

Cutting slots in hardened Steel – *made easy*



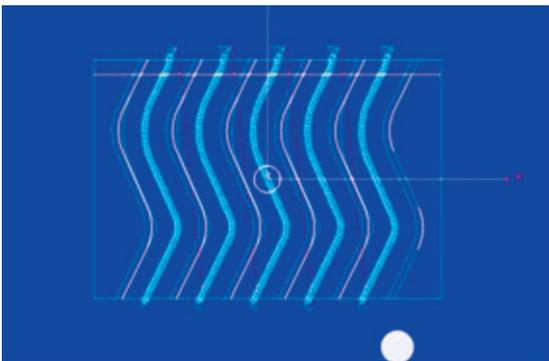
Cutting narrow slots in hardened steel has long been one of the most difficult machining tasks - and one that OKK, Union Tool and DP Technology teamed up to solve.

One problem is that a *large proportion of the tool* is continuously engaged with the workpiece, so cutting forces and heat are very high. Another problem is that the *chipload is uneven* – very high at the point where the cutter is advanced furthest into the workpiece and lower in other areas. Another problem is that, with the cutter filling up most of the width of the slot, there is *very little room for chip evacuation*, so the danger of re-cutting is high.

The result is that machining slots presents a very tough machining challenge.

The challenge is even greater when the slots are relatively *deep* in comparison with their *width*, because this increases the difficulty of evacuating the chips. When the slots are curved rather than straight, this makes it even more difficult to evacuate chips. Machining a hardened steel workpiece adds further challenges. These difficulties typically make it necessary to run at very low feed rates and depths of cut when machining slots in order to avoid premature cutting tool failure. Even at low feed rates, cutting tool life tends to be very low.

Trochoidal Machining



Trochoidal machining provides a potential solution to this problem.

The basic idea is to move the cutter around in a circular pattern with each circle advancing into the cut. Trochoidal machining is so named because a trochoid is the path traced by a point fixed on a circle that rolls along a line. One key advantage of Trochoidal machining is that only a small area of the cutting tool is engaged at one time. The feed rate is always constant; and trochoidal machining makes it possible to use an end mill that is smaller than the width of the slot to allow room for chips to be easily evacuated.

Despite its potential, Trochoidal machining presents a number of challenges. The cutter must undergo a very complicated motion that is beyond the capabilities of conventional computer numerical control (CNC) software programming systems. The machine tool must have a high level of rigidity and be very fast to take advantage of the benefits of Trochoidal cutting. The cutter likewise must possess the ability to operate at high speeds and stand up to the material.

Three companies collaborate

OKK, Union Tool and DP Technology teamed up to solve this problem. They started by designing a very challenging workpiece. The workpiece has slots that are 12mm wide and 20mm deep and a wavy shape. **The high depth of the slots and the wavy pattern create major challenges in evacuating the chips. To add to the difficulties, the workpiece is cut from tough P20 steel.**

Jonathan Hay, VP Sales and Marketing for US Union Tool, said: 'This part would be extremely difficult to cut using conventional milling methods.' While Richard Klein, Applications Manager, OKK USA, continued: 'We started by selecting the machining center from OKK's broad line.' The basic idea of trochoidal machining involves substantially increasing the cutting speeds and feed rates. The VM5III is a high performance vertical machine that can be fitted with a pallet changer. It can deliver spindle speeds up to 20,000revs/min depending on the spindle configuration.'



The next consideration was to select the cutting tool. 'We picked a 10mm diameter CZS four-fluted square end tool which is coated with a chrome based UT coating', said Hay. 'These tools are specifically designed for machining hardened steels up to 50 Rockwell C. The CZS end mill also has drilling geometry on its point so it is able to cut a slot or pocket without the need to drill a starter hole.'

DP Technology provided Esprit Mold CNC machining software, which gives you 20 different milling strategies from 2 1/2 axis to 5-axis for optimised tool paths.

For example: *Z-plane concentric roughing functionality* includes rounding of sharp angles and fluent stepover with chordal feed to avoid straight paths, allowing climb milling in all situations. The toolpath is optimised based on the results of the previous machine cycles, eliminating air cutting and minimising retract movements. The rest roughing capabilities of Esprit Mold enable the re-machining of previously cut areas of the model, resulting in a constant volume of remaining material.

Conventional CNC programming software cannot generate a program to perform trochoidal milling. In the past, the only way that it was possible to perform trochoidal milling was for the programmer to *manually code* the very complex tool motions involved. This is a very challenging task and there is no way for the programmer to visually check the program without running it on a machine. For this reason, trochoidal machining is currently used only very rarely.

DP Technology has added a special routine for trochoidal milling to Esprit Mold.

This routine greatly reduces the amount of time required to produce a CNC program for trochoidal machining. It also gives the programmer access to the many other capabilities of Esprit Mold, including the ability to graphically simulate the machining operation. The user simply defines the solid model of the part that will be cut, either by importing native CAD geometry from any popular CAD system or by using Esprit Mold's built-in geometrical editing tools. The user then selects 'trochoidal milling' and is prompted to enter the diameter of the circle and the advance per resolution. The software then generates the program for machining the part.

Klein said: 'It only took 30 minutes to program the part. We just entered a few parameters and the software did all the work behind the scenes. We used spindle speed of 1500revs/min and a feed rate of 384mm per minute. We experimented with tools with different radii in order to improve the shape of the finished part. We used the simulation and verification capabilities of Esprit Mold to render the complete cutting process with life-like realism.'

The simulation is not limited to simple graphical effect but provides the advanced detection of any unreachable axis, position or collision of the machine's moving parts, the tool and its holder, and the part being produced.

Dramatic improvement in productivity – higher feedrates

'Trochoidal milling demonstrated the ability to substantially improve productivity of slot milling operations,' Hay adds. 'Normal practice when machining a slot is to feed at a rate of about 20% of the rate used in normal side milling. Using trochoidal milling, we were able to increase the feed rate to about 80% of the normal side milling feed. Also, it's typical in slot milling operations to cut at a depth of 2 or 3mm, which would have required at least six passes to cut the part. In this case, we were able to cut at a depth of 10mm, which meant that only two passes were required. The net result was that we were able to cut the part in only 37 minutes and 42 seconds, about 12 times as fast as normal.'

This application demonstrates clearly how trochoidal milling reduces the stress and heat involved in cutting,' Klein concludes. 'Despite that fact that we used much higher speeds and feeds than in normal slot milling, the wear on the cutting tool was very light. This is because trochoidal milling keeps the cutting tool load very consistent and provides for easy chip evacuation. The fact that only one side of the end mill is in contact with the workpiece at any one time reduces cutting forces and heat. It is normally very difficult to keep the tool cool in slot milling. But, in this application, we used air cooling alone to demonstrate that trochoidal milling reduces the cutting forces and heat. During our demonstration, we cut six parts with a single tool without seeing any noticeable wear. This demonstration clearly indicates the advantages of trochoidal milling and its potential to improve productivity of slot milling operations.'

www.dptechnology.com

www.rainfordprecision.com

Union Tool endmills are sold in the UK by:

Rainford Precision Machines Ltd	T	01744 889726
Pasture Lane Business Centre	F	01744 885201
Rainford, St Helens, WA11 8PU	E	sales@rainfordprecision.com