Putting the Design in Computer Aided Design

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Abstract

Nearly all students in technical programs take an engineering graphics course, which implements computer aided design (CAD) tools. Most of these courses have the phrase Computer Aided Design in their title. The focus in these courses is on drawing standards and techniques for documenting machine components and assemblies. After reviewing outlines for courses offered by many institutions, the word design does not even appear in the outline, beyond the course title. The majority of learning comes through completing several drawing assignments of existing parts.

The Mechanical Engineering Technology graphics courses at the University of Dayton are similar, in that the fundamental graphics principles are applied through several assignments. However, the assignments involve open-ended, design scenarios, which integrate the traditional topics. With this strategy, the students have the opportunity to employ creativity, while applying the fundamental principles. Additionally, these scenarios familiarize the students with many common mechanical devices and using industrial catalogs. They are also able to explore design issues such as manufacturability, assembly, serviceability and cost. This strategy in using scenarios emphasizes the design in computer aided design.

This paper will also explore the implementation of design scenarios in engineering graphics courses, along with highlighting the results, benefits and drawbacks.

Introduction

Over the past twenty years, computer aided design has become an irreplaceable tool in the design of machinery [2]. As the use of this technology has matured, design and drawing instruction at educational institutions has evolved [3].

As CAD was initially being adopted in industry, CAD courses were added to technical college curriculum. These courses were meant to teach the student, who had already mastered technical drawing techniques, the procedures and syntax to use CAD software. The CAD courses were identical to commercial software training programs [9]. The existing manual drafting courses remained untouched.

As CAD replaced board-based drawing methods, educational programs began integrating the drafting and CAD courses. Many institutions eliminated manual drafting techniques. In these combined courses, students learn to use CAD software, while applying a variety of fundamental graphic principles. The primary purpose remains as providing the ability to read and prepare several types of technical drawings. The courses, and available textbooks, are developed as an integrated approach in teaching technical drawing and

CAD [1,4, 5, 7, 8]. In a sense, students are introduced two languages: the protocol related to the graphic universal language of technical drawing and the computer commands of a CAD program.

In most institutions, competency is gained by preparing several technical drawings, with little, or no regard to critical thinking skills. The development of easier to learn CAD software, and a classroom of students who have more "computer savvy", provide instructors the opportunity to give the students more rich design experiences [6]. Coupled with the proliferation of online catalogs for machine components, the author proposes that students can learn the software and graphic fundamentals while completing actual detailed design exercises.

Topics Covered

Introductory courses in technical drawing and CAD are usually the first phase in preparing students for careers in mechanical design. After surveying on-line materials from several institutions, the objectives for an introductory course are strikingly similar. The courses outlines all contain statements about introducing the student to established standards of design documentation through technical drawings. Additionally, many courses include a phrase about familiarizing the student with machine components.

The topics presented in virtually every introductory technical drawing and CAD course includes:
- Geometric constructions: ability to use graphical methods to solve analytical geometry problems.
- Orthographic projection: ability to draw an object at 90^0 intervals to illustrate a three dimensional part with two dimensional views
- Auxiliary views: ability to project a view from a sloping surface, which does not appear true size in a primary orthographic view.
- Sectional views: ability to construct a view of a cross-cut through a part to illustrate internal details of an object.
- Threads & fasteners: introduction to thread forms and fasteners, which are the most popular method of joining mechanical components.
- Dimensioning: ability to identify the size and shape of features by including dimensions on a part. Many standards and guidelines must be reviewed, which dictate proper form.
- Tolerances: ability to decide and include a range of variation on dimensions to ensure interchangeability of parts, yet minimize production costs.
- Assembly drawings: ability to construct a drawing that gives graphical directions to assemble a device of identified components.

Design Exercises

Traditionally, exercises to practice each topic discussed in the previous section require students to interpret an illustration and create the appropriate drawing. Through these experiences, students learn drafting conventions and skills. While proficiency is gained from repetition, these exercises can become dull and monotonous.

The main premise of this paper is to propose that the topics of fundamental engineering graphics can be applied, while providing a more stimulating experience. This can be accomplished through exercises that require open-ended design solutions. The author uses this approach through short, detailed design assignments. Additionally, these assignments require students to implement machine components from industrial catalogs. The following sections illustrate examples of such detailed design exercises.

Orthographic Projection & Manufacturing Processes Exercise:
A bracket is needed that will bolt to the machine base and support the idler pulley shaft shown in figure 1. Design a bracket that will satisfy this need. The wall thickness of all sections of the bracket must be at least 0.25 in thick. Create a technical drawing of the bracket. Lastly, on a separate sheet prepare a manufacturing plan, indicating the specific processes that are required to fabricate of your bracket.

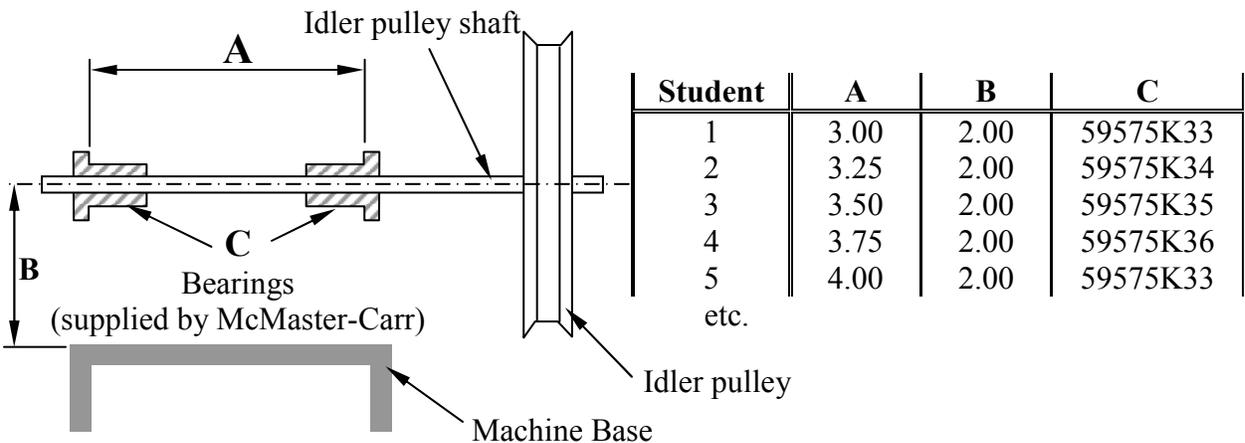| Student	A	B	C
1	3.00	2.00	59575K33
2	3.25	2.00	59575K34
3	3.50	2.00	59575K35
4	3.75	2.00	59575K36
5	4.00	2.00	59575K33
etc.			

Figure 1

Orthographic Projection and GD&T Exercise:
A bracket is needed to mount a motor to a machine base as shown in figure 2. The bracket should sit flush with the C-Face (front) of the motor and allow bolts to fit into the tapped holes on the motor. The bracket should also allow bolts to run into the machine base. The wall thickness on all sections should be at least 0.375" thick. Create a detailed drawing of the bracket, using appropriate GD&T call-outs.

The surface contacting the motor front should be flat to within .001" and perpendicular to the machine base to within .002"

Student	A	B	C
1	5.00	4.00	48
2	5.25	4.00	56
3	5.50	4.00	143T
4	5.75	4.00	145T
etc.			

The surface contacting the machine frame should be flat to within .001"
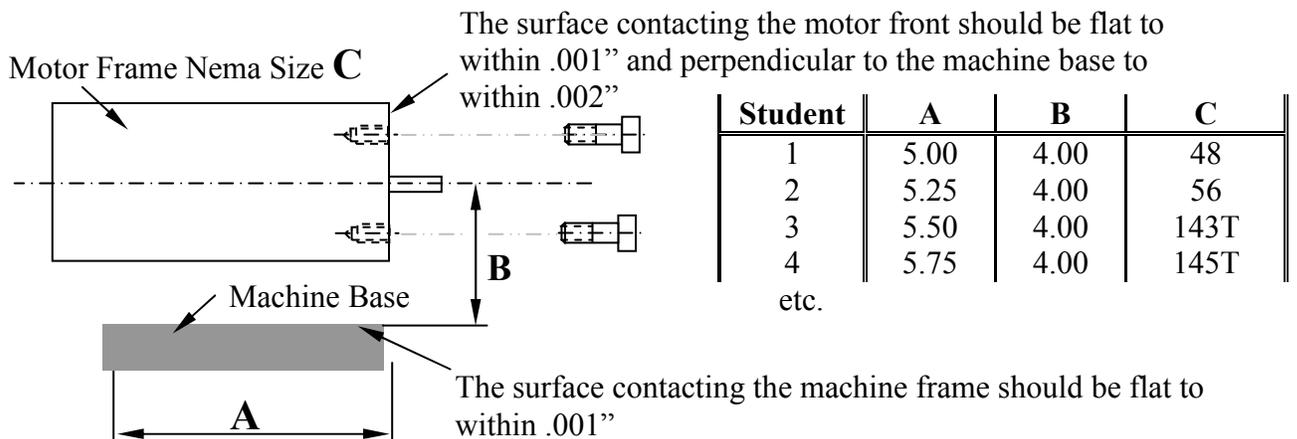
Figure 2

Cross Section Exercise:
A cap is required for an oil reservoir access hole as shown in figure 3. The cap should have a groove for a standard Quad$^{\rightarrow}$, O-ring, which will reliably seal the tank. Select an appropriate o-ring that will fit on the flange of the reservoir, but inside the mounting bolt holes. Then design and create a technical drawing of the cap.

TAP **B** ⊤ .75
(8) HOLES EQUALLY
SPACED ON ∅(.8**A**) B.C.

∅(.5**A**)

Oil
Reservoir

∅**A**

16

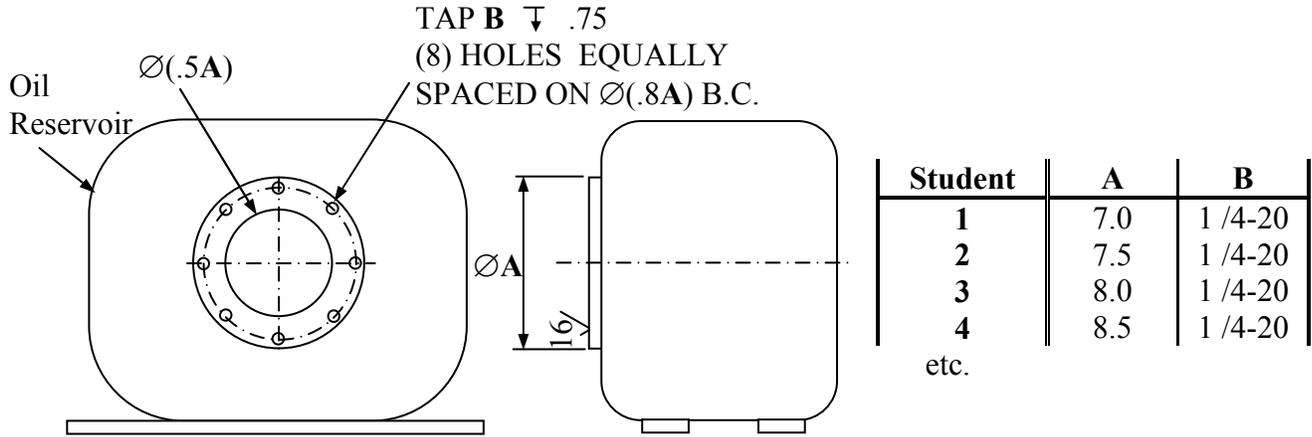| Student	A	B
1	7.0	1 /4-20
2	7.5	1 /4-20
3	8.0	1 /4-20
4	8.5	1 /4-20
etc.		

Figure 3

Fastener Exercise:
Figure 4 illustrates a ballscrew and a sliding plate. Design a bracket that will attach the ball screw to the sliding plate and select the appropriate fasteners. Create a technical drawing of the bracket.

Sliding Plate
Assembly

Ballscrew
McMaster-Carr
B

A

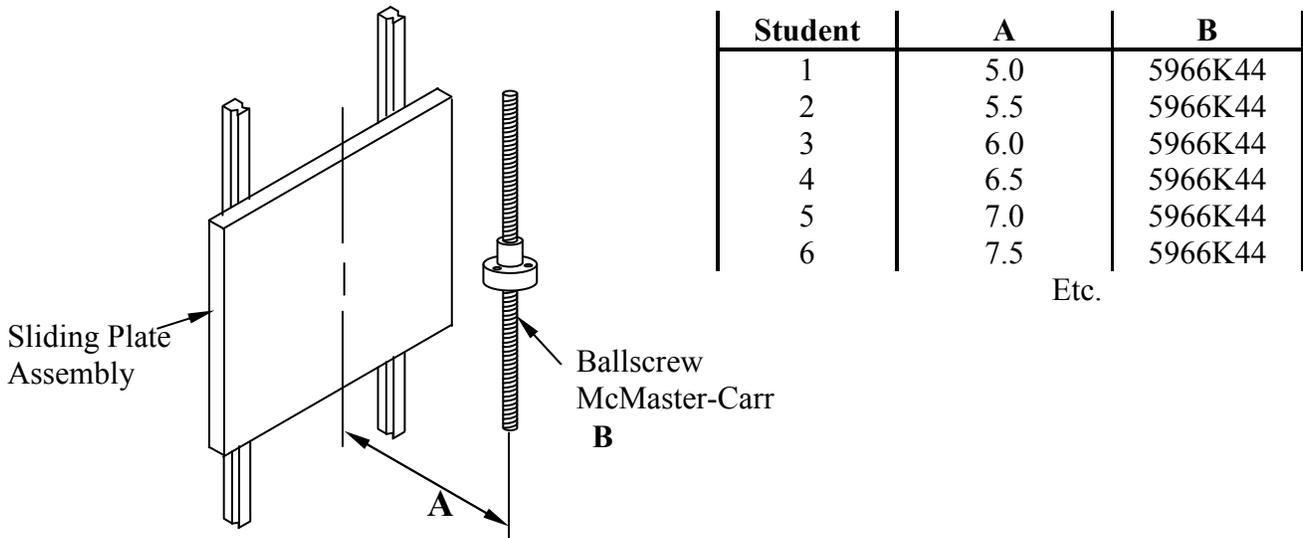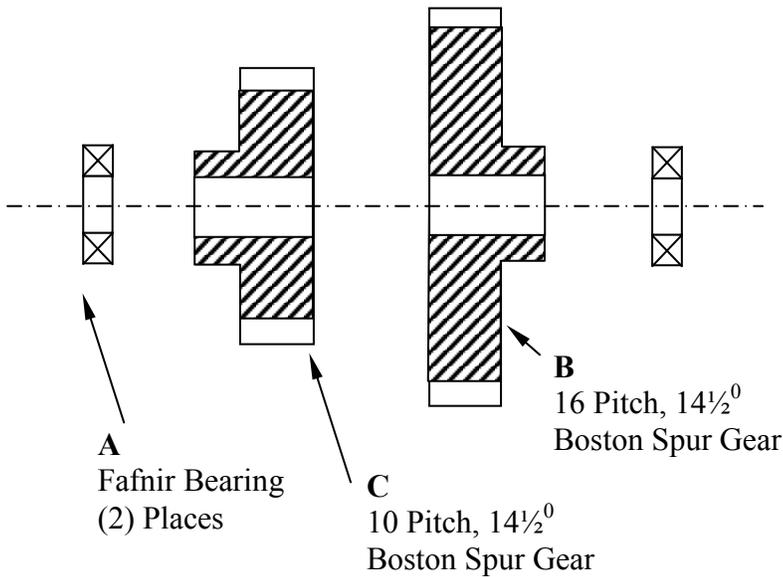| Student	A	B
1	5.0	5966K44
2	5.5	5966K44
3	6.0	5966K44
4	6.5	5966K44
5	7.0	5966K44
6	7.5	5966K44
	Etc.	

Figure 4

Cylindrical Fit Exercise:

A transfer shaft is required that will be held by two bearings and support two gears shown in figure 5. Design and create a technical drawing of the shaft.

Notes:
1. A minimum gap of .25" must be used between the gears and bearings.
2. The bearings are to have a press fit (FN1) with the shaft.
3. The gears are to have a clearance fit (RC5) with the shaft.
4. A keyway should be machined into the shaft to lock the rotation of the gears with the shaft.
5. Shoulders, collars or retaining rings should be used to prevent axial motion of the elements.
6. Leave at least .063" between

B
16 Pitch, $14\frac{1}{2}^0$
Boston Spur Gear

A
Fafnir Bearing
(2) Places

C
10 Pitch, $14\frac{1}{2}^0$
Boston Spur Gear

Figure 5

Team	A	B	C
1	200K	46042	46082
2	201K	46045	46082
3	202K	46048	46082
4	200K	46052	46082
etc.			

Tolerance Exercise:

A set of brackets is needed that will bolt to a machine base and support two bearings shown in Figure 6. The brackets should be bolted to the machine base and the centerline of the two bearings must be within .015" of each other. Design two brackets that will satisfy this need. Then create two detailed drawings, which should be fully dimensioned and toleranced. Lastly, on a separate sheet include a chart that illustrates the minimum and maximum difference between the *A* distance for each bearing.

Bearings
(supplied by McMaster-Carr)
C

A Machine Base

B ±.003
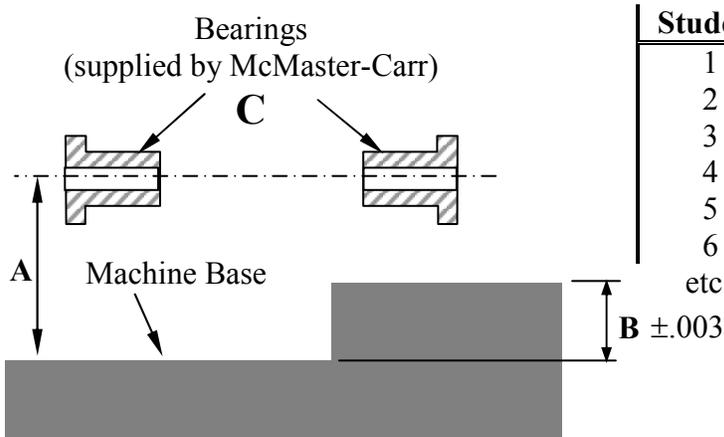
Student	A	B	C
1	3.00	1.00	59575K33
2	3.25	1.00	59575K34
3	3.50	1.00	59575K35
4	3.75	1.00	59575K36
5	4.00	1.00	59575K33
6	4.25	1.00	59575K34
etc.			

Figure 6

Results

This paper described teaching technical drawing and CAD, with an emphasis on design, in a mechanical setting. An identical approach could be taken with a civil, architectural, or electronic viewpoint.

As a result of the design exercises, the students have the opportunity to employ creativity, while applying the fundamental principles. The students become more comfortable with open-ended problems. This is a real benefit as students advance through more analytical design courses.

Additionally, these exercises familiarize the students with many common mechanical devices and using industrial catalogs. This ability to work with actual hardware is directly aligned with the mission of engineering technology programs.

Student satisfaction and motivation has also significantly increased. Using the traditional exercises, students appreciated learning CAD, and saw the benefits. That was good. However, with the design exercises, students are exited about using real parts, and inventing solutions. This is fantastic.

Quantitative results from the formal student evaluation of instruction include:

	Average prior to implementation	Average after implementation
The course effectively met program objectives.	3.1/4.0	3.4/4.0
Supplemental materials enriched this course.	2.6/4.0	3.6/4.0
Assignments were relative to program objectives.	3.1/4.0	3.5/4.0
Textbook was an asset to the course	2.3/4.0	2.8/4.0
Everything considered, how would you rate this course?	3.2/4.0	3.5/4.0

Qualitative results from the formal student evaluation of instruction include:

Prior to implementing the design exercises:
- "Class was interesting at times"
- "Class will be important for summer jobs"
- "CAD is something I wanted to learn and will be an asset"
- "I liked working with CAD"

After to implementing the design exercises:
- "I really liked the assignments that relate to practical situations"
- "Great class. Plenty of hands-on design"
- "The course was a tremendous benefit and lots of fun"
- "Excellent class with very practical projects"

Two primary drawbacks were observed as the design exercises were implemented. First, current graphics textbooks do not include such detailed design exercises. The author has

spent a good deal of time developing a series of real-world, practical exercises that integrate commercial machine components.

The second drawback is the time it takes for the students to merely understand the assignment. Using the traditional assignments, the students would just "roll up their sleeves" and start drawing. Using the design exercises, students are frustrated with not being able to see the part that they need to draw. The instructor must have the ability to describe the scenario in many different ways, without providing a solution. While it may wear on the patience of the instructor, it is truly believed that the learning has vastly increases. Basically, students spend less time drawing, but more time thinking.

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