MechNEWS

February 2003

Welcome

Welcome to the second, monthly edition of Mech*NEWS*™, a service provided by MechSigma Consulting, Inc. As we mentioned in the first issue, we want to use this forum to highlight issues related to mechanical dimensioning and tolerancing. We hope you'll find this useful and tell your colleagues about it.

Since our philosophy is to focus on mechanical dimensioning and tolerancing, let's go to our first topic, which focuses on the exceptions to ASME Y14.5M-1994's[1] Rule #1. We hope you enjoy this, and all subsequent issues of Mech*NEWS*™.

Events:

The next GD&T committee meeting is May 5-8, 2003 in San Diego, CA. These meetings are open to the public. For more information, contact ASME or their website at: http://www.asme.org/cns/departments/Standardization/Public/Y14/nextmeetNEW.htm#Meetings%20Schedule

Free Newsletter

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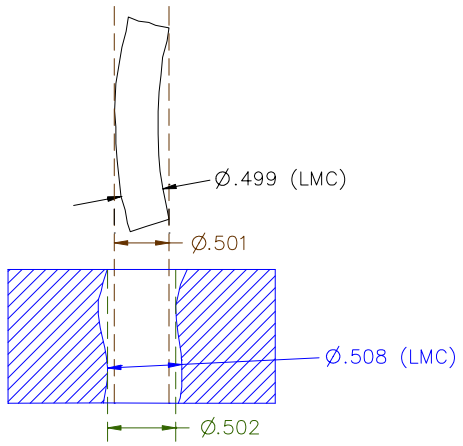
Rule #1 "Exceptions"

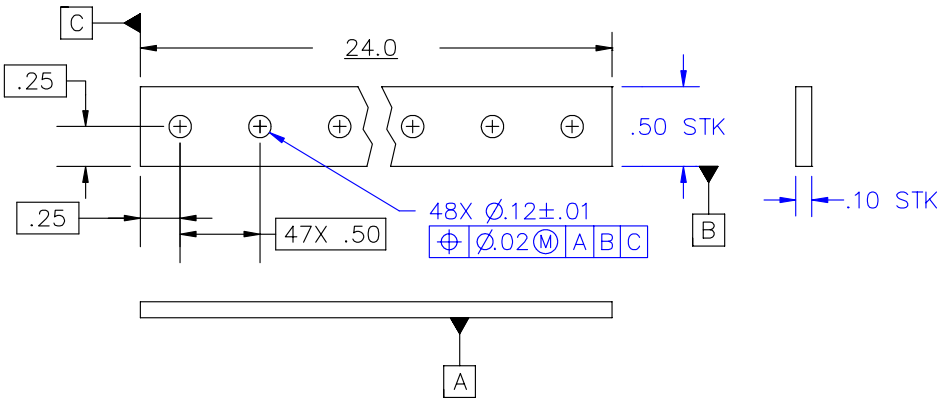
In our January 2003 newsletter, we discussed the consequences of ASME Y14.5M–1994's Rule #1. Essentially, the rule states that the form of a feature of size is controlled by its tolerances. Simply stated, the surface of any external size feature must always be within a boundary defined by a perfectly formed feature of the same shape at its largest size (MMC). For an internal size feature, the surface must always be outside a boundary defined by a perfectly formed feature of the same shape at its smallest size (also MMC). The figure at the right illustrates both of these conditions for a Ø.500±.001 pin and a Ø.505±.003 hole. Except for the instances we're going to discuss in this article, Rule #1 always applies when Y14.5M is referenced, unless it is explicitly exempted on the drawing.



What are the exceptions to Rule #1?

Three of the exceptions to Rule #1 are easily found in Y14.5, and are referenced in the sub-paragraphs of 2.7.1. Another exception exists but is more obscure. We'll look at each of them and show how they work.

The first exception to Rule #1 is defined in Y14.5M, paragraph 2.7.1.3(a), which specifically exempts items that are manufactured to established industry or government standards. Primarily, this includes stock material such as bars, sheets, etc. When using this material, Rule #1 will not apply to the stock dimensions, but will apply to any features added. For example, in the figure below, the thickness and width of the part are exempt from Rule #1, allowing the part to vary in flatness or straightness to whatever degree allowed by the applicable industry standard. The overall length and the surfaces of the holes that are added, however, are required to stay within a boundary of perfect form at MMC.



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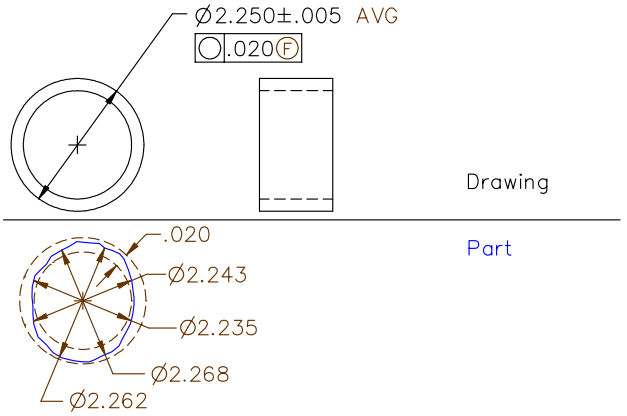
1. ASME Y14.5M-1994 is the current release of the Dimensioning and Tolerancing standard, published by the American Society of Mechanical Engineers. To obtain a copy, go to http://www.asmeny.org/cgi-bin/WEB017C?888870+0001+00+00000+N00594.

A second exception is noted in paragraph 2.7.1.3(b), which states that *"parts subject to free state variation in the unrestrained condition"* are not subject to Rule #1, and references paragraph 6.8 where nonrigid parts are described. The sub-paragraphs of 6.8 outline approaches that can be used to verify dimensions that may not retain the desired form in their free state. The paragraphs outline methods to restrain the part, usually simulating conditions after assembly, before validating the dimensions and tolerances. Also included is an explanation about how to designate some of the dimensions and tolerances in the restrained condition and some in the free state. Unfortunately, experts have interpreted these paragraphs differently. The table below summarizes these interpretations.

Option	Type of part	How is the size feature referenced on the drawing?	Interpretation
1	Flexible	Restrained	Perfect form at MMC is *not* required for features of size in the *restrained* condition.
2	Flexible	Unrestrained	Perfect form at MMC is *not* required for features of size in the *unrestrained* condition.
3	Flexible	Restrained	Perfect form at MMC *is* required for size features in the *restrained* condition. Perfect form at MMC is *not* required for features of size in the *unrestrained* condition.

We believe Option 3 is the correct interpretation. We interpret paragraph 2.7.1.3(b) to say that Rule #1 applies to the restrained size dimensions, but does not apply after the restraint is removed (free state). Our interpretation treats rigid and nonrigid parts the same. If a rigid part is verified in the free state, Rule #1 applies (unless an exception is taken). Likewise, if a nonrigid part is verified in a restrained state, Rule #1 also applies (unless an exception is taken). A simple way to state our interpretation is that Rule #1 applies to size features in the *condition of restraint (or non-restraint) in which they are referenced on the drawing.*

A less controversial application of the same principle is shown in the figure to the right. In this case, AVG is used on a nonrigid feature (noted in Y14.5, paragraph 6.8.3) that is unable to maintain its ideal form in a free state. When AVG is applied to a dimension, the size of the feature is verified by averaging a series of measurements. Conformance is satisfied if the average is within the range established by the dimension and tolerance. In our example, we have two measurements above the upper tolerance limit and two measurements below the lower limit. The two larger measurements indicate that the feature violates the perfect form at MMC envelope but it is still acceptable since the average value is within the stated limits. Where average diameters are specified, we recommend



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Public and On-Site Seminars

MechSigma offers several GD&T and Mechanical Tolerancing for Six Sigma courses. If you are interested, please take a look at our website: www.mechsigma.com/training.asp or the following:

- Description of GD&T courses: http://www.mechsigma.com/MechSigma GD&T.pdf
- Description of Mechanical Tolerancing for Six Sigma course: http://www.mechsigma.com/MechSigma Mech Tol for Six Sigma.pdf

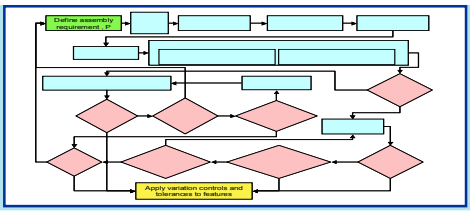
If you are interested in signing up for a public offering, please call or email us.

Geometric Dimensioning and Tolerancing
- Dallas, TX: March 24-26, 2003
- Atlanta, GA: June 9-11
- SanAntonio, TX: Sept. 8-10
- LosAngeles, CA: Nov. 10-12

Mechanical Tolerancing for Six Sigma
- Dallas, TX: March 27-28, 2003
- Atlanta, GA: June 12-13
- SanAntonio, TX: Sept. 11-12
- LosAngeles, CA: Nov. 13-14

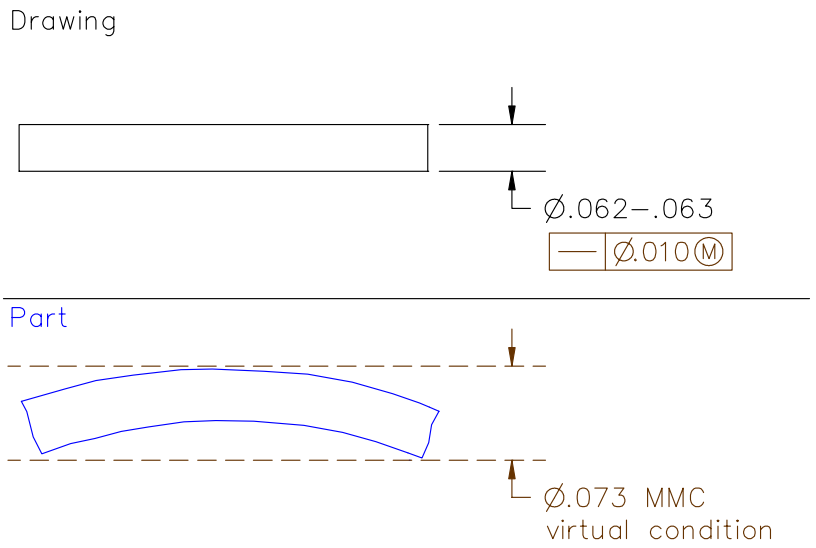
Mechanical Tolerancing Methodology

We offer a comprehensive methodology, *MechPRO™*, that takes your assembly tolerance requirements and automatically defines the (GD&T) controls and allowable tolerances to control part variation to Six Sigma quality. We offer: an analysis software tool, *MechTOL™* ; a database software tool, *MechDATA™*, and a three-day workshop to support this methodology.



that you consider adding a form control, such as circularity, and apply it in free state, to maintain control over the maximum deviation from ideal form.

The third obvious exception to Rule #1 comes into play when a straightness control is added to the axis or center plane of a size feature as noted in Y14.5, paragraphs 6.4.1.1.2 and 6.4.1.1.3. In this case, the feature's envelope cannot exceed the one established by the virtual condition instead of the MMC boundary. We know that the virtual condition is defined as *"A constant boundary generated by the collective effects of a size feature's specified MMC or LMC material condition, and the geometric tolerance for that material."* In the figure to the right, the MMC diameter of the pin is .063, with a straightness tolerance of Ø.010 at MMC. Thus, the virtual condition of the pin is Ø.073, and the pin must always fit within a perfect form boundary of that diameter.



It's fairly obvious why the first two exceptions to Rule #1 exist. In the case of stock materials, the form is based on industry standards that evolved over many years, and to try to override them might lead to many unforeseen consequences. Similarly for nonrigid parts, imposing Rule #1 would be inconsistent with allowing a part's form to vary while it's not restrained. For straightness, it is simply part of the evolutionary process in the development of the standard.

We mentioned earlier that a fourth exception to Rule #1 is more obscure. Where a size feature is required to have an adequate amount of material at its smallest size for an external feature (or largest size for an internal feature) an effective way to ensure it is by applying an LMC modifier to the geometric tolerance. In this situation, the shape of the feature is more important at its LMC size than its MMC size. Thus paragraph 5.3.5 of Y14.5 states that such features are required to meet a boundary of perfect form at LMC, with no requirement for perfect form at MMC, *which is the exact opposite of Rule #1.* This applies to both the feature itself, and any datums that are referenced at LMC. The specific paragraph noted in Y14.5 is related to position tolerancing, but we feel that, by extension of principles, the rule should be applied to all geometric controls. Since the standard does not explicitly state this for the other geometric controls, we suggest adding a note to the drawing to clarify this interpretation.

Engineering Services

MechSigma offers consulting in:

- Optimizing assembly and manufacturing tolerances for cost and quality.
- Performing tolerance analyses that trade off assembly tolerance requirements and manufacturability.
- Optimizing part documentation.
- Reviewing drawings to reduce manufacturing and inspection costs.
- Reviewing drawings for correct application of GD&T.
- Interpreting customers' and suppliers' drawings.

Summary

Except for the use of stock dimensions, the exceptions we've noted to Rule #1 are not frequently used. As with Rule #1, if we don't want these conditions to apply to our design, we can add a drawing note exempting a particular size feature from the default rules. If one of these exceptions to Rule #1 occurs, it's important to know the implications for your design. If a designer expects a form control from Rule #1 and does not know the exceptions, it could have unintended consequences. Likewise, unexpected problems could occur if a designer understands the implications but the manufacturer does not, and we receive parts that don't work properly. Understanding (by all) is the key to the least expensive designs that will work properly. Ⓐ

Other Links

- Deploying Mechanical Tolerancing for Six Sigma http://www.sme.org/cgi-bin/get-newsletter.pl?SIGMA&20020523&1&
- MechSigma Executive White Paper: http://www.mechsigma.com/Exec White Paper.pdf
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Joke of the Month

Three engineers and three accountants are traveling by train to a conference. At the station, the three accountants each buy tickets and watch as the three engineers buy only a single ticket.

"How are three people going to travel on only one ticket?" asks an accountant. "Watch and you'll see," answers an engineer. They all board the train. The accountants take their respective seats but all three engineers cram into a restroom and close the door behind them.

Shortly after the train has departed, the conductor comes around collecting tickets. He knocks on the restroom door and says, "Ticket, please." The door opens just a crack and a single arm emerges with a ticket in hand. The conductor takes it and moves on.

The accountants saw this and agreed it was quite a clever idea. So after the conference, the accountants decide to copy the engineers on the return trip and save some money (being clever with money, and all). When they get to the station they buy a single ticket for the return trip.

To their astonishment, the engineers don't buy a ticket at all. "How are you going to travel without a ticket?" asked one perplexed accountant.

"Watch and you'll see," answered an engineer. When they board the train the three accountants cram into a restroom and the three engineers cram into another one nearby. The train departs.

Shortly afterward, one of the engineers leaves his restroom and walks over to the restroom where the accountants are hiding. He knocks on the door and says, "Ticket, please."

We need your input!

- If you have a particular topic that you would like us to discuss in a future issue, please let us know.
- If you want to submit an article for a future issue, please send it.
- If you have a joke (acceptable for printing) that you are particularly fond of, please send it.

Please submit all correspondence to:
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