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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.

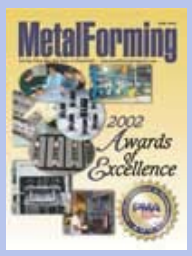
ETImail is a regular online publication devoted to Geometric Dimensioning & Tolerancing. Each edition features a host of GD&T resources and links, as well as dimensioning tips by noted GD&T author and ETI founder, Alex Krulikowski. We also invite you to visit our website, etinews.com. To view past issues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

Web Highlights



Metal Furniture Makers Turn to GD&T
Making sure that metal-furniture components assemble easily requires precision--not just the first time the parts are run, but for years and years into a program. Read about companies that have begun to use GD&T symbols on their part drawings to help ensure that the products will go together as designed. *Brad F. Kuvin*

The Tao of Tolerancing, *Part I: Nominal Thinking*

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 covers nominal thinking. The second part covers how to specify datums and dimensional relationships for all part features and explores the great controversy on how parts should be dimensioned. The third part of the article covers how to establish meaningful tolerance values for each dimensional relationship on a part, and the fourth outlines a plan on 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.

Let's begin this journey with 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.

Nominal Thinking

Nominal thinking is where a designer or engineer believes that if a part design is theoretically correct in its nominal state, it will work in its produced condition.

looks at GD&T as part of his article in Metal Forming Magazine online.

To read the article, Click here

This article is in pdf format. To get a free Adobe Acrobat download, click here.

Medical Device Manufacturers Use GD&T
Today's designers of medical devices are faced with demands for smaller, better, more sophisticated, and more cost-effective products. This article by Ron Roth explains why GD&T aids in the successful development of small-diameter tubings. *From the Devicelink.com online 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

Nominal thinking is a simplistic way of looking at a design; it excludes the effect of the tolerances. Nominal thinking increases the risk of problems for the customer and in production. Nominal thinking is often embraced as a timesaving measure or as a convenience when using CAD models.

The list below shows some of the fallacious thoughts that are common with nominal thinking:

NOMINAL THINKING EXAMPLE	REALITY
Our assembly problems can be avoided by making an assembly of nominally designed models or drawings (of parts) and verifying they fit together.	Some assembly problems can be found using nominal models or drawings, but many interference conditions cannot be found until the effects of tolerances are analyzed.
We design parts using solid models in the nominal condition; therefore, the tolerances are not needed. The tolerances are going to be whatever the process gives us.	This is a dangerous paradigm. What if the tolerances produced from the processes result in a product that doesn't function as intended?
Omitting tolerances will minimize disputes.	Omitting tolerances doesn't minimize disputes; it delays the recognition of problems to after the parts are built. This is the most expensive time to discover and resolve tolerance issues.
Tolerance specification is too time consuming.	Specifying tolerances early in the design process takes some time, but it saves valuable time in process planning and problem resolution that can delay production schedules.
We design our parts at nominal for initial prototypes and assign tolerances before the part is released for production.	This will result in several problems. A cost estimate cannot be accurately achieved until tolerances are specified. Process plans and gaging plans cannot be done until tolerances are specified. The earlier the tolerances are specified, the more time you allow for accurate production planning, tool design, die design, and gage design.
We make a cross-section layout of our products in the nominal condition to estimate the space required for the product.	In a design, the nominal often changes once a tolerance analysis is performed. A tolerance analysis requires tolerances to be specified. The sooner the tolerances are specified, the sooner an accurate cross-section picture can be established.

One thought that helps to avoid falling into the trap of nominal thinking is, "You can *ignore* the effects of tolerances, but you cannot *avoid* the effects of tolerances." Tolerance will exist in the produced product even if you don't acknowledge it in the design stage. If you want the part to function as intended, the effects of part tolerances should be analyzed in the design stage.

The earlier you understand the impact of tolerances, the more time you have to deal with any problems the tolerances may present. Nominal thinking is risky, and will launch you to Tolerancing Hell.

Tolerancing Hell
Many companies live in "Tolerancing Hell" and suffer needlessly. Tolerancing Hell is a state of confusion that exists when tolerances are poorly specified. They can be vague, not in accordance with standards, or incorrectly specified. Poor tolerance specifications are often interpreted inconsistently or incorrectly during manufacturing and inspection, and are often not adhered to in the plant.

When an organization is in Tolerancing Hell, one or more of the following symptoms are often present:

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

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.

To read more about it, Click here

To download a demo, Click here

GD&T Instructor's Kit Goes Digital

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.

To read more about it, Click here

To download a demo, Click here

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ETI Services

- Numerous drawing revisions
- Start-up problems during new product launches
- High warranty costs
- Disputes over drawing interpretation
- High manufacturing costs

To sum it up, huge amounts of time and money are wasted in the organization.

Many engineers, designers, inspectors, and toolmakers live in Tolerancing Hell and don't even realize it. These individuals think they are doing a good job, from their department perspective, but the overall organization is experiencing significant waste from the misuse of tolerances. There is a better option: I call it "Tolerancing Heaven." In part four of this article I will explain "Tolerancing Heaven" and provide a path to achieve it.

Why Tolerances are Necessary

Life would be simple if the designer or engineer could design parts at nominal condition and did not have to specify tolerances. However, then manufacturing would be faced with not knowing how much tolerance was acceptable. This would lead to two logical paths for manufacturing:

1. Striving to achieve perfect part features (zero tolerance)
2. Using as much tolerance as they felt they needed to produce parts economically

If the first path was chosen, parts could not be manufactured economically. All processes require some tolerance. Reducing tolerance where it is has no effect on part function is a waste of time and money. It is not practical to try to produce parts with no tolerance.

If the second path was chosen, parts could be manufactured economically, but they probably would not function well. Often the ability for a part feature to function is limited by the variation that exists in the part feature.

The two primary reasons tolerances are specified are: to protect part function and to allow for economical production. Tolerances should protect the function of the product and represent the maximum amount of allowable variation permissible. Specifying the largest tolerance provides manufacturing with the maximum flexibility for selecting and maintaining processes.

Tolerance specifications on a part are a critical element of the design. In industry, some engineers believe that part tolerancing is responsible for about 80% of the part cost. Part tolerances affect: tooling costs, manufacturing costs, gaging costs, start-up problems, warranty costs, and part revisions for the life of the product.

The method used to establish tolerances is really a method for specifying and managing part variation. Geometric Dimensioning and Tolerancing (GD&T) is the accepted industrial language used to specify and interpret allowable part variation. ASME Y14.5 is the most widely used standard for GD&T in the United States, and in other countries around the world. Tolerances are most often communicated through the use of a detail drawing.

Need for a Common Tolerancing Method

Which method to use for tolerancing a part is one of the most controversial subjects in industry. In many companies, tolerancing methods have been an ongoing debate for years and years. Establishing a common tolerancing method is much like establishing a common philosophy or religion for everyone to follow. A common tolerance specification method will benefit the entire organization.

It takes time and effort. It isn't easy, but it can be done, and will result in huge cost savings. Without a common method for specifying tolerances, tolerancing hell will exist in the organization. I will close by summarizing the Tao Tolerancing Principles (TTP) from this part of the article.

TTP #1 - Nominal thinking will always result in tolerancing hell.

TTP #2 - You can *ignore* the effects of tolerances, but you cannot *avoid* the effects of tolerances.

TTP #3 - Tolerances protect part function and allow for economical production.

TTP #4 - A common tolerance specification method will benefit the entire organization.

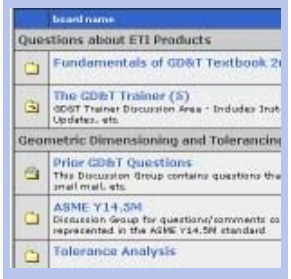
ETI Offers On-Site Training

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

Next issue: Part 2 - A prologue to the System Approach to Component Design. In this part, two topics are covered: an explanation of the great controversy over tolerancing methods and an introduction to a logical method for determining datums and dimensional relationships for part features.

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: Chrysler combats poor quality standards in parts from suppliers.*

Automotive News

Story from Automotive News website.

LDCX SPELLS OUT VENDOR LIABILITY

DETROIT - Frustrated by the high failure rate of components it has been buying and the recalls and service problems they cause, the Chrysler group has begun requiring suppliers to sign contracts that assign specific financial responsibility for the cost of recalls and warranty work.

"[The new plan] assigns responsibility and authority. The side benefit is lower warranty costs and higher quality," said Donald Dees, vice president of quality.

"One of the first things I saw when I came here is that there was no process for determining responsibility," Dees said.

"If it was a manufacturing issue, that was clearly the supplier's fault. And if it wasn't manufactured to specifications, that also was the supplier. But who designed the part and who came up with the specifications? That was the gray area. We would give the supplier the blueprint but never talk about the details." Full story

This article was written by Diana T. Kurylko and Robert Sherefkin and was featured in Automotive News Online -- Autonews.com / June 10, 2002

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The ETI Mailbag

What is the difference between Virtual Condition, Resultant Condition, vs. Inner Boundary, and Outer Boundary?

The definitions of these terms, with examples of each, can be found in ETI's Fundamentals of GD&T textbook, published by Delmar. Click on the links below to access pages 57 through 61, the pages that cover this subject. I hope they help you to understand the differences between the terms. Links to pages: 57 58 59 60 61

This particular topic has bothered me for years. I'm finally taking the time to address it. I know that in your Fundamentals of GD&T textbook you clearly show that circularity and cylindricity can only be applied to a surface, not to a feature of size. However, the examples shown in the standard

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-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

Everything we do that relates to quality is central to quality control, yet our efforts should be directed to prevention rather than correction.

--Shigeru Mizuno, from *Company-Wide Total Quality Control* (Tokyo: Asian Productivity Organization, 1992)

clearly indicate that these form controls are placed right under the FOS dimension (page 163 of the ASME Y14.5-1994 standard).

I always tell my students that the examples are incorrect. What is your opinion on this?

You pose an interesting question. The method I use in my books is as follows: where a geometric control is placed beneath the dimension, the control applies to the dimension (the feature of size); where a geometric control is directed to a surface, it applies to the surface.

This is a simple method to help the reader of the drawing figure out what the control applies to. This is the method used at GM for years. The Y14.5 standard does not follow that convention. You will see several examples where a geometric control is placed beneath a dimension and the tolerance applies to the surface. I would not say the standard is wrong; it is just a little more confusing when they do not follow a convention. They leave it up to the reader to figure out what the control applies to, based on the type of control.

The evolution of Y14.5 has resulted in many changes that make it easier for engineers and designers to optimize the use of GD&T in transforming functional design requirements into engineering drawings.

However, I understand some of the enhancements have forced CMM programmers to develop "work-arounds" when setting up equipment. For example, we have a great deal of flexibility in establishing datum reference frames that simulate actual assembly environments (multiple feature of size datums, composite feature control, etc.). With the option to define secondary and tertiary datums as features of size, it may not be possible to establish a CMM datum reference frame with the traditional plane of reference, axis of alignment, and origin functions that I am told are customary for CMM set-up.

I would like to know if this has been discussed in your forum in the past. If so, has information been exchanged regarding how CMM programmers have dealt with these problems.

There has been little discussion of CMM "work-arounds" in the ETI Discussion Board; however, it is an excellent topic for discussion. We recommend that you post your question on the board, and start a new thread. Hopefully, your question will generate some comments and ideas from other readers regarding this topic.

If you haven't posted any items before, simply click on this link to begin the Discussion Board registration.

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: GyroRemote, a great new teaching tool.

NEW PRODUCT AIDS IN PRESENTATIONS

When I find something that aids me in a lecture as much as this product did, I have to share it with others. The Cordless GyroRemote by Gyration, is a wonderful new technological tool that gives instructors and presenters freedom of movement, as well as more precise control of digital presentations during lecture.

While on the road recently, I decided to try out the new GyroRemote. I was teaching the fundamentals of GD&T to a

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large group, and was using ETI's *Digital Instructor's Kit* to teach the 3-day workshop. On the first day, I used the GyroRemote. Unfortunately, due to technical problems (which were quickly resolved by Gyration), I was unable to use the product for the second and third days of the workshop.

I was quickly able to see the benefits of the GyroRemote. The presentation on day one was excellent. The number one advantage to using the GyroRemote is that it allows freedom of movement. I can't stress enough how wonderful it was to be able to move around the room during my lecture. Instead of being stuck next to the keyboard and mouse, forced to be near a desk or podium, I was able to move freely. I could look at my audience and walk around, even stand at the back of the room, all the while being able to use the full functions of the remote. Unlike using a keyboard or mouse, no tabletop or flat surface is necessary. I had *unlimited* freedom of movement.

I was also able to utilize many functions that made the presentation more powerful. The GyroRemote has 6 easily-programmable buttons, letting you choose from a variety of features:

- Activate highlighter with a click and drag
- Spotlight a screen portion
- Hide and reveal portions of the screen at a time
- Zoom in with the push of a button
- Program keyboard commands into the buttons, such as return, enter, alt/tab, and more
- Select from various pointing devices: pointer, arrow, hand, and more
- Drop any number of pointers on the digital slide, to point out various concepts at the same time
- Activate a ticker tape with a pre-programmed message
- Clear the screen with the touch of a button
- Bring up an analog or digital clock
- Activate the countdown timer for breaks or classroom activities

The benefits to using this tool during lectures are endless. I highly recommend the GyroRemote for instructors who use digital imagery in their lectures and as a companion to our own product, ETI's *Digital Instructor's Kit*. It's compact and fits easily in the laptop bag. I liked the GyroRemote so much, that I not only bought a back up to carry with me on my next trip, I also decided to add it to ETI's product line. With tech tools like the Digital Instructor's Kit and the GyroRemote, teaching couldn't be easier.

Once you've tried it, you'll be hooked.

To see more about the GyroRemote, or to order online, click here.

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 Brazil:
I'm writing from Brazil. I'm starting my studies on GD&T and a coworker gave me your web address. Your page is very interesting and has much good information. I wish to keep in contact with you for more information. Regards, Luiz Henrique Marques.

Hi Luiz, Thank you for writing. Glad you like the ETImail; we hope it will help you with your studies. Did you get a chance to visit the ETI discussion board? You may find answers to some of your GD&T questions there. You can also register to ask your own questions and others will answer them. Here is the direct link: ETI Discussion Board

You can also go there from the first page of the website, under the Interact section.

The link I gave you is to the GD&T section. There is also a section on the ASME Y14.5 standard. Again, good luck with your GD&T studies. Let us know if we can be of any help.

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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We would appreciate it if you'd keep us in mind when you need GD&T training, consulting, or GD&T products. Feel free to contact us by email or by phone at 734-728-0909 or 800-886-0909.

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