CUSTOMER: Hypertherm □ P.O. Box 5010 □ Hanover, NH 03755 □ 800-643-0030 □ www.hypertherm.com

Automated, 5-Axis Micro Drilling.

This case study describes how Hypertherm, manufacturer of the world's most advanced plasma cutting systems, automated a manufacturing process to improve quality, increase volume and minimize handling, scrap and attended operation — in an industrial 24/7/365, three shift per day manufacturing environment . . . machining abrasive material with non-uniform density.

HYPERTHERM HISTORY.

Hypertherm was founded in 1968 by president Dick Couch and Bob Dean when they made the greatest breakthrough since the initial discovery of plasma cutting fourteen years earlier. They discovered that by radially injecting water into a plasma cutting nozzle, they could create a narrower arc, capable of cutting metal with a speed and accuracy never before seen. In addition, two issues that had plagued the industry from the start – the accumulation of dross and a phenomenon called double-arcing – were virtually eliminated. Hypertherm's new water injection technique introduced another first to the industry. Instead of relying on several different types of gas for cutting, the Hypertherm system relied on only one: nitrogen. This single gas requirement made plasma cutting more economical and easier to use since customers no longer had to purchase and stock several different types of gas. Customers also saw a marked improvement in nozzle life because steam from the water helped to cool and protect the nozzle, significantly slowing down its wear rate. Mr. Couch patented his new radially injected water technique and unveiled Hypertherm's very first plasma cutter, the PAC400. Forty years and seventy five patents later, Hypertherm still designs and manufactures the world's most advanced plasma cutting systems for use in a variety of industries such as shipbuilding, manufacturing, and automotive repair. Their product line includes handheld and mechanized plasma cutters and consumables, as well as CNC motion and height controls. Hypertherm systems are trusted for fast, precision metal cutting and reliability that results in increased productivity and profitability for tens of thousands of businesses.

CHALLENGE: 5-AXIS MICRODRILLING IN ABRASIVE MATERIAL.

Many of the plasma cutter nozzles and swirl rings at the heart of Hypertherm technology are made of lava — a natural, but abrasive material mined in South Africa in 13" x 13" blocks in a "green state" where it can actually be cut with a knife. The material comes to Hypertherm in boxes of 6" rods (or "bars") that are approximately 1" in diameter. All of the swirl rings are cut on a lathe, machined and drilled and then baked in an oven. But even in green state lava is abrasive and extremely aggressive on tooling — particularly small micro drills where a fine dust can quickly fill the flutes and snap the tool. Making the drilling process even more challenging, is the fact that the holes are often drilled on an angle and that lava will grow variably during baking and the tolerances change. So holes that are slightly out of spec prior to baking can be even more so after baking. Additionally, the density of the material can change not only from one blank to the next, but from one end of the 6 inch bar to the other. Finally, the more the product is handled, the greater the chance of chipping, breaking and scrapping parts — which is clearly bad for any company, but is particularly frowned upon at Hypertherm where they have embraced the 5S methodology.

Photo 1:
A finished Hypertherm plasma cutter swirl ring with .011" holes micro-drilled in lava on a DATRON high speed machining center.

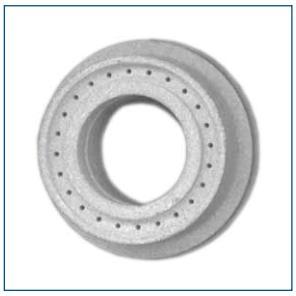

Photo 2: Hypertherm makes dozens of different plasma cutter nozzels and swirl rings from lava blanks.

Photo 3:
While the range of color and marbling from one section of lava to another is no problem, the varying density and growth properties even within a single blank poses a real machining and part uniformity challenge.

DATRON Dynamics, Incorporated
North American Distributor for DATRON AG
Makers of high-speed CNC Machining Centers
115 Emerson Road ▫ Milford, NH 03055 ▫ USA
t 888.262.2833 ▫ f 603.672.8067 ▫ www.datron.com

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ACCURACY AND AUTOMATION.

In order to increase volume, improve accuracy and minimize attended operation associated with the production of swirl rings, Hypertherm visited the EASTEC show several years ago, specifically searching for a way to automate the drilling process — which, up until that time, was done manually, one part at a time on arbors and benchtop machining centers by several operators working 3 shifts per day.

Hypertherm ultimately decided to install two DATRON M8 high-speed machining centers with pick and place automation systems — a cost effective alternative to robotics for unattended part changes. These machines were installed to drill face holes, back holes and radial holes ranging in diameter from .011" to 025" on all of the various swirl rings in their product line.

Photo 4

Photo 5

Photo 6

Photo 7

Tim McCarville, Manufacturing Process Technician for Hypertherm's Lava Division explains, "Now, we're able to load 100 pieces into the DATRON and they all come out ready to go in the oven. There's no handling. To do the volume we're doing on the DATRON the way we did it before would take at least 4 people drilling all the time, plus 2 operators running the lathes — probably up to 8 people total. Instead, we have just 2 operators per shift running 2 lathes and loading 1 DATRON each. It only requires 5 minutes for the operator to load the DATRON with a tray of 100 blanks and inspect the parts coming off the DATRON. The pick and place system picks each blank off the lathe tray for drilling and puts it on the bake sheet in a pattern that's ideal for controlled baking. After inspection of the 1st and last piece of a 100-piece run the entire sheet goes right in the oven. I don't have to give the DATRONs a lunch break, I don't have to let them go to the bathroom, they don't have to be shut down. They shut themselves down when they're done."

PHOTO NOTES:

Photo 4: Hypertherm CNC operator, Mike Wilson, loads the DATRON high-speed machining center with a sheet of 100 lava blanks and then goes back to operating two lathes.

Photo 5: Equipped with an automated pick & place system the DATRON machine picks lava blanks from the pallet, drills them using a 4th and 5th axis and returns them to a baking sheet in a pattern that's ideal for controlled baking.

Photo 6: Hypertherm CNC operator, Larry Wainwright checks completed swirl rings under a microscope.

Photo 7: Racks loaded with pallets of lava blanks to be micro drilled on the DATRON high-speed machining center.

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DEALING WITH VARYING DENSITY & THERMAL GROWTH.

Because of the varying density from one blank of lava to the next, as well as the growth that occurs during the baking process, Hypertherm has developed a process to maintain product uniformity through constant measurement and testing. Each box of bars is tested, and machining variables are established for the QDCS (Quality Data Collection System) and lathe control. So, when an operator loads a run from a given lot of blanks, they simply enter those variables into the DATRON control and hit go. Once the operator verifies the dimensions, they go back to their work operating two lathes turning parts directly across from the DATRON machines.

Photo 8

Through testing the bars and getting the growth properties for each lot the tolerances can be adjusted based on what they predict will happen to the blank during baking. McCarville conveys just how tricky this can be. "You have to be very accurate at the drilling stage because any inaccuracy will be compounded by growth resulting from the firing process later. Your bolt circles are going to grow, the location can shift on the part, if it's a radial hole it can shift laterally on the part and open up the bolt circle as well as the drill hole. Therefore, you've got three potential problems – so if you're the slightest bit off on the drilled hole to begin with, it just gets worse in baking." He goes on to explain that once the tolerances have been determined, they only use half of that tolerance span during the drilling process. "That keeps us just inside ... so even if we use all one side or the other of tolerance at machining, we still have half our tolerance left to accommodate excess growth."

Photo 9

TOOL LENGTH MEASUREMENT MINIMIZES SCRAP.

Hypertherm relies heavily on DATRON's Automatic Tool Management (ATM) system in their ongoing effort to minimize waste — a practice critical to 5S of which Hypertherm is a huge proponent. The ATM is made up of three separate components working synergistically — the tool checker, the tool changer, and the software. The tool checker is a mechanical sensor that measures tool length and detects the broken tool. The tool changer is a rack or tray that has space for spare tools and sockets where the machine places broken tools before picking up a replacement. Operators can stock the rack with spare tools, thereby having a ready supply should tools break during unattended operation. The software is a macro program that can be set up to run a tool check after executing a number of lines of code. For example, a tool check macro can initiate a check after every 10 - 20 parts worth of code by employing an "if/then" statement such as, "Measure this tool; if the length is shorter than the parameter (listed in the software's tool database), then change the tool."

Photo 10

McCarville explains how this system is utilized by Hypertherm, "You have the option of setting up for a piece count. If you have a batch of real grainy lava, you can change the program for where your drill failure is. By preemptively scheduling a tool length check you eliminate tool breakage and scrap in your process. I have three ranges that I check for based on drill diameter. 11 – 15 thousandths I'll check every 10 pieces. With a larger drill, every 20 pieces ... and no more than 25 pieces regardless of drill size. Since the tool check is automated and fast, we can afford to do that ... and we can't afford not to considering the reduction in scrap. Now, that's not 25 holes, it's 25 completed parts which is generally 150 holes."

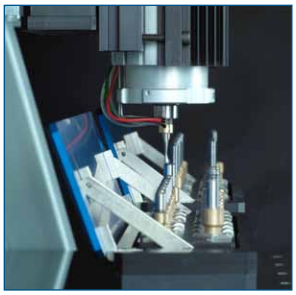

Photo 11

PHOTO NOTES:

Photo 8: A row of ovens wait to bake the swirl rings microdrilled on the DATRON high-speed machining center.

Photo 9: Hypertherm CNC operator, Larry Wainwright removes the baked lava swirl rings from the oven.

Photo 10: A sheet of 100 plasma cutter swirl rings cut on a lathe, drilled on a DATRON machine and baked in an oven.

Photo 11: A tool length check is automatically performed after every 10 - 20 parts worth of code based on a macro.

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If the DATRON finds that the length or wear are lower than the parameters that Hypertherm has set in the control it will automatically shut down and warn the operator with a flashing light – which is a key to waste reduction because these parts cannot be redrilled. If a tool is worn or broken, once it is detected and the part is put down on the baking sheet it can't be redrilled even if the part is deemed to be accurate thus far in the machining process. McCarville says, "So, if I can lose only 1 part, or better yet, set the tool check more frequently and lose none, that's huge. That said, we don't want to check the tool after every part or even too frequently because that's non-cutting time that is not beneficial to the process and the loss of time is also considered waste."

Photo 12

MACHINING VERSATILITY.

The M8 machines that Hypertherm purchased for micro hole drilling are not just drilling machines and have been employed all over the world for a range of applications requiring milling and engraving. Such applications include EDM electrodes, embossing dies, 3D mold making, rapid prototyping, 3D precision engraving, front panels and the production of automotive, medical and aerospace parts. Speaking to this versatility, Hypertherm's Tim McCarville says, "We have two DATRON machines and if one of them is not busy and our lathes are backed up, we can move some of their work, like drilling face holes, over to the DATRON and it can drill those holes as well as the back holes and radial holes. All the way around, these machines have given us a lot better throughput. Not only that the pick and place automation works so well for our application, but they can also take parts from another place in the process and they'll still get the product through in a timely manner."

Photo 13

A SUCCESS STORY & A NOTE ON THE ECONOMY.

Having begun as a garage operation 40 years ago, Hypertherm is now an associate-owned company with 9 buildings oand 1,100 employees. During this recession they have avoided layoffs by utilizing the various other talents of their workforce. As many as 75 associates are performing jobs other than the ones they were hired to do. McCarville explains, "Like most companies, Hypertherm isn't manufacturing as much product as it did before the recession hit. In order to keep associates busy, Hypertherm's human resources department worked to match associates' skills with jobs it needed to have done. So for instance, an associate with a background in construction, might be asked to help build a new lab while an associate with professional painting experience might be asked to repaint a conference room. Hypertherm has never had a layoff in its 40 year history and doesn't intend to, even in today's tough economic climate."

Photo 14

Photo 15

PHOTO NOTES:

Photo 12: DATRON's Automatic Tool Management performs regular tool length checks to assure Hypertherm's part uniformity.

Photo 13: Hypertherm's Tim McCarville with the DATRON machines responsible for micro drilling back holes and radial holes in lava swirl rings.

Photo 14: The garage that served as Hypertherm's original headquarters 40 years ago.

Photo 15: Hypertherm's 1,100 employees now occupy this main building and 8 others on 26 acres in Hanover, NH.

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