# MechNEWS

April 2003

## Welcome

Welcome to the April edition of MechNEWS™, a service provided by MechSigma Consulting, Inc. In this issue, we discuss one of our favorite topics... threaded holes. We have seen threaded holes toleranced different ways at different companies. We have also seen threaded holes toleranced different ways by different groups within a single company. We look forward to feedback on our recommendations in the article that follows. If you tolerance threaded holes differently, we are especially interested in hearing what you are doing and why.

We hope you enjoy this issue of MechNEWS™ and continue to tell your colleagues about it.

### 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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## Locating Threaded Holes

Often, we get into lively discussions regarding the *best* way to locate threaded holes. If your experiences are similar to ours, what a person considers *best* is usually determined by the impact it has on his or her job. As with many variation controls, a designer, a manufacturer, or an inspector may use different criteria to determine what is best. We consider the best approach to be the one that documents all parts that function, while rejecting all parts that do not function.

In order to locate screw threads, there are four major considerations:

- What is the tolerance value that ensures interchangeability with the mating part?
- What feature should we control (major diameter, pitch diameter, or minor diameter)?
- What material condition modifier is appropriate?
- Should we use a projected tolerance zone?

### Using the Fixed Fastener Rule to Ensure Interchangeability

Appendix B of ASME Y14.5M–1994 provides two formulas to calculate the tolerance values for the location of holes related to screws. These are commonly referred to as the "Floating Fastener Rule" and the "Fixed Fastener Rule." Floating fasteners are ones in which a clearance hole is provided on both parts, and a nut is used to secure the screw, allowing the fastener to "float" with respect to both parts.

The fixed fastener situation occurs when one of the parts has a clearance hole and the other has a fastener that is "fixed" to it. This typically occurs in two situations: a pin is pressed into a smooth hole (see Figure 1), or a screw is installed in a threaded hole (see Figure 2). In both cases, the fastener is "fixed" with respect to one of the parts and the mating part has clearance holes.

Let's apply the Fixed Fastener Rule to the situation where a pin is pressed into a smooth hole. Referring to Figure 1, how do we calculate the tolerance values that go in the two position feature control frames? The Fixed Fastener Rule states that the tolerance is equal to half

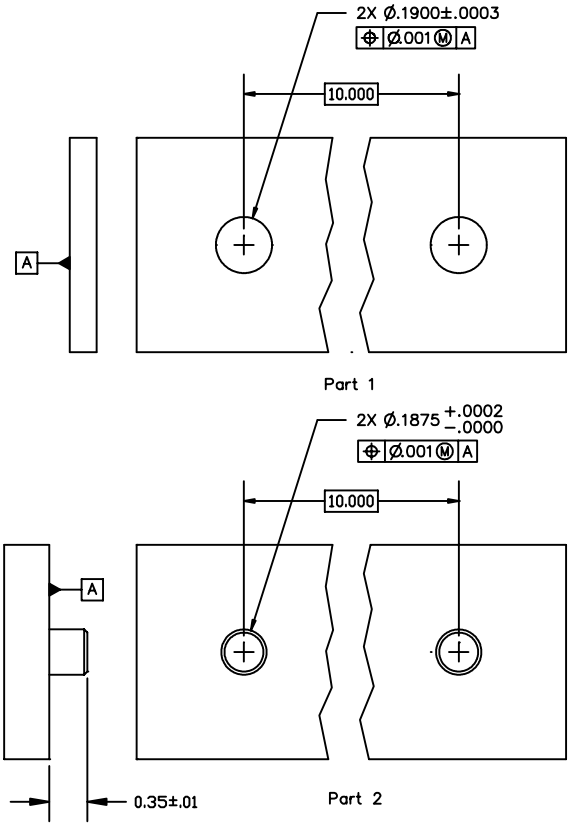



**Figure 1**

*(Continued)*

the difference between the MMC size of the hole and the MMC size of the fastener.[1] In this case, the MMC size of the hole is Ø.1897 while the MMC size of the fastener is Ø.1877. Half the difference between these is Ø.001, which is the tolerance shown.

Let's apply the same concept to a threaded fastener. Figure 2 shows two parts, one with threaded holes and one with clearance holes. The MMC size of the clearance hole is Ø.192 (Ø.195-Ø.003), but what should we use for the MMC size of the threaded hole? In the Figure 1, we used the MMC size of the pin that was inserted into the hole. For threaded fasteners, the screw will be inserted through the hole, so the general practice is to use the MMC size of the screw, or Ø.164. The tolerance is again half the difference between the two MMC sizes (Ø.192-Ø.164) and Ø.014 is placed in each feature control frame.[2]

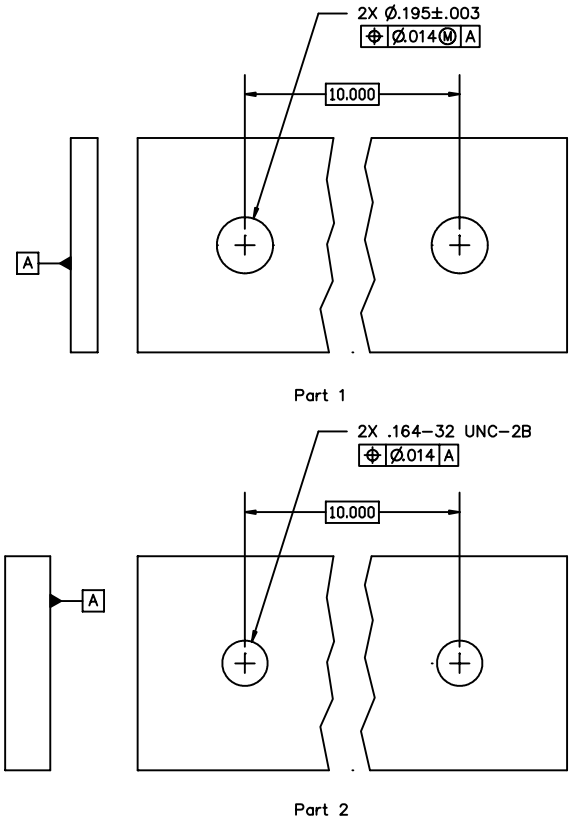



**Figure 2**

## Major, Pitch, or Minor Diameter?

Here's where things get tricky. In section 2.9, Y14.5 states that the "tolerance of orientation or position and datum reference for a screw thread applies to the axis of the thread derived from the pitch cylinder." Typically, the default pitch cylinder establishes the location of the screw in the hole and is therefore more functional, but it is difficult to inspect. Y14.5 does, however, allow exceptions to be taken by noting a different feature of the screw thread, such as the major or minor diameter, below the feature control frame.

For the parts in Figure 2, we used the major diameter of the screw to calculate the tolerance. Should we use the major diameter of the screw thread to locate the hole? Maybe we should use the minor diameter since that's easier to inspect. The pitch diameter is functional, but we didn't use it to calculate the tolerance. So what's a designer to do? We'll look at each of the options.

First, suppose we use the major diameter for the position tolerance. There are two problems with this approach. First, the major diameter used to calculate the tolerance is on the screw, not the hole. Since the screw and hole are separate parts made by separate processes, the major diameter of the screw is certainly not a practical feature to use for the material condition modifier. If we use the major diameter of the hole, we are not relating a physical feature on the part to the method we used to calculate the tolerance. Second, and more importantly, the major diameter is not functional, so its use may allow functional parts to be rejected or non-functional parts to be accepted. So we probably don't want to use the major diameter. That leaves us to choose from the *minor* diameter or the *pitch* diameter. The minor diameter is non-functional, so it has the same problem that we had with the major diameter.[3]

At this point, there's only one possibility left, which, in our opinion, is the best choice. That is, apply the tolerance to the pitch diameter. If we do so, we're communicating design requirements that accept all functional parts and reject all non-functional parts.

## Material Condition Modifier

What material condition modifier should we use? In Figure 1, we used the MMC size of the hole and fastener to calculate the tolerances. Therefore, the MMC material condition modifier is applied to the tolerances on both parts.

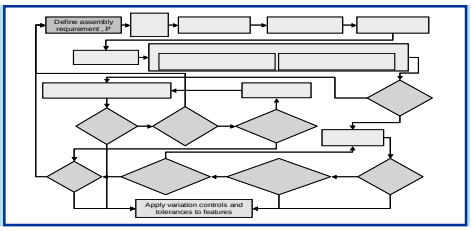
*(Continued)*

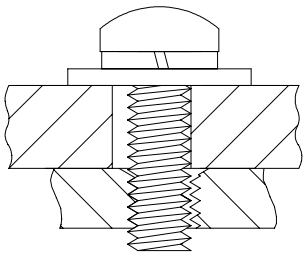


1. We do not have to divide the Ø.002 by 2 to calculate a tolerance for each part. The sum of the tolerances for the two parts must add up to Ø.002. For example, the part with the holes could be Ø.0005 M A and the part with the pins could be Ø.0015 M A and they would still mate with 100% interchangeability.
2. The Fixed Fastener Rule does not address the coaxiality of the pitch axis and the major axis. This is something we will address in a future article.
3. In a future article, we will discuss the tradeoffs between dimensioning functionally and dimensioning non-functionally.

# 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.



In Figure 2, if we apply MMC to the pitch diameter, is it really appropriate to use the "bonus" tolerance as we depart from MMC, or do some undesirable conditions arise? To decide, we must consider the change in location of the axis of the screw's pitch cylinder as the pitch cylinder of the internal thread increases. Since the screw threads will tend to self-center, there is no functional justification for the use of MMC.

Still, many times we see MMC applied to screw threads. What is the risk in doing so? In theory, you may induce some additional stress to the threads if the situation shown in the figure (at the right) occurs. When tightened, the screw will try to center on the mating threads, and it will bend slightly, inducing additional stress. In reality, it's unlikely that any additional stress will be greater than what occurs due to errors in perpendicularity between either the screw head and the screw's pitch cylinder axis, or the perpendicularity of the threaded hole and the surface that the bottom of the screw head contacts. If you believe these additional stresses may be significant and want to use MMC, you should analyze them separately.

### Projected or Not Projected?

On Part 2 of Figure 1, we applied the feature control frame to the pin. For this type of application, the positional tolerance applies to the height of the projected portion of the pin after installation, as described in paragraph 5.5.3 of Y14.5.

On Part 2 of Figure 2, paragraph 5.5.3 of Y14.5 suggests that a projected tolerance zone is applicable. For these situations, the height of the projected tolerance zone should equal the maximum thickness of Part 1. Our experience is that projected tolerances are rarely used on threaded holes, even where it is the most functional method of tolerancing. In most cases, omitting the projected tolerance zone does not adversely impact the design. We plan to discuss these issues in a future article.

## 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

In summary, our recommendation is to calculate the tolerance for threaded holes using the Fixed Fastener Rule in Appendix B of Y14.5M, and apply MMC to the clearance hole and RFS to the screw thread pitch diameter. The use of MMC on the pitch diameter is unlikely to cause you any problems, but is non-functional so we don't recommend it. We do not recommend the use of other screw thread features, such as the minor diameter, to locate threaded holes.

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## We need your input!

If you have a mechanical tolerancing question, a GD&T application, or if you want to submit an article for publication, please let us know at:

NEWS@mechsigma.com

## 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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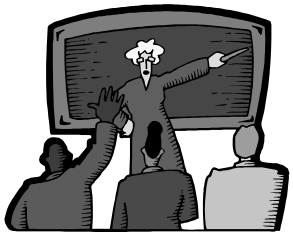
# Joke of the Month

A Programmer and an Engineer were sitting next to each other on an airplane. The Programmer leaned over to the Engineer and asked if he wanted to play a fun game. The Engineer just wanted to sleep so he politely declined, turned away and tried to sleep. The Programmer persisted and explained that it was a real easy game. He explained, "I ask a question and if you don't know the answer you pay me $5. Then you ask a question and if I don't know the answer I'll pay you $5." Again the Engineer politely declines and tries to sleep.

The Programmer, now somewhat agitated, says, "Okay. If you don't know the answer you pay me $5, and if I don't know the answer I pay you $50!" Now, that got the Engineer's attention, so he agrees to the game. The Programmer asks the first question, "What's the distance from the earth to the moon?" Then Engineer doesn't say a word and just hands the Programmer $5.

Now, it's the Engineer's turn. He asks the Programmer, "What goes up a hill with three legs and comes down on four?" The Programmer looks at him with a puzzled look, takes out his laptop computer, looks through all his references and after about an hour wakes the Engineer and hands the Engineer $50. The Engineer politely takes the $50, turns away and tries to return to sleep.

The Programmer, a little miffed, asks, "Well what's the answer to the question?" Without a word, the Engineer reaches into his wallet, hands $5 to the Programmer, turns away and returns to sleep.



# 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**

- Atlanta, GA: June 9-11
- SanAntonio, TX: Sept. 8-10
- LosAngeles, CA: Nov. 10-12

**Mechanical Tolerancing for Six Sigma**

- Atlanta, GA: June 12-13
- SanAntonio, TX: Sept. 11-12
- LosAngeles, CA: Nov. 13-14