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Toolholder Balancing in Manufacturing: G2.5 vs. G6.3

Kip Hanson | Nov 08, 2022

Except for large boring bars and similarly off-center cutting tools, machinists once gave little thought to toolholder balancing. Those simpler times are long behind us as spindle speeds grow ever higher, tolerances tighter and the cost of an unexpected spindle failure increasingly unacceptable.

"We balance all of our toolholders to G2.5 at 25,000 rpm, or 1 gram millimeter, whichever comes first."

That's according to Jeff Wills, group manager for tooling components for ***Schunk USA***, who says the company fields many questions about tool balancing. That's somewhat surprising, considering the G2.5 specification is approaching its 50th birthday.

50 Years of Balancing Standards

Manufacturers have long recognized the need to quantify the unbalance present in rotors, turbine shafts and other rotating machinery components. The result was ***ISO 1940-1***, "Balance quality requirements for rotors in a constant (rigid) state," first published in 1973.

It defines 11 balancing grades, ranging from G4000, suitable for the large diesel engines used on marine vessels, to G0.4, required for gyroscopes and scientific instruments.

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> Brendt Holden
> Haimer USA

The concept of applying ISO 1940 to machine tools and toolholders would have been laughable when it was published, however, considering that none came anywhere near today's 10,000 rpm and ***higher spindle speeds***.

But toolholder balancing is no laughing matter in a modern machine shop—failure to do so can cost tens of thousands of dollars in spindle damage. "It's also important in terms of surface quality and tool life, especially as you reach higher spindle speeds," Wills says.

Read more: How Tool Balancing Boosts Tool Life and Productivity

Today's standard is ***ISO 16084:2017***, "Balancing of rotating tools and tool systems." It's chock-full of complex formulas and dozens of variables such as weighting factors, force vectors and angular velocity.

Comparing G2.5 and G6.3

For the toolholders used in machining centers, the most common values are G2.5 and G6.3, but the latter is falling out of favor as high-rpm spindles are now common and becoming faster all the time.

Before discussing why G2.5 is preferred over G6.3, let's first discuss what these values mean. In a nutshell, balancing grades (or G values) are based on the distance at which the center of gravity—the imbalance—sits from the rotational center of a toolholder at a maximum spindle speed.

"As the G value goes down, so does the allowable imbalance," Wills says. "A toolholder assembly balanced to G6.3 has two and a half times as much imbalance as one with a G2.5 rating."

For a standard CAT40 ¾" hydraulic holder, a G2.5 is allowed to have 1.24 gram-millimeters of imbalance, he adds. This means it could have 1.24 grams at 1 millimeter from the toolholder centerline or 1 gram at 1.24 millimeters. By comparison, a G6.3 will measure 3.125 grams at 1 millimeter. That might not seem like much, but it starts to become significant above 8,000 rpm or so.

Haimer's Tool Dynamic TD Comfort Plus Balancing Machine boasts a touch-screen interface and accessory storage and balances toolholders on one or two planes. (Photo courtesy of Haimer)

High-Speed Machining Needs G2.5

"When machining centers were limited to 6,000 or 8,000 rpm, builders balanced the spindles to G6.3, and toolholder manufacturers followed suit," says Brendt Holden, president of balancing machine manufacturer ***Haimer USA***. "That all changed as the industry moved to 10,000 rpm and then 15,000 rpm spindles, which required builders to adopt more stringent balancing requirements."

Today, practically all toolholders come from the factory balanced to G2.5 at 20,000 or 30,000 rpm, says Holden, who suggests that this is adequate for many applications.

"If I run that holder at 12,000 rpm, the small amount of imbalance will probably never be a concern," he says. "But add a retention knob, collet, nut and end mill to the toolholder, spin the assembly up to 25,000 rpm, and it's going to be out of tolerance. I guarantee it."

Holden's solution: "Prebalancing the toolholder is a great start, but for the best results, you should measure the entire assembly, pull stud and cutting tool included. We find that even the small imbalance of a variable flute end mill can affect the machining operation, which is why we strongly recommend that shops invest in a balancing unit at higher spindle speeds or where tolerances are tight."

A Case for Balanced Toolholders

Holden shares a story from a training session with a product distributor. Midway through the session, an applications engineer asked Holden to check several HSK-63 shrink-fit holders he'd been using on a moldmaking application. The engineer said he couldn't get a good surface finish and his tool life was terrible.

Sure enough, the toolholders were "way out of whack," Holden recalls, even though HSK-style and shrink-fit holders are well-suited for high-rpm applications and known for their excellent balance characteristics.

"The root cause of his machining problems in this case was low-quality toolholders," Holden says, "but he would never have known that without access to a tool balancer."

Shrink-lock toolholders are known for their superior balance, but it’s still a good idea to verify this, especially in critical applications. (Photo courtesy of Techniks)

None of this surprises Greg Webb, executive vice president for business development and OEM sales at ***Techniks Tool Group***, although he is quick to point out that some applications don’t require balanced toolholders. “A large face mill, for example, will never reach the spindle speed at which imbalance will play a factor in its performance,” he says.

To Balance or Not: Factors to Consider

So what’s the answer? Should a manufacturer worry about balancing toolholder assemblies, or just consider the prebalanced ones good enough and get to work?

Webb would say (and Holden and Wills would agree) that it’s not that simple. Every application is different, he notes, and whether to spend the money on a balancing unit and the time to use it depends on many factors:

- At what rpm will the tool operate? The faster it spins, the greater the need for balance.
- What type of toolholder? Weldon holders are notorious for imbalance, while shrink-fit and mechanical or hydraulic chucks fare much better.
- What’s the spindle interface? An HSK-style or PSC-style toolholder is inherently more balanced than one with a steep taper.
- How about part tolerance and surface finish? Submicron tolerances and mirror-surface finishes require that every box be checked, balance included.

Read more: Lessons in High-Performance Machining: Don't Forget the Tool Holders

Lastly, what does the machine tool builder recommend? One supplying high-speed mold and die equipment will have more stringent requirements than a commodity machining center provider. When in doubt, ask.

From Webb’s side, he’s not too worried about it (at least for companies using Techniks tooling). “We guarantee G2.5 at 25,000 rpm, but I can tell you that most of our toolholders leave here with room to spare,” he says. “By the time you add the retention knob, the cutting tool and other sources of imbalance, you should still be fine.”

Do you balance your toolholder assemblies, or do you use them prebalanced from the factory? How did you decide? Let us know in the comments below.

