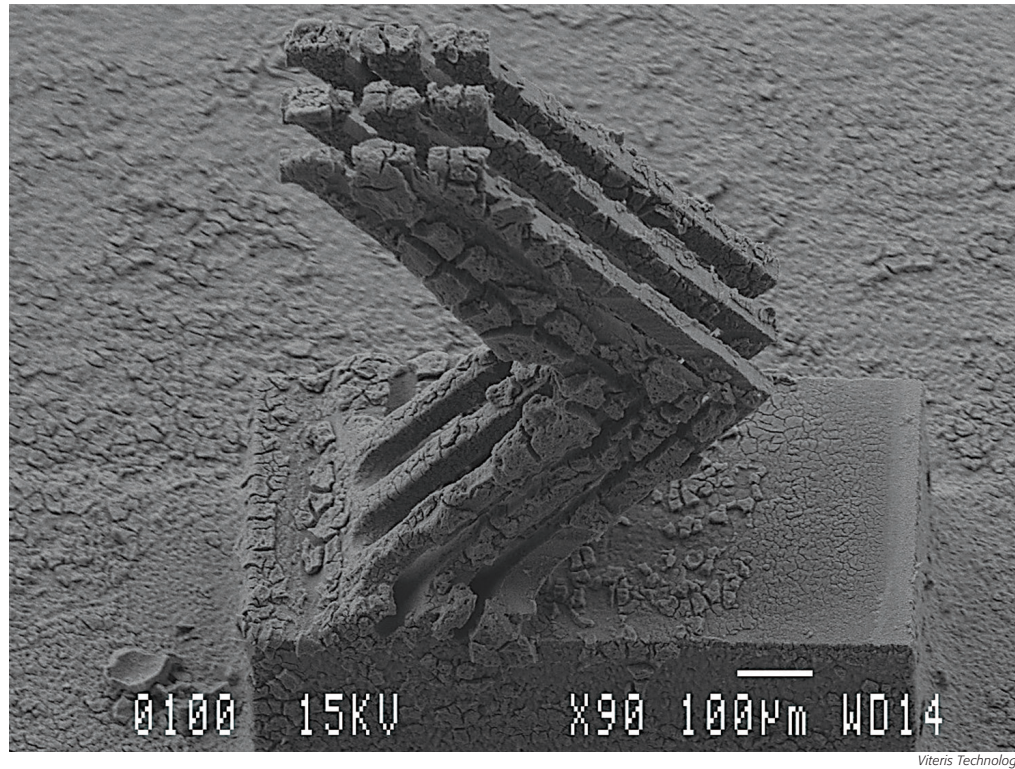
Tightrope Walkers

There's still a lot to learn about EDMing with wire 0.0008" and smaller

By Kip Hanson, Contributing Editor, and Larry Adams



Viteris Technologies

A 0.04mm-pitch beryllium-copper electrode array made via wire EDMing.

In his 2011 MICROmanufacturing article, "Life on the Small Wire," Dave Kari, director of wire electrical discharge machining at Top Tool Co., discussed the challenges of learning to machine parts with extremely thin wire. Three years later, Kari's learning curve with micro wire-EDMing is far from over. While a typical EDM shop uses wire 0.008" and above, Kari works with wire one tenth that size—0.0008" in diameter.

"It's nearly invisible to the naked eye," he said. "For every new job that comes through the door, you take everything you know and throw half of it out the window. What's left is the basis for a whole new page in the EDM playbook."

Minneapolis-based Top Tool makes ultra-precise microcomponents, explained Kari. And the company's experience with 0.0008" wire has allowed it to produce previously impossible parts and part features. For instance, Kari recently cut a set of offset holes in an electronics component. "There's a little flat spot where the holes intersect," he said. "That's where the leg of a computer chip might sit, or a connector might rest to make contact with a wire. In the past, a feature like that might have been 0.010" to 0.020" wide. Now it's only 0.001" wide. Making a part like this is a daunting task."

Threading the needle

One of the biggest challenges is wire management. Top Tool operates an AgieCharmilles Vertex1F EDM from GF Machining Solutions LLC, Lincolnshire, Ill., which, like most wire EDMs, incorporates a series of pulleys to carry the wire to a guide directly above the workpiece. There, a high-pressure water jet pulls the wire tip through a threading tube, then directs the wire into a predrilled hole in the workpiece and down into the opposing guide. At this point, another set of pulleys grabs the wire and ejects it into a waste receptacle. After the wire has been threaded through this convoluted path, current is applied and EDMing begins.

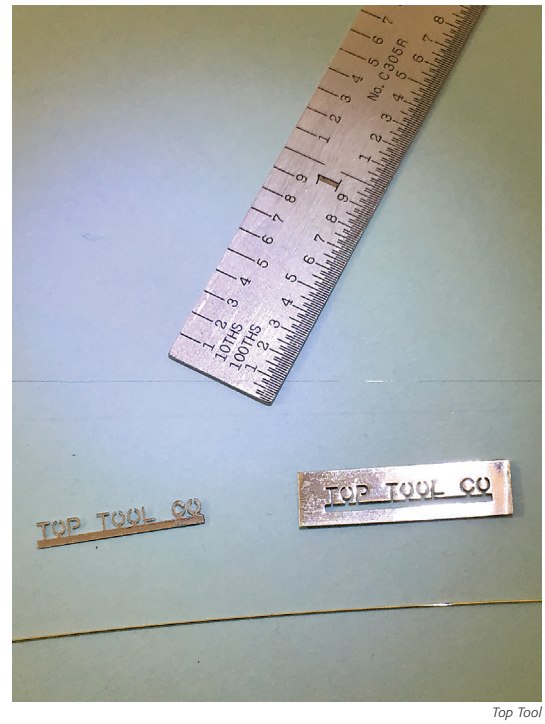
The problem is that 0.0008" wire is delicate and prone to breakage, far more so than its relatively mammoth peers. "Feeding the

wire is a critical part of the process," Kari said. "Without smooth and consistent tension, the wire can break. Any irregularities in how the spool was wound will cause the wire to break." Even engaging the pulleys, Kari explained, must be done gradually—any sudden jolt can break the wire. Machine builders approach these challenges by placing sensors at various points in the wire path. This closed-loop system provides feedback to the pulleys, constantly monitoring wire tension and adjusting motor power when necessary.

Another consideration is the water jet itself. Kari compared the course of 0.010" wire in a threading tube to that of a big fish swimming in a river—any rocks or debris in its path are easily overcome. But send minnow-sized 0.0008" wire down that same waterway and even the smallest rocks might as well be boulders. "Everything is magnified at this scale. How the wire is handled, its straightness, and the cleanliness of the machine and water," he said. "The slightest thing out of whack can spell disaster."

Mark Cicchetti, technical director for AccuteX EDM, Mason, Ohio, a division of Absolute Machine Tools Inc., agreed that threading is the biggest issue with micro wire-EDMing. "We're able to use a standard auto-threader, as with our larger machines, but have made the sensitivity of the spool tension and roller pressure adjustable to a very fine level." Cicchetti also noted that the small wire cannot be cut mechanically, "so we use an electrical discharge to simultaneously melt and pull the wire, creating a bullet-shaped point that feeds easily through the wire guides."

Cicchetti said applications for micro wire-EDMing are vast and growing. The company's AccuteX SP-300iA handles wire down to 0.0008" in diameter, and is used for a wide range of applications. For example, the computer industry wire-EDMs tools for electrical connectors and IC lead frames used in semiconductor manufacturing. Medical manufacturers use the superthin wire to manufacture devices able to cut minute incisions in veins and arteries, as well as parts with extra-fine surface finishes. Even the nuclear industry wire-EDMs diaphragms that transfer gaseous fuels and components used with optical lenses that focus light at the atomic level.



Top Tool

In this photo, 0.0008"-dia. tungsten EDM wire is barely visible crossing the bottom end of the ruler. Below it is the more commonly used 0.008"-dia. brass wire.

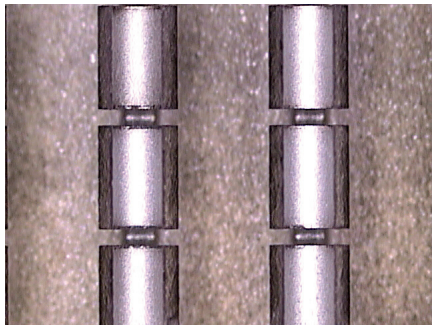
While this range sounds impressive, Cicchetti admitted that he rarely knows exactly what the machines are used for, because most of the parts are proprietary.

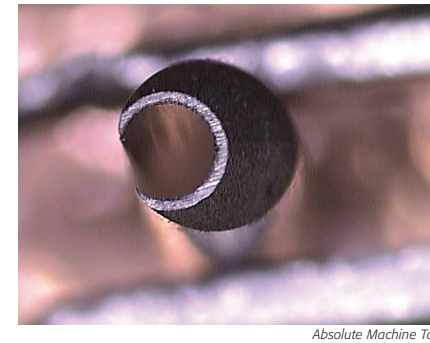
Hot topics

Another machine builder with nuclear experience is Viteris Technologies LLC, Salt Lake City. Eberhard Bamberg, president, and his team have developed wire EDMs that produce magnetically driven microswimmers able to navigate inside the human body, electrode arrays for semiconductor testing and even a radiation-hardened wire EDM used inside a hotcell to prepare test specimens from highly radioactive nuclear fuel rod cladding.

Bamberg also builds EDMs that employ wire just 0.0004" in diameter. "There's almost no margin for error at this size," he said. "We had to develop a spark generator that provides extremely short 'on' times, down to 0.6 microseconds; otherwise, the wire lights up like a light bulb and vaporizes."

Not only must those sparks be quick,





Absolute Machine Tool

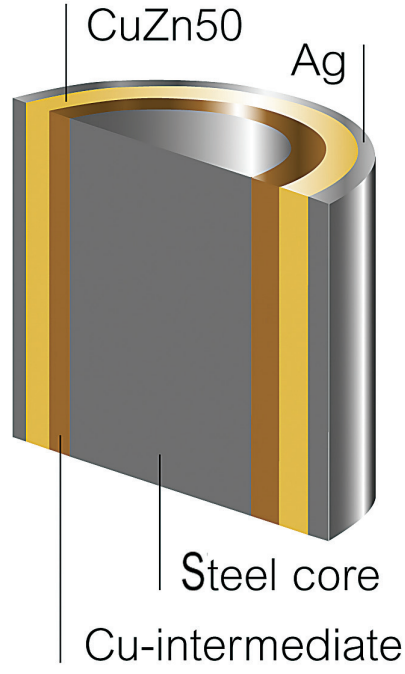
These surgical device parts, used to remove plaque in arteries, were wire-EDMed with AccuteX's micro sparking technology, which imparts finishes as fine as 0.18 µin. R_a.

Tightrope Walkers continued

they must be gentle. The reason is simple: The current-carrying capacity of any wire is inversely proportional to its diameter. Whereas a machine fitted with a 0.004" wire might generate 0.25 amps of current, the spark generator on Viteris' MW250 must generate no more than 1 percent of that value, or 0.0025 amps.

Spark generation isn't the only challenge. Auto-threading is out of the question, as is the high-pressure flushing employed in conventional wire-EDMing. Instead, the area surrounding the wire is cleared via convection. "We use a horizontal wire arrangement," Bamberg explained. "This allows the heat generated during EDMing to rise, carrying waste material away from the workpiece. The absence of power flushing is aided by the low power levels involved, and by our use of tungsten wire."

Tungsten has the highest melting point of any metal (3,422° C, 6,192° F). This melting point would make it an ideal electrode material but for two factors: it's brittle and expensive. Bamberg said a spool of 0.0004"-dia. wire that looks suitable for a sewing machine costs several hundred dollars. The price is one reason most wire manufacturers, at least those making wire 0.0008" in diameter and above, turn to steel and copper.



Berkenhoff

The core of Microcut EDM wire is coated with three materials: copper, brass and silver.

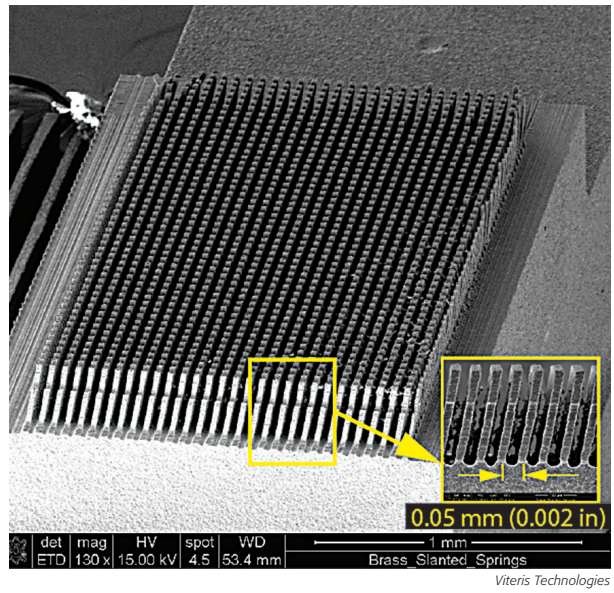
Tobias Nöthe, senior vice president for Berkenhoff GmbH, an EDM wire manufacturer based in Heuchelheim, Germany, said its Microcut product combines several different materials, each with distinct properties, into a single wire. The core is made of high-performance steel with more than 290,000 psi tensile strength and extreme stiffness. It has a homogeneous microstructure to allow cold drawing down to a diameter of 0.0008".

The core is coated with three materials: a copper layer to enhance electrical conductivity; a brass layer for good material removal rates and fine surface finishes; and a thin, outer silver layer to minimize electrical contact resistance and keep tolerances to 1µm to 2µm. The overall diameter tolerance of the Microcut wire is kept below ±0.5µm.

Nöthe warned that care must be taken with any small-diameter wire. Pre-tension force, or the load under noncutting conditions, is typically in the range of 1 to 4 Newtons for wire diameters from 0.003" down to 0.0012". "The force for a 0.0008" wire is less than 1 Newton," he said. "If

the wire were only under static mechanical load, it could bear higher forces, but under the dynamic mechanical and temperature load experienced during EDMing, pretension is limited."

Over the years, EDM wire has evolved and continues to do so, according to Nöthe. "Cutting with diameters from 0.002" to 0.0012" was state of the art by the mid-1980s. However, it was performed only by a handful of tool and die shops and watchmakers," he said. For the standard diameter range (0.012" to 0.008"), Nöthe said brass is the preferred material. "But the tensile strength of brass does not provide enough resistance against wire breakage when diameters are less than 0.003". This requires stronger materials with reasonably good electrical properties."



Viteris Technologies

A 0.05mm-pitch, brass electrode array. It measures 1.5mm × 3mm and includes 3,000 electrodes 0.2mm high.

Not so fast

ARC Nano is another shop with its feet firmly planted in micro wire-EDMing. The company manufactures an eclectic mix of products, including microfluidics and DNA sequencing equipment, magnetic instrumentation, thermal management devices and infrared focal plane arrays for radio telescopy.

Many of the components in these products are made on ARC Nano's Sodick AP200 5-axis wire EDM, which runs wire down to 0.0008" in diameter.

Marlow Roberts, vice president of manufacturing at the White Bear Lake, Minn., shop, said that as wire size goes down, production costs go up. "Going from 30µm (0.0012") wire down to 20µm (0.0008") could easily increase manufacturing costs by 30 percent," Roberts said. "Some of this is due to wire cost—the smaller wire is often 50 percent more expensive—but the majority is due to much lower cutting speeds. Depending on the workpiece and material, these could be two to three times slower than with larger wire."

It all comes down to the size of the required corner radius. Roberts said customers often back off on their requirements when they hear the price tag. Other times, even a 0.0005" radius won't do (roughly the smallest radius possible with 0.0008" wire), and ARC Nano is forced to "clean out the corners" with its sinker EDM. "We've done square holes with a 1.5µm (0.00006") radius in the corners. It wasn't easy."

Like Viteris, ARC Nano occasionally resorts to expensive tungsten wire, but mostly uses steel and copper. The decision on which wire works best and how to apply it is largely a matter of workpiece material, dimensional requirements and good old-fashioned know-how. Like Dave Kari at Top Tool, Roberts said there's a long learning curve with micro wire-EDMing, and that understanding the best cutting technique is a matter of trial and error.

As Kari put it, "Moving to ultrasmall wire was the complete opposite of what we knew, and it took us a long time to really do much of anything. Once we learned how to operate it, though, we found we couldn't live without it."

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