Use of Engineering Standards for Introduction to Global and Local Aspects of Engineering

Author:

Zbigniew Prusak, Central Connecticut State University, New Britain, CT, USA prusakz@ccsu.edu

Abstract — *This paper describes use of selected engineering standards to introduce students to engineering aspects of business environment in global manufacturing. Classes are comprised of students who to date received mostly American education and their familiarity with different cultures, foreign languages and foreign technical cultures is extremely limited. The paper presents background of the need for inclusion of global aspects of various technical cultures in engineering curriculum. It shows results of surveys on various impediments to successful business collaboration on international level and within multinational companies. One of the primary obstacles in smooth functioning of an engineering venture is lack of knowledge of local standards and technological customs. An overwhelming majority of Central Connecticut State University graduates of Mechanical and Manufacturing Engineering Technology programs find jobs within the state, which is one of the highest income areas in the nation and still is one of the most industrialized regions. It is home to a variety of companies of all sizes, which are involved in businesses ranging from high tech to traditional subcontracting; OEMs and suppliers of components to heavily globalized aerospace, automotive and medical equipment markets.*

In the course described in this paper, teaching Geometric Dimensioning and Tolerancing (GD&T) standards, their meaning and applications is based on the current ASME Y14.5 standard. Some aspects of its international counterpart, set of ISO standards, are also taught. Where appropriate, examples of common practices from selected countries and their national standards are included as well. Additionally, cultural and historic differences in matters as basic as writing numbers, abbreviations and engineering symbols, as well as some most poignant differences in common nomenclature and drafting assumptions are also addressed. Selected topics of assumptions (things that are not written on engineering print yet universally or locally understood) are also covered. The examples include various aspects of tolerancing, general tolerances of non-toleranced dimensions, and surface conditions descriptions and assumptions. Results of simple pretests designed to gage the incoming knowledge of SI and some basic differences between American and foreign technology-related customs are also presented.

Index Terms — *engineering standards, global engineering, GD&T, ANSI standard, ISO standards.*

INTRODUCTION

One of the primary obstacles to smooth functioning of an engineering venture is lack of knowledge of local standards and technological customs. Countless surveys of multinational companies list lack of understanding of local (read: local in a foreign land) standards as one of the four most significant obstacles towards maintaining good collaboration with foreign branches or establishing functional relationships with foreign business partners. The remaining three obstacles are lack of knowledge of: local legal systems and customary ways, technical culture, and communication which include language proficiency.

The industry at large continues to rely on a very limited number of knowledgeable people who act as integrators and translators for a project at hand. They are usually go-to people for knowledge related to international activities. Their job activities are still too often defined by reactive rather than proactive activities which result in costly time delays, revisions and reengineering cycles. The problems very often go unreported and remain known within two layers of organizational structure. That still does not change the fact that they are numerous and very time consuming. An example of using non-local intellectual products for leisure purposes was reported in the case of studies focused on usability of American e-commerce web sites by American and European users [1]. On the average, domestic users reported 46% higher usability than their overseas counterparts. The staggering difference in success rates of the site was attributed primarily to site design that did not meet expectations of some users. Standardization is not always the solution, but smart customization usually is.

Differences in the use of various manufacturing technologies for producing similar automotive components in North America and in Europe can serve as an example. Dry machining is used in Europe about twice as often as in North America (exact numbers depend on source). Shifting a proven production from one place to another with a different technical culture in place, which is used to different processes and environmental requirements, very seldom results in immediate savings. This results in fast compunding of problems starting with understanding of intent of process or product designer.

“Poor standards, poor technology, poor business”, “No standards – reign of disorder”, “No standards – no trade”, and various other sayings relate level of standardization to sophistication of technology and to a possible business success. Discipline-specific standards used in engineering are one of the pillars of engineering knowledge in every culture. The importance of teaching some of these standards was documented in numerous surveys seeking opinion from industry practitioners. Bahner reported that 71% of industrial leaders specified “Geometric Tolerancing” as one of the twenty most important Product Realization Skills (PRS) [2]. The number refers to graduates of BS Mechanical Engineering programs. Although no data exists for graduates of BS Engineering Technology programs, based on author’s consulting work in industry and placements of BS Engineering Technology graduates from Central Connecticut State University (CCSU) and job tasks they perform, it is estimated that expectations about their fluency in GD&T are substantially higher than for graduates of BS Mechanical Engineering programs.

Worth noting are individual notes and comments attached to a survey of engineers and engineering managers conducted by Eggert in 2005 [3]. They show a common theme - about 20% of all comments made were about need of not only understanding but knowing GD&T by mechanical engineering graduates.

GRADUATES AND THEIR WORK ENVIRONMENT

An overwhelming majority of Central Connecticut State University Mechanical Engineering Technology and Manufacturing Engineering Technology program graduates find jobs within the state, which is an area with one of the highest income in the nation and still is one of the most heavily industrialized regions. It is a home to a variety of companies of all sizes, which are involved in businesses ranging from high-tech to traditional subcontracting; from original equipment manufacturers (OEMs) to suppliers of components to heavily globalized aerospace and automotive markets and emerging biomedical manufacturers. Continuous refinements of supply chain management result in moves of production from one subcontractor to another (some overseas) usually on a very short notice. Acquisitions of related businesses overseas also unleash technical challenges usually not taken into account at high corporate level of strategic decision making. As an example, acquisitions of WSK Rzeszow in Poland by aerospace engine maker Pratt & Whitney in the late 1990’s and WSK Mielec also in Poland by Sikorsky Aircraft in 2000’s necessitated great effort in terms of learning, understanding and integration of foreign technical standards and procedures. Recent subcontracting commotion related to ramping up production of Airbus A380 is especially visible in the past 5 years. The author of this paper continues to encounter these challenges first hand during his consulting assignments. Having fluency or at least working knowledge of appropriate foreign language, local customs and at least some knowledge of local technical culture has already put scores of CCSU Engineering Technology graduates in great position for professional and financial advancement within international companies.

With the exception of some details particular to aerospace and computer equipment, industries outside of North America use only the metric system. In fact, the USA is the only technologically advanced country in the world still using customary inch system (sometimes called Imperial System of Units). Other countries using inch system are: Liberia, Burundi, Rwanda, Yemen and Myanmar [4]. Although the author of this paper does not foresee conversion from inch to metric taking place in USA for at least a few decades, the signals from industry are clear. Corporations involved in global market waste resources by realizing their products in two systems of measurements. Thus, while invisible to customers, most of automotive design done by American automotive companies is carried out in metric system. Significant number of Connecticut businesses involved in plastics and composites industries function largely in metric system [5]. All certificates from the National Institute for Standards and Technology (NIST) have been given in SI only for many years now. On the other hand, NASA still uses both systems and hundreds of Canadian companies associated with or owned by American companies continue to use the American customary inch system, sometimes in a mix with the Imperial System.

WHY EDUCATION WITH INTERNATIONAL FLAVOR?

In general, American students seldom participate in study abroad programs. That is in stark opposition to the easy access to diverse training and cultures experienced by their European counterparts. For example, from 1987 to 2004 about 1.2 million students benefited from Erasmus program which enabled them to study abroad [6]. The program targets higher education in 31 European countries and had budget of about 225 million dollars in year 2004.

When to start including aspects of foreign cultures in education process? Opinions and approaches are numerous, ranging from introduction of a foreign language at the very beginning of grade school throughout Scandinavian countries, to one year of study abroad required by many universities of old European Union of twelve. Adaptability to different cultures, some work experience in a diverse international environment are in process of becoming university education outcomes expected by employers in EU. American universities are in process of catching up. Few years ago, The University of Connecticut set a lofty goal of increasing the number of undergraduates studying overseas from 7% in year 2003 to 30% in year 2011 [7]. Worth mentioning is also fact that “UConn [University of Connecticut] plans to encourage a wide spectrum of students, including engineering and science majors”. However, it needs to be understood that undergraduate population at UConn is almost exclusively full time, whereas at CCSU majority of students are full time students having various jobs to pay for their study. Majority of Engineering Technology majors graduate as part time students already having full time jobs in their discipline of study. Leaving area and work for even one semester is not an option for most of them. The outside world needs to be somehow brought to classrooms and labs

WHEN TO INTRODUCE INTERNATIONAL FLAVOR OF ENGINEERING?

Classes at CCSU are attended by students who, to date, received a primarily American education and their familiarity with different cultures, foreign languages and foreign technical cultures is extremely limited. Inclusion of global aspects of various engineering and technical cultures in engineering curricula seemed to fit most naturally in the Geometric Dimensioning and Tolerancing (GD&T) course. It is easy and time efficient to do side-by-side comparisons of the world's two most prominent standards: ISO and ANSI.

Choice of academic course for introduction to standards used different countries was rather obvious. Mechanical and Manufacturing Engineering Technology programs require taking a course in GD&T. Although meaning and applications are still based on the most current, 2009 version of ASME Y14.5 standard, selected aspects of its international counterpart - set of ISO standards - are also taught. Where appropriate, examples from previous versions of the ASME standard (1994 and 1982) are introduced. Certain common practices, also past and present, from selected countries (Canada, UK, Germany, Poland, France, Japan, Switzerland and Italy) and their national standards are incorporated as well. They include:

- customs in writing numbers
- meaning of number of significant decimal places in a dimension
- various ways of writing toleranced dimensions and resulting interpretation
- tolerances of non-toleranced dimensions
- IT grades
- fits between mating parts
- surface finish specification and assumptions
- prefixes in physical units used in metric system
- comparative overview of ANSI and ISO for GD&T symbols used
- differences in GD&T English language nomenclature between ANSI and ISO
- drafting assumptions and practice
- drafting projections and scales
- drafting cross-sections and cutouts.

Selected topics on assumptions (things that are not written on engineering print yet locally understood) are also included. Additionally covered are cultural and historic differences in matters as basic as writing:

- date and time
- currency representation
- telephone number
- abbreviations and corresponding engineering symbols

I used to give pretest comprised of questions on the very basic knowledge of SI units (taught in physics classes) and of some aspects of the above listed issues (some taught during courses in CAD, Information Processing and a foreign language). The results were repeatedly so dismal that after five years the pretest was abandoned altogether in favor of more extensive lecturing on the issues followed by frequent testing imbedded in regular GD&T testing. The best class environment for using standards in teaching is when class roster is comprised of students of various ages, and most students have either full time jobs or some internship experience in the discipline they study. By virtue of its professional diversity, such group of students is the most receptive and capable of generating cogent questions that promote discussion.

EDUCATING ENGINEERS WITH GLOBAL AWARENESS

Advantages of using standards

The issues at stake are the skills of collaboration and communication that are increasingly more valued by employers. To cite just one of numerous surveys conducted in the past decade, teamwork and communication placed first and second in the previously mentioned survey reported by Bahner [2]. Teamwork was specified by 94% and communication by 89% of respondents. Neither can exist without possessing means of technical communication: written and spoken language, and technical common knowledge such as standards. Worth mentioning is also the fact that Design for Manufacture was specified by 88% as the highest placed technical skill. That signifies importance of proficiency in utilizing already existing body of engineering knowledge: manufacturing processes, design procedures, already existing solutions and industry best practices and various standards. The standards in engineering practice often act as enabling guides and as constraints alike. The industrial revolution was born and is still driven by: energy, automation, standardization and informatization. They all gave rise to mass markets and continue to promote innovations and their further applications.

A survey-based study on economic benefits of standardization was initiated by Deutsches Institut für Normung and by German Federal Ministry of Economic Affairs and Technology. The 1997-2000 study was conducted in Germany, Switzerland and Austria. Benefits for business and the entire country economy are listed by Khan and Raouf [8]. Among many findings listed on pages 68-73, some are very telling:

- There are three major indicators of technological progress:
  (1) patents,
  (2) expenditure on export licenses and
  (3) number of standards.
- "International standards encourage trade".
- "International and European standards are more significant for German export than are national standards".
- "Standards should be concentrated in sectors where greater national innovation potential exists".
- Economic benefits of standardization are approximately 1% of GNP. The benefit to German national economy amounts to over 15 billion US dollars per year.
- "Standards contribute more to economic growth than do patents and licenses".

Examples of fruitful use of standards or effort of simplifying access to standards abound. In the fast growing field of medical devices medical professionals can now access over 1300 medical device standards from a single database developed jointly by the Association for the Advancement of Medical Instrumentation (AAMI), the American National Standards Institute (ANSI), ASTM International and Deutsches Institut für Normung (DIN) [9]. Toyota's recent problems with vehicle control, possibly resulting from glitches in software, have already sparked drive to develop standards for automotive software [10].

Engineer work with standards, even if they are domestic standards only or are in a different field than the ones taught at the university. The "Technically Speaking" report from National Academy of Engineering defines technical literacy as three dimensional expansion "knowledge, ways of thinking and acting, and capabilities" [11]. The first and third are inherently related to existing set of standards. Possibilities and constraints. Standards are about order, and dispelling of misinformation or partial information. Therefore, the issue at stake is not about teaching standards (learning them usually comes automatically with professional practice), but about teaching how to recognize differences, understand the standards, navigate and use them.

Disadvantages of using standards

In comparison to technological and scientific innovations, technical standards are technically more conservative. Using them in instruction does not have academic appeal of path blazing activities. The main challenge in using any standards in instruction is enormity of information contained in them, and difficulty presentation without generating boredom in students who cannot fathom use of that knowledge yet. And yes, despite designed-in logic, learning any standard always looks like rote memory exercise.

Papers reporting on issues of innovative curricula design do not show concern with using standards in particular and developing a true global engineer [12]-[17]. Intentionally or not, these issues are left for professional practice as the formative years of university education can barely accommodate learning the necessary basics of engineering science and practical skills of engineering profession.

STANDARDS UTILIZED IN THE COURSE

The GD&T course is based on ANSI Y14.5M (ASTM Y14.5M) standard. To illustrate various approaches used by engineers outside of the USA, certain information from the below listed standards is also presented for comparison purposes with the ANSI standard. The common platform for examining different approaches is achievement of same or comparable design and manufacturing outcome.

Related to SI units:

- ANSI Z210.1
- ISO 1000

Related to drafting:

- ISO 128, 129, 406, 5455
- BS 308
- PN-78/M-01145

Related to dimensioning and tolerancing:
- ANSI Y14.5M
- ISO 1101, 2692, 5458, 5459, 7083, 406, 8015
- CSA B78.2
- PWA 360
- PN-66/M-02137, PN-66/M-02139

Related to surface texture and lay, and their assessment:
- ANSI B46.1
- ISO 1302, 468
- DIN 3141, 4767, 4760
- PN-73/M-04251, PN-73/M-04252
- PN-58/M-04251, PN-58/M-04252
- UNI 3963
- BS 1134
- JIS B0601
- NF Automotive Standard

Students are also given references where to look in case of doubt or need for more precise information [8], [18]-[20]. Especially book by Khan and Raouf [8] is very useful in locating standards and information sources in various engineering fields. The other three books contain more in depth information about standards in disciplines they cover, such as GD&T and numerous aspects of geometric product definition, inspection and metrology.

Examples of past and present standards are presented on examples involving the evolution of GD&T standards ANSI Y14.5M from years 2009, 1994, 1982 and 1973; and ISO 1101. Wherever appropriate, examples of past and present common practices from selected countries are also presented. They were accumulated during years of author's international industrial experience.

EXERCISES AND TESTS

As mentioned earlier, a pretest aiming at verifying incoming knowledge of SI units, general nomenclature, prefixes to units and abbreviations was used for five years. Repeatedly dismal results (common medians for a class were about 40 to 50% with 15 to 40% of students passing the test) led to abandonment of pretesting in favor of more extensive lecturing and repetitious in-class exercises on the issues. Questions from previous pretests are imbedded into ANSI-based tests throughout the semester. Recent end-of-semester tests show class medians of 70 to 85% with over 80% of students passing metric test. Although majority of students continues to show a big lack of feel for SI physical units, they are able to recognize foreign ways of describing a design and are capable of asking meaningful questions.

Most important indication of usefulness of the approach described in this paper comes months or years after graduation. The former students are regarded in their workplaces as capable of dealing with foreign metric designs and are assigned related tasks. Sometimes they still seek advice, but by then are able to research the subject on their own.

CONCLUSIONS

The main challenge in using any standards in instruction is enormity of information contained in them, and difficulty in presenting it without boring the students. The issue at stake is not about teaching standards, but about how to convey knowledge necessary to recognize differences and ask to the point questions. Students seldom see use for foreign based knowledge and consequently treat learning any aspect of a standard as rote memory exercise. Activities aiming at recognizing differences between ANSI and foreign standards, and how to navigate them and where to look for precise information are the most efficient learning topics. Also, end of semester course evaluations indicate that side-by-side comparisons of various standards are regarded by the students as the most informative and useful.

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