Machining Gears 'Not-As-Gears' Pays Off

Look beyond the obvious and you may well find a better way to machine a part, and serve your customer better. That's the lesson illustrated in a gear-machining application at Allied Specialty Precision Inc. (ASPI; Mishawaka, IN). To make a long story short, the company dramatically improved the material removal rate and yield while reducing fixture cost and delivery lead time on a family of gears by "not treating them as gears."

First, the tooth-forming operation was moved from a traditional gear shaper to a CNC multitasking center. Next, the tooth throat was treated as a short slot rather than the usual tooth throat, using a form-matched Chip-Surfer replaceable-tip carbide slotting tool from Ingersoll Cutting Tools (Rockford, IL).

Allied Specialty Precision's CEO Pam Rubenstein and Todd Stoddard (right) discuss with Ingersoll's Andy Thornburg "done-in-one" production of gears from 17 4PH cut-off bar stock using Ingersoll's Chip-Surfer T-slotting tool.

Step one enabled "done-in-one" machining, which led to simpler in-process parts handling and shorter delivery lead times as well as reducing total machining cycle time by more than 2 to 1. Step two streamlined the tooth-cutting operation itself, the longest operation on the part, by about 3 to 1.

Running 24/6 with 60 employees in the shop, Allied Specialty Precision has earned a reputation as the "go-to guys" for challenging manufacturing projects, said CEO Pam Rubenstein. Because of its location and that reputation, ASPI has become a preferred supplier for aerospace manufacturers.

"When you see a gear, you naturally think of a stroker-type gear shaper, equipped with the familiar single-point high speed steel form tool," said Todd Stoddard, ASPI manufacturing engineer. "But completing this particular part is more about machining the web, hub and stepped shaft bore—seven operations in all—than just cutting the teeth. Now we grab the part once and complete all seven operations."

A typical workpiece is a sector gear, machined from solid 17-4PH bar stock, that looks like half a gear with a lever arm attached. Measuring about 3½" (89-mm) diameter with 46 teeth over a 180° arc, the gear goes into helicopter flight controls. Annual volume for the earliest orders was just 100 pieces, all similar.

In 2008, ASPI initiated the "done-in-one" approach on a plant-wide basis. To that end, the company moved the job to a new Integrex CNC multitasking center from Mazak Corp. (Florence, KY) with all available auxiliary axes. "In effect it's a 9-axis machine," said Stoddard.

Originally on the new Integrex, teeth were formed with a 2" (51-mm) high speed steel (HSS) gear gasher, essentially a slitter with form-matched teeth. It completed the teeth in two roughing and one finishing pass. Total cycle time for tooth machining was 28 minutes, the same as before on the shaper. The big savings were in the other operations and in reduced part handling.

Orders for the sector gears started to increase in 2011, and expanded into a family of about a dozen different part numbers. Total annual volume grew to around 500 pieces. The parts varied in diameter, arc, number of teeth and extra features like linkage arms, but used just two different tooth forms. In other words, the job became a big enough piece of business to warrant some additional process optimization. Tooth formation, the most time-consuming of the seven operations, naturally became a prime target.

Stoddard reached out immediately to Ingersoll's Andy Thornburg who, in Stoddard's words, "knew more about gear machining than I did—especially nontraditional gear machining. It's a pretty specialized area." Thornburg suggested treating the teeth as short slots and machining them with a 1" (25.4 mm) form-matched Chip-Surfer T-slotting mill oriented like a slitting tool. The cutter features a small replaceable tungsten-carbide tip mounted on a threaded carbide shank.

Modified standard Chip-Surfer slotting tool forms teeth in just two passes, shaving 20 minutes off tooth-forming cycle time for this sector gear at ASPI. Eliminated is the tooling baggage usually associated with gear-tooth machining. No swapping out HSS gear gashers or dealing with regrinds. Operator simply changes tips in seconds and starts up again.

By itself, moving from HSS to carbide would enable much higher machining rates and extend edge life. "The replaceable tip design, moreover, would minimize the amount of carbide used and enable in-spindle tip replacement. The carbide shank, which was reusable, would stiffen the cutting system for a better finish on the wear surfaces of the teeth," said Thornburg.

During trials, Stoddard and Thornburg worked together to optimize parameters for the new process. They decided to quadruple the surface speed and double the feed rate, and to take just one roughing and one finishing pass. Final settings for the 1" (25.4-mm) tool are 1500 rpm, 0.060" (1.5-mm) depth of cut for roughing and 0.010" (0.25 mm) for finishing. This process change reduced cycle time for the teeth from 28 to 11 minutes.

Once the new process went operational for a couple of months, tool life could be compared. The Chip-Surfer tips typically last through 50 pieces in this application, while the gear gasher needed a regrind every 10–20 pieces, reducing stoppages for tool replacement and cutting tool inventory costs as well.

Even though it is form matched, the Chip-Surfer tip costs about $125 apiece, the same as one regrind on the gasher. Keeping spares is much more economical, too, because a single gasher can cost more than $400 and $100 a pop to regrind and can take weeks for delivery. Bottom line: tooling cost per part dropped from $20 to $2.56, an 8 to 1 reduction.

Sector gear, machined from solid 17-4PH bar stock, looks like half a gear with a lever arm attached. Measuring about 3½" (89-mm) diameter with 46 teeth over a 180° arc, the gears produced by ASPI go into helicopter flight controls.

The improvement in throughput stems from the proven capability of carbide over HSS, plus the Chip-Surfer's free-cutting presentation geometry that enables higher feeds and speeds without chatter, said Thornburg. The Ingersoll Chip-Surfer mill features a replaceable carbide chip that screws onto a threaded shaft with 0.0002" (0.005-mm) repeatability to datum. Tips can be swapped out right in the spindle. The shaft can be either alloy steel or carbide depending on stiffness requirements and impact loads. "Even with the carbide shaft, the only throwaway carbide is the tip," said Thornburg. Ingersoll custom-grinds a standard Chip-Surfer T-Slot tip to match ASPI's required form.

Modified standard Chip-Surfers are very common for slotting and T-slotting and die and mold applications. "As in the ASPI case, it's a simple matter of a custom grind on a standard Chip-Surfer T-slot tip, which is always available off the shelf," said Konrad Forman, Ingersoll's national milling product manager. **ME**

For more information from Ingersoll Cutting Tools, go to www.ingersoll-imc.com, or phone 815-387-6600.