AC 2007-154: PROJECT REJUVENATION: A TIME-TESTED 1ST YEAR MACHINE TOOL PROJECT

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Dr. Harriet Svec has a background in Curriculum and Instruction and assisted with the curriculum rejuvenation of the project.

Project Rejuvenation: A time tested 1st year machine tool project

Abstract

An engineering prerequisite course for Mechanical and Manufacturing Engineers has stood the test of time as it has changed with technology. The course laboratory project was originally designed to offer students a hands-on approach. The rejuvenation of the project retained the hands-on approach with updates to meet technological changes. More importantly, the outcomes and objectives were updated to meet the current department and ABET standards. In addition, more complete assessment tools were included in the course to provide greater input concerning the success of the class. Today, the *Survey of Machine Tool Applications* course is a prerequisite for a sophomore level *Introduction of Mechanical Design* course and is intended to expose students to material selection and equipment used in an engineering shop setting.

The *Survey of Machine Tool Applications Course* addresses issues contemporary design engineers face when they must apply their knowledge of material fatigue, durability, recycleability, disposability, availability, and aesthetics in addition to the traditional concerns of strength, sizing, and cost. Modern computer aided design software can render elegant functional parts but the associated manufacturing costs for producing these pieces can be prohibitive. The project offers fundamentals for evaluating how materials and processes relate to the basics of manufacturing. In addition to being useful for students as they progress through their program, it sets the stage for their senior engineering design project and ultimately their career. This paper speaks to the curriculum design needed to bring the project up to 21st century academic standards.

Changes in the curriculum design identify the outcomes of a project originally designed in 1955 and how those outcomes and expectations have been aligned to meet the department outcomes and ABET standards of today. The course identifies and addresses using more than one assessment tool that translates well to the department and ABET standards for assessment. Rejuvenation of a time tested project provides a sound model for a hands-on, lab oriented first-year project.

Purpose of the paper

The paper addresses the rejuvenation and redesign of the GE255 Survey of Machine tool applications. The course has been taught since 1954 to Mechanical Engineering students as well as other engineering majors over the last 50-plus years. When the College of Engineering expanded to include a Manufacturing Engineering and Technology major, the course was included as a foundation for them as well. This paper discusses the curriculum design needed to bring the project up to 21st century academic standards.

The course laboratory project was originally designed to offer students a hands-on approach. The rejuvenation of the project retained the hands-on approach with a re-design of outcomes, objectives, materials, processes, assessment, and presentation to meet current department objectives and ABET standards. More complete assessment tools were included in the course to provide greater input concerning the success of the class.

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A Historical perspective

During the 1954-1955 academic year at South Dakota State University, George Harvey Wakeman defined a project that would offer the mechanical engineering students, and others who enrolled in the machining course, a laboratory experience. He would not have known that his curriculum design would last for 50 years and beyond. The uniqueness of his prototype and his attention to the design experience has stood the test of time.

Engineering education faces significant challenges in an attempt to meet the demands on the engineering profession in the 21st century. At a national level, a number of well-know reports, circulated during the mid to late 1990s have stressed reformation in engineering education for more relevance and compatibly with a technically inter-connected workplace. The reports – national and international – call for curricula that include, among other areas, integrated and experiential activities. The rejuvenation of the project begins the process for student engagement in the technical workplace.

Further, engineering facilities across the nation focus on new and better technology. Design and milling processes continue to be the basis of good engineering. At the university, the students are provided with the background information to understand the basics, to recognize quality machining, and to succeed in their careers introduces them to career expectations. The rejuvenation of the time tested "Tap Wrench" project has been updated to include machining techniques, metallurgy, machining vocabulary, and the jargon as well as helping students become familiar with and use actual machines in production. The experience provides a base for other engineering design courses, senior design projects, and careers in manufacturing or mechanical engineering.

The "Tap Wrench" project provides a sound participatory approach of tradition engineering education. Well know theorists in principles of learning recognize Wilbert McKeachie as one of the leading authorities of his day. McKeachie, a behavioral psychologist, believed that only two principles of learning held with any consistency were: a) active participation is still better than passive learning, and b) meaningful learning is still more effective that rote memory.[5] Well before McKeachie conducted actual research on theories of learning, engineering was taught, to a large extent, in a "hands-on" learning environment. Through the rejuvenation process, care has been taken to maintain a "hands-on" approval approach with the original specifications of the product.

A short summary of "who we are"

The College of Engineering departments share courses including instruction through the Engineering, Technology, and Management Department (MNET) where GE255 *Survey of Machine Tool Applications* is housed. Mechanical Engineering as well as Manufacturing Engineering and Technology students are typically the majors enrolled in the course.

A brief summarize our position in the University and in the college, will be helpful in appreciating the need for the rejuvenation and re-design of the course. South Dakota State University is a land-grant institution established in 1881 located in Brookings, South Dakota. SDSU is the largest university in the state of South Dakota. The total enrollment is in the 11,000 to 12,000 student range. Of those, around 8,000 are full-time undergraduate students. Approximately 1,000 are full-time undergraduates majoring in a CSEMP (Computer Science, Engineering, Mathematics or Physics) discipline. All CSEMP disciplines are under the College of Engineering umbrella.

In November, 2006, the MNET program successfully sought ABET/TAC approval for the first time. The rejuvenation of the GE255 was guided by the ABET/TAC guidelines[1]. For obvious reasons, the course re-design was necessarily to bring the course up to current technology and to meet curriculum standards for ABET/TAC approved courses. As one of the foundation courses in both MNET and ME, the re-design was essential.

The Curriculum Re-Design:

Based on the extensive information published by educational researchers, we know that education has three purposes: to pass on knowledge acquired through the ages, to help students discover their potential, and to equip them with the tools and skills for self-directed learning[2]. The MNET program has an established program in place for continuous improvement based on the Deming Wheel (PDCA Cycle), a widely recognized method for improving processes where the participants (in our case educators) "Plan, Do, Check, and Act" and repeat or loop through the cycle typically every three years. The cycle includes testing, learning experiences, and class performance. In addition student surveys, employer surveys, alumni surveys provide support along with accreditation audits, advisory council input, and an SDSU institutional review.

The curriculum re-design addresses the ethos of the college and department, the program goals and objectives, and the criteria and guidelines for the MNET Programs under ABET/TAC. The decision to rejuvenate the curriculum in the (GE255) *Survey of Machine Tool Applications* course was not taken lightly. The objectives and outcomes of the project were scrupulously reviewed as part of a larger picture of curriculum redesign prior to the ABET/TAC application.

ABET/TAC Goals and Objectives:

The ABET/TAC guideline found in the Criteria for Accrediting Engineering Technology Program that most appropriately describes the curriculum in GE255. (Outcome a).

An integral part of ABET/TAC "Objective a" is the importance of precision and the quality of the product. The project provides one of the first opportunities for the budding engineer to realize the importance of accurate measurement, building to specifics, and product precision. The expectation is a quality product. For some students, this means "starting over" if their product is outside the range of acceptability and speaks to mastery.

a. an appropriate mastery of the knowledge, techniques, skills, and modern tools of their disciplines.

Clearly, engineering programs aspire to provide students with an educational background to have good problem solving skills enabling them to reach sound conclusions. To reach that goal, the basics of engineering techniques, a sound understanding of materials, and the ability to read and follow engineering specifications can be initiated in a laboratory setting such as the rejuvenation project.

The curriculum provides for specific instruction using machines to mill, drill, tread, broach, and turn. Integral to the process is the ability to identify and analyze the attributes and limitations of the materials used in machining and good stewardship of resources. Understanding limitations is paramount in thinking about materials and design in their projects as they work around those limitations to achieve the end product. Congruent with materials and their application is a discussion about "Feeds and Speeds". Whether the student is using a CNC machine or manual machining, whether the student is using carbide tooling or high speed steel, the concepts are universal. The value of looking outside the process to solve the specific problem is an area that discussed throughout the project.

Another element vital in all manufacturing is accuracy and repeatability. With the "Tap Wrench" project, students use their mathematical skills to measured and evaluate their project at all levels. Feedback is immediate. The project holds no secrets, the student doesn't have to "guess" what is required to achieve the level of proficiency desired, and the opportunity for mastery (perhaps beginning again) is always present.

Students use the vocabulary and jargon of machining and manufacturing while working with their project. Understanding the jargon will be helpful later in their design classes and it is important in their careers. Ultimately, basic machining exposure opens the door to engineering design and analysis. Although the curriculum doesn't include ABET/TAC "Objective f" specifically, the ground work for meeting the objective in higher level courses is laid.

f. the ability to identify, analyze, and solve technical problems.

With regard to students' careers, graduates take the knowledge they have gained and creatively and constructively use that knowledge to give themselves or their employers an advantage in the marketplace. The students' commitment to product quality, timeliness, and continuous improvement are all important objectives in a program that meets ABET/TAC standards. Again, although not included in the course objective grid, GE225 sets the stage for the development of "Objective k" in their core course work.

k. a commitment to quality, timeliness, and continuous improvement.

Unexpected benefits:

An unexpected benefit of the curriculum design is students' discovery of the potential for creating a product from a solid piece of steel. For some, the course cements an interest in manufacturing and mechanical engineering. Many traditional aged students have not worked with machining processes. For some, their high schools experiences focused on mathematics and sciences without exposure to technical classes. The curriculum expands the visions of many students as they look at an engineering career path.

Course planning:

Good curriculum design dictates the importance attached to course objectives from the perspective of both the instructor and the student. The course objective tells the student exactly what is expected and assessed. The objective gives a description of the conditions under which the performance is to occur. By following guidelines for instructional objectives, any ambiguity is eliminated[4].

Level: The ME program and the MNET program offer GE255 during the sophomore (2nd) year as a prerequisite to higher level courses. At some institutions, it may be possible to offer the course during the first year, depending on student requirements. The course is a prerequisite to the Mechanical Engineering and Manufacture Engineering Senior Design Projects taken during the 3rd and 4th years.

Instructional Objectives: In addition to the ABET/TAC general objective, the specific course objective is: To introduce the engineering student to machining processes including: measuring, milling, drilling, turning, threading, programming, etc. using manual and CNC (computer numeric control) machines.

Broadly, the course provides new knowledge about engineering processes where the processes for each step are presented and discussed in the classroom prior to the laboratory activity in the machine shop. Prior to each experience in the lab, the course includes a presentation and discussion of materials relating to metallurgy, the basics of feed and speed, and developing prototypes relative to each step in the process.

During pre-laboratory instruction, interjection of various topics can be included such as the "time and motion" studies of the early 20th century. Also, advantages or limitation of time at production in relation to number of items produced is discussed. The project provides an opportunity to discuss the cost of resources and the relationship to the value of the product. Clearly, as students actually mill a "Tap Wrench" the perspective of parts per hour and production requirements are evident.

Perhaps the best instructional tool is the finished product. When the faculty member "holds up" the completed "Tab Wrench" project and says, "This is what you will have when you have completed the project from this block of steel." The project is very specific, visual, and linear with expectations for the level of quality and precision clearly defined.

Assessment

Three types of assessment are used in the course. The first, and obviously more traditional method, is strictly objective. The project is evaluated using the specific precision defined in the project. The student grade is directly related to the product specifications. (See Attachment Excel Grade Sheet) Although there is specific lab time dedicated to completing the steps, students have the opportunity for mastery if they choose to spend more time in the lab during open hours. Students can "begin again" as many times as they wish enabling them to master the techniques and determine their own level of success. An assisting technician is available full time in the machine shop to help with mechanical difficulties.

The second type of assessment enhances the PDCA Cycle mentioned earlier in this paper. The students are asked to complete a student survey at the culmination of their project experience. The survey provides information on a number of fronts. It provides clear information concerning the student readiness for the course material. Although the majority of our students are within the traditional age group, they come to us with a variety of high school level experiences.

As with most basics courses, students finish the course much more homogeneous in their mastery than they begin. The assessment provides direction for our program of continuous design. We find that high school experiences and interests change as the technology changes. The level and specifics of instruction must be monitored while maintaining the rigor of the course work.

In addition, we are interested in identifying students' attitudes regarding courses. The survey focuses our attention on the importance of student attitude toward production engineering. Although given at the end of the project, the survey provides an opportunity for reflection by the students as they internalize the importance of the specifics to their career path. In summary, the survey provides a focus for the PDCA cycle. (See attached Student Self-Assessment Survey.)

The third assessment instrument used is the student evaluation of the course and instructor. SDSU has made significant changes in their student evaluation process of the past few years. Most recently, SDSU has contracted with the *IDEA Center* for student evaluations. The *IDEA Center,* from Kansas State University, defines effective teaching in terms of progress on the objectives of a particular course[3].

The course and instructor are consistently evaluated with results showing high marks. Although taking full credit for the high ratings may be advantageous as a faculty member, a more realistic approach is to acknowledge that the students enjoy the course and rate it highly because they enjoy the process, recognize the value of the material presented, and are offered the opportunity to work the technology each class session. It is a win/win situation for both the faculty member and the students. (See attachment *IDEA Center* Student Evaluation.)

Course Delivery

Conducting a successful laboratory experience requires organization, diligence, adherence to a course plan, apportioning class time, and class size appropriate to the number of classroom facilitators available. Clearly, the step-by-step process of a hands-on project requires the instructor to follow the specific steps in order. It requires providing materials at the correct stage in the process at the correct time, and getting "ready to being". It requires that the instructor get each student off to a good start through discussion and presentation of materials relevant to the specific step in the process.[2]

First, and extremely important is the safety lesson that all students must have before entering the machine shop. Although far from fool proof, the faculty member's and assisting technician's thorough knowledge of the machines and the process is beneficial. The experienced machinist can detect and correct potentially serious damage to a product or machine tool simply by hearing the "sound" of the feed or speed. More importantly, risk to the students is minimized by having experienced individuals in the laboratory.

A representative lesson is included in this paper to better demonstrate the instruction process. As part of the rejuvenation of the project, drawings, instructions, and photographs were prepared for clarity. During pre-laboratory instruction, directions are repeated, demonstrated, and hand-outs distributed. (See Attachment The Project 2006). In addition to discussions on metallurgy and the basics of machining, possible pitfalls are included. By being very explicit, some of the miss-steps by the students are eliminated providing a safe environment for successful completion of the project.

Good machine shop standards are essential. Students are expected to "clean up" before departing, know the mantra of a "clean shop is a safe shop", and facilitators encourage common sense decisions in the shop. Although these are minor expectations regarding outcomes, the clean shop philosophy adds yet another element to safe engineering experiences.

Finally, working with students in a shop setting provides an opportunity to develop rapport among the faculty member, the lab facilitators, and the students. The shop setting is conducive to building rapport with the students as faculty and facilitators assist the students one-on-one. It is a valuable opportunity for the retention of students in both the ME and MNET programs.

A final word on educational perspectives:

The educational community has long been aware of differences in learning styles. Undeniably, a faculty member in the institutions of today must address the extensive research conducted describing various student learning styles. In actuality, the hands-on approach for aspiring engineers seems to work well. We have not conducted research to determine if mechanical and manufacturing engineering students have a predisposition to being hands-on learners, but we do know that the evaluations by students indicate that they like a hands-on approach to the topic.

The outcomes were clear in 1955 based on the prototype and they remain clear in 2006. In 1955, the educational pedagogy didn't include the specifics of outcomes and objectives as it does in 2006. (See attachment The Project 1955) A project with a clearly defined outcome will stand the test of time. By reviewing the outcomes established in both mechanical engineering and in manufacturing engineering, we knew which outcomes the project demonstrated. The curriculum was updated to include factual knowledge in material fatigue, durability, recyclability, disposability, availability and aesthetics in addition to the traditional concerns of strength, sizing, and cost. In addition, the assessment of the project, based on accuracy, repeatability, and process remain integral throughout industry. The outcomes and assessment process fit easily into the ABET criteria. The process of rejuvenation was a positive experience initiated because of ABET/TAC criteria that resulted in a better, more well defined project in 2006.

Excel Grade Sheet – Tap Wrench Project

Student Projects are measured, measurements are entered and points are assigned.

Tap Wrench Excel Grade Sheet

1.25									
0.8125									
0.4375						Points for lengths		Grade	
2.75						0.000	10	0	F
2.75						0.009	9	1	D
0.5625						0.020	8	2	C-
0.5625						0.029	7	3	C
						0.040	6	4	C+
						0.049	5	5	B-
	NAME					0.059	4	6	B
						0.069	3	7	B+
						0.079	2	8	A-
	BODY LENGTH	1.25	0.000	10		0.089	1	9	A
	BODY DIAMETER	0.8125	0.000	10		0.099	0	10	A+
	SMALL DIAMETER	0.4375	0.000	10					
	HANDLE LENGTH 1	2.75	0.000	10		Points for Diameters			
	HANDLE LENGTH 2	2.75	0.000	10		0.000	10		
	HANDLE DIFF.		0.000	10		0.001	9		
	NEXT TO KNURL 1	0.5625	0.000	10		0.002	8		
	NEXT TO KNURL 2	0.5625	0.000	10		0.003	7		
	HAND WORK			10		0.004	6		
	KNURLING			10		0.005	5		
	OVERALL APPEARANCE			10		0.006	4		
						0.007	3		
						0.008	2		
		OVERALL GRADE		10		0.009	1		
						0.010	0		

Student Self-assessment Survey GE 225
Survey of Machine Tool Applications

Student Name: ___________________________________

The following survey is to help us know more about you and your perceptions of your success in the course. Your responses will help you focus on evaluating your interest and success in this project. In addition, your responses will provide the feedback needed to continue to offer a current and viable course.

Please mark your answers with 1 being the highest and 5 being the lowest as related to the questions **Before** and **After** taking this class

How would you rate your ability to make internal and external threads?					
Before	1	2	3	4	5
After	1	2	3	4	5
How would you rate your ability to knurl a cylindrical part?					
Before	1	2	3	4	5
After	1	2	3	4	5
How would you rate your ability to turn a diameter to within plus or minus .001”?					
Before	1	2	3	4	5
After	1	2	3	4	5
How would you rate your ability to repeatedly turn a diameter to within plus or minus .001”??					
Before	1	2	3	4	5
After	1	2	3	4	5
How would you rate your ability to face a cylinder to within plus or minus .001”?					
Before	1	2	3	4	5
After	1	2	3	4	5
How would you rate your ability to repeatedly face a cylinder to within plus or minus .001”?					
Before	1	2	3	4	5
After	1	2	3	4	5
How would you rate your ability to polish cylindrical parts?					
Before	1	2	3	4	5
After	1	2	3	4	5
Do you think this course will be helpful to you in your career?					
Yes	No	Comments:			

Attachment – *IDEA Center* Student Evaluation results

Evaluation based on 5 point scale with 5 being the highest.

South Dakota State University
Engineering Technology & Management

Student Evaluation Summary

Instructor: Harvey Svec   Semester: Spring 2006

Course No.-Section #:	GE 122-S01	GE 122-S02	GE 225-S01	GE 231-S02	MNET 231-S01
Course Title:	Engineering Graphics II	Engineering Graphics II	Survey of Mach Tool	Study Abroad	Manufacturing Processes
Course Reg. No. (CRN):	41862	41863	41870	48022	42447
Number Surveyed/Enrolled:	23/27	27/30	11/12	2/13	16/18

See attached copy of *IDEA Diagnostic Form Report* from SDSU Testing & Assessment Office: (5-point scale average:)

	Raw/Adj.	Raw/Adj.	Raw/Adj.	Raw/Adj.	Raw/Adj.
A. Progress on Objectives:	3.9/4.0	4.0/4.2	4.2/4.2	No Data	3.9/4.0
B. Excellent Teacher:	4.5/4.6	4.7/4.8	4.7/4.8		4.7/4.7
C. Excellent Course:	4.2/4.2	4.2/4.4	4.6/4.8		4.5/4.4
D. Average of B & C:	4.4/4.4	4.5/4.6	4.7/4.8		4.6/4.6
Summary (Average of A&D):	4.2/4.2	4.3/4.4	4.5/4.5		4.3/4.3

1. Typical comments by students:

GE122(2 sections): 10 of 50 students wrote comments: Positive remarks about instructor, his knowledge and approachability.
GE225: 1 of 11 students wrote comments: General comment regarding course content.
GE231: 1 of 2 students wrote comments: Positive with suggested improved information.
MNET 231: 2 of 16 students wrote brief positive comments.

2. Remarks by preparer:

The student ratings and accompanying analysis validate the excellent teaching you provide to our students. There are many teaching methods that are noted with 'strength to retain' – a further indication of good teaching. All comments, when provided, were positive. Keep up the great work, Harvey!

Summary prepared by: [signature] 21 Aug 06
Dr. Teresa Hall   DATE
Department Head

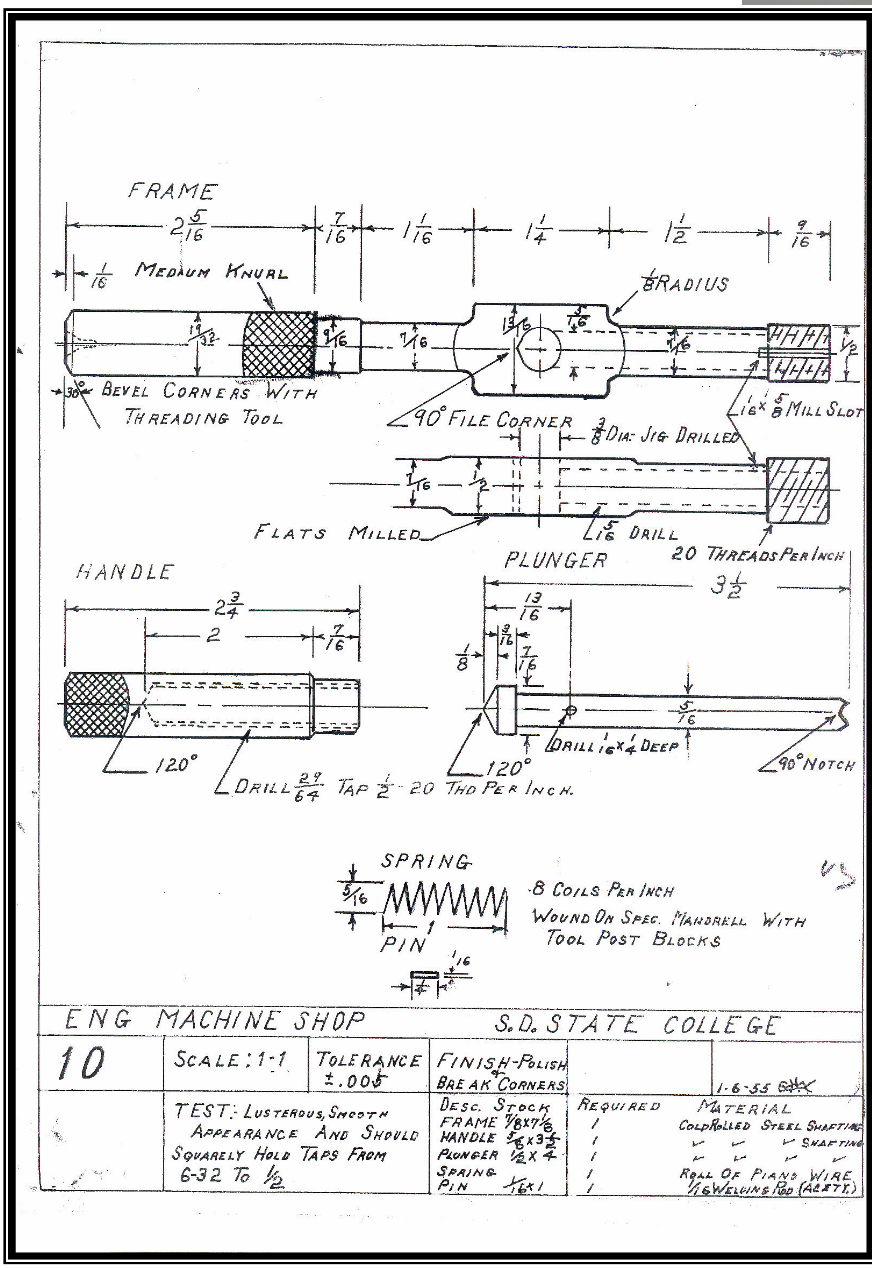
Check Response:
In general, I agree ☒ disagree ☐ that the above summary accurately reflects the students' evaluations administered during the above-mentioned period.

[signature] 24 Aug 06
Harvey Svec   DATE

The Project -- 1955

The precision specifications are listed in the graphic. This graphic was used in the original design for the course. Through the many years, the project has evolved, but the precision has remained the same.

Figure 1 Completed tab wrench

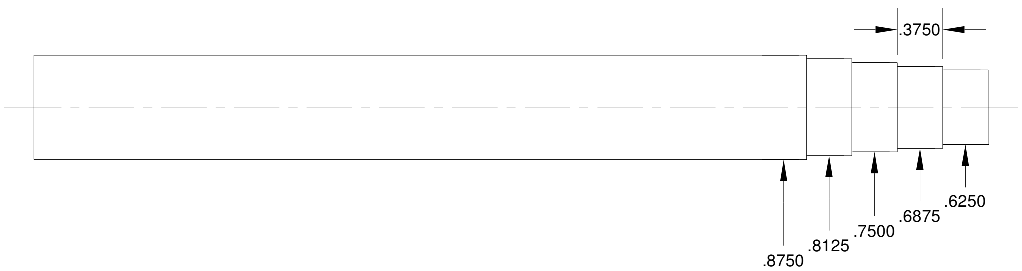


The Project – 2006

These graphics along with classroom instruction direct the students in the course as it is seen today.

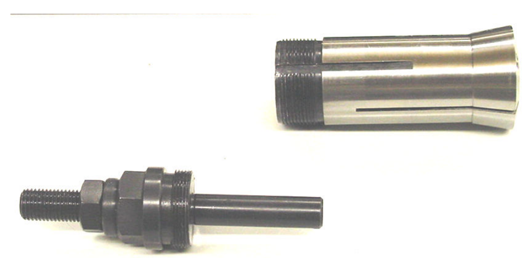
Learning Objectives:

1. Be able to read and accurately interpret shop drawings
2. Set up and safely operate the lathe, mill, drill, cut off saw, and other related shop equipment.
3. Machine parts to .001 in accuracy.
4. Plan and execute a series of steps that will result in an acceptable project.
5. Maintain a clean shop.

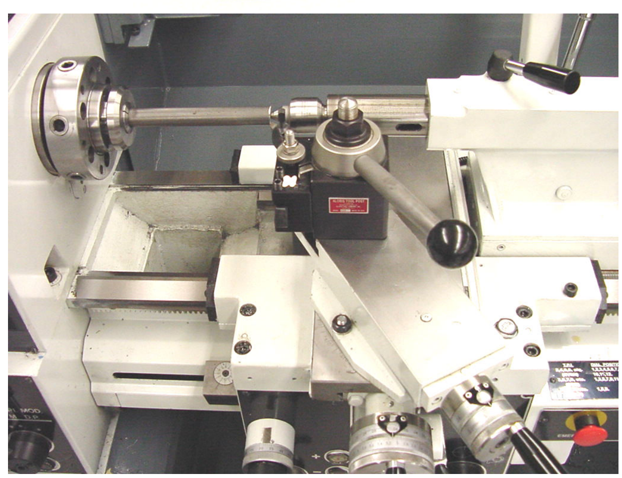


MACHINING THE TAP WRENCH
LESSON 1

Procedure:
Tap Wrench Body:



1. Install tool holder and check to be sure the cutting bit is at or slightly lower than the lathe’s centers. Be sure the cutter is sharp.



2. Install the blank (7.125” x 0.875”) in a 7/8” collet against the collet stop.

3. Support the blank on the tailstock end with the tailstock center.

4. Make sure the tailstock quill is extended enough that the tailstock doesn’t interfere with the carriage travel to the right end of the workpiece.

5. After securing the tailstock to the lathe bed, 1. adjust the load on the center and 2. lock the quill after determining the part is not loose between the center and the collet stop. This adjustment should be monitored as work commences and the part heats and expands.

6. Use a spindle speed of 430 RPM and a feed rate of either 0.004"or 0.006" per revolution (depending on the finish desired), and a cut depth no more than 0.050".

7. The diameters should be turned starting with the largest diameter, from the right end of the part. After the largest diameter has been turned, turn the next largest diameter - starting from the right side of the part – each diameter should be turned to the length specified on the drawing. Repeat this procedure (always starting from the right side of the material) until all diameters have been turned.

8. To expedite turning the diameters use the digital readout. If for example after making the first cut and measuring the diameter of the part it is determined the diameter is 0.837", the reading on the digital readout should be edited to read the same value. This is accomplished by first verifying the correct tool number is on the digital readout (DRO). Select the "X" axis, enter the measured value, and push enter. Be sure to repeat this procedure to verify you are as right as you think you are.

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