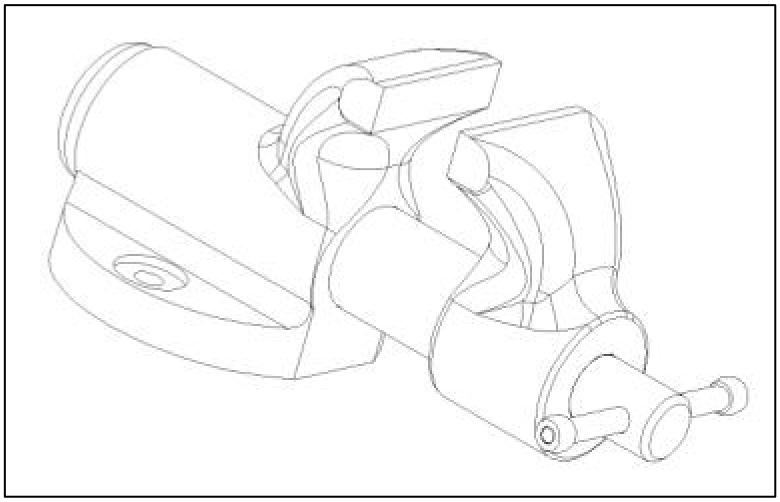

Figure 1 – Bench Vise Project

Other Lab Constituents

Given the considerable investment required for a modern manufacturing laboratory, additional constituents beyond courses that cover manufacturing processes should be actively sought out. At PUC, additional lab uses fall into three areas:

1. Senior projects
2. Industrial training
3. Community outreach

A number of technology and engineering students have taken advantage of their lab experience and used the laboratory to build their senior project. Some of the more interesting projects include a golf putter[3], two types of wear testing machines, a dual thermostat housing for a truck, and two Mini-Baja cars that participated in the annual SAE race. Through anecdotal evaluations, students that actually build a senior project seem to have a more fulfilling experience and have an easier time obtaining employment than students who do theoretical projects.

Industry training has been an important part of the manufacturing laboratory. Basic machining processes and CNC programming have been the most common courses taught. These courses usually run from two days to a full week. Many companies, especially smaller ones, send their employees to the credit manufacturing courses rather than requesting special courses.

Because of the dynamic nature of machining, the manufacturing laboratory is a popular stop for high school students, teachers, and counselors. Each year, several groups of interested students from local high schools are given tours of the lab where the CNC machines manufacture an aluminum pen holder as shown in Figure 2. These holders are raffled off to the students in return for filling out an evaluation sheet. In addition, local high school teachers and counselors visit the lab in the summer to learn more about careers in engineering and technology. Finally, the university hosts a minority engineering program each summer for local junior high students in hopes of interesting them in technical careers. Once again, the manufacturing laboratory is a popular place during their month of learning at Purdue University Calumet.

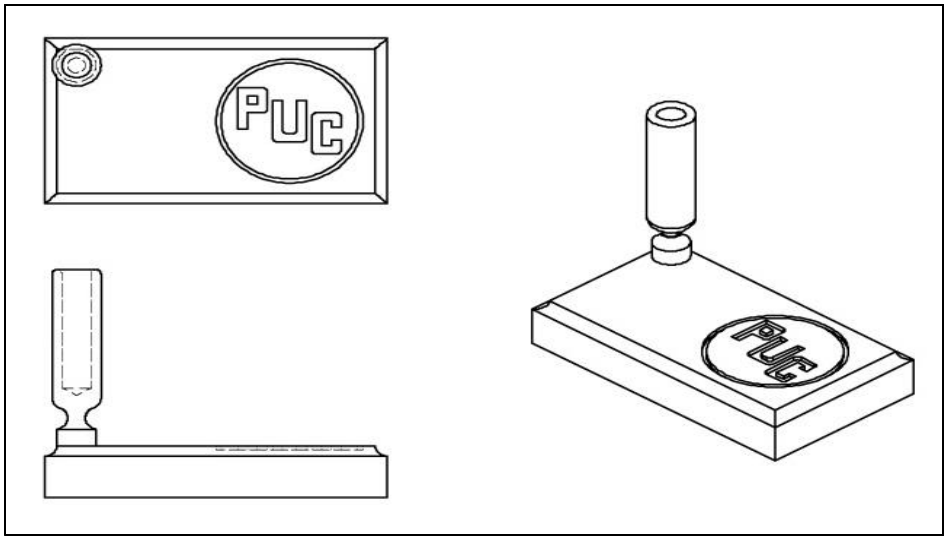

Figure 2 – Pen Holder

Funding Sources

A modern manufacturing processes laboratory for machining with small but industrial quality CNC and conventional equipment represents an investment of $200,000 or more, depending on the quantity of equipment required. Given this high level of investment, several funding sources should be investigated. Typical sources include:

1. University funds
2. Grants
3. Donations
4. Partnerships
5. Gifts

In this day of tight budgets, university funds are increasingly difficult to obtain. At a minimum, about $5,000 per year is needed to maintain the perishables and small equipment used in a manufacturing lab. New equipment may be purchased from capital equipment funds when they are available, but such funds are generally actively sought for use in computer and other labs. To help correct this situation, PUC instituted a Technology Fee in the mid 1990's. Now at approximately $5 per credit hour, the funds are used to purchase equipment ONLY for student labs. This small surcharge has greatly increased the quality of all labs at PUC, including the manufacturing lab.

Grants offer a viable alternative for funding, but they require careful research and thought on how to propose a project. Perhaps the most commonly sought after funds are the National Science Foundation's (NSF) Course, Curriculum, and Laboratory Improvement (CCLI) program. PUC received such a grant in 1997 and those funds were used to purchase a Haas VF1 vertical machining center (see the next section).

Donations of lab equipment can be a blessing, but can also be expensive. Prior to the Technology Fee, most of PUC's manufacturing equipment came in the form of used equipment donations. All but a few pieces of equipment needed cleaning and some repair, but all gave good service at that point. Occasionally, excellent pieces will be donated as well. PUC's DoAll vertical milling machine was donated from a small research lab that closed, and it was in practically new condition. Networking with local manufacturing companies helps increase the chances of obtaining equipment donations.

Some equipment vendors are interested in setting up partnerships with universities, and some machine tool vendors will even allow classes to be taught in their showrooms. Haas has a special program for colleges and universities where CNC equipment is loaned to the college or university in a partnership arrangement called a Haas Technical Education Center. A number of these centers have been set up around the USA. The program is administered through local Haas Factory Outlet locations, so that is a good place to start inquiries. (At the time this paper was written, PUC was just starting the process of applying for Haas Technical Education Center status; therefore, the author does not have complete details yet.)

Gifts from Alumni and faculty are viable sources for funding as well. Be sure to check to see if your state has any special programs for donations to schools. For instance, Indiana gives a state tax credit of up to $200, so an individual can donate $400 to any Indiana school and receive 50% back in a state tax credit. That along with the federal deduction results in the donation not costing much in real dollars. Often, with this as an incentive, individuals will donate much more.

Laboratory Equipment

One advantage to Purdue University Calumet's location is the proximity to the International Manufacturing Technology Show (IMTS) held in even numbered years at McCormick Place in Chicago. Given that the campus is but 30 minutes from the show, the author is able to attend regularly and study the available equipment. Based on many IMTS shows, discussions with numerous local manufacturing companies, and a dozen years teaching manufacturing processes, the author's opinions on equipment for a manufacturing laboratory are presented in this section. Note that the author is not connected to any of the following manufacturers in any way; the opinions presented are from past experience.

CNC MACHINES: Haas is a clear choice for a college or university. Many manufacturers have excellent machines, but Haas machines are typically the least expensive, and they offer a substantial educational discount on top of an already low list price. In fact, an educational institution can often purchase a full size, industrial quality Haas machine for little more than a training machine after the discount. Purdue University Calumet has a VF-1 vertical machining center and an SL-20 turning center. Both machines have given excellent service. In fact, the VF-1 has never needed a service call in the five years that it has been in use. The SL-20 is much newer and has run perfectly as well. Figure 3 depicts both machines in PUC's laboratory. Haas also has excellent educational materials available[4].

Figure 3 – Haas Turing and Machining Centers

LATHES: There is only one American made lathe left – the Hardinge Toolroom Lathe. The Hardinge is a beautiful piece of engineering and is manufactured to exacting standards, but its $43,000 price tag puts it in the same range as many CNC lathes. Sharpe makes a very nice copy of the Hardinge for about half as much. PUC has been using one (Figure 4) for over a year now and it is excellent for single point threading. This presents an interesting ethical dilemma that can be discussed with students. Hardinge originally designed the machine and Sharp (and several others) reverse-engineered it and produced nearly an exact copy. Which one should a person purchase? The author has philosophical problems with an unlicensed, exact copy of the Hardinge, but the Hardinge was just too expensive for PUC's budget, so a Sharp was purchased. The Sharp excels at threading, but it is too small for general lab use in PUC's courses. In retrospect, a 15" Colchester lathe at about $18,000 probably would have been a better and more versatile choice. These lathes are made in the UK, have many years of experience behind them, and will last for decades. In a highly used lab, they are probably the best choice. Down in the $12,000 range there is the Spanish-made Clausing/Metosa and a number of Taiwanese lathes of which PUC has found the 17" Acer (Figure 5) to be very good. PUC now has four Acers in the laboratory, and they have been satisfactory. The feed controls on the Acer work well in a laboratory since a plunger changes between cross and longitudinal feed and the same lever engages both, so the students cannot accidentally slip from longitudinal to cross feed. Many of the imported lathes use one lever with up for longitudinal feed and down for cross feed. With this setup, inexperienced students will sometimes disengage the longitudinal feed and then slip into cross feed which invariably causes the cutter to plunge in ruining the work. Another significant advantage to the 17” Acer is its footbrake. Stepping on this brake immediately stops the machine and turns off the motor, an excellent safety feature for inexperienced students.

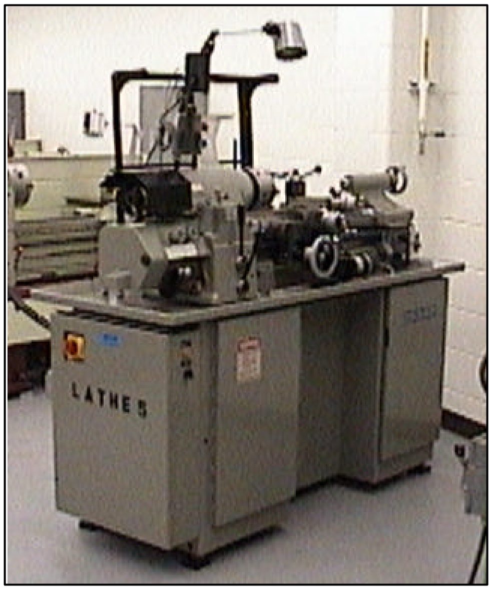

Figure 4 – Sharpe Toolroom Lathe

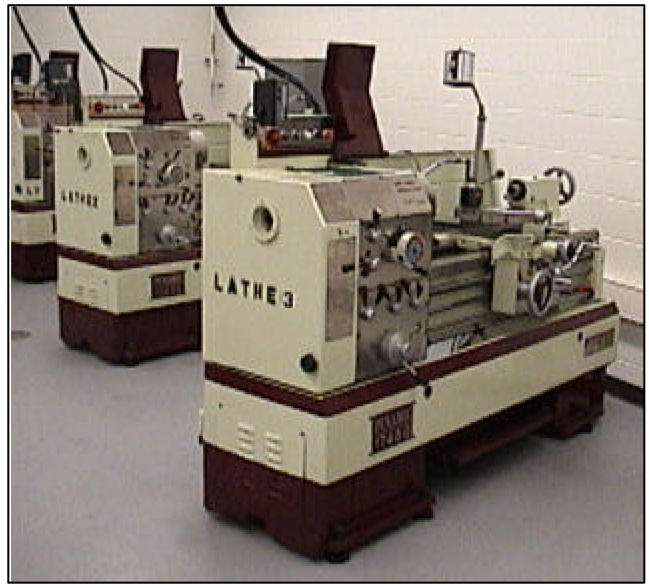

Figure 5 – Acer 17” Engine Lathes

LATHE TOOLING: Bison, Aloris, Skoda, and Jacobs tooling have performed well in PUC’s laboratory. For the money, Bison Set-Tru chucks seem to be the best value costing about half as much as comparable Buck or Pratt-Bernard chucks. Less expensive imported chucks are available, but they are not as well made as the Bisons and probably will not last as long. Aloris quick-change tool posts allow the students to easily remove the cutter enhancing safety. Other brands are available, but the imported ones seem soft, and the more expensive brands don’t have as large of a selection of tool holders. Skoda live centers are quite inexpensive, and their long point centers give good access to small diameter work pieces. Jacobs ball bearing chucks hold tools well and last a long time. For more experienced users, Albrecht chucks are faster to use, but Jacobs chucks are more rugged and stand student use better. The author’s contacts that have purchased inexpensive drill chucks report that they feel they wasted their money, and they end up purchasing Jacobs or Albrecht chucks anyway.

VERTICAL MILLING MACHINES: PUC has three vertical mills in its lab – a Series I Bridgeport, a DoAll copy, and an electronic variable speed (EVS) Acer (Figure 6). All three are the same size. The Bridgeport Series I is still the standard conventional mill in the United States. At $12,000 stripped it is still fairly affordable. Contacts in local companies report that the sliding pulley variable speed wears out about every five years or so under heavy use. While not difficult to rebuild, it does take time. Parts for Bridgeport machines are available from third party vendors quite reasonably – another plus. Imported copies of the Bridgeport are available from all corners of the globe, but the Taiwanese machines seem better than most at the present time. The Taiwanese DoAll at PUC has given good service for about half the cost of the Bridgeport. The

Acer with the EVS is the nicest to run with its smooth, quiet drive. The EVS system should last much longer than the sliding pulley arrangement on the Bridgeport. Acer reports that they do a brisk business selling the EVS heads as replacements on Bridgeports. Interestingly enough, Bridgeport ceased operations recently, and their availability was in question. However, Hardinge took over production of Bridgeport machine tools, so it seems their availability is no longer a problem.

Figure 6 – Vertical Milling Machines

HORIZONTAL MILLING MACHINES: This is the hardest machine to purchase. The only new ones available are Taiwanese at around $30,000 or Polish at around $40,000, but smaller CNC machining centers are available for the same price. PUC has a Cincinnati horizontal that the school purchased rebuilt in the late 1960's. It is a wonderful machine and will probably never wear out. PUC was also fortunate to have two Kearney & Trecker mills and an earlier Cincinnati donated. All three machines required disassembly, cleaning, and some repair, but they are giving good service now. Used horizontal milling machines can generally be obtained through donations. If that is not possible, it might be better to reconsider laboratory projects and adapt them to other machines before spending $30,000 or more on a new horizontal milling machine.

MILLING MACHINE TOOLING: Kurt 6" vises at about $350 are the best value in milling machine vises. PUC has never worn or broken one. Again, less expensive vises are available, but they generally are not as accurate as the Kurt and do not hold up as well. Hardinge makes the nicest R-8 collets, but most brands seem to work fine in the laboratory. Fitz-O-Rite from Michigan sells reasonably priced American made CAT taper milling holders, and these work well even on the older machines designed for National Standard Taper tooling. Criterion boring heads have given reliable service for many years. PUC uses their boring/facing head to bore the vise base and face the far end off in one setup. Criterion is very friendly to schools, and they can often be counted on to supply second quality boring tools which just have cosmetic defects but which still work perfectly.

DIGITAL READOUTS: After much study, PUC settled on Newall readouts. They are easy to install on existing machines, most dealers can install them on new machines, they have a reasonable guarantee, and they operate simply and intuitively. Many other readouts require odd combinations of buttons to be pressed for some functions. The author has personally used 10 different Newalls with no problems and industry contacts report excellent service as well.

MEASURING INSTRUMENTS: The author prefers Starrett micrometers and steel rulers because their black markings on satin chrome seem easier to read than other brands. Any of the name brands work well, but the contrast on Starrett instruments is easier on most people's eyes. Brown & Sharpe dial calipers have given good service. They cost more than the imports but not as much as other name brands, and they are very smooth in operation. The covered rack keeps dirt out, and they rarely skip a tooth unless dropped. PUC uses Starrett dial indicators on the lathe beds, but the application where they are used causes them to get sticky fairly quickly. Any brand would have the same problem, so inexpensive imported indicators will be used in the future. Once digital readouts are installed on all the lathes, the indicators will no longer be needed.

CARBIDE INSERTS: All major brands that PUC has tried work well. Local Kennametal representatives are very easy to deal with, and they have donated tooling in emergencies on several occasions when students have wrecked tooling and the university did not have time to process a purchase order. They also give a substantial discount to educational institutions when ordered directly from Kennametal. Often, they seem the most expensive carbide tooling company until taking the discount, which often leaves them the most competitive.

WELDING EQUIPMENT: Both Lincoln and Miller equipment have given excellent service in the PUC's Manufacturing Laboratory. Individual weldors have personal preferences, but both brands are reliable. Advice from a program's local advisory committee might be useful when purchasing welding equipment.

FOUNDRY EQUIPMENT: McEnglevan Industrial Furnace Company offers a nice line of furnaces capable of melting aluminum, copper alloys, and even grey iron. PUC has used one for a number of years with excellent results. Many ancillary items are needed to run a foundry, and McEnglevan has complete packages with molding benches, riddles, etc.[5]. Often, local chapters of the American Foundryman's Society[6] can be counted on to provide donations of consumables and student scholarships.

Conclusions

The process of rebuilding PUC Manufacturing Processes Laboratory began long before assessment and continuous improvement became common terms among educators. The author followed an intuitive Demming[7] approach without realizing it. While no quantifiable data exists to assess the project, much anecdotal data in the form of comments does exist. First, the interest level of high school students touring the facility has improved considerably as CNC equipment and digital readouts found their way into the lab. Second, alumni who visit the facility are uniformly impressed with the progress and express sorrow that the lab was not as modern during their class. Third, industry representatives are impressed with the lab both when they come for tours and when they send students to classes. And fourth, the level of senior projects that use the manufacturing laboratory has increased significantly.

In a similar experience, Purdue University's Mechanical Engineering Program at the West Lafayette campus revitalized its student machine shop in the 1990's. This shop is used by the ME students for any project related to their program. The most visible evidence of this is the SAE Formula and Mini-Baja races. Purdue ME students have placed high in these races in the past few years, in part because the students have a modern shop to build their cars in. The gearbox on the 2002 Mini-Baja car was CNC machined entirely in the student shop. With quality laboratory facilities available, engineering and technology students can learn more than ever before.

Rebuilding a manufacturing processes lab is a long, expensive process. However, modern manufacturing equipment is less expensive and more capable than ever. Modern laboratories with multi-axis CNC machining and modern conventional machining, welding, and casting equipment impress students, alumni, industry, and administrators and generate considerable interest in engineering and technology. The author feels the results are worth the investment.

Bibliography

[1] PUC METS Department Web Page, http://www.calumet.purdue.edu/mets/.

[2] PUC Engineering Department Web Page, http://www.calumet.purdue.edu/engr/.

[3] Vrska, M., and Higley, J., Putter Head Design, Proceedings of the Flexible Automation and Intelligent Manufacturing conference, June 25th -28th, 2000, Baltimore, Maryland.

[4] Haas Web Page, http://www.haascnc.com/training/.

[5] McEnglevan Industrial Furnace Company Web Page, http://www.mifco.com/index.htm.

[6] American Foundryman's Society Web Page, http://www.afsinc.org/.

[7] Deming, W.E., "Out of Crisis," Center for Advanced Educational Services, Cambridge, MA, 1986.

Biography

JAMES B. HIGLEY, P.E. holds the rank of Professor of Mechanical Engineering Technology at Purdue University Calumet. He is responsible for coordinating the Mechanical Engineering Technology (MET) program, as well as teaching courses in parametric modeling; integrated design, analysis & manufacturing; manufacturing processes; and thermodynamics. He holds Bachelor and Masters Degrees in Mechanical Engineering from Purdue University.