A Geometric Dimensioning and Tolerancing Course for Engineering Technology Students

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Abstract

The purpose of this digest is to give an overview of a newly created course in Geometric Dimensioning and Tolerancing at Illinois State University. This digest will describe the rational for the new course, outline the main topics and structure of the course, and describe some of the labs and activities that students will complete.

Introduction

Geometric dimensioning and tolerancing (GD&T) is a precise international engineering language used to describe the form, orientation, and location of features with 2D and 3D zones of tolerance (Neumann & Neumann, 2009). Unfortunately, there are many false ideas within the manufacturing and education communities about GD&T, which have kept companies and schools from implementing it or implementing it in a poor way. Some of these false ideas include: a lack of need for GD&T because of a preference for coordinate dimensioning; a misunderstanding that it automatically increases costs; a belief that the symbology is confusing; and problems that occur because of inadequate training (Krulikowski, 2003).

Rational for the Course

The Engineering Technology Program at Illinois State University prepares professionals who integrate engineering principles with modern manufacturing technologies. In addition, the program prepares individuals to manage people, processes, and materials through application-oriented activities. An industrial advisory board, which consists of 16 members from a wide cross section of companies, meets annually with faculty to reaffirm program goals and make recommendations for adjusting the curriculum.

During a recent advisory board meeting it was recommended that more GD&T be integrated into the curriculum. GD&T is currently integrated into a second level constraint-based modeling course in the program (Devine, 2012), but only four class periods are dedicated to the topic. Based on feedback from the industry advisory board, a new elective course was developed and is being taught for the first time during the Fall 2016 semester.

Outline of Course

The three credit hour course was designed to give students an overview of the basic terminology used in GD&T, opportunities to apply GD&T in a design setting for modestly complex parts, activities where students apply GD&T within a CAD environment, and laboratories where students inspect parts using calipers and coordinate measuring machines (CMM). The class meets twice each week for 1 hour and 50 minutes. The maximum capacity is 30 students, but enrollment for the Fall 2016 semester is currently at 12. Prerequisites include the course on manufacturing processes (basic measurement methods, plastics, milling, turning, shearing, casting, hot forming, cold forming, sheet metal, additive manufacturing techniques, and welding) and the second level constraint-based modeling course (parts, drawings, and assemblies in Siemens NX; introduction to dimensioning and tolerancing; and advanced working drawings). Specific learning outcomes for the course include: identify the geometric characteristic symbols and other symbols associated with geometric dimensioning and tolerancing; identify features with size and features without size; specify limit dimensions within a given design scenario; calculate the virtual condition for features; determine the advantages of using different material condition modifiers; apply appropriate datum reference frames to designs; apply appropriate geometric tolerances to designs; and execute proper inspection set-ups and procedures for checking geometric tolerances. The main source for the content knowledge in the course is *GeoTol Pro: A Practical Guide to Geometric Tolerancing per ASME Y14.5 – 2009* (Neumann & Neumann, 2009). Table 1 shows a general layout of the daily topics, quizzes, and labs in the course.

To assess the entry level content knowledge of students in the course, a pretest was given during the first class. Topics on the pretest were selected to provide a broad range of material related to GD&T. It included questions related to the following areas:

- Identifying current standards related to dimensioning and tolerancing.
- Giving a drawing, label symbols (all around, countersink, datum feature, basic dimension, etc.).
- Given a drawing, label the dimensions referring to a feature with size.
- Given a drawing: identify the MMC of a specified hole; the amount of tolerance allowed if a boss/hole is produced at a certain size; and label the datum reference frame origin.
- Given a drawing with a profile tolerance applied, identify the type of the profile tolerance (bilateral-equal, bilateral-unequal, unilateral-in, and unilateral-out).
- Given a drawing, sketch datum feature symbols per descriptions.

- Given a drawing with position tolerances, calculate virtual sizes.
- Given a sentence description of a composite position tolerance, sketch the feature control frame.
- Given a nominal size, specified fit (e.g., RC2), and a fit table, write out the limit dimension for a hole and pin system.

Table 1. Outline of GD&T Course.

Week	Topic	Assignment
1	Orientation / Safety discussion	
	Introduction to GD&T	**Quiz 1 – Online**
2	Limit Dimensioning / Limits of Size	**Quiz 2 – Online**
	Lab Activity	**LAB 1** – Measuring with calipers
3	How the GD&T System Works	**Quiz 3 – Online**
4	**Lab Activity**	**LAB 2** – Introduction to Romer Arm Lab **LAB 3** – NX model/drawing of PLATE
	Position Tolerance Verification	**Quiz 4 – Online** **LAB 4** – Excel table for pos. ver.
5	**Lab Activity**	**LAB 5** – Romer Arm – Position Verification **LAB 6** – NX model/drawing of BRACKET
	Production Plans and Virtual Condition	**Quiz 5 – Online**
6	**TEST 1**	**Review Readings**
	The Datum Reference Frame	**Quiz 6 – Online**
7	**Lab Activity**	**LAB 7** – Introduction to Brown & Sharpe **LAB 8** – Functional Gage Activity
	Lab day	**Continue working on labs**
8	Form Tolerances	**Quiz 7 – Online**
	Orientation Tolerances	**Quiz 8 – Online**
9	EDGD Conference	**Catch up on assignments**
10	Profile Tolerances	**Quiz 9 – Online**
	Lab Activity	**LAB 9** – Checking Profile Tolerances **LAB 10** – NX Lab for Profile Tolerances
11	Datum Feature Modifiers	**Quiz 10 – Online**
	TEST 2	**Review Readings**
12	The Datum Reference Frame II – Targets Irregular Surfaces	**Quiz 11 – Online**
	Lab Activity	**LAB 11** – Casting Drawings in NX
13	The Datum Reference Frame III – Advanced Concepts	**Quiz 12 – Online**
	Lab Activity	**LAB 12** – Pattern of Holes as a Datum
14	Position Tolerances	**Quiz 13 – Online**
	Lab Activity	**LAB 13** – Checking Composite Position
15	Coaxial Controls	**Quiz 14**
	Fastener Formulas & Screw Threads	
16	**Final Exam**	

All of the items on the pretest will be assessed again at some point in the course. Test 1 will cover material from the first part of the course. Test 2 will assess the material between Test 1 and Test 2. The final exam will be comprehensive.

Neumann & Neumann (2009) is a workbook style text that contains end-of-unit exercises geared toward industry professionals. Rather than evaluate students' content knowledge by collecting their workbooks each period, exercises are discussed in class and online quizzes of unit material are administered through the university's learning management system. Figures 1 & 2 show examples of the types of assessment questions included in the course.

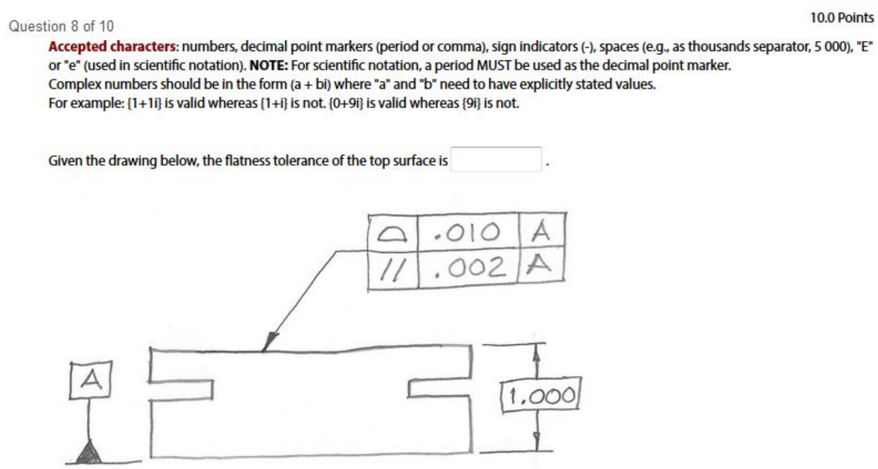


Figure 1. Example Fill-in-the-Blank Question.

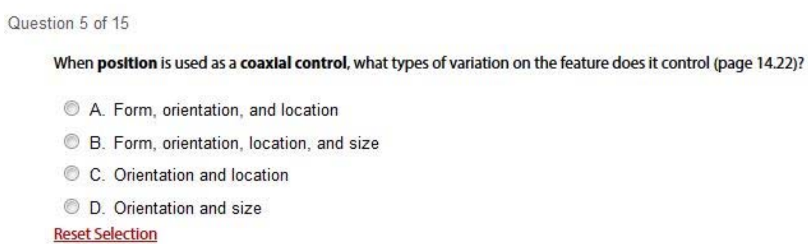


Figure 2. Example Multiple-Choice Question.

Lab activities were designed so that all students are engaged during lab days. This is challenging since the program only has two CMMs. For example, LAB 2 and LAB 3 are both introduced on the same day. LAB 2 is an introduction to the Romer Arm CMM. This lab was designed for groups of 2-3 students, so students rotate through the activity one group at a time.

Simultaneously, the rest of class works on LAB 3, which involves creating a model and drawing of a part and applying GD&T.

Examples of Labs in the Course

The labs are designed to give students practical, hands-on application of the topics covered during the course. The first lab was designed to have each student measure parts with calipers to illustrate some of the potential problems with conventional coordinate dimensioning. The class is given 12 similar parts to measure with dial and/or digital calipers (Figures 3). In addition, a drawing is provided with the specified dimensions for the parts (Figure 4). Students are asked to take 2 measurements of 4 dimensions on each of the 12 parts and record their values on the lab table (Figure 5). They are then asked to graphically represent their data collection using an Excel table for each of the 4 dimensions (Figure 6). The last section of the lab requires students to make decisions about whether or not they would accept or reject each part and give reasons why if a part is rejected.

Figure 3. Example of LAB 1 Part.

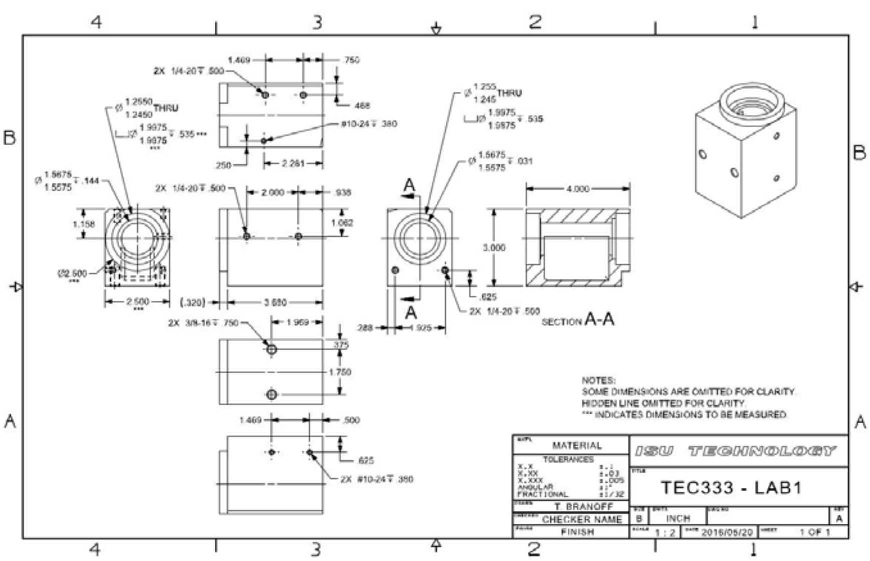


Figure 4. Drawing of LAB 1 Part.

Dim / Part		1	2	3	4	5	6	7	8	9	10	11	12
Width (2.500)	Measurement 1												
	Measurement 2												
OD (2.500)	Measurement 1												
	Measurement 2												
ID (1.9925)	Measurement 1												
	Measurement 2												
Depth (.535)	Measurement 1												
	Measurement 2												

Figure 5. LAB 1 Table.

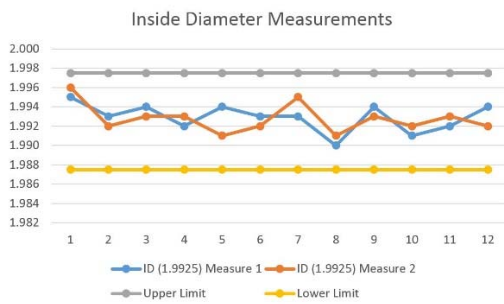


Figure 6. LAB 1 Data Example.

Students also complete labs on both Romer Arm and Brown & Sharpe coordinate measuring machines. In addition to gaining practical experience operating a CMM, these labs help to illustrate the power and consistency of GD&T within well thought out datum reference frames. Figures 7-10 illustrate the set-up, feature location, and report generation for inspecting the previously used block using a Romer Arm and PC-DMIS software.

Figure 7. Romer Arm Set-Up of Part.

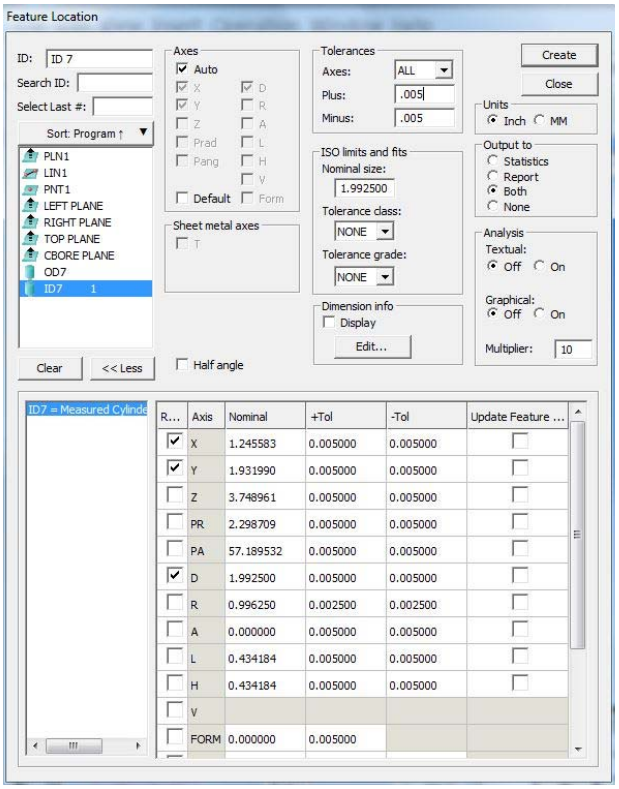


Figure 8. Feature Location within PC-DMIS.

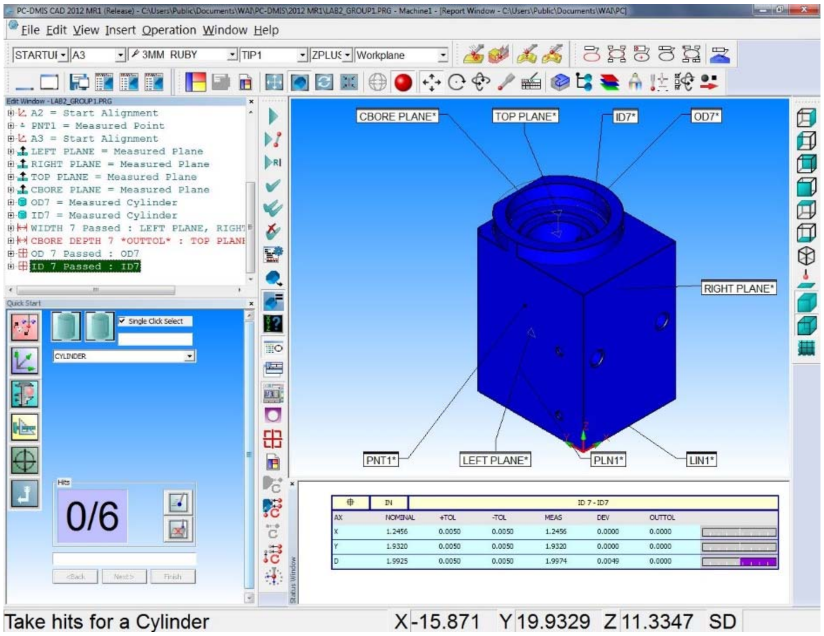
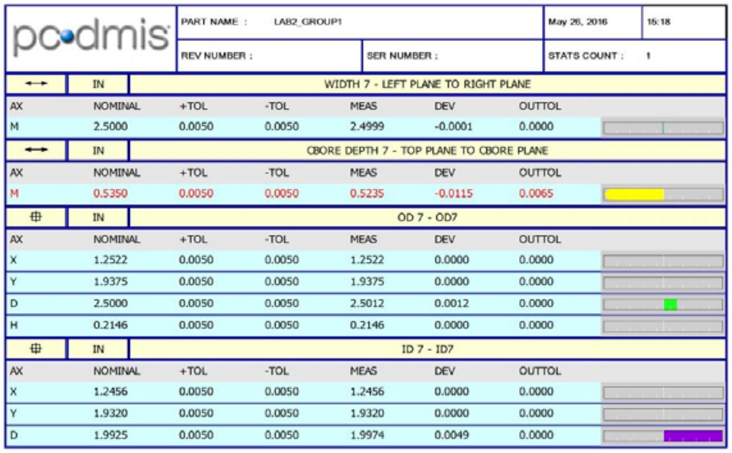


Figure 9. Example of Final Evaluation within PC-DMIS.



pc•dmis

PART NAME : LAB2_GROUP1 | May 26, 2016 | 15:18

REV NUMBER : | SER NUMBER : | STATS COUNT : 1

AX	NOMINAL	+TOL	-TOL	MEAS	DEV	OUTTOL
IN	WIDTH 7 - LEFT PLANE TO RIGHT PLANE					
M	2.5000	0.0050	0.0050	2.4999	-0.0001	0.0000
IN	CBORE DEPTH 7 - TOP PLANE TO CBORE PLANE					
M	0.5350	0.0050	0.0050	0.5235	-0.0115	0.0065
IN	OD 7 - OD7					
X	1.2522	0.0050	0.0050	1.2522	0.0000	0.0000
Y	1.9375	0.0050	0.0050	1.9375	0.0000	0.0000
D	2.5000	0.0050	0.0050	2.5012	0.0012	0.0000
H	0.2146	0.0050	0.0050	0.2146	0.0000	0.0000
IN	ID 7 - ID7					
X	1.2456	0.0050	0.0050	1.2456	0.0000	0.0000
Y	1.9320	0.0050	0.0050	1.9320	0.0000	0.0000
D	1.9925	0.0050	0.0050	1.9974	0.0049	0.0000

Figure 10. PC-DMIS Final Inspection Report.

Conclusions

Since the course is being offered for the first time during the Fall 2016 semester, a full evaluation is not available at the time of this publication. A comprehensive pretest was administered at the beginning of the semester, which will be formally compared to the results of the two tests and the final exam. In addition, students will be surveyed at the end of the semester to gain their feedback and thoughts on the course.

References

ASME (2009). *Dimensioning and Tolerancing, ASME Y14.5-2009*. NY: American Society of Mechanical Engineers. 2009. ISBN 0-7918-3192-2.

Devine, K. L. (2012). Dimensional tolerances: Back to the basics. *Proceedings of the 66th Midyear Conference of the Engineering Design Graphics Division of the American Society for Engineering Education, Galveston, Texas, January 22-24, 2012.*

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Neumann, S., & Neumann, A. (2009). *GeoTol Pro: A practical guide to Geometric Tolerancing*. Longboat Key, FL: Technical Consultants, Inc.