Achieving process repeatability

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To increase the productivity of a machine tool, the process must be repeatable. In addition, boosting machine tool productivity strongly depends on the dynamic characteristics of the machine. The stable spindle speeds and permissible chatter-free DOCs expressed in the stability diagram (see last month's column) depend on the natural frequency, stiffness and damping of the entire machining assembly.

For most milling operations, the diagram reveals stable pockets, particular spindle speeds where substantially larger chatter-free DOCs are possible. The tool, toolholder, spindle, machine tool, workpiece and fixture all affect where the stable zones are. Once a process has been optimized using the stability diagram, changes in the setup are detrimental to performance. Yet, oddly, many of the tools and techniques available to machine tool users, such as tool length offset adjustment and post-processing of CNC programs, encourage nonrepeatable setups. So what items matter?

Let's start with tool length. CNC machine tools allow users to approximately set tool length, measure that length and then enter a correction as an offset. If workpiece geometry were all that mattered, then that offset would work, but achieving high productivity depends on more than just workpiece geometry. If a user sets a tool longer than nominal, it is less stiff and has a lower natural frequency. In the stability diagram, the stable pockets then move to lower spindle speeds, and the chatter-free DOC is reduced. If the tool is set too short, it is stiffer and has a higher natural frequency. The stable pockets then move to higher spindle speeds. However, it is only possible to take advantage of the large axial DOC available in a stable pocket if the pocket does not move. To optimize productivity, end users must control tool length.

The number of tool teeth also impacts the location of stable spindle speeds. The most stable pocket occurs where a tooth's passing frequency matches the natural frequency. Therefore, switching from a 2-flute to a 4-flute tool, for example, would decrease the spindle speed corresponding to the most stable pocket by 50 percent. Because staying in a stable pocket means tightly controlling the spindle speed, it also means avoiding use of the spindle speed override function. The appropriate spindle speed must be selected and programmed, and the spindle must run at the programmed speed.

The style of toolholder also matters. Collet-type, hydraulic, shrink-fit, Weldon and other holders all have different dynamic properties. It might be possible to adjust the part program to account for the geometric change caused by a new holder, but changing the holder means the stable spindle speeds move and the permissible chatter-free DOCs change.

Other repeatability items might be less obvious. For example, with a collet-type toolholder, the torque on the collet nut can affect repeatability. Most manufacturers of collet-type toolholders specify a torque on the nut, and that torque should be set using a torque wrench or torque-setting fixture. If the torque is too high, the holder's stiffness could increase, but the damping would be lost. If the torque is low, the stiffness could be too low and—even worse—the tool might pull out of the holder. While on the topic of torque, for an ISO or CAT toolholder, the torque on the retention knob is critical and should also be set with a torque wrench. If it is too tight, it will cause the tail end of the toolholder to bulge, which changes the holder's fit in the spindle taper and directly influences the stiffness and damping of the connection.

For ISO- and HSK-type connections, drawbar force matters. It might seem desirable to have the drawbar force as high as possible, but it isn't. A high drawbar force does increase the stiffness of the connection, but it also eliminates damping. Machine tool builders specify an acceptable range, and it is a good idea to check the drawbar force with a drawbar dynamometer.

Because cutting performance is specific to the setup of the tool and its holder, among other items, you might suspect machine and spindle selection influences cutting performance. You're right. Different machines perform differently, even with the same tooling. This means part programs should be written for a specific machine to take advantage of that machine's stability diagram. The stability diagram for the same tool looks different on different machines.

NC programming software currently allows the part program to be written considering only workpiece geometry. The program is then post-processed to run on a variety of machines. This is a geometry-only strategy, and using it means a machine tool is underutilized and could benefit from significant improvements in productivity. CTE

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