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Known as the "Doctor of Dimensioning," Alex Krulikowski is a noted educator, author, and expert on Geometric Dimensioning and Tolerancing (GD&T). A design manager with one of the world's largest manufacturing corporations, he has more than 30 years of industrial experience putting GD&T to practical use on the shop floor.

Web Highlights

Improving E-Learning Outcomes
e-Learning.com provides information on building and delivering advanced learning environments for business, government, and higher education.

This feature article explains how to realize the full impact of e-learning by establishing the way in which learners digest information through this relatively new medium.

Cheryl Flagler explains how to keep students interested in e-Learning Magazine online.

To read the article, Click here

ETImail *is a regular online publication devoted to Geometric Dimensioning & Tolerancing. Each edition features a host of GD&T resources and links, as well as dimensioning tips by noted GD&T author and ETI founder, Alex Krulikowski. We also invite you to visit our website, etinews.com. To view past issues of ETImail, see the archives.*

ETImail is now available in PDF format. To read the PDF file, you will need Adobe Acrobat Reader.

In This Issue

Here are this issue's highlights. Click on any link to jump directly to a feature:

The Tao of Tolerancing
Part III: How to Establish Meaningful Tolerance Values for Each Dimensional Relationship on a Part

Alex Krulikowski

This five-part article covers my experiences, thoughts, and beliefs on tolerancing. It is based on observing how many organizations around the world currently handle tolerancing and how I believe tolerancing can be handled in a far more successful way in industry. I believe that using the tolerancing methods discussed in this article can save as much as 30% of part costs.

The first part of this article covered nominal thinking. Part 2 discussed how to specify datums and dimensional relationships for all part features. In this issue of ETImail, the article continues with Part 3: how to establish meaningful tolerance values for each dimensional relationship on a part.

The next part of the article will outline a plan for how to lift your organization from Tolerancing Hell to Tolerancing Heaven. The fifth and final part of this article reviews and summarizes all of the Tao Tolerancing Principles covered in Parts One through Four.

An explanation of the title of this article: Tao (pronounced "dou" or "tou") means "the path" or "the way." Tao is an ancient Chinese religious belief and contains a philosophical aspect that can be applied to how we specify tolerances in industry. A tolerance is simply "the allowable variation for a part feature," so this article is an enlightenment of a philosophical approach to assigning tolerances to part features.

Virtual Measurement There's a new line of thinking that says it's not enough to know that you're producing the correct part when all is said and done. Nowadays, manufacturers and customers want to understand more about the entire process, find out where the snags are, where measurements errors take place, learn the limitations of the process and how to work around them.

Shawn Ryan looks at this trend in manufacturing in the NDX.com article archives.

To read the article, Click here

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ETI Products

Advanced Concepts of GD&T Textbook

The textbook stresses the applications of GD&T in industry and takes an in-depth look at many GD&T topics. Position, profile, and datums are are covered in detail. It discusses several common industry tolerancing practices that are not documented in ASME Y14.5M-1994. Three chapters are devoted to tolerancing of non-rigid parts. This book is an indispensable on-the-job reference. The text has numerous tips, suggestions and practical applications.

To read more about it, Click here

GD&T Trainer Makes Learning Fun

Introduction

In Part 2 of this article, we learned how important it is to have dimensional relationships communicate the functional requirements of a part. In this part, we will look at the importance of specifying the optimum tolerance values. The amount of tolerance on a part directly affects the costs to produce the part. If part tolerances are too loose or too tight, your company will fail. A loose (large) tolerance is less expensive to produce than a tight (small) tolerance. However, just as the method of tolerancing is controversial, so is specifying the amount of tolerance.

Engineers often believe the tolerance should be related to the functional requirements of the part, and the manufacturing community often believes that the amount of tolerance should represent their process capabilities. This results in another tolerancing controversy.

At the heart of this controversy, is one simple question: Should tolerance values be based on manufacturing capability or functional requirements? There are stalwart believers on both sides of the argument. Some even believe a combination of both methods should be used to establish part tolerances. (Looks like a "peace-keeping" compromise to me; the kind that will ultimately lead to failure!)

I discourage compromising tolerances, but input from manufacturing is encouraged. Part of the SACD philosophy is to structure component tolerances to optimize the system. Functional requirements usually translate into system or subassembly tolerances, within which the individual component tolerances can be derived.

As an example, let's look at the flatness tolerance on two parts with nominally planar surfaces. The parts mate together with a gasket between them to create a joint that has a function to seal. The gasket thickness and its compressibility are major factors in establishing the amount of flatness tolerance that the parts may have to ensure the gasket will be compressed when the parts are at their extremes. (The method to calculate the flatness tolerance values is shown in Chapter 12 of my book, *Advanced Concepts of GD&T*.) The analysis of the functional requirements of the gasket joint results in a total amount of flatness tolerance that can be distributed between both parts. The flatness "budget" could be allocated between the two parts according to the process capabilities, so that there is input from manufacturing without a compromise.

The Ultimate Goal

Many workers do not have a clear understanding of the ultimate goal of all companies: to make a profit. This is accomplished by manufacturing products that function as intended and are a good value to the customer (meaning that the product functions as intended and is competitively priced). Most companies strive to make products that are a good value and generate a profit as well. The chart in Figure 1 shows the relationship between cost, product function and customer value.

Cell I shows products that have a low cost to manufacture, but do not function well. In this case, the part manufacturing may be profitable, but the customers will not be satisfied with the product, so sales will diminish to the point of failure for the company.

Cell II shows products that have a high cost to manufacture, but do not function well. In this case, the amount of customers will diminish. They will not pay a higher cost for a poor product. The company will struggle in Tolerancing Hell and eventually fail. (For a definition of "Tolerancing Hell," see Part I of the Tao of Tolerancing.)

Cell III shows products that function well but have high manufacturing costs. Customers will love the way the product works, but sales profits will be poor because the product manufacturing costs are too high. The company will struggle in Tolerancing Hell and will eventually fail.

Cell IV shows products that are a good value to the customer. I think we all agree that if a company manufactures a product that functions well, and has low manufacturing costs, customers will want the product and the company will prosper. The customers will love the product and sales will be strong because the product will be a good value.

ETI's GD&T Trainer is the perfect solution to your training needs. It's an entire interactive GD&T fundamentals course on one handy CD -ROM. It's convenient, portable, and fun.

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ETI launches its new Digital Instructor's Kit – all the course materials an instructor needs to teach an entire GD&T course included on one handy CD -ROM.

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ETI Web Special

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ETI Services

New Fundamentals Class Begins Jan. 2003

Effective Training is offering a Fundamentals of GD&T course at their Westland, Michigan, location. This evening class begins the last week of January, 2003.

To learn more about our fundamentals class, click here.
To register or receive more information about this class, click here.

		Function	
		Poor	Excellent
Cost	Low	**I** **Poor value to customer** (Low-cost junk products)	**IV** **Good value to customer** (Low-cost good functioning products)
	High	**II** **Poor value to customer** (High-cost junk products)	**III** **Poor value to customer** (High-cost good products)

Figure 1

When tolerances are based on manufacturing, one is constrained to the manufacturing method from which the tolerance is derived. When tolerances are based on functional requirements, flexibility is available to select different manufacturing methods.

Tolerance Values Based on Function or Processes?

Figure 2 expands the information from the chart in Figure 1 to relate components of the chart to how tolerances are determined. This time, the cells are labeled with the type of tolerance based on manufacturing capability or functional requirements. It shows the results for a company, based on how it determines tolerance values.

If product tolerances are based on the manufacturing processes, the company will always end up with the results in cell I, II or III. If the tolerances are based on manufacturing processes (optimizing manufacturing) and are looser than required for function, this will result in products that will be easy to manufacture and will function poorly. Thus, the company will have the results illustrated in cell I.

If product tolerances are based on manufacturing processes and are tighter than they need to be for product function, the parts will be difficult to manufacture and may or may not function as intended. The results are reflected in cell II or III. Surprisingly, many times a manufacturing engineer will request a tolerance based on a process that is tighter than it needs to be for product function. This is costly and does not necessarily result in a better functioning part.

If product tolerances are based on functional requirements, it does not automatically mean the company will prosper. Basing product tolerances on functional requirements can result in a company having the results in cell III or IV.

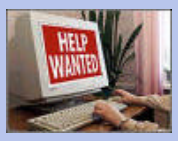
If the tolerances are based on functional requirements, but not assigned properly (due to poor processes, skills, or compromises) the organization will end up with the results in cell III. Having the results from cell III is still a state of Tolerancing Hell, and will lead to struggles and eventual failure. As the organization improves its abilities to assign tolerances, it may receive the results shown in cell IV.

If a company produces products with the results reflected in cell I, II, or III, it will struggle in Tolerancing Hell and eventually fail. As the ability to use the system approach to component design increases, the company's results will improve and reflect those in cell IV, and the company will prosper.

ETI Offers On-Site Training

Effective Training brings the most up to date, easiest to understand GD&T instruction in the industry right into your location. Either Alex or one of his personally trained instructors will come to your site to conduct a series of three workshops that add up to a total GD&T education. Workshops can be customized to include your drawings and parts.

To find out more about what ETI has to offer your organization. Click here



ETI's Employment Opportunities Board

ETI provides a free forum that enables job seekers and employers to meet. If you're looking for employment in a GD&T -related industry or you're a company who needs someone with GD&T knowledge, post your needs here.

Click here

ETI'S Discussion Board

ETI's website has an interactive forum that's easy to access and may give you a broader knowledge of GD&T -related topics. Drop by the Interact section of our website and take a look at the Discussion Board. Click on any subject title and you can browse through GD&T topics, where you may find ideas to spark your own questions.

ETI's Discussion Board can provide a place for you to find answers to questions, an exchange of ideas, and a continued discussion of the ever -

		Function	
		Poor	Excellent
Cost	Low	**I** **Poor value to customer** Loose tolerances based on manufacturing processes	**IV** **Good value to customer** Loose tolerances based on functional requirements
	High	**II** **Poor value to customer** Tight tolerances based on manufacturing processes	**III** **Poor value to customer** Tight tolerances based on manufacturing processes or functional requirements

Figure 2

Optimizing Function and Cost

The obvious question is: what happens when a tolerance is based on the product functional requirements, but the tolerance cannot be manufactured? Should the tolerance change or the process change? Optimizing function and cost can be a difficult task. The task involves understanding measurement uncertainty, functional requirements, process capability, tolerance analysis, and tolerance optimization. The process is too lengthy to explain in this article. However, I will say that every tolerance must be manufacturable or the part cannot be produced. The fact that tolerance values are determined by functional requirements, does not mean that process capability should be ignored. The process of how to balance (optimize) functional requirements and process requirements are explained in my upcoming book on system approach to component design.

The optimum part tolerance is the tolerance that is not too tight or too loose. The optimum tolerance is the tolerance that protects the part function without unnecessarily restricting the manufacturing process.

Conclusion

Parts with larger tolerances are less expensive to produce than parts with tight tolerances. Tolerances that are based on functional requirements ensure product function. Parts that contain large tolerances, and function as intended, are a good customer value. Therefore, the most successful path for a company is to use the largest possible tolerance that will protect the function of the product.

When tolerances are based on manufacturing processes, it is difficult to produce good value products; however, when a company bases tolerances on the functional requirements of the product, it can produce products that are a good customer value.

I will close by summarizing the Tao Tolerancing Principles (TTPs) covered in this part of the article. (TTPs 1-4 are covered in Part I of the article. TTPs 5-9 are in Part 2.)

TTP #10 - The amount of tolerance on a part directly affects the costs to produce the part.

TTP # 11 - If part tolerances are too loose or too tight your company will fail.

TTP # 12 - It is the ultimate goal of all companies to make a profit.

TTP # 13 - The optimum tolerance is the tolerance that protects the part function without unnecessarily restricting the manufacturing process.

TTP #14- If a company bases tolerances on the functional requirements of the product, it can produce products that are a good customer value

Next Issue: Part 4 - Tolerancing Heaven: a plan for how to lift your organization from Tolerancing Hell to Tolerancing Heaven.

changing world of GD&T.

To visit the board, click here.

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Tech Calendar

Stay up to date on the latest industry news with the ETI Tech Calendar. Click here

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Quality Quote

If the process is right, the results will take care of themselves.

—Takashi Osada, from *The 5 S's: Five Keys to a Total Quality Environment.* (Tokyo: Asian Productivity Organization, 1993)

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We welcome your feedback. Send comments about this article to ETImailbag.
Your opinions will be posted in the next issue.

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Standards in the News

ETImail's Standards in the News *takes a look at real-life issues involving standards. This month: China works to create standards for new rock climbing industry.*

Excerpts from china.org.cn website.

POPULARITY OF ROCK CLIMBING CREATES NEED FOR STANDARDS
While China promotes the new sport of rock climbing, efforts are being made to work out a set of rules governing the administration and safety for designing and manufacturing artificial rock surfaces, climbing gears and management of climbing sites.

"Compared with the countries where this sport has had a long history, China is still lag [ging] behind in terms of standard and development in general. We are some 30 years behind the pioneering Europeans," said Li Zhixin, director of the MSAC and executive vice-president of the CMA. Full Story

Excerpt from, "Popularity of Rock Climbing Creates Need for Standards" in (Xinhua News Agency May 7, 2002)

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TheETI Mailbag

On page 15-3 of Advanced Concepts Of GD&T Alex states that the basic dimensions used with datum targets have a gagemakers tolerance. My question is: where are we getting this tolerance from? If the dimension was not basic and was not toleranced we would have to go to the unspecified
tolerance in the title block. Is this what we would take 10% of?

Thank you.George

The gagemakers tolerance that applies to a datum target is an area that is not standardized. Often the tolerance for the location and size of the gage simulators that represent the datum targets is an agreement between the gage buyer and supplier. The 10% rule for gagemakers tolerances that we often refer to is in regards to the gage for a toleranced feature, it is not necessarily for datum targets.

Often the tolerance for the size and location of datum targets is in shown in the gage design and is accepted thru the gage approval process. If the tolerance for the datum targets was very large, it would make it difficult to pass the gage R & R for other toleranced features on the part.

I have attached a .pdf file of some drawings from the *MIL HDBK 204: Standards Handbook Design of Inspection Equipment for Dimensional Characteristics* that show typical gage tolerances. To see them, click here. To download Acrobat

Reader, click here.

Alex

ETI appreciates your questions and comments.
Send your GD&T questions to: ETImailbag.

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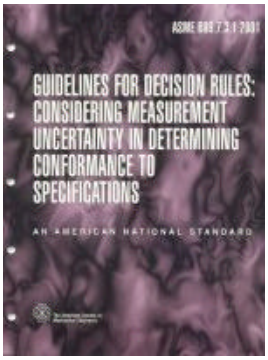
Alex's Tech Tip

From teaching ideas to new products that will assist you in training or on the job, the ETImail Tech Tip will keep you informed about new technology and ideas. This month's Tech Tip: a useful book on dimensional measurement.



SOLVING THE PROBLEMS OF MEASUREMENT UNCERTAINTY
This month's Tech Tip is a recommendation for a great book on measurement: *ASME standard B89.7.2, Guidelines for Decision Rules: Considering Measurement Uncertainty in Determining Conformance to Specifications* . Dimensional measurement planning is an important yet often overlooked step in the product development process. The ASME standard B89.7.2 offers many insights for establishing a policy on measurement plans.

This standard is also recommended reading for designers and engineers. The book is only 31 pages long, but contains many useful ideas on measurement planning, such as:

· A set of definitions of terms used in inspection
· A sample measurement plan
· An appendix that provides a list of references, which are useful for measurement planning
· An appendix on gage selection
· An appendix on measurement uncertainty

The book can be purchased from the Global Engineering Documents website. Here's a link to its exact location on the site:
Guidelines for Decision Rules: Considering Measurement Uncertainty in Determining Conformance to Specifications

This book in an important addition to your reference library.

If you know about a new tech tool or an innovative idea that would aid our readers, please write us: ETImailbag.

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ETImail Feedback

Have comments about anything you've read in ETImail? ETI will post your comments here and provide a forum for more discussion about GD&T topics.

Comments from Canada:
I really appreciate this part II [of the "Tao of Tolerancing" article]. I am a customer who bought the first batch of your latest book, *Advanced Concepts of GD&T*. In this issue, you had talk about this book, *System Approach to Component Design*. I do not have your expertise, but your way to see GD&T

is perfectly in line with mine. I have tried more than 5 years to convince my manager that GD&T shall be put in front in the Design process to validate new ideas and concept to respond to customer need, but with not a lot of success. Do not worry; I will not stop.

Gilles Fournier

Overtolerancing
In "The Tao of Tolerancing," Part 2, you missed one of the most widely used (and misused) methods of tolerancing: OVER TOLERANCING i.e. making a tolerance so close the likelyhood of a misfit is very small. Over tolerancing allows the designer to save time (doesn't have to calculate & think through tolerances) and offers security. I believe over tolerancing is practiced more than all the others you mentioned.

Joe

Tolerancing Hell
So far, these articles have maintained my utmost interest. I am looking forward to the remaining 3 articles and maybe some guidance toward a more practical/hands on approach to geometric tolerancing applications.

I only found this page on the Web purely by accident - I was browsing for some inspiration due to several hours of frustration this morning. It was spent trying to interpret a drawing in response to one of our Inspectors plea for help " What does this mean?/How do I measure this part/How do I interpret the results in relation to the GD&T? (etc etc etc). The print has quite a number of GD&T's with composite position tolerances applied to threaded holes, seating faces and a number of other "port holes" that are perpendicular to each other and meant to be parallel with the seating faces.

Three hours and 4 people later, we believe we had an idea of what the drawing intended. I am still not convinced that we got it right.

When I saw the line "Tolerancing Hell", I immediately felt at home reading the article. ASME Y14.5 is the standard that is used at this facility and we still have difficulty with practical interpretation. When you get, "I think it means this, or I reckon it means that" then there is scope for much misinterpretation.

As mentioned previously, I look forward to the next three installments of this article. I live in hope!

Ann Hannan

ETI would like to hear from you. If you have an opinion about any ETImail article or feature, please write to our ETImailbag.

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