Mech*NEWS*

May 2003 (Rev. 1)

Welcome

Welcome to the May edition of Mech*NEWS*™, a service provided by MechSigma Consulting, Inc. We began last month's article, **Locating Screw Threads**, by discussing the Fixed Fastener Rule. In this issue, we expand the discussion of Fixed Fasteners and contrast them with Floating Fasteners.

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

Fixed and Floating Fasteners

The appendices of the 1966, 1973, 1982, and 1994 Y14.5 standards offer formulas to derive positional tolerances for fastening systems. As we discussed in the April issue, there are two types of fastening systems; the "Fixed Fastener Case" and the "Floating Fastener Case" (Figure 1). Although the formulas have evolved through the years, they are essentially unchanged. For some, it is obvious why these formulas work; for others it is not so obvious. This article offers insight on how the formulas were derived, the conditions under which they apply, and assumptions that go along with them.

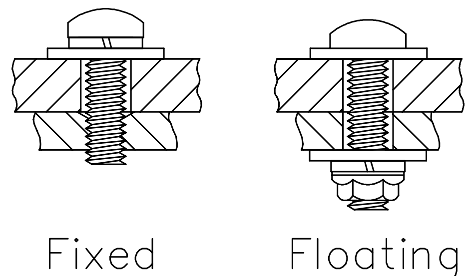

Figure 1

The key element of the formulas is described in paragraph B1 (Appendix B) of the current (1994) standard. It states: "The formulas are valid for all types of features and will give a "no interference, no clearance" fit when features are at their maximum material condition with their locations in the extreme of positional tolerance." We describe this as a "line-to-line" fit under worst-case manufacturing and assembly conditions. Designing the *virtual conditions* of the mating parts *to be the same* ensures this line-to-line fit.

Floating Fastener Case

Where the fastener "floats" with respect to all of the parts in the assembly, it is termed a Floating Fastener Case. This includes assemblies, such as the one shown in Fig. 2, where two parts are fastened with bolts and nuts and both parts have clearance holes.

The formula for this case is: $T = H - F$

where:

T = positional tolerance diameter for each part
H = minimum diameter of the clearance hole
F = maximum diameter of fastener

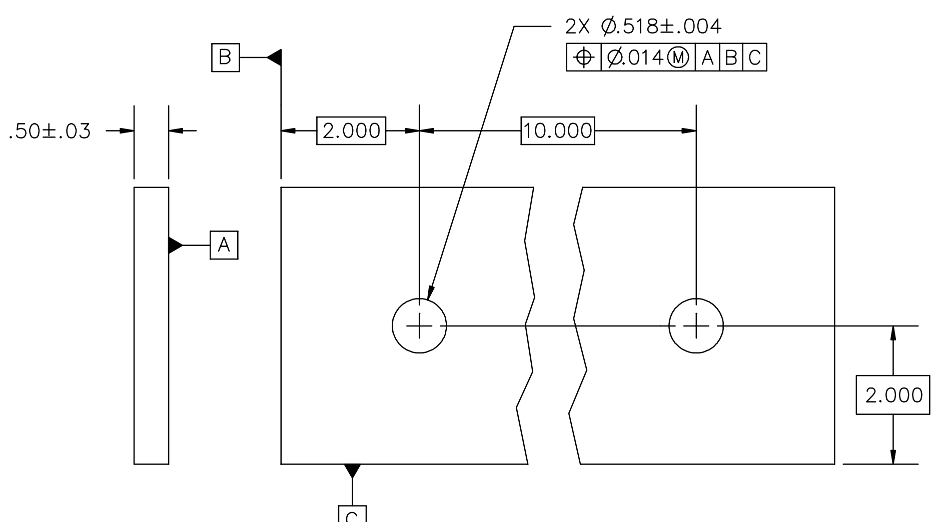

Figure 2

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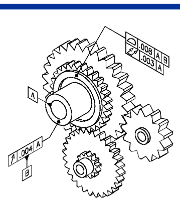

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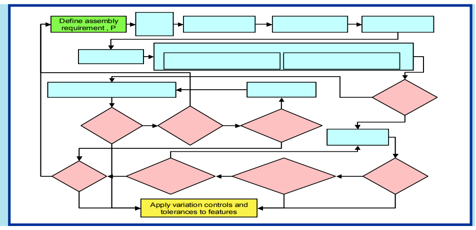
Mechanical Tolerancing Methodology

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.



The virtual condition of an internal feature is equal to the maximum material condition (MMC) minus its applicable tolerance of location. The virtual conditions for Part 1 and Part 2 (Figure 3) are equal and are calculated as: $VC = H - T$

where:

VC = virtual condition of each part

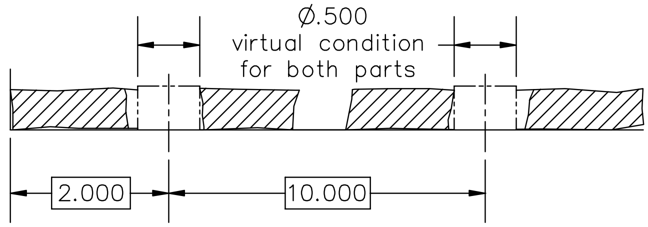


Figure 3

Since the virtual conditions are equal to the maximum material condition of the fastener, 100% interchangeability is ensured.

Fixed Fastener Case when a Projected Tolerance Zone is Used

Where the fastener is "restrained" with respect to one of the parts in the assembly, it is termed a Fixed Fastener Case. This includes assemblies made from the parts shown in Figure 4 that are fastened with screws, tapped holes on one part and clearance holes on the other.

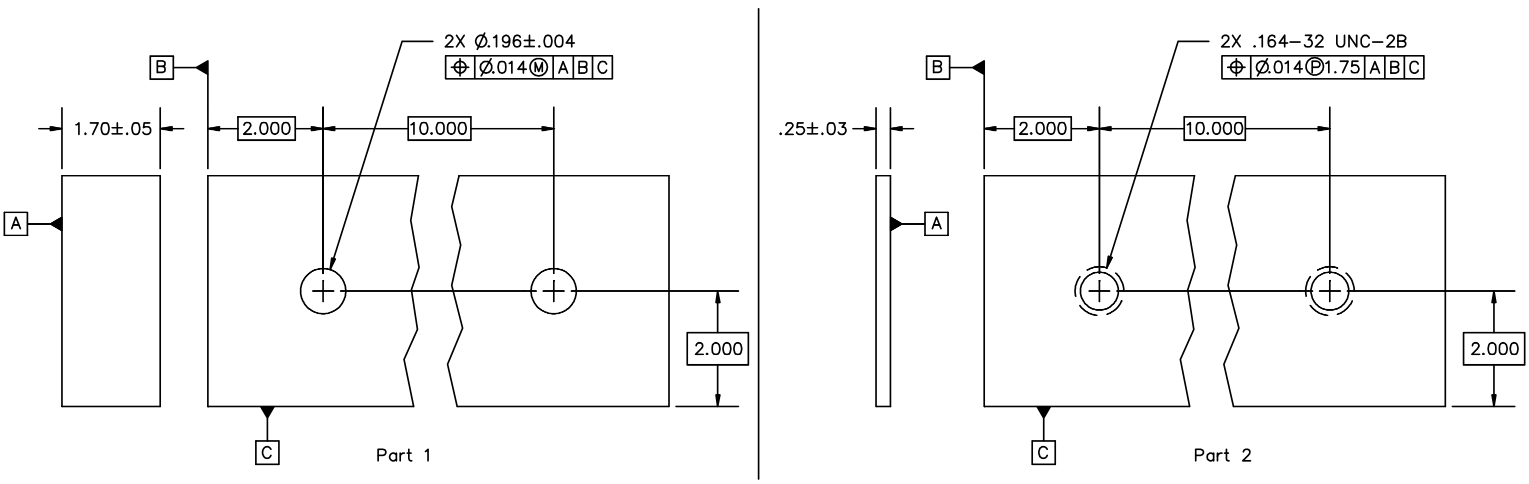


Figure 4

The formula for this case is: $H - F = T_1 + T_2$

where:

H = minimum diameter of clearance hole
F = maximum diameter of fastener
T_1 = positional tolerance diameter for Part 1
T_2 = positional tolerance diameter for Part 2 where a projected tolerance zone is used

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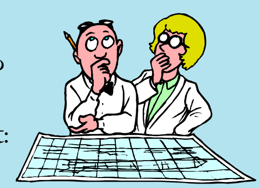
Engineering Services

Having problems with your designs? MechSigma offers consulting in mechanical tolerancing. Contact us at:



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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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The virtual conditions for both Part 1 and Part 2 are shown in Figure 5. For Part 1, the virtual condition is calculated as: $VC_1 = H - T_1$. The virtual condition of the threaded hole is trickier, because, even though it's an internal feature, the tolerance zone is projected above the part. Therefore, it acts like an external feature and its virtual condition is calculated as: $VC_2 = F + T_2$. Since $H - T_1 = F + T_2$, the virtual conditions are equal ($VC_1 = VC_2$).

Since the virtual conditions are equal for both parts, 100% interchangeability is ensured.

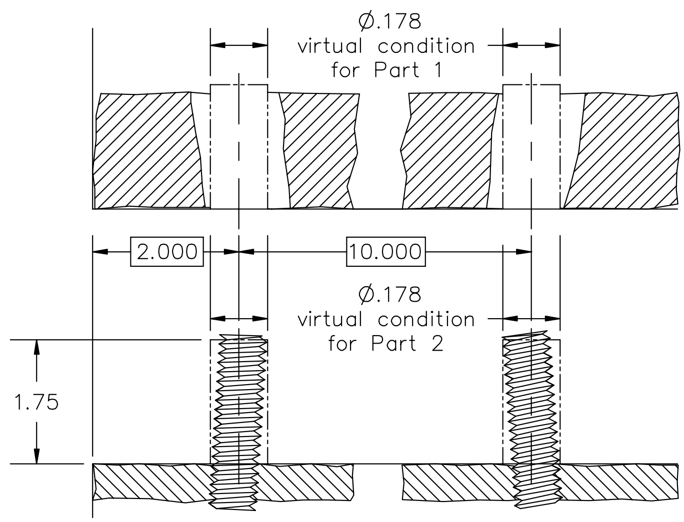

Figure 5

Fixed Fastener Case when a Projected Tolerance Zone is Not Used

In the fixed fastener example above, a projected tolerance zone on the threaded hole accepts all parts that assemble and rejects those that won't. Y14.5, however, shows an alternate formula where a projected tolerance zone is not used.

The formula for this case is: $H - F = T_1 + T_3\,(1+2P/D)$

where:

T_3 = positional tolerance diameter for Part 2 where a projected tolerance zone is not used
P = maximum thickness of part with clearance hole or maximum projection of fastener, such as a stud
D = minimum depth of thread or minimum thickness of part with restrained or fixed fastener

Comparing the prior formulas, we can see that:

$$T_3 = T_2 \,/\, (1+2P/D)$$

This relationship compensates for the allowable out-of-squareness (perpendicularity) that contains the fixed fastener. Figure 6 demonstrates this relationship and shows why T_3 is always smaller than T_2. The above relationship is proven by:

$$T_3 / D = ((T_2 + T_3) / 2) / (P+D)$$
$$2\,(P+D)T_3 = D\,(T_2 + T_3)$$
$$(2P+2D-D)\,T_3 = D\,(T_2)$$
$$T_3 = D\,(T_2) / (2P+D)$$
$$T_3 = T_2 / (1+2P/D)$$

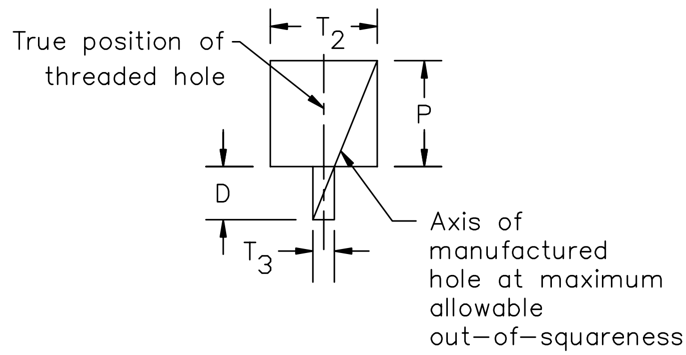

Figure 6

For example, if $P = D$, then $T_3 = T_2 / 3$. From the graphic, we can see that this ensures that the parts will fit together where the threaded feature is tilted the most. Since a position tolerance zone controls both location and orientation, the smaller tolerance zone (T_3) restricts the location of the hole. Therefore, it may reject parts that would function (See Figure 7.)

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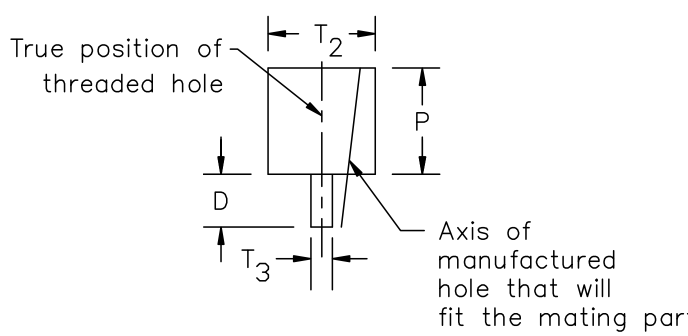

Figure 7

Joke of the Month

After every airlines flight, pilots complete a sheet which conveys to the mechanics problems encountered with the aircraft during the flight. The mechanics read and then respond in writing on the lower half of the form what remedial action was taken. Never let it be said that ground crews and engineers lack a sense of humor. Here are some actual logged maintenance complaints and responses:

P = the problem logged by the pilot

S =the solution and action taken by engineers.

P: Left inside main tire almost needs replacement.
S: Almost replaced left inside main tire.

P: Test flight OK, except auto-land very rough.
S: Auto-land not installed on this aircraft.

P: Something loose in cockpit.
S: Something tightened in cockpit.

P: Dead bugs on windshield.
S: Live bugs on back-order.

P: Autopilot in altitude-hold mode produces a 200 feet per minute descent.
S: Cannot reproduce problem on ground.

P: Evidence of leak on right main landing gear.
S: Evidence removed.

P: DME volume unbelievably loud.
S: DME volume set to more believable level.

P: Friction locks cause throttle levers to stick.
S: That's what they're there for.

P: IFF inoperative.
S: IFF always inoperative in OFF mode.

P: Suspected crack in windshield.
S: Suspect you're right.

P: Number 3 engine missing.
S: Engine found on right wing after brief search.

P: Aircraft handles funny.
S: Aircraft warned to straighten up, fly right and be serious.

P: Target radar hums.
S: Reprogrammed target radar with lyrics.

P: Mouse in cockpit.
S: Cat installed.

Other Considerations

Although the fixed and floating fastener formulas ensure fit, they don't tell us anything about the "other extreme". A common concern for mating parts is how much "shift" (or relative movement during assembly) is allowed between the parts. These formulas don't tell us anything about part shift.

Neither the fixed nor floating fastener equation includes any fastener variation. If the bolt for the floating fastener is not straight (and Rule 1 doesn't control it), then this should be considered. For the fixed fastener, the variation of the pitch diameter to the major diameter is not considered. Our experience is that these variations are usually minor, but it may be important to some designs.

For threaded holes, there is another small discrepancy. As discussed in the **April newsletter**, the position feature control frame in Figure 4 (right) controls the pitch cylinder for the thread. The fixed fastener formula, however, uses the major diameter of the thread. If any part of the pitch cylinder of the thread contacts the boundary of the projected tolerance zone (lower Figure 5), then the major diameter of the thread will be outside the tolerance zone. The part will be within the position requirement, but the major diameter violates the "line-to-line fit" assumption.

Lastly, it's important to remember that the fixed and floating fastener formulas are based on a "line-to-line" fit. The likelihood of all the parts being at their extremes is very small. Therefore, these equations are conservative. We recommend that you consider statistical methods if the tolerances (from the prior equations) are not manufacturable.

Events:

The next GD&T committee meeting is scheduled for the week of Oct. 13 in Kansas City, MO. These meetings are open to the public. For more information, contact ASME.

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:

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