

2006-1514: STANDARDIZATION – LEARNING FROM THE PAST; PREPARING FOR THE FUTURE

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Standardization

Learning from Past; Preparing for the Future

Abstract

This paper will look at the importance of standardization on manufacturing. The paper will compare and contrast ANSI B4.1 Preferred Limits and Fits for Cylindrical Parts and ANSI B4.2 Preferred Metric Limits and Fits and provide a practical example of how of to utilize these standards in a freshman technical graphics course to show how standardization can reduce cost through simplifying design and part reduction.

ANSI B4.1 and B4.2

ANSI B4.1-1967 (R1974), Reaffirmed in 1999 – Preferred Limits and Fits for Cylindrical Parts has been the historical standard for designing the relationship between shafts and holes and is based upon work which began in 1920. The Scope and Application of the standard states, “The recommendations are presented for guidance and for use where they might serve to improve and simplify products, practices, and facilities.

ANSI B4.2-1978, Reaffirmed in 1999 – Preferred Metric Limits and Fits describes the ISO system of limits and fits for mating parts. Notice that this standard does not include the words, “Cylindrical Parts” in its title. This standard expanded its scope by redefining “the general terms “hole” and “shaft” to also refer to the space containing or contained by two parallel faces of any part, such as the width of a slot, the thickness of a key, etc.” There are other important improvements in this standard over B4.1 that will be discussed in the balance of this paper.

Standardization and Design for Manufacturability

Standardization in the context related to technologies and industries, is the process of establishing a technical standard among competing entities in a market, that will bring benefits without hurting competition.³ Standards can be de facto, which means they are followed for convenience, or de jure, which means they are used because of (more or less) legally binding contracts and documents.³ In the case of ANSI B4.1 and B4.2 the titles includes the word *Preferred* and are therefore generally considered to be de facto.

Design for Manufacturability (DFM) is the practice of designing products with manufacturing in mind, so they can⁴:

- Be designed in the least time with the least development cost.
- Make the quickest and smoothest transition into production.
- Be assembled and tested with the minimum cost in the minimum amount of time.
- Have the desired levels of quality and reliability.
- Satisfy customers’ needs and compete well in the marketplace.

At the basis of DFM are the concepts of fewer parts and simpler designs.

Dr. David Anderson a well known expert on DFM suggests a zero-based approach to part reduction which focuses on development of a minimum list of parts needed for new designs. He states, "It is not necessary to eliminate parts used on existing products, except, when the common parts are functionally equivalent in all respects. In this case the new common part may be substituted as an equivalent part or a "better-than" substitution, where a common part with a better tolerance can replace its lesser counterpart in existing products." He goes on to say, "Even if part standardization efforts only apply to new products, remember that in these days of rapid product obsolescence and short product life cycles, all older products may be phased out in a few years."⁵ For this paper we are mostly interested in Dr. Anderson's comments with regard to raw materials. "If raw materials can be standardized, then the processes can be flexible enough to make different products without any setup to change materials, fixturing mechanisms, or cutting tools."

Standardization of raw materials and a focus on reduction of parts and processes will result in simpler more cost effective designs.

Classroom Application with the Inch System

The freshman technical graphics course at Ball State University has four primary component areas: sketching, three-dimensional modeling, dimensioning theory, and an introduction to design. This paper will focus on the last two components: dimensioning theory and introduction to design. With regard to dimensioning theory the focus will be on limits and fits for cylindrical parts and the need for teaching the importance of standardization in order to improve manufacturing economics.

At the foundation of "fit calculations" are the equations:

$$MMC_{\text{hole}} - MMC_{\text{shaft}} = TF$$

$$LMC_{\text{hole}} - LMC_{\text{shaft}} = LF$$

where: MMC = Maximum Material Condition

LMC = Least Material Condition

TF = Tightest Fit

LF = Loosest Fit

The purpose of this paper is not to go in depth into all aspects of tolerancing so please refer to a technical graphics text or The Machinery Handbook if you are not familiar with classes of fit and tolerancing. The procedure most frequently taught is:

- Select a class of fit. For this example, we will use a Running Clearance (RC4) fit which means there will always be some clearance between the shaft and hole.
- Select a basic size. The basic dimension most commonly is based upon a fractional nominal dimension. For this example, we will use a nominal size of $\frac{1}{2}$ "; a basic size of .5000"
- Select whether hole basis or shaft basis. In this example we will use hole basis.
- Use the Standard (B4.1) to gather appropriate data for the calculations

Limits are in thousandths of an inch			
Nominal Size Range inches Over To	Class RC 4		
	Limits of Clearance	Standard Limits	
		Hole H8	Shaft f7
0.40-0.71	0.6	+1.0	-0.6
	2.3	-0	-1.3

- Perform Calculations

- $MMC_{\text{hole}} = .5000 + (-0) = .5000$
- $LMC_{\text{hole}} = .5000 + .0010 = .5010$
- $MMC_{\text{shaft}} = .5000 + (-.0006) = .4994$
- $LMC_{\text{shaft}} = .5000 + (-.0013) = .4987$
- $MMC_{\text{hole}} - MMC_{\text{shaft}} = \text{TF}$
 $.5000 - .4994 = .0006$
- $LMC_{\text{hole}} - LMC_{\text{shaft}} = \text{LF}$
 $.5010 - .4987 = .0023$

Notice that the TF and LF calculations of .0006 and .0023 respectively are equal to the coded values of 0.6 and 2.3 for Limits of Clearance in the table.

Based upon the above procedure we would specify the upper and lower limits for the hole and shaft on the appropriate drawings. More likely than not limits provided by the calculations are such that custom manufacturing is required in order to meet the requirements. Custom machining of these parts is expensive; particularly if we do not need mass quantities.

An option to custom manufacturing would be to outsource the parts by finding off-the-shelf components that meet the requirements stipulated by the calculations. Students are asked to use the McMaster-Carr website (www.mcmaster.com) for selecting parts. We use this site as it has a wide variety of standard components. We also allow students to use other sites at their discretion. They are advised that they should search for off-the-shelf shaft material and an off-the-shelf bearing that are as close as possible to the calculated values. Students soon learn that finding off-the-shelf components that satisfy the standard limits provided by ANSI B4.1 is difficult if not impossible. This is a severe weakness of ANSI B4.1 and its use by component manufacturers. It has served us well as a standard in terms of standardizing clearances. However, B4.1 has not been utilized extensively to establish commercially available product. If commercial product cannot be found to satisfy the limits, an option would be to select the components that are as close as possible to the limits and then decide if the limits of clearance would be acceptable by inserting the MMC and LMC values for the commercial components into the equation. Note: This is a freshman technical graphics course so we do not get into the nuances of bearing design. We are simply exploring the concept of fits and clearances.

An example of this method is as follows:

- A bearing is found that has limits of .5020/.5010.
- Shaft material is found with limits of .5000/.4999
- Calculations:
 - $MMC_{\text{hole}} - MMC_{\text{shaft}} = TF$
 $.5010 - .5000 = .0010$
 - $LMC_{\text{hole}} - LMC_{\text{shaft}} = LF$
 $.5020 - .4999 = .0021$
- The limits of clearance are .0010 and .0021 or 1.0 and 2.1 coded. This is reasonably close to the 0.6 and 2.3 requirements of an RC4. An RC3 fit has limits of clearance of 0.6 and 1.7 and an RC5 fit has limits of clearance of 1.2 and 2.9. The designer must decide whether the limits of clearance provided by the commercial parts are satisfactory.

Classroom Application with the Metric System

Historically, the design project in the freshman technical graphics course had always been done in the inch system and very little emphasis was placed on the metric system and ANSI B4.2. Without getting into the controversy of adoption of the metric system and “which” metric system to adopt, suffice it to say that when we attend a meeting of international manufacturers, the standard language is English and the standard measurement system is the metric system. It is based upon this rationale that we elected to use the metric system and ANSI B4.2 as the basis for the design project.

As stated above, ANSI B4.2 broadened the definition of “hole” and “shaft” as provided in ANSI B4.1 to include other mating shapes. While there is no practical reason why the broadened definition cannot be applied to B4.1 as well, the B4.1 standard is intended for cylindrical parts only.

When utilizing the metric system it is important to provide students with an understanding of the preferred numbering system. The preferred numbering system in the inch system is a bit convoluted. The inch system actually has two preferred numbering systems:

- Fractional based: We prefer whole numbers to fractions. We prefer 1/2’s to 1/4’s; 1/4’s to 1/8’s; 1/8’s to 1/16’s, etc.
- Decimal based: We prefer whole numbers to decimal increments. We prefer .1’s to .01’s; .01’s to .001’s; .001’s to .0001’s, etc.

Knut O. Kveneland is the chair of the ANSI B4.2 standard and the author of *Metric Standards for World Wide Manufacturing*. The readers are encouraged to investigate this reference for a complete explanation of the preferred numbers for the metric system.

“The system is called the Renard numbering system after Charles Renard, a French army captain, who was able to reduce the number of different dimensions of rope for military balloons from 425 to 17, with the aid of the series in the 1870’s. In today’s world it has become increasingly important, from a cost standpoint, to reduce the number of different standard parts, materials, and components used in products.⁶” Suffice it to say that part reduction and design simplification is not a new topic.

Mr. Kveneland points out that “Specific areas where the use of preferred numbers can be applied to your advantage are as follows: Inventory Reduction by applying preferred numbers to sizes for such items as: holes, pipes, cylinders, shafts, fasteners, steel material, drills, reamers, motors, pumps, tanks, pressure gages, wires, etc. Product Line Simplification and Planning by choice of preferred numbers in planning production of model sizes to cover a given range of performance such as: lift capacity, fill capacity, rotating speeds, power ratings, etc. Efforts to minimize cost by reducing the number of manufactured sizes help reduce inventory for the consumer of Semi-finished products, down the line to inventory at the hardware store.”

The preferred sizes from Table 1 of the ANSI B4.2 standard are:

Basic Size mm		Basic Size mm		Basic Size mm	
First Choice	Second Choice	First Choice	Second Choice	First Choice	Second Choice
1		10		100	
	1.1		11		110
1.2		12		120	
	1.4		14		140
1.6		16		160	
	1.8		18		180
2		20		200	
	2.2		22		220
2.5		25		250	
	2.8		28		280
3		30		300	
	3.5		35		350
4		40		400	
	4.5		45		450
5		50		500	
	5.5		55		550
6		60		600	
	7		70		700
8		80		800	
	9		90		900
				1000	

Notice from the table that the values in the second column are 10 times the first and that the values in the third column are 10 times the second. “It should be noted that any series can be extended indefinitely upward or downward by multiplying or dividing repeatedly by 10. The Renard system derived from a geometric series having one of the following common ratios: $5\sqrt{10}$ $10\sqrt{10}$ $20\sqrt{10}$ $40\sqrt{10}$ or $80\sqrt{10}$.”⁶

The concept of the preferred numbering system separates the B4.2 standard from the B4.1 standard in an important way. In the B4.1 standard, one entered the table by locating the range of

nominal values that contained the basic size. In our example, the basic size of .500 was found in the nominal size range of “Over 0.40 to 0.71.” In the B4.2 standard one enters the table by selecting a basic size based upon the preferred numbering system. The B4.2 standard by its design controls not only the limits of clearance but also constrains the basic size.

When the metric system is used for the design project, students discover that when searching for off-the-shelf parts that they can often find parts that meet the requirements of the B4.2 standard. In fact, they find that many suppliers reference components not with limits but with the ISO symbol identifying the limits listed in the standard. For example, one might find a shaft listed as a g6 or a bearing listed as an H7 representing a hole basis sliding fit. Adoption of the B4.2 limits of clearance is not complete. One can find commercial components for “sliding fits” in many basic sizes. However, other classifications are found less frequently off-the-shelf.

Conclusion

American manufacturing is competing in a worldwide market. Conversations with personnel at the American Society of Mechanical Engineers indicate that it is unlikely that the B4.1 standard will be reaffirmed in the next cycle. It seems that now is the time for American manufacturers to seriously consider moving to the metric system. The preferred numbering system and ANSI B4.2 provide tremendous opportunities for standardization. Adoption of the metric system could be done on a zero-based approach as advocated by Dr. Anderson. Develop a policy that all new designs be done based upon the metric system. With today’s reduction in product life cycle, it is not that important to reach back to existing product.

No doubt there is a “Catch 22”. Standardized metric raw materials are not readily stocked in the U.S. so initially, raw material cost might rise. However, as more companies adopt the B4.2 standard and insist that their suppliers maintain inventories of raw materials to these sizes, economies of scales should soon be realized.

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5. Anderson, David M., *Design for Manufacturability & Concurrent Engineering: How to Design for Low Cost, Design in High Quality, Design for Lean Manufacture, and Design Quickly for Fast Production*, CIM Press, www.design4manufacturability.com/books.htm, 2004
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