Manufacturing Engineering Curriculum Renewal in a General BSE Program

David Che, David Clark, Tom Magnone

Geneva College

Abstract

After many years of absence, in the spring of 2009 we started to offer the manufacturing engineering curriculum again to the students in the BSE program at Geneva College as engineering electives. The aim was to strengthen the manufacturing engineering preparation/background of our engineering students (especially those in the mechanical engineering concentration) to meet the needs of local industry. A three credit course in manufacturing engineering and a three credit course in quality engineering are being offered in the spring semester in alternate years. We immediately saw the benefit of this arrangement from the feedback of our recent graduates in the industry. In this paper, the authors summarize what was learned from integrating manufacturing engineering concepts into mechanical design curriculum, and incorporating global aspects of manufacturing in manufacturing engineering curriculum. We will outline some of the changes we have made to the curriculum and the challenges we have faced. Topics of discussion also include immersing students in an industrial setting in and outside of classrooms and hands-on project-based experiential learning.

Keywords: manufacturing engineering education, globalization, experiential learning

Introduction

Historically, civil and industrial engineering were the largest concentrations, producing the majority of engineering graduates at Geneva College, a Christian liberal arts college in western Pennsylvania[1]. Since the mid-1960's, however, the engineering program saw an increase of diversification into mechanical, electrical, computer and chemical engineering. By the early 1990's, the Bachelor of Science in Industrial Engineering (BSIE) program, once the mainstay of the Engineering Department, was attracting less and less students. This trend was in line with the termination of the GI program after World War II and the steady decline of the steel industry in the area. In 1993, the BSIE program was officially terminated[1], and the instruction of manufacturing related courses eventually stopped.

Currently, the two largest groups of students in the ABET accredited general BSE program at Geneva College are in civil and mechanical engineering concentrations. Although many manufacturing jobs have been lost in the last several decades, there are still significant amount of manufacturing related industry in the area. These companies are more focused now and are transforming themselves into either high-tech or serving a niche market with increased productivity and competitiveness. In the greater Pittsburgh area, there are still a large number of engineering positions available to our engineering students that would require some manufacturing background. In recent years, with the continued rise in the cost of labor and transportation overseas, there has been an undercurrent of manufacturing “flow-back” going on in America[2]. Some American companies have been returning some or all of their manufacturing operations back to America[3]. In addition, many foreign manufacturing companies, taking advantage of tax breaks offered by different localities, have started to invest in new factories in US. This has been prompted partly by the call to be closer to customers and/or to meet the needs of satisfying the domestic content requirements of certain defense contracts[4].

Since the spring semester of 2009, the manufacturing engineering curriculum has once again been offered to the students in the BSE program as an engineering elective. The aim was not to restart the BSIE program, but instead, to strengthen the manufacturing engineering preparation/background of our engineering students, especially those in the mechanical engineering concentration of the BSE program, to meet the needs of local industry. In the following sections, we will summarize what we have learned from integrating manufacturing into mechanical component design curriculum, integrating globalization issues in manufacturing engineering education, immersing students in an industrial setting in and outside of classrooms, and incorporating hands-on project-based experiential learning.

Integration of Manufacturing Engineering with Mechanical Design

Why incorporating manufacturing engineering in a traditional mechanical engineering program? The answer is simple: manufacturing is inseparable from design. If you teach mechanical design, you have to cover some manufacturing, or vice versa, to complete the story. We believe that manufacturing engineering should be a required course of study in any mechanical engineering curriculum. Design engineers need basic knowledge of manufacturing processes and materials to do his/her job well.

Manufacturing is also a fun topic to teach – people in general are curious about how things are made. In one lecture of the mechanical component design course, for example, while we were covering fasteners, we challenged the students to design a machine or a process to produce nuts and bolts. The instructor would give students 20 minutes to think and talk about it in class. Then he would ask them one by one (or group by group, depending on the class size) to explain their designs to the class. Many of our students suggested machining as the primary method to make nuts and bolts. Others suggested casting. After they all shared their designs, the instructor told them: "None of you will make any money by doing it that way!" He then showed them a video clip[5] on how fasteners are actually made. The students watched with wide open eyes as they observed how a bolt was made from cold forming processes (cold heading of bolt heads and cold rolling of thread), and how a nut was made from hot forging and high speed tapping processes (up to 300 bolts/nuts per minute). It really stoked their interests. They were deeply impressed and fascinated by the ingenious designs of modern high volume manufacturing processes and related machinery.

Once the students had learned how fasteners are manufactured, it became so much easier to talk about fastener design issues, such as corrosion considerations, grade selection, and economic implications of a particular design. The seemingly most mundane and uninteresting of all machine elements came alive to the students. We then talked about various types of fasteners and their unique applications and introduced them to fastener standards[6] and trade associations such as IFI[7]. By now, our mission was accomplished – the gaps between design and manufacturing were bridged. The students really liked this approach to teaching mechanical component design. As one student shared,

> *"First, I would like to thank you for an exciting and very informative semester. I did learn a great deal not only from the course textbook, but also from your own working experience. I now have a better understanding of the manufacturing process and steps required when constructing a design. ... The videos we watched in lecture were also*

> *instructive. Working in the shop helped me think more critically about the stages during construction and how to make quick adjustments after testing."*

We also introduced our students to the manufacturing of gears when discussing gear design. As shown in a later section of this paper, this also greatly enhanced the student's learning experience.

Global Aspects of Manufacturing

Why do we need to talk about globalization? Coming fresh from an overseas assignment, one of the authors of this paper was keenly aware of the debate of the day in America: is globalization good or bad for America? Some see it as a threat to American jobs, especially in the manufacturing sector; others see it as an opportunity for US companies to tap into growing economies in the world, grow revenue, and retool our own industry. Many in the industry and academia realize the need for our engineering students to know the competitive world of a new global economy, especially as it relates to manufacturing and engineering. Stephan and Sriraman in 2005 commented that "very few U.S. manufacturing engineering programs explicitly recognize the global aspects of manufacturing at the course level" [8].

To help the students understand the issues involved, Figure 1 was shown in the introduction lecture of manufacturing engineering. It was pointed out to the students that at this day and age, as a mechanical engineer, they will often be thrown into a situation where they will have to communicate with multiple vendors and subcontractors. They will probably be working with vendors or engineers from outside of America. In Figure 1, RFQ refers to "request for quote", and SOR refers to "statement of requirement". These are common terms engineers use to communicate to the vendors/subcontractors what they want in the designed product/process and to solicit bids to the project. Specification of requirements is becoming an important part of the engineering profession.

To help students understand the global aspects of manufacturing, we asked them to read Thomas Friedman's "*The World is Flat*"[9] and journal their response to it. Towards the end of the semester, each student was then required to give a presentation and write a reflective paper on the topic. Since Friedman is a proponent of globalization, we needed an opposing view to help our students see both sides of the issue.

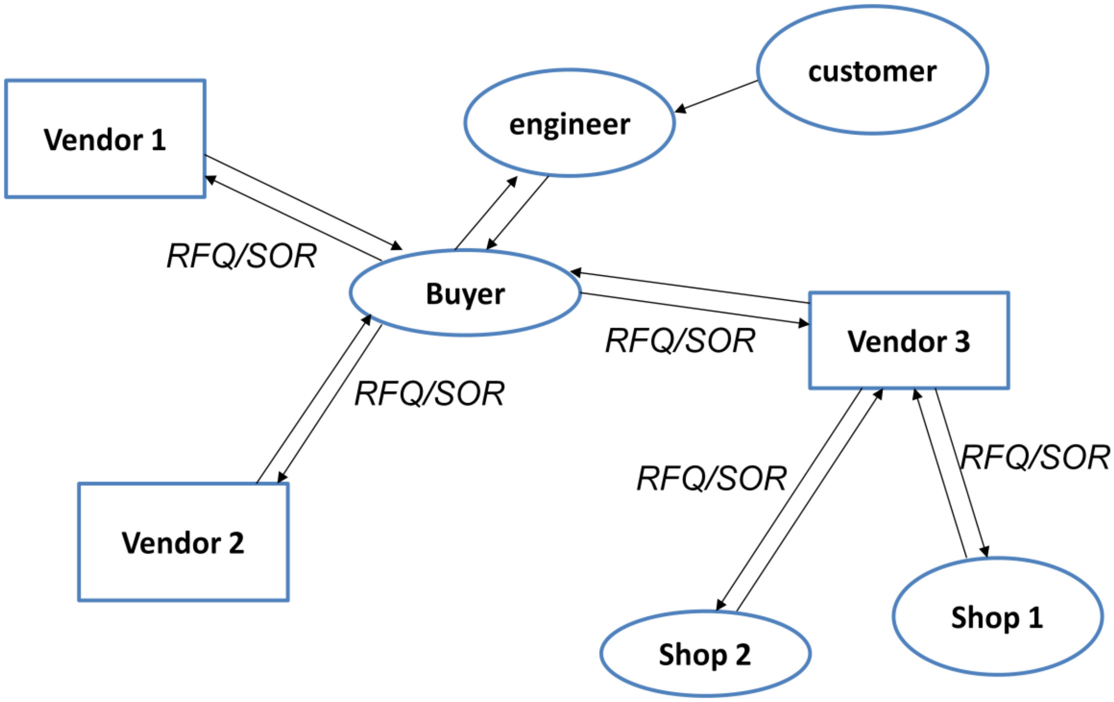

Figure 1 Business model of a modern manufacturing enterprise

Fortunately, the opponents were right in our backyard. The State of Pennsylvania, like many states in the Midwest, was hard hit with manufacturing job losses over the past several decades ever since the decline of the steel industry in the mid-60s. Through the connection of friends, we got to know Mr. David W. Frengel[10], government affairs director for Penn United Technologies, Inc. of Saver, PA. He has been working on lobbying the Congress to level the playing field for American manufacturers since 2002. Mr. Frengel is also a member of the Coalition for a Prosperous America[11], a nonprofit that has pushed for trade reform in the US. We invited him to give our students a guest lecture on the pitfalls of globalization. We also opened his talk to the whole campus, resulting in the participation of several students who were studying similar topics in a liberal arts class at the college. Mr. Frengel relayed the concerns that many Western Pennsylvania officials and companies held, that China's practice of undervaluing its currency to make its exports cheaper in the United States needed to be changed in order for manufacturing to recover from the recession. Others, however, disagreed. Gilbert Koedel, an advisory board member for Bon Tool Co. of Richland, PA, which makes tools for construction trades, contended that "manufacturing in the United States would be better served by reducing its cost structure problem. Costs related to health care, regulations and labor, among others, have more of an impact on American manufacturers competing in the world“[12].

We exposed all these views of globalization and its impact to manufacturing to our students. The instructor also shared with the students views from the book “*Globality*”[13]. According to the authors of this book, “*Globality* is not a new and different term for globalization; it is the name for a new and different global reality in which we’ll all be competing with everyone, from everywhere, for everything”. In other words, globalization is already a reality whether you like it or not. One local example we gave our students was the one of Nova Chemicals Corporation, Canada's largest chemical maker, whose shares more than quadrupled after it agreed to be acquired by Abu Dhabi-based International Petroleum Investment Co. for $499 million in cash[14]. Another local example was that of the Hershey Co., who closed its plant in Reading, PA on Feb. 20, 2009, shutting down production lines that for 23 years have produced such storied sweets as York Peppermint Patties and 5th Avenue Bars. The production lines at the plant have been moved to Monterey, Mexico and other facilities in the United States as part of a restructuring of Hershey's, the nation's largest candy manufacturer[15].

Towards the end of the semester, we allowed students to present their views based on the information they had acquired. They each had about 15 minutes to make a presentation. It was interesting to see the broad range of opinions these students developed towards globalization, as shown in Figure 2.

There were strong opponents of globalization, who cited many negative effects such as environmental degradation and pollution, poor quality control of imported products, unfair trade practices, loss of American jobs, etc. There were also strong proponents of globalization, who in turn, brought up the benefits globalization brings to America: “right now, outsourcing looks like a bad thing, but it is forcing America to have the strongest, smartest labor force in the world”. The student went on to say, “the old middle needs to recover from its “sucker punch,” and get back on its feet. It needs to see the benefits and opportunities that outsourcing has given it”. Outsourcing is taking unskilled labor such as assembly line work or data entry and shipping it to other countries where it can be done for a much cheaper price - Friedman refers to these jobs as the “old-middle” jobs[9].

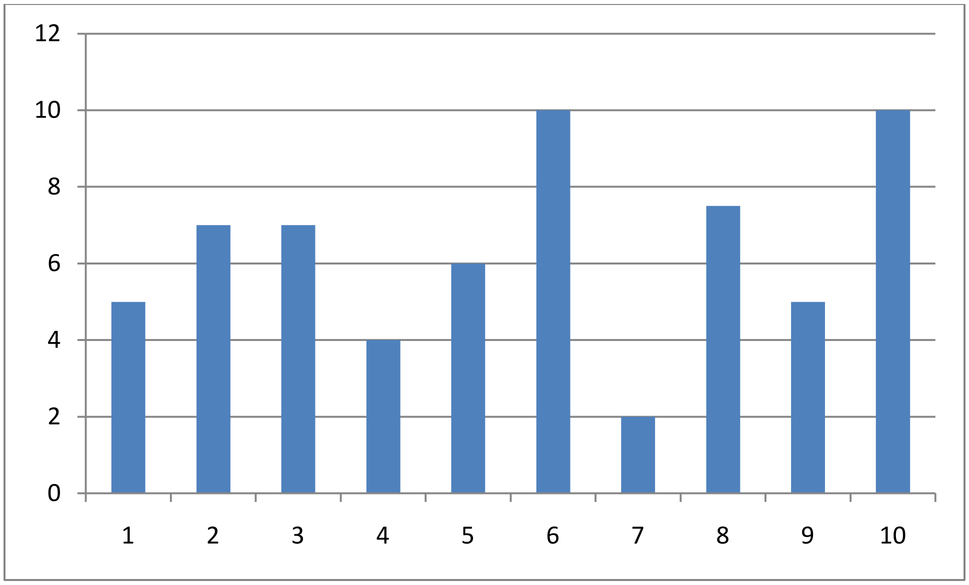

Figure 2 Survey of student reactions to globalization with a score of 1 being strongest support and 10 being strongest against (horizontal axis represents each individual student and vertical axis representing their scores based on their reflective paper)

This same student then argued that "outsourcing is forcing the entire "old middle"—I say *entire* because one day there will be no "old middle" left in this country—to learn a skill or trade that cannot be outsourced …… Outsourcing not only can eventually help our America, but it is also helping other less fortunate countries". He also mentioned the benefits of globalization on engineering as "globalization also promotes a faster, more efficient design and engineering". To counter the negative impact of globalization such as the tremendous increase in environmental pollution, he proposed that "with this problem, also comes an opportunity. America's new middle can shift to become a "green powerhouse ... The world is moving toward a global economy. In order to be successful in this global economy, we have to be willing to change … We have to be willing to change the way we do business, the way we deal with people, and the way we live our own lives. America is still struggling with globalization because we are still struggling with change."

There were also students that shared their personal experience with family members losing jobs due to globalization and its impact to manufacturing,

> "… it has not been easy for my family. It's difficult because my father lost two different jobs while my mother and younger sister both have some medical problems. Also both me and my younger sister are in college. So money has been like gold in my household because of the effects of globalization. My father actually just started a new job this past Monday where he will be making hip and joint replacements. My dad is a machinist. This is one of the largest manufacturing processes that were hit by globalization".

Another student who was a strong opponent of globalization blamed the American economic crisis on globalization,

> "Because of the globalization movement the United States is in a great economic crisis. This happened because most of the much needed production jobs here in this country were shipped to foreign nations which led to a great reduction in the U.S. workforce. In an effort to help other nations and proceed with globalization, the United States government has been importing more than they are exporting. … Just as a business cannot survive in this way, neither can a government or a nation. The effort of the U.S. to support globalization has made other nations richer and has dilapidated our own economy" …

Another student, though not as negative, did have some serious doubts that globalization is a good thing for America,

> "Thinking back on these points that I discussed, I don't feel as though I've come to a conclusion on whether or not globalization is an overall good or bad thing, the only conclusion I've come to is that it is happening, and there isn't really much that anyone could do to stop it. I think that certain aspects of globalization have the potential to do much good for the world in that if it were to be somehow guided in the direction of bringing the poor and starving nations up to a level where at least the standard of living was acceptable, then that would be a great thing for us, however as I said earlier we live in a broken world polluted by sin, and the greed and selfishness of a powerful few has the potential to drive the gap between poor and rich even further apart. If Thomas Friedman[9] believes that globalization will bring about an economic victory for the world when left to itself, that may be true for some, but the victory overall will most likely be a Pyrrhic one."

These wide ranging views on globalization from our students further confirmed the need to better inform them and educate them on the pro's and con's of globalization and its impact on manufacturing engineering and society as a whole, so that they might obtain a more balanced view.

Bridging the Gap between Theory and Practice

One of the keys to an effective engineering education is bridging the gap between engineering theory and engineering practice. How can this be done? The authors found two ways of doing it: (1) bringing a factory to the classroom and (2) bringing the classroom to a factory.

Bringing factory to the classroom

It would be ideal if the classroom is right next to the factory floor or engineering design house where all the action is going on. Unless one's university or college is equipped with a large industrial grade lab, it would be impossible to immerse students in a factory setting. However, due to introduction of wireless Wi-Fi on campus, we were able to bring a factory to the classroom via broadband video streaming. In spring 2009, when we were teaching the manufacturing engineering class at the college, bandwidth for the campus Wi-Fi was not yet ready for real-time streaming – a Youtube video would take forever to load. However, in spring 2011, when we were teaching it again, we were able to play Youtube videos in class because the Tech Services at the college had already upgraded the hardware for on-campus wireless internet connection and increased bandwidth. That allowed us to show a lot of Youtube videos that demonstrated how different manufacturing processes work. It made the lectures more lively and really helped the students understand the course material better.

Another reason we used a lot of video was because the students were raised in a totally different environment than most of our current faculty. They are more visually oriented. They watched more TV and played more video games. Visual aids are important in educating this generation of engineering students. We tried very hard to gather all that we could find on the internet in the form of computer animations, video clips, images, or even general discussions of the engineering topics in more “laymen’s terms” from such popular websites as the Wikipedia.org, HowStuffWorks.com, You-tube.com, etc.

We also took advantage of some industrial seminars offered by our industry guests. In one occasion, we invited a former graduate back to give a guest lecture on plastics extrusion processes, because he was working for a local plastics extruding company. In another occasion, we invited a member of the board of trustees for the college to talk to the students about economic and industrial development developments in the Huntsville, Alabama area. In yet another lecture, we invited representatives from the hot-dip galvanizing industry to talk to our students about the benefits of galvanization in combating corrosion in engineering structures and machinery. These are all examples of bringing “the factory” to the classroom.

Bringing the classroom to the factory

In the mechanical component design class, after we covered some gear design materials, we arranged for our students a plant tour of a local gear engineering and manufacturing firm - Akron Gears[16]. It was an eye-opening experience for everyone, including the instructor, as we had never been to a gear engineering and manufacturing facility before. We were immersed in an environment with gigantic gears being cut, gear housing being repaired, etc. Mr. Tom James, owner of this firm and a 30 year veteran in gear making, gave the students a lecture on gears. He also invited us to participate in their early morning staff meeting where customer issues were discussed. The impact of this immersion was so great that one student couldn’t help but exclaim, “I feel like I have learned more this morning than I learned the whole semester in the classroom!” That comment struck us. We knew it could be dry if there were no lab or project work associated with the teaching of theory. Sure, the students learned a lot of theoretical analysis in the classroom that would include gears, but we all know how fast they can forget what they learned without internalizing it. In our lectures on gear design that semester, we already made a conscientious effort to use multimedia, including computer animations and videos to give the students a realistic view of how the gears work with the theory behind it. In other words, we thought we already did a decent job of engaging the students and making the subjects alive. But by now, we had to admit, that immersing all our senses, or rather, our whole beings, in this real life engineering environment, resulted in a whole lot more learning.

The old adage goes, "a picture is worth a thousand words". May we venture to say, "a video is worth a thousand pictures", and "a pertinent, timely plant tour is worth a thousand videos". After this tour, a lot of the things we covered in class made more sense to the students, and the concepts really sunk in. Things they learned this way will stick with them for a long time.

In spring of 2011, we also arranged a tour of the General Motor's Lordstown Assembly Plant. This is after we discussed sheet metal stamping and assembly in lectures. We toured the assembly line for the new Chevy Cruze (Figure 3). We also toured the CMM room where Coordinate Measurement Machines (CMMs) are used for periodic checking of build quality of body-in-white (the body after welding but before painting is applied), as shown in Figure 4. This experience gave our students some idea of what a high-volume and modern manufacturing operation looks like. It also reinforces what they learned about quality control, inspection, welding and automation. It helped bridge the gap between theory and engineering practice.

Figure 3 Tour of the bodyshop at GM's Lordstown assembly plant

Figure 4 Tour of the CMM room at Lordstown assembly plant

Hands-on Experiential Learning

An important aspect of a manufacturing engineering curriculum is its hands-on projects or activities. Students like to make things, and they are not afraid of getting their hands dirty. For a small engineering program at Geneva College, we do not have extensive manufacturing engineering labs and facilities. What we could do is try to make the best use of what we have and gradually expand on it. Our shop has a Rockwell lathe, a Rockwell milling machine, a grinder, band saws, drill press, some MIG welders, and an old Tinius Olsen tensile testing machine. In 2010 we acquired a brand new 4-axis CNC mill. We did not have time to incorporate the CNC mill into our curriculum this past semester, however, we did design a hands-on project that made use of a lot of what we have in the labs.

We grouped the students into five teams of three. They were to make parts according to the drawings shown in Figure 5. Then they would weld them together in two configurations, as shown in Figure 6. One configuration is forming a butt joint and the other a lap joint. Tools we provided them included: (1) a Metalworker shear; (2) the milling machine with a 1" diameter end mill, and a 45^{o} chamfer end mill; (3) layout blue; (4) scales, Vernier calipers, scribes, etc.

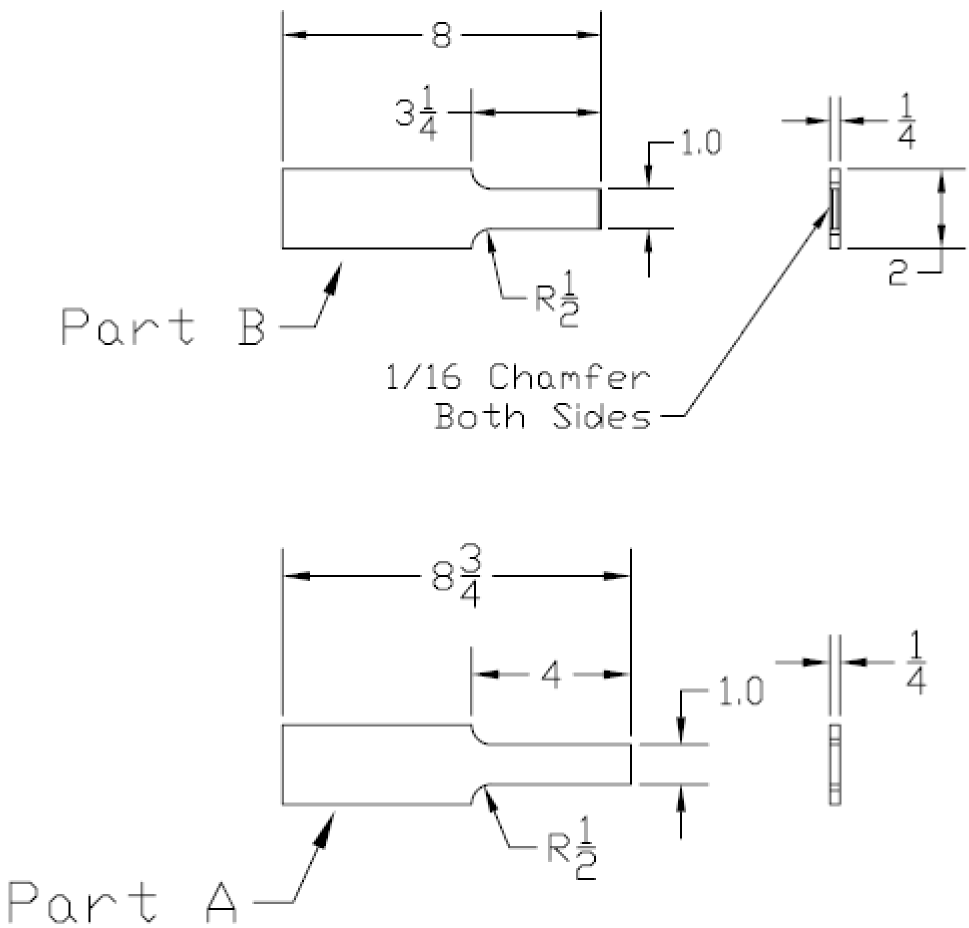

Figure 5 Dimensions of Parts A and B

The lab procedure is as follows:

1. Shear to length two pieces each of Part A and Part B according to Figure 5.
2. Mill sides of Part A as per drawing. Always mill into the work so that the rotational direction opposes the direction of feed. Or use a band saw to rough cut out the middle section of the parts, and then use the milling machine to refine the dimensions and cut out the ½" radius portions.
3. Check and record the dimensions of the two parts of Part A. Verify that the parts are within tolerance.
4. Overlap the two pieces of Part A and weld them together in double-welded lap joint configuration. Overlapping length should be 1½". Set this welded piece aside.
5. Square the end to be chamfered of the two pieces of Part B if needed.
6. Chamfer the ends of Parts B per drawing. The 1/16" chamfer at the ends of the "dog-bone" provided the "V" gaps for the double "V" butt weld[17].

7. Mill sides of Part B as per drawing. Or use a band saw to rough cut out the middle section of the parts, and then use the milling machine to refine the dimensions and cut out the ½" radius portions.
8. Check and record the dimensions of the two pieces of part B. Verify that the parts are within tolerance.
9. Butt together the 2 parts of Part B as per drawing and weld them together in double "V" butt weld configuration[17].
10. Calculate the yield strength and the ultimate strength for your parts.
11. Put the test pieces into a tensile machine and record the yield and ultimate strengths for each sample. Compare the measured results with the calculated results.

Ultimate strength data obtained are plotted in Figure 7. For comparison, we also pulled a piece that never had been cut off and welded – that is, we tested a piece that is simply from the original coupon.

Feedback from students was overwhelmingly positive this past semester – all of the students who wrote down something in the comment section of the evaluation forms said they loved and enjoyed the hands-on projects.

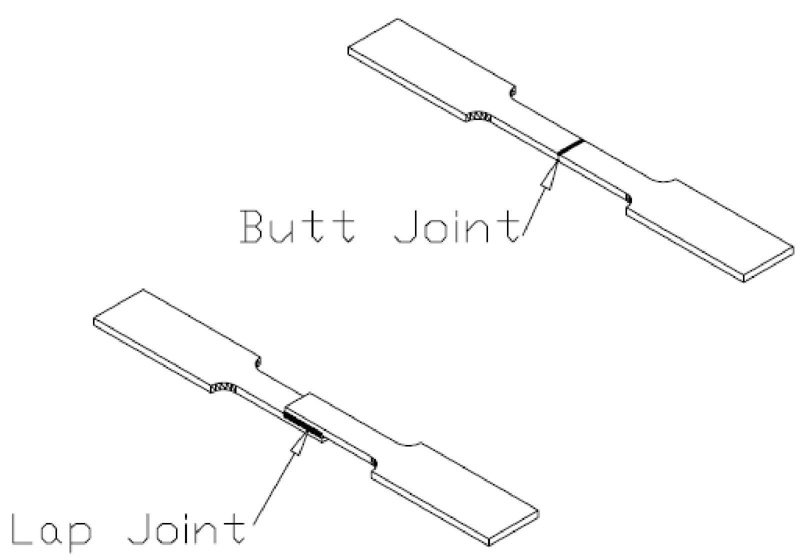

Figure 6 Weld configurations

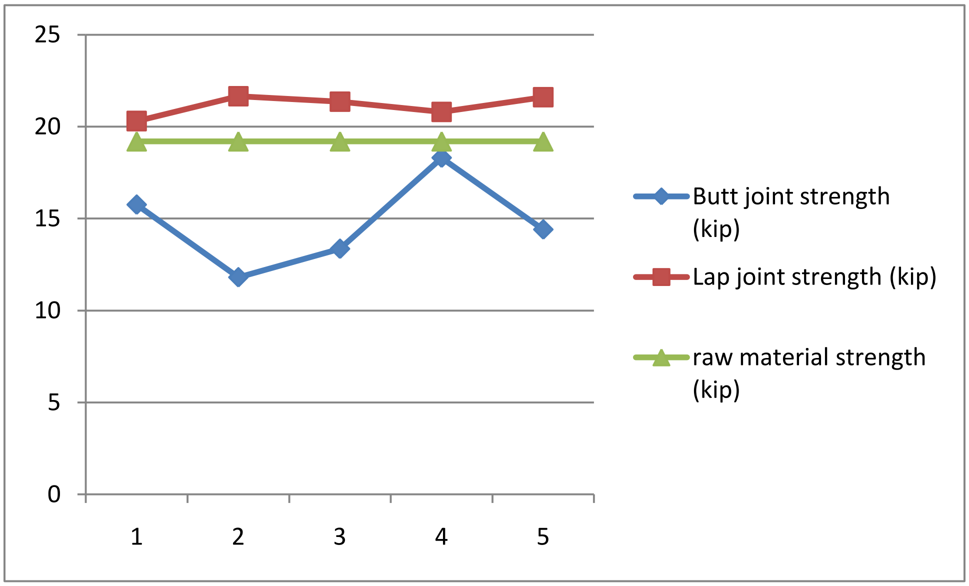

Figure 7 Test results (horizontal axis is group #, vertical axis is tensile strength in kip)

Conclusion

Ever since we started to integrate manufacturing engineering into the mechanical design curricula and started to offer manufacturing engineering in the general BSE program, we began receiving positive feedback from recent graduates. One student shared with us that the exposure to different manufacturing processes helped him communicate with the hiring manager during his job interview and it helped him land an engineering job at a local extrusion manufacturer. Another student got an internship in a local circuit breaker manufacturing plant and last year obtained a job in medical equipment manufacturing industry.

There are a lot of materials to cover in the general field of manufacturing - the instructor needs to pick and choose which materials to cover based on his or her expertise. It might be difficult to put everything all in one class. One semester we talked about globalization, but we did not have time to talk about environmental impacts of manufacturing. Another semester we used a lot of web-based instruction videos and spent a few class sessions on a hands-on project, but we did not have time to cover globalization issues. In the future, we might want to increase the total credit hours for this manufacturing engineering class to four, with one of the four credit hours devoted to a weekly lab session. We are thinking of incorporating CNC into our curriculum and labs.

Each instructor is gifted in different areas of expertise, and has a passion for different things. But none of us have expertise in everything. From the facility and lab equipment standpoint, very few universities or colleges have everything. However, we can always surround ourselves with a team. In the process of our designing and delivering this curriculum as a team, we came up with a new name for this approach - "indigenous engineering". Basically it is take what you are given and give what you have taken. It is a strategy to maximize the use of local resources which include both lab resources and human resources to achieve the goal of a quality education. The instructor is more like a manager – he needs to be able to identify local resources and pull them together in developing and delivering a fresh and up-to-date curriculum that will meet the needs of students and the industry.

Acknowledgement

We'd like to thank Dr. James Gidley, chair of the Department of Engineering at Geneva College, for his support of our work in this paper.

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Biographical Information

DAVID CHE

David Che joined Geneva College in Beaver Falls, PA as an Associate Professor of Mechanical Engineering in 2008, where he also currently serves as the Director of the Pinkerton Center for Technology Development. He received his B.S.E in precision engineering from Harbin Institute of Technology, China, a M.S from Ohio State University and a Ph.D from University of Michigan, all in mechanical engineering. He was a senior research/project engineer at General Motors Corporation from 1997-2005. He also served as general manager of Stafast Products, Inc.'s Asia operations in China from 2005-2008.

DAVID CLARK

David Clark currently serves as Co-director for the Pinkerton Center for Technology Development at Geneva College. He obtained his B.S.M.E, B.S.E.E. and B.S. in applied mathematics from Geneva College. He had 13 years of industrial experience working at Ellwood City Forge, Ellwood City, PA.

TOM MAGNONE

Tom Magnone has been a staff member in the Physical Plant department of Geneva College for the past ten years. After completion of coursework in welding from Lawrence County Vocational Technical School in 1976, Tom started his work in welding at Garrett Railroad Car and Equipment Company. Prior to his work at Geneva College, Tom spent 21 years utilizing his welding knowledge at several industrial sites including Forney, Inc., American Industries Inc. and Taylor Winfield Inc.