Session No. 1325

Integrating an Industrial Design Project into a MET Course

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Introduction

I teach a course in Mechanical Engineering Technology called Production Drawing. It is offered in the spring semester during the students' sophomore year. At this level the students have taken two courses in AutoCAD and are proficient in the use of CAD. In Production Drawing, AutoCAD is not specifically taught although some aspects of the software are reviewed as required. Production Drawing covers how to develop working drawings and a Bill of Materials for a design project. Working drawings are assembly drawings that show the parts assembled and numbers all the parts to correspond with the Bill of Material. The bill of material is a parts list that provides all specifications of manufactured parts, purchased parts, and fasteners needed for the design. The students learn how to detail and select parts that are needed for the design project. Detailed parts are specialized parts that are manufactured instead of purchased. Students learn the proper techniques to dimension, tolerance, call out material, weld symbols, finished surfaces, geometrical tolerances, and fits between parts.
In this course, an Industrial Design Project was introduced to have the students apply the skills they are learning to a real design project. A local manufacturing company of high speed rotating equipment for the printing industry has allowed us to design one of their pieces of equipment. The paper will discuss what the students learn and how it applies to the real world. It discusses the what the students learned before the industrial project was introduce and what impact the project has made on student learning. The students get real practice for industry and the project covers all the topics taught in this course.

The Company

Western Printing Machinery is a custom manufacture of advanced high speed inline and offline web (paper) finishing machinery systems for commercial printing and converting businesses. The web is a continuous stream of paper that attains speeds up to 2000 fpm. Figure 1 shows a typical inline system. The inline system is typically configured after the printing press system. The operation of a printing press is to place images and text on the web and dry the ink before heading into the inline system or a folding system.

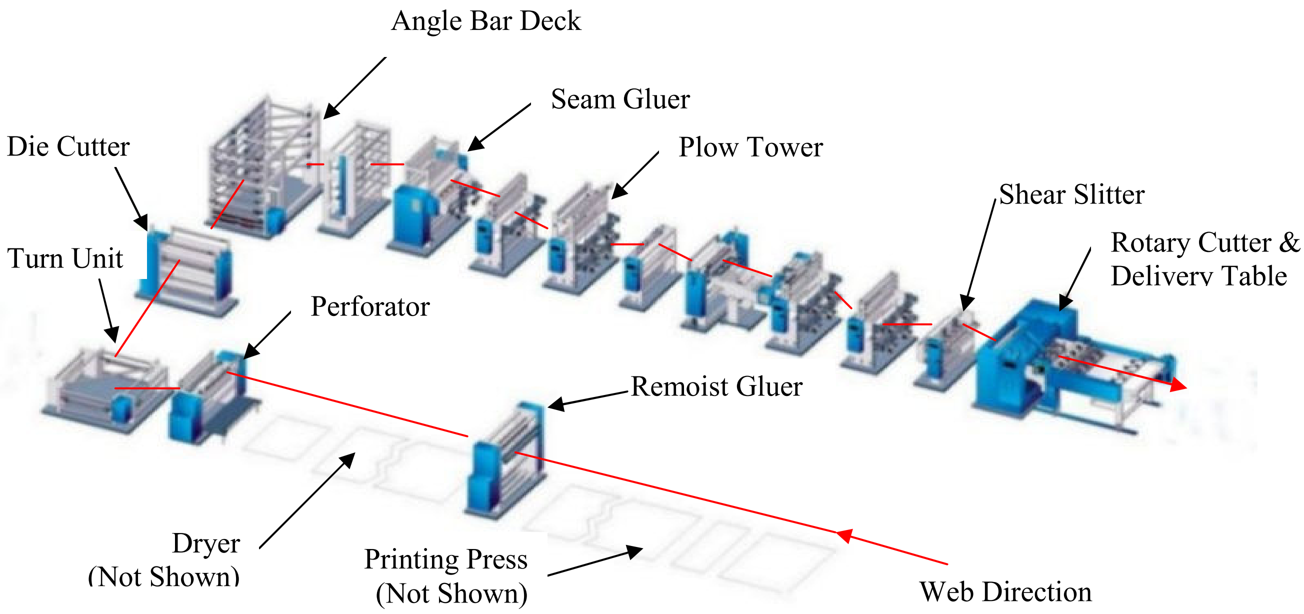

Figure 1. Western Printing Machinery Co. Inline System

The remoist gluer is positioned between the last print unit and the dryer. The remoist gluer puts down a layer of glue on the web, which is then dried and can be remoistened. The flap of an envelope would be glued in here. After the web leaves the dryer, it enters the perforator. The perforator can apply perforations in either direction of the web. This can be used for coupons or where a product needs to be separated. The turn unit turns the web towards the rest of the inline. The die cutter can put in any type of contour cut in the web. The die cutter is used for making windows or special contours in the product. The angle bar slits the web into ribbons and repositions the ribbons. The ribbons may be stacked on top of one another or positioned next to one another. The plow towers pull the web through the inline and can also slit, edge trim, and fold the web. The rotary cutter cuts the web into its final product and the delivery table stacks and delivers the products. Figure 2 shows the types of end products that can be produces in an inline system.

Figure 2 Sample products from an Western Printing Machinery Co. Inline System.

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The Class

The class number is MET 102 and is called Production Drawing. The students take the course in taken in the spring semester of the 2nd year. The course introduces design, evaluation, and documentation of engineering specifications required for manufacturability and assembly. Emphasis is on computer aided design based details, assemblies, design layouts, equipment installations and related industrial practices.

Students learn to build assembly drawings and to specify all components of the assembly drawing in a bill of material. The assembly drawing is a multi-view drawing that shows how all the manufacture parts, purchased components, and fasteners go together. All components on the assembly are ballooned to correspond to the bill of material. The bill of material is a parts list that shows the detail numbers and the description of the manufactured parts. The bill of material shows the catalog number, vender name, and description of a purchased parts and fasteners. Last it shows the quantity required of each component.

A manufactured part is called a detail. Manufactured parts cannot be purchased and must be custom made. To manufacture a part, a machine shop or fabrication shop will require a drawing that shows all the specifications required to make the part. A detail drawing describes a part both visually and dimensionally. Views are used to show the general shape and all the features of the part. Besides the 6 orthogonal views, auxiliary views and cut-away section views are used to show hidden details of the part. The views are appropriately dimensioned. The dimensions give the size of the part and the location of any features on the part. The accuracy of the dimensions needs to be determined. The part should only be made as accurate as necessary. The more precise the part needs to be, the more expensive the manufacturing process used to maintain the accuracy of the part. The accuracy of the dimension is indicated by how many places the dimension is carried to. Some part dimensions need to be toleranced. A tolerance dimension gives a high and low value that the dimension must be held within. A tolerance dimension may be based on a parts fit to a mating component. Parts can have clearance, transitional, and interference fits. The dimension tolerance would change to accommodate the required fit of the part. Again, the tighter tolerances maintained on a dimension of a part, the more expensive the manufacturing process of the part. Another type of tolerance used is a geometric tolerance. Geometric tolerances keep features and surfaces within the orientation tolerance specified. This tolerance is used to keep surfaces perpendicular, parallel, or concentric to one another. Any surface of a part that is machined needs to have a specified finish mark. The finish mark informs the machinist how rough or smooth the surface needs to be. Surfaces have different finishes based on how the surface is used. The finish on a surface is a function of the machining process. As an example, a shaft can be turned, ground, and then polished for a fine finish. The drawing needs to specify the material the part is made from. Parts can be made from many different types of materials such as steel, aluminum, bronze and plastic. Some parts can be made from bar stock, while others are made from structural steel. Parts that are complicated may need to be welded together in order to be made. If this is the case, the drawing needs to specify the size and type of welds required. Some parts are made from a forging or casting. They require a drawing for the forging or casting and a secondary machining drawing to add any features or to clean up and finish any surfaces. Parts can be coated or heat-treated. These processes need to be clearly specified on the drawing. Detailed drawings can be complicated and hold a lot of information. The detail drawing shows all the appropriate views and calls out all final dimensions, finishes, geometric tolerances, and features of the part. The detail drawing needs to convey all this information in a simple and accurate manner.

Not every component is a custom component that needs to be manufactured. Some components can be procured from a supplier. These components are call purchased parts. Many of these components are used in class assignments and on the project. Retaining rings or snap-rings are used to trap a bearing or a gear to a shaft. Dowel pins are used to pin machine components together so the do not vibrate loose. There are many power transmission components used in the design of machinery. Shafts, keyways, gears, bearings, belt drives, chain drives, and coupling are all used to transmit power. The specifications given by the supplier of the components is used to integrate the manufactured components into the design. It is important to follow the vendors recommended tolerances, fits, finishes, and application of the component.. This will ensure a proper fit between the purchased component and the manufactured component.
Fasteners are used to connect or join parts together. There are many different types of fasteners used in building machinery and equipment. All fasteners are called out on the Bill of Material. Hole features such as tapped holes, clearance holes, counter-bored holes, and counter-sink holes are required when using fasteners. The designer must know how to call out these hole features on a manufactured part in order to ensure the mating components go together.
The software used in the course is AutoDesk Inventor. AutoDesk Inventor is a 3-D solid modeling software package. The students come into the course with 2 semesters of AutoCAD 2-D. So they have no experience in 3-D design. This requires the students to learn the software while they are learning the required material. When using solid modeling, the parts are first modeled in 3-D then a detail drawing is made from the part model. Purchase parts only need to have a part model and not a part drawing since they will not be manufactured.
The following topics are thoroughly covered before the project starts.

1. Views
2. Dimensioning
3. Tolerancing
4. Geometric Tolerancing
5. Fits and Finishes
6. Detailed Drawings
7. Working Drawings
8. Machine Elements
9. Bill of Material
10. Fasteners

Students are given assignments specific to each of the individual topics. These assignments help prepare the students by having them practice a specific topic. The students work on the project in the last ten weeks of the class.

The Project

The project has students design a simplified version of a plow tower shown in figure 3. The plow tower assists in pulling the web through the inline. It slits, trims, and folds the web into its final product. Western Printing Machinery Company has supplied the basic specifications and the design parameters of the plow tower. They have supplied drawings and brochures to aid the students in understanding the design project. The equipment had to be simplified due to time constraints in the class and the complexity of the equipment. Any material that was considered proprietary information was not used in order to protect the interests of Western Printing Machinery Company.

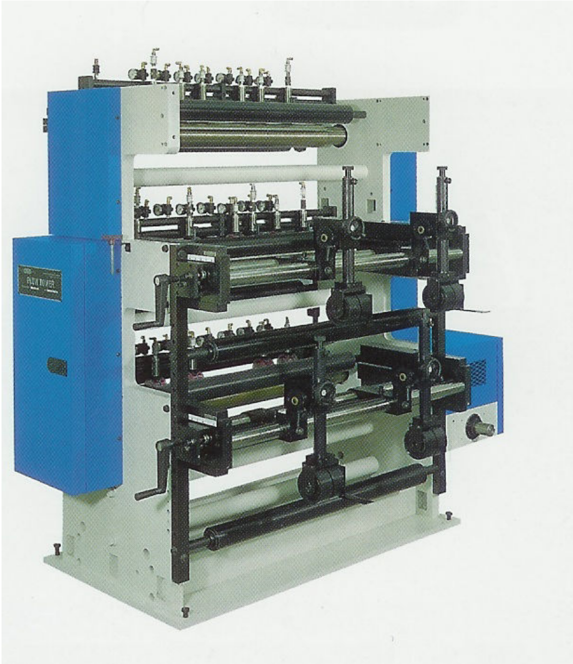

Figure 3 Plow Tower by Western Printing Machinery Co.

Figure 4 shows the 3-D assembly model of a plow tower designed by the students. The basic design consisted of two side frames with crossbraces to hold them together.

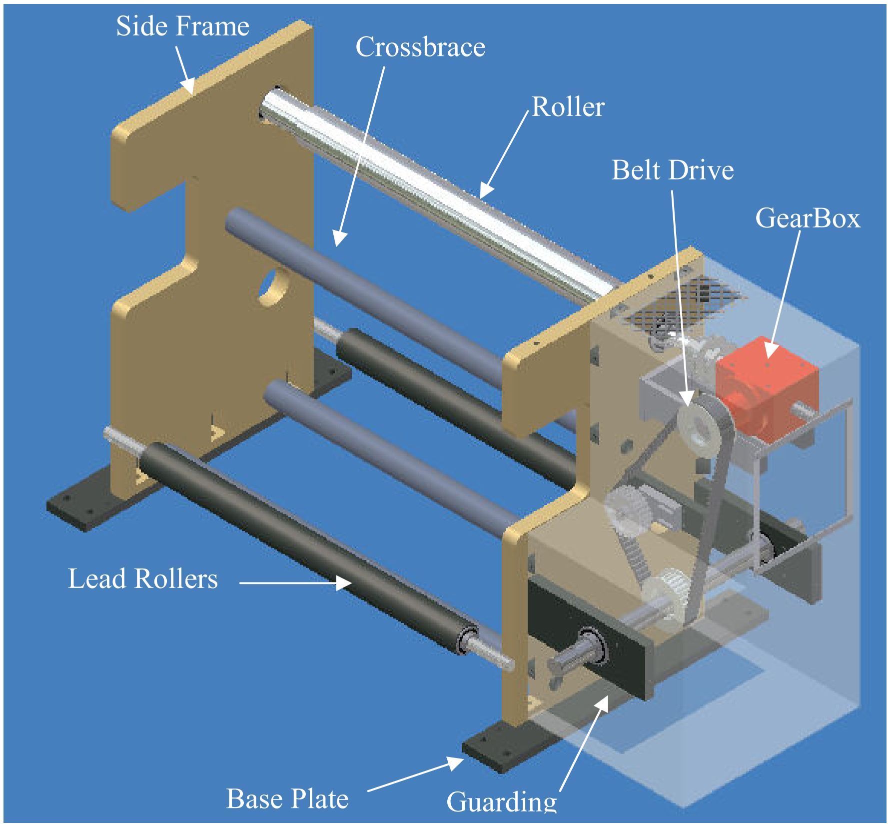

Figure 4 Student Version of the WPM Plow Tower.

Base plates are used to mount the equipment to the floor. A chrome roller pulls the paper through the system. The drive consisted of a shaft, bearings, belt, pulleys, gearbox, and a coupling. The power transmission components are used to drive the chrome roller. Guarding is used to cover the drive components.

An assembly drawing is made from the assembly model and is shown in figure 5. The assembly drawing is used to communicate the final design for production. The assembly drawing incorporates the bill of material. The bill of material is a list of all the purchased parts, manufactured parts, and fasteners used on the assembly of the machine. The balloon call outs coordinate the build list to the assembly drawing. This allows the machine to be properly assembled. All drawings have a title block which specifies the name of the company, the name of the engineer/draftsman, title of the part, scale of the drawing, date drawing was made, and other various information. The assembly drawing shows different views of the machine in order to assist the assembler in understanding the machine. Section views are used to reveal features that would otherwise be hidden.

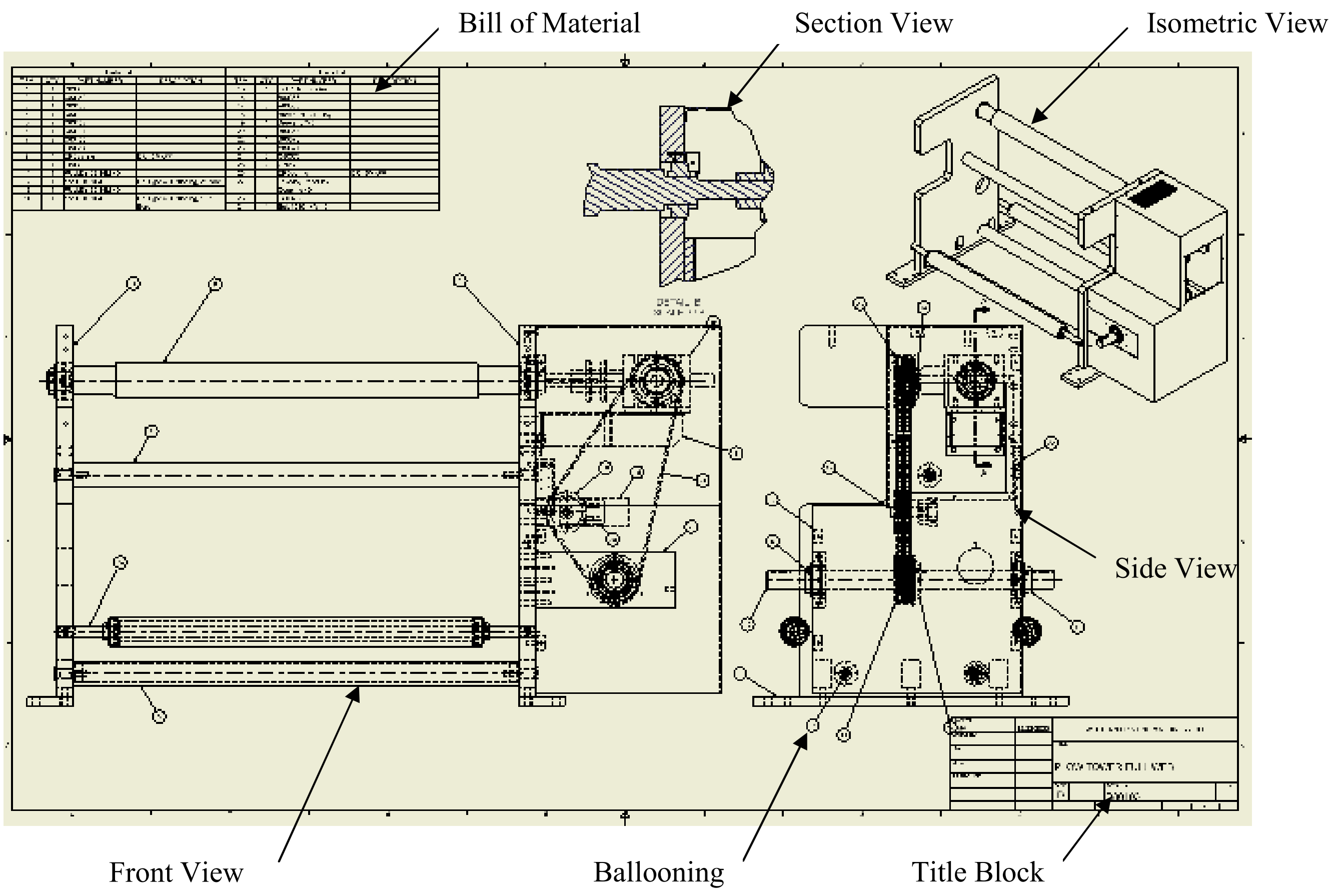

Figure 5 Assembly Drawing of Plow Tower

Some of the detailed drawings completed by the students on the project are shown in the figures below. The side frame drawing for the plow tower is shown in figure 6. The student incorporates many of the topics learned in the class to detail the side frame. The side frames themselves need to be made straight and true. These frames are blanchard ground and are held within tolerance and a geometric tolerance. Geometric tolerances are used in order to ensure the surfaces the sides and faces of the frame must be held parallel and perpendicular to one another. The two bores in the frame house the bearings of the roller. These two bores have a finish, dimension tolerance, and a geometric tolerance. The student uses the manufactures bearing catalog to obtain all the recommended specifications to the bores. The frames have drill through holes and tapped holes used to mount different components to the frame. The location and size of the holes are called out in a bore chart. The students learn the importance of the location and callouts of these holes. If the holes are not in the correct location, the mounting component will not fit. If the tapped holes or the clearance holes are not the correct size the fasteners will not fit in the hole feature. The side frame is made from ASTM A36 steel. A piece of steel this large needs to be flame from a steel plate and then machined to the final size. There is a separate burnout drawing the frame machining drawing is made from. Pockets are also flame cut into the side frame. The pockets are to allow bolt access. The frame detail reinforces concepts in dimensioning, tolerancing, geometric tolerancing, drill and tapped holes, and surface finishes. This detail is a complicated and time consuming drawing. It is the first detail started and the last detail finished.

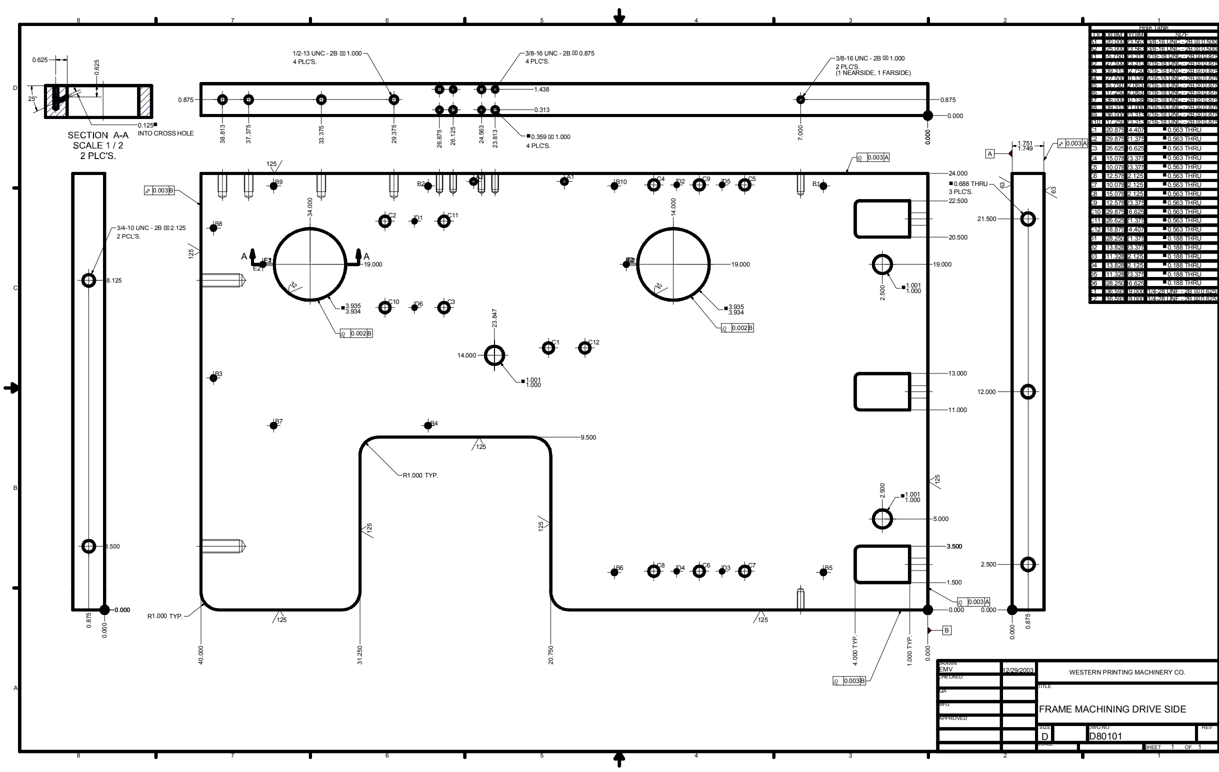

Figure 6 Side Frame Detail

Figure 7 shows the recommended housing bore tolerances for an ER bearing. The side frame is considered the housing for the bearing and is stationary. The students select the tolerance based on a stationary housing for the bore from the table shown. This is just one example of the many tables and figures the students are required to use to look up information on the project. This teaches the students that not all information is located in one spot and that they are not given all the information.

BEARING NUMBER	OUTSIDE DIAMETER OF BEARING		ROTATING HOUSING				STATIONARY HOUSING			
			Diameter		Resultant Fit		Diameter		Resultant Fit	
	Max.	Min.	Min.	Max.	Loose	Tight	Min.	Max.	Loose	Tight
ER-8, 9, 10, 11, 12	1.8504	1.8499	1.8498	1.8504	.0005	.0006	1.8503	1.8509	.0010	.0001
ER-14, 15, 16	2.0472	2.0466	2.0466	2.0471	.0005	.0006	2.0471	2.0476	.0010	.0001
ER-17, 18, 19, 20S	2.4409	2.4403	2.4403	2.4408	.0005	.0006	2.4408	2.4413	.0010	.0001
ER-20, 21, 22, 23	2.8346	2.8340	2.8340	2.8345	.0005	.0006	2.8345	2.8350	.0010	.0001
ER-24, 25	3.1496	3.1490	3.1490	3.1495	.0005	.0006	3.1495	3.1500	.0010	.0001
ER-26, 27, 28	3.3465	3.3457	3.3458	3.3464	.0007	.0007	3.3464	3.3470	.0013	.0001
ER-30, 31	3.5433	3.5425	3.5426	3.5432	.0007	.0007	3.5432	3.5438	.0013	.0001
ER-32, 34, 35	3.9370	3.9362	3.9363	3.9369	.0007	.0007	3.9369	3.9375	.0013	.0001
ER-36, 38, 39	4.3307	4.3299	4.3300	4.3306	.0007	.0007	4.3306	4.3312	.0013	.0001
ER-40, 43	4.9213	4.9203	4.9204	4.9212	.0009	.0009	4.9211	4.9219	.0016	.0002
ER-46, 47	5.1181	5.1171	5.1172	5.1180	.0009	.0009	5.1179	5.1187	.0016	.0002
ER-48, 51	5.5118	5.5108	5.5109	5.5117	.0009	.0009	5.5116	5.5124	.0016	.0002
‡ER-52, 54, 55	5.9055	5.9045	5.9046	5.9054	.0009	.0009	5.9053	5.9061	.0016	.0002

‡Not always available from stock. Consult factory for availability.

Figure 7 ER Bearing Housing Fit

The roller detail is shown in figure 8. The students design a roller to fit within the side frames, fit the bearing inside diameter, and have a specific face width and face diameter. The material of the roller has to be heat-treated and surface hardened. This allows a knife blade to cut paper on it without grooving the roller. The face diameter, face width, material, and heat treatment is specified by Western Printing Machinery to meet their customer's specifications. The roller face and journal ends must be design to be concentric within a few thousand of an inch. This will keep the roller running true and keep the run-out to within specifications. The journals of the shaft mount inside of the bearings. The journals are dimensioned, toleranced, and have a surface finish to meet the bearing manufactures specifications.

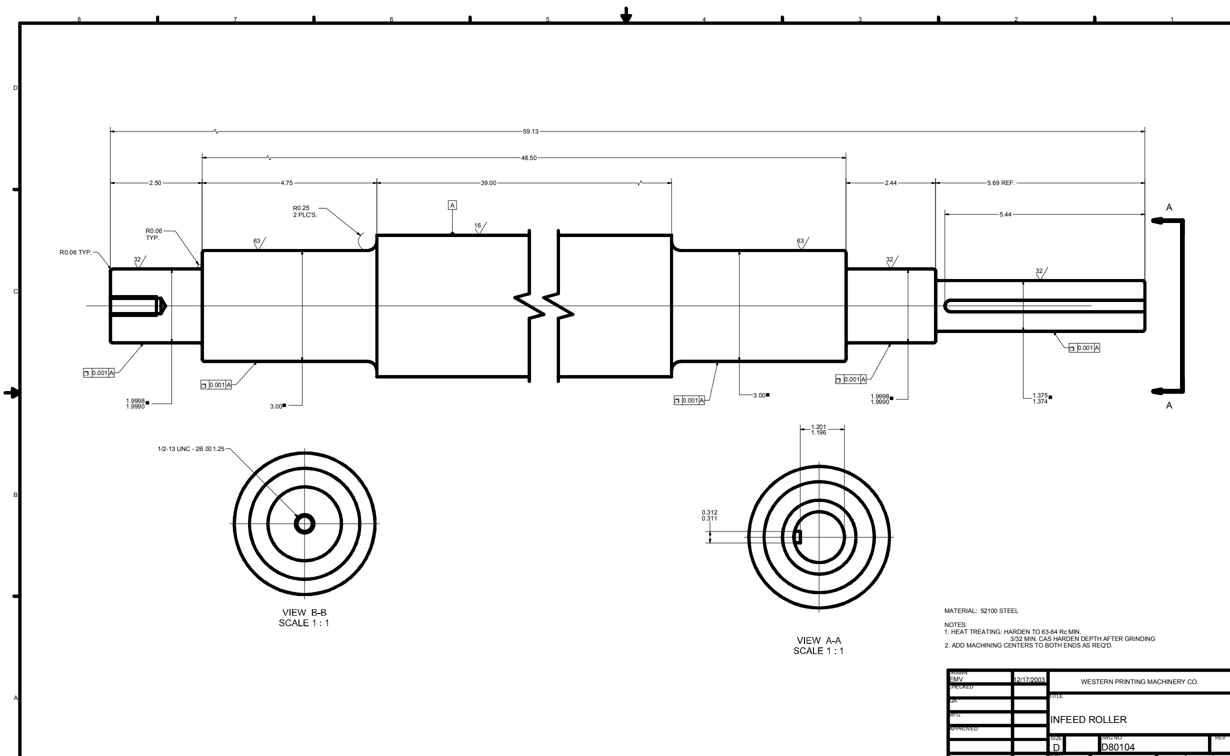

Figure 8 Roller Detail

On one side of the roller, the journal end has a coupling mounted to it. This journal end has a key way cut into it. This allows the roller to be keyed directly to the coupling. The keyway dimensions are shown in figure 9. The keyway is selected based on the size of the shaft.

Nominal Shaft Diameter	Parallel and Taper		Parallel		Taper	
	Square	Rectangular	Square	Rectangular	Square	Rectangular
	S	S	T	T	T	T
1/2	0.430	0.445	0.560	0.544	0.535	0.519
9/16	0.493	0.509	0.623	0.607	0.598	0.582
5/8	0.517	0.548	0.709	0.678	0.684	0.653
11/16	0.581	0.612	0.773	0.742	0.748	0.717
3/4	0.644	0.676	0.837	0.806	0.812	0.781
13/16	0.708	0.739	0.900	0.869	0.875	0.844
7/8	0.771	0.802	0.964	0.932	0.939	0.907
15/16	0.796	0.827	1.051	1.019	1.026	0.994
1	0.859	0.890	1.114	1.083	1.089	1.058
1 1/16	0.923	0.954	1.178	1.146	1.153	1.121
1 1/8	0.986	1.017	1.241	1.210	1.216	1.185
1 3/16	1.049	1.080	1.304	1.273	1.279	1.248
1 1/4	1.112	1.144	1.367	1.336	1.342	1.311
1 5/16	1.137	1.169	1.455	1.424	1.430	1.399
1 3/8	1.201	1.232	1.518	1.487	1.493	1.462
1 7/16	1.225	1.288	1.605	1.543	1.580	1.518
1 1/2	1.289	1.351	1.669	1.606	1.644	1.581
1 9/16	1.352	1.415	1.732	1.670	1.707	1.645
1 5/8	1.416	1.478	1.796	1.733	1.771	1.708
1 11/16	1.479	1.541	1.859	1.796	1.834	1.771
1 3/4	1.542	1.605	1.922	1.860	1.897	1.835
1 13/16	1.527	1.590	2.032	1.970	2.007	1.945
1 7/8	1.591	1.654	2.096	2.034	2.071	2.009
1 15/16	1.655	1.717	2.160	2.097	2.135	2.072
2	1.718	1.781	2.223	2.161	2.198	2.136

Figure 9 Keyway Dimensions

Some of the parts on the project are purchased components. Students learned how to source components using the suppliers catalog. The catalogs supplied dimensional information and sizing information. While the students were not required to size any components, they are made aware of the different sizes available. The components were sized and selected by Western Printing Machinery Company. The student needed to only find the dimensional information required on the purchased component. Figure 10 shows the part model of the Hub City gearbox.

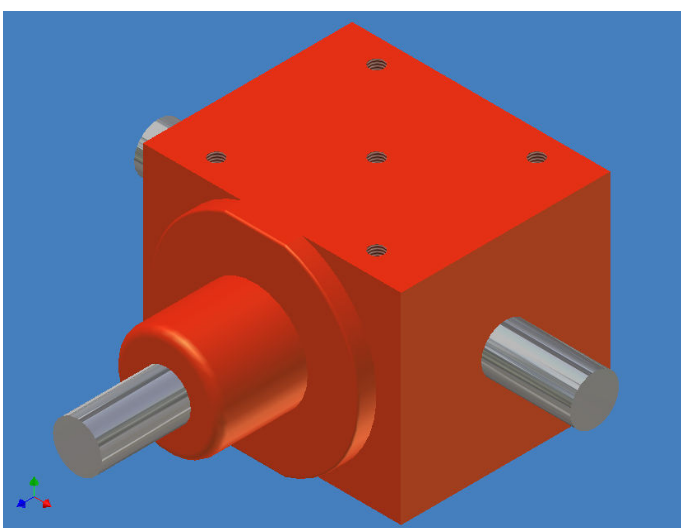

Figure 10 Part Model of Hub City Gearbox

Other purchased components are the bearings, pulleys, bushings, and belt. Students learn that accuracy in there work is important. If the mounting tapped holes in the gearbox are not drawn in correctly on the gearbox, the gearbox will not mount on the bracket the students designed. While none of the purchase parts require a detail drawing, all of them need to be model in order to be placed in the assembly drawing. The bracket for the gearbox is shown in figure 11. The bracket incorporates many of the concepts covered in class. The students call out the different sizes of the steel material and the weldment symbols required to make the bracket. Geometric tolerances are used in order to keep the mounting surfaces of the gearbox bracket perpendicular to each other.

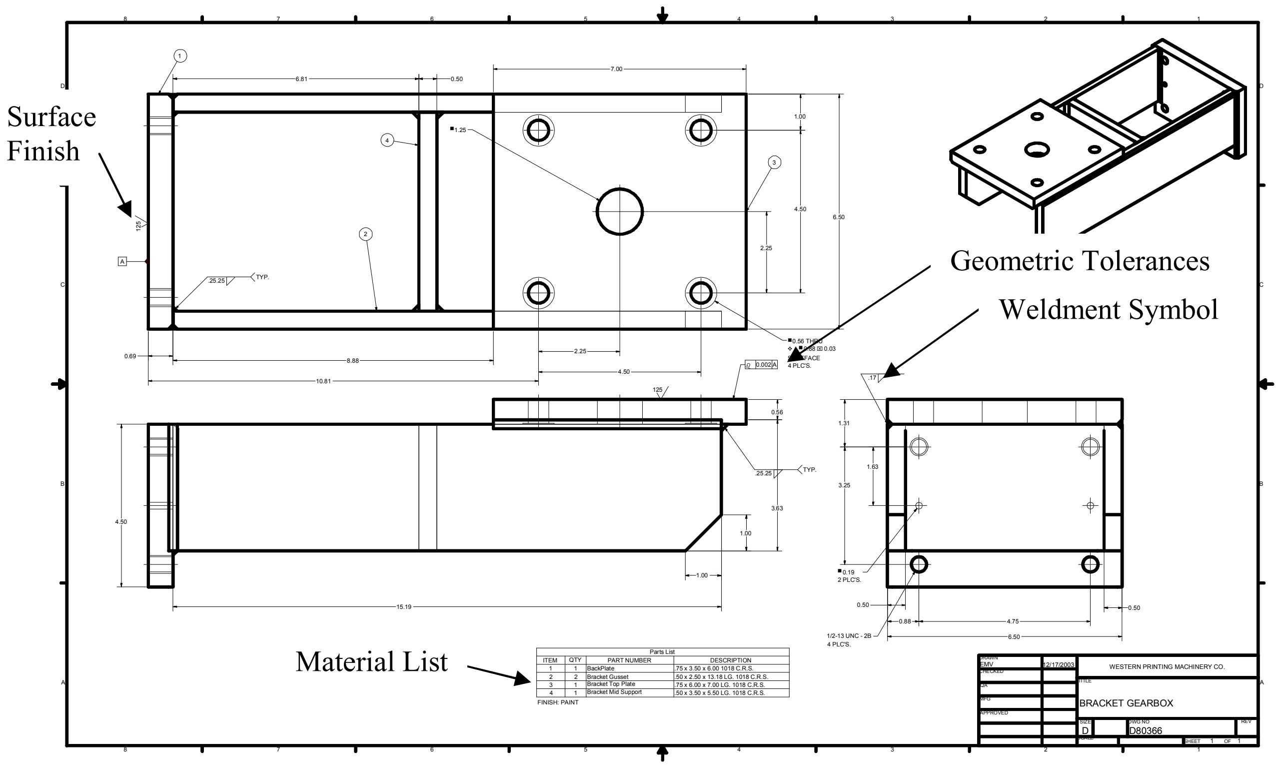

Figure 11 Gearbox Bracket Detail

Conclusion

The lecture focused on one topic at a time allowing the students to get comfortable with the topic before moving on. Students worked on problems taken from the class text. Although these problems were not exciting and interesting, they were important in building the students skills in the lecture topics. All though the problems had descriptions of the part, there were no connections or understanding the use of the part by the students. Since the problems were taken from the textbook, they did not have a realistic feel to them. It felt as if they were just another problem solved from a textbook. The largest assembly drawing done was moderately small, about four to five parts. These were also taken from the textbook. Although the students still learned the same concepts, it was not as interesting or motivating for the students to work with these problems.

The project has been used for the last three times the class has been taught. Initially, all the class material was finished before starting the project. Now the project is intertwined with the lecture. If the lecture topic was "views of a drawing", instead of only solving problems from the textbook, a part on the project could be included. This gives the students more time and allows them to complete more work on the project.

The design project covers all aspects of machine design and production drawing using computer-aided-design. This was a big benefit in adapting the project to the course. The design project reinforced and pulled together all the topics taught in a course. Students got a chance to be involved and work on a project that is used in industry. When doing a problem from the book all the necessary information and specifications are given. The design project does not work that way. The students had to determine what was the important design criteria based on the given design parameters. This mean the students were determining what material should be used, what surfaces need to have finishes call out on them, and what dimensions needed to be toleranced. This goes beyond just dimensioning a part. The students are also given some leeway in the design area of the project. For example, instead of showing the student how the gearbox bracket would look, the students are encouraged to come up with their own design. The gearbox bracket could be designed many ways and still be functionally acceptable. This gives the students the opportunity to discuss the design process. We do not do any sizing of components in this course. This means we do check deflections and stresses on the gearbox bracket or the drive shaft.

This course is taught in Mechanical Engineering Technology. The program has both the Associates Degree and the Bachelors Degree. Many of our students start working in the engineering related jobs after they receive their Associates Degree and continue their education part time for the Bachelors Degree. This project gives the students an opportunity to do a large design project at the Associates Degree level.

I would like to give special thanks to Mike Musgrave CEO and Mike Dunn Engineering Manager of Western Printing Machinery for the help and permission to use this design project.
It gave the students a real life application. The project was something that they could keep in their portfolio and show to potential employer. It was also a motivating factor for the students learning. The student leave this course with a strong background production drawing.

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