EDM turning in ESPRIT by Maroney Company, Northridge, California

ROTARY WIRE EDM

By Ann Mazakas

Advances in rotary technology for wire EDM (electrical discharge machining) have been accelerating in recent years. These developments in multi-axis wire EDM open up exciting new opportunities for cutting complex shapes unattended, cost-effectively and precisely in one setup.

As the technology for wire EDM advances to new levels, it's time to take a look at how this technology can replace traditional processes in EDM as well as milling and turning.

- It is becoming more common to find EDM machines with built-in ports that allow the easy installation of a rotary table. It is also more common to find vendors that supply submersible rotary tables for wire EDM.
- The technology to easily produce NC programs for rotary EDM is advancing. CAM software has been developed specifically to take advantage of rotary EDM technology and to output the NC code for these specialized processes.
- The demand for complex part geometries and micro parts is growing. Manufacturers who can prove their capability to produce such parts can capture that demand.
- Unattended machining with fewer setups increases accuracy and reduces the per part costs for both the machine and labor.

There has never been a better time to invest in multi-axis EDM technology.

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Traditional Wire EDM

In wire EDM, a thin single-strand of metal wire is fed through a work piece that is submerged in a tank of dielectric fluid. The wire, which is constantly fed from a spool, is held between upper and lower guides. Material removal is based on electrical discharges that erode the material rather than traditional machining where material removal is based on mechanical forces.

A traditional wire EDM has what's called XYUVZ control. The XY axes relate to the movement of the lower head in the X and Y directions. The UV axes relate the movement of the upper head in the U and V directions. The Z-axis moves the upper head up or down before XYUV movement starts. In standard wire EDM cutting, the part is held stationary while the upper and lower heads move the wire as it erodes the material.

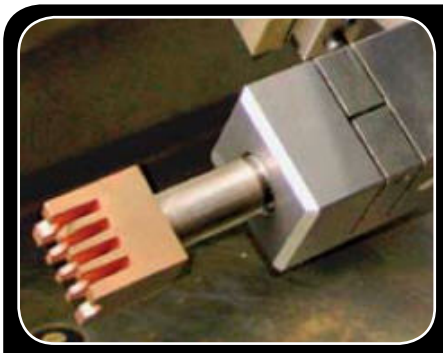
Wire EDM is widely used in the medical, aerospace, and injection-mold industries to produce parts in complex shapes that cannot be achieved with traditional cutting tools.

Because wire EDM uses a thin wire to erode a path through the metal, this process is ideal for:

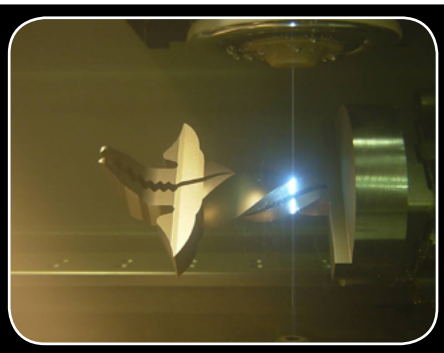
- Cutting hardened and exotic metals, and even some conductive ceramics
- Cutting intricate contours or cavities
- Cutting internal corners with extremely small radii
- Eliminating lateral forces due to conventional tool pressure
- Cutting complex tapers
- Small hole drilling

Rotary Wire EDM

Submersible rotary tables for wire EDM allow the programming of continuous variable high-speed rotation and indexing. Instead of clamping a part to the work table, it is held in a chuck mounted on a rotary table. The rotary table then allows the rotation and cutting of the part without the need to unclamp and reposition the part between cutting operations.



A rotary table can be used as an indexer to rotate the work piece into position before cutting starts.



The table can rotate in synchronized motion with other axes for simultaneous 5-axis cutting.

A high-speed spindle can rotate continuously at speeds up to 1500 RPM for EDM turning operations.

Rotary Wire EDM At-A-Glance

- Two basic types of rotary tables are available: stand-alone and integrated
- Built-in clamping systems make setups a snap
- Fewer set-ups on complex parts
- An integrated control allows for unattended machining
- Extend the capability of a standard machine with the simple addition of a rotary axis
- Expand business into an entirely new range of part geometries
- Cut geometry not possible with any other machining method

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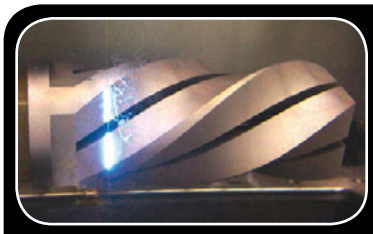
Applications for Rotary Wire EDM

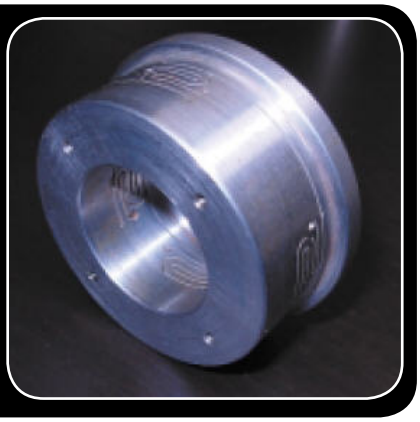
Imagination is the biggest limitation on the parts that can be cut with rotary EDM. The combination of part rotation and movement of the wire during the burn supports part geometry that often cannot be created in any other manner.

Micro-machining is one area where rotary EDM has big benefits. Small dynamically balanced parts that require a high surface quality are cut accurately with high-speed erosive turning because the absence of tool pressure allows for minimal diameters. Notches or other flat features can also be cut in the same setup.



Example of helical geometry cut with synchronized rotary motion.

Cut high-precision tools to virtually any symmetrical shape in one setup (top). Achieve small, complicated slots with varying tapers without the need for deburring. (right)



An Alternative to Micro Turning and Micro Milling

It is important to note that small, delicate parts cannot be cut efficiently and with high quality using mechanical milling or turning methods.

EDM is the perfect solution for cutting delicate parts since there are no cutting forces involved.

It is even more advantageous when dealing with difficult-to-cut materials, such as titanium (Ti-6Al-4V) or Inconels or Hastelloys. These materials are very tough and "springy", so when mechanical processes are used cut them, chatter is a huge problem, causing high tool wear, poor surface finish and broken workpieces.

Rotary wire EDM lets you produce parts with an excellent surface uniformity and roughness, without having to endure high tooling costs and broken parts causing wasted material.

For many manufacturers, there is great potential for adding rotary-axis EDM technology to their current capabilities. In many cases, it is a better alternative to machining processes that use traditional tooling.

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Types of Rotary Tables

Two basic types of rotary tables are available: stand-alone and integrated.

Stand-alone Rotary Table

A stand-alone rotary table with an external control can be positioned anywhere on the table and moved to any machine where it's required. In this case, the operator is required to push a start button every time an index move is required. This type of table is simple to install and has no interface.

Hirschmann H160R Rotary Indexing Table

Tables that fall into this category:

- Indexers
- Spinners
- Any table accompanied by its own control unit

Automatic sequencing with the machine tool program can be achieved through a simple interface cable usually via "M"-code (24V signal). In order to move the table and control to any machine, each machine would need to be furnished with the connector for the interface cable.

Limitations of stand-alone tables:

- Without an interface, the rotational portion of the NC program must be handled manually by the operator. The main CNC program waits for the indexer to move to the next programmed position before it continues with the cut.
- Moves are limited to simple positioning only. It is impossible to coordinate the positioning moves with other axes.

Also available are high-speed spinning-only units that are used when no indexing is necessary. These require a simple variable speed control. An AC drive motor is critical to the EDM process at high speeds up to 1500 RPM.

A more recent development is a 2-axis tilting unit. These units can be run with an independent control or, just recently, by the machine control of some of the OEM's.

Integrated Rotary Table

The second type of rotary table is a machine-adapted table integrated to the machine control as an additional axis that allows for continuous machining as well as indexing.

Integration into the machine control allows for constant feedback and monitoring of the servo speed and rotary positioning. Integration of the rotary unit is done by the machine tool manufacturer because the components of the table (motor, encoder, etc.) must match the requirements of the machine control. For synchronized rotary machining, a precision spindle is critical.

Tables that fall into this category:

- Any table that utilizes the machine for control and function as an additional programmable axis
- Tables that can function both as a spinner and indexer under machine control

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Criteria for Selecting a Rotary Table

- Corrosion resistance. The submersible rotary unit must be completely sealed and designed to withstand the effects of the dielectric fluid as well as the eroded particles from the EDM process.
- Positioning accuracy. The smaller the incremental angular precision, the better the tolerance margin of the yielded final shape.
- Minimal part rotational deviation from center-of-axis rotation
- Compatibility with the machine (for an integrated control)
- Variable speed motor
- Available space on the machine table and Z travel limitations
- Workpiece size. The spindle must accommodate work pieces of different diameters, lengths and weights.
- Workpiece mounting method (clamping system, face plate, jaw chuck, taper shank)
- High current electrical connection
- Good electrical grounding between part, rotary table, and machine work table
- 360-degree rotation
- Minimal radial run-out
- Minimal backlash
- Low maintenance
- Warranty

Software for Rotary Wire EDM

CAM software developers often overlook rotary wire EDM because it is an emerging technology. However, adopting a wait-and-see attitude toward the development of rotary EDM solutions until the technology becomes mainstream is a missed business opportunity for the software developer and a disservice to the manufacturing industry.

Without proper control of the rotary motion directly through the NC program, the functionality of the rotary axis is seriously hampered. This is particularly a hindrance when trying to synchronize the rotary axis with the standard linear axes of movement.

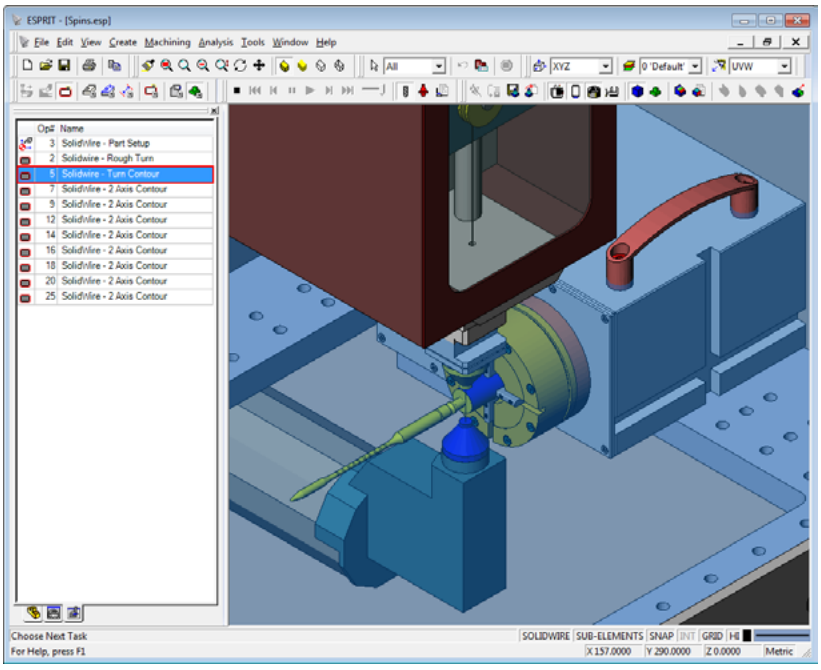
With properly engineered and implemented CAM support for rotary EDM, machinists can take advantage of the full capabilities of an additional rotational axis with full confidence that the NC program will be reliable and correct.

Rotary Wire EDM and ESPRIT

ESPRIT supports rotary EDM technology with functionality designed specifically for indexers, integrated rotary axes, and spinners. Rotary technology is easily enabled in ESPRIT by defining at least one rotary axis for the EDM. Once a rotary axis is defined, rotary technology is available for all EDM cutting cycles.

After a rotary axis is set up, users are presented with technology settings that are very similar to the standard wire EDM operations in ESPRIT. In fact, indexed EDM operations are created the same way as standard EDM operations and synchronized rotary operations are created just like any 4-axis contouring operation.

EDM turning operations are also based on familiar 2-axis contouring operations. This makes it easy to take advantage of the full capabilities of an additional rotational axis with complete confidence that the NC program will be reliable and correct.



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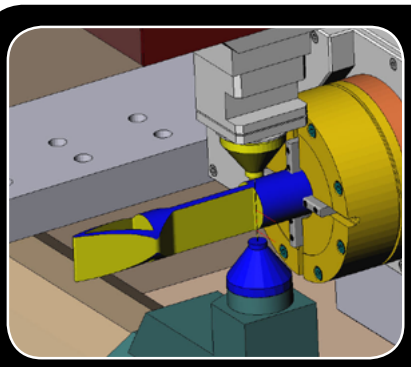
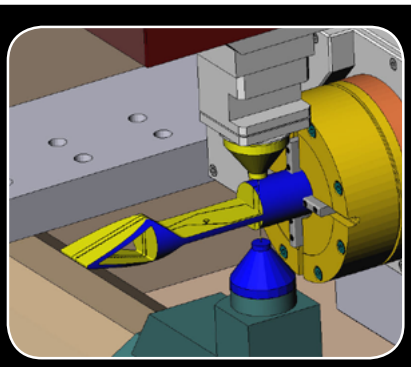
Turn-and-Burn

Indexed wire EDM operations are commonly referred to as "Turn-and-Burn" or "Turn-then-Burn". This process is simple because the EDM operations are created like any other EDM operation, except that a positioning move is added between them.

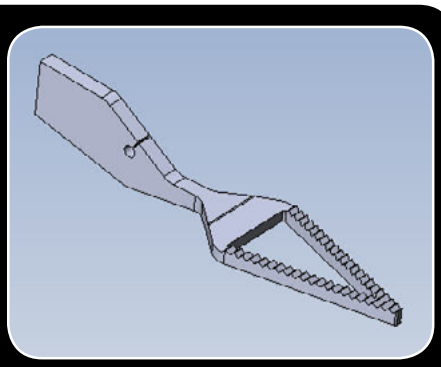
An advantage to Turn-and-Burn is the reduction in set-up time. The stock is mounted on the rotary table with a built-in clamping device and then rotated into as many positions as required. There is no unclamping of the workpiece, so accuracy is maintained between cutting operations.



In this example, the first two profiles of a medical pincer are cut in a standard position.

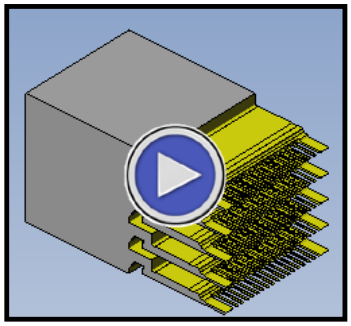


The workpiece is then indexed 90 degrees and locked into position before the third profile is cut.

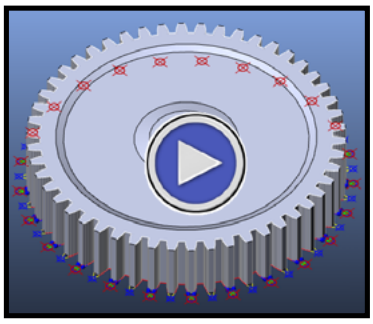


The entire pincer is cut in a single setup with a single NC program.

An excellent use for this type of indexed movement is to produce multiple parts from a single setup. Some examples are the wire EDM of multiple pin gates used in plastic injection molding or the cutting of multiple copies of the same part.



Indexing can also be used for workpieces with symmetrical features such as gear teeth. The workpiece can be rotated to the wire, instead of the wire rotating about the workpiece.



Work Planes for Turn-and-Burn operations

An important aspect to indexed machining is the ease with which a user can create the work planes that are used to automatically orient the part for each cutting operation.

In addition to the three predefined work planes provided by ESPRIT (XYZ, ZXY, and YZX), it is easy to create new work planes by selecting the faces of solid models or any other geometry that defines a plane. ESPRIT also makes it easy to change the orientation and location of existing work planes.

When a feature is created with ESPRIT's EDM Feature Recognition, the active work plane controls two important aspects of rotary machining:

- The direction of the W axis defines what is vertical so the indexer can rotate into the proper orientation. In EDM operations, the wire is aligned along the W axis of the feature work plane.
- The origin of the work plane sets the Z zero location of the cutting operation. The locations of the UV and XY planes are measured from the origin.

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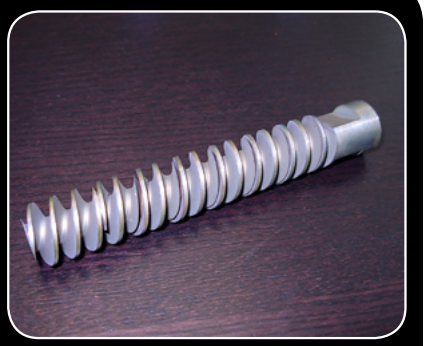
Turn-while-Burn

Synchronized rotary motion is commonly referred to as "Turn-while-Burn". Rotation of the part occurs during the burn at the same time as the XY or other rotary movements. This type of motion requires a fully integrated rotary axis.

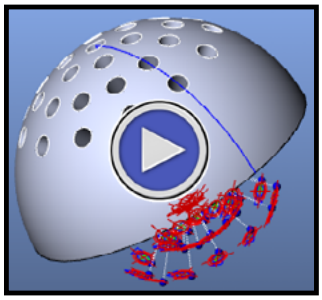
With an integrated rotary axis, the efficiency of taper cutting is increased through the use of a rotary axis placed horizontally. With the workpiece positioned on its side instead of vertically, the part can be rotated to the wire instead of tilting the wire into positions that are not optimal for flushing. Rotating the part not only improves flushing but also allows much higher taper angles.

An integrated rotary axis also makes it possible to machine part geometries that were previously impossible on a wire EDM. In some cases, rotary EDM can cut geometry that is impossible to produce with any other machining method.

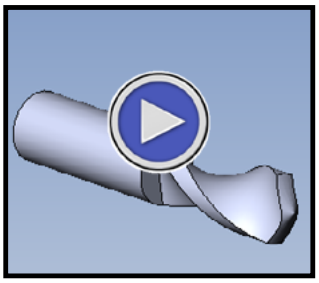


A helix screw can be machined using Turn-while-Burn functionality. Also notice the flats at the base that are cut using Turn-and-Burn technology.

Tiny holes can be cut on a domed surface without the need to de-burr the edges.



A common application is the cutting of helical surfaces. The wire remains vertical as the workpiece rotates to cut what appears to be a curved surface.



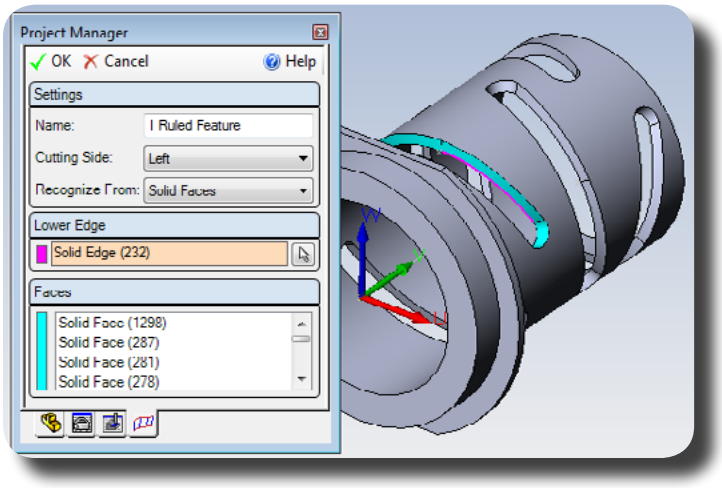
Rotary axis movement makes it possible to cut small, complicated slots. Slots with tapered walls are also possible.

Features for Turn-while-Burn operations

Unlike standard or indexed EDM operations, Turn-while-Burn functionality requires a multi-axis feature that is not restricted to a single work plane. However, the active work plane is still important because the work plane associated with the feature sets the orientation of the wire at the lead-in position.

ESPRIT has a specialized feature, called a Ruled feature, for applications such as rotary wire EDM and swarf milling where a wire or the side of a milling tool must follow the flow lines of a part regardless of the work plane.

The surfaces contained in the feature must be ruled, meaning that a straight wire traveling along the upper and lower profiles can maintain contact with the surface at all times.



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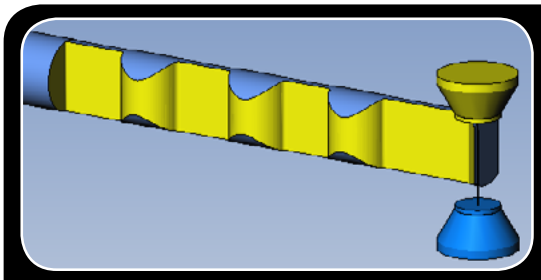
Spin-and-Burn

EDM turning is similar to lathe turning except that the wire does not exert mechanical pressure on the workpiece. The advantages of Spin-and-Burn are high accuracy with zero part stress. This allows for the production of symmetrical parts with minimal diameters and tiny details.

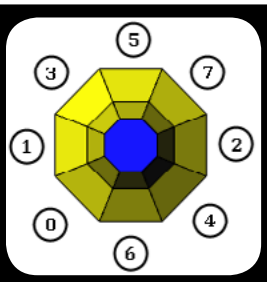
For slow-rotation cutting applications, an integrated rotary table is typically adequate. However, for lathe-type applications a high-speed spinner type rotary table is more suitable.

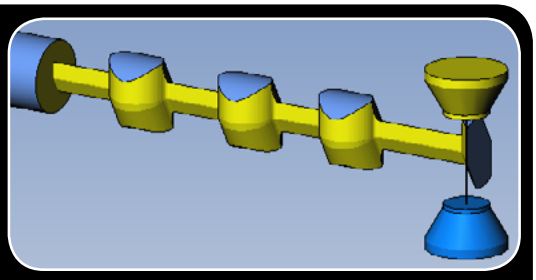
High-speed spinning units are capable of rotation speeds ranging from 0 to 1,500 RPM. Typically, the minimum speed for EDM turning is about 800 RPM or higher. To maintain rigidity of the wire during the high-speed spinning process, the wire must stay vertical at all times while the workpiece spins.

Getting the workpiece to the proper net shape before the spinning process requires a specialized rough turning process. Since the material used for EDM turning operations is typically expensive, the EDM rough turning operation uses balanced indexing moves to remove the stock material in pieces large enough to allow for easy recovery and recycling of the unused material.

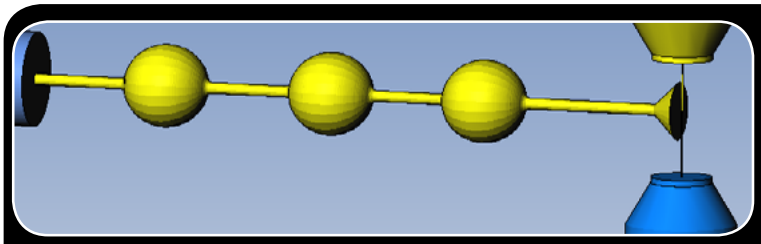


In the roughing operation, the first two indexing cuts are created on opposite sides. This removes large pieces of material on both sides and aids in balancing the workpiece.

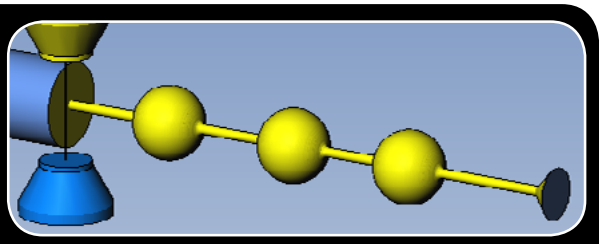




The same technique is used for the subsequent indexing moves. The workpiece is rotated to the next angular position for the cut and then the part is rotated 180 degrees for a balanced cut on the opposite side.



A single roughing operation can include any number of indexing moves to produce a shape that is close to the final shape before finish turning begins.

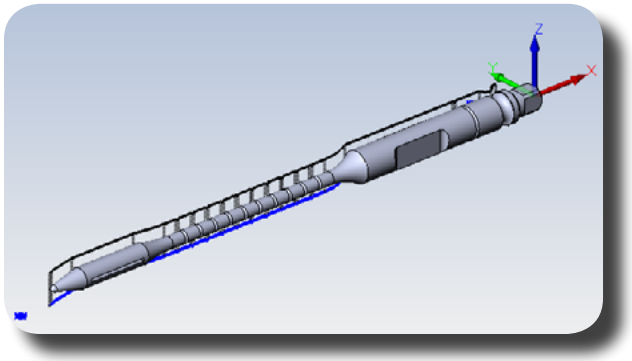


The finish EDM turning operation is similar to a lathe contouring operation. The workpiece spins while the wire cuts a 2-axis profile.

Features for Spin-and-Burn operations

For both conventional lathe and wire EDM turning, ESPRIT has features that recognize the true turned profile of a solid model or selected faces of a solid model. This is useful when the solid model contains flats or other geometry that must be machined using another method.

ESPRIT calculates the shape of the true turned profile by rotating the solid model or solid faces around the U axis of the active work plane. Part features that cannot be turned, such as the flats shown in the illustration, are ignored.



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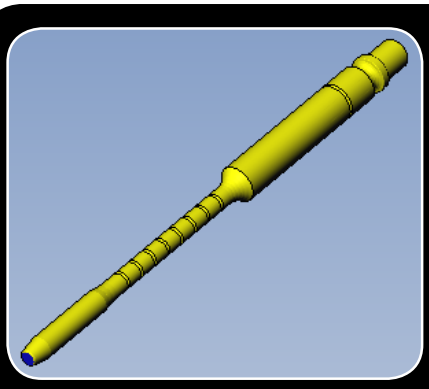
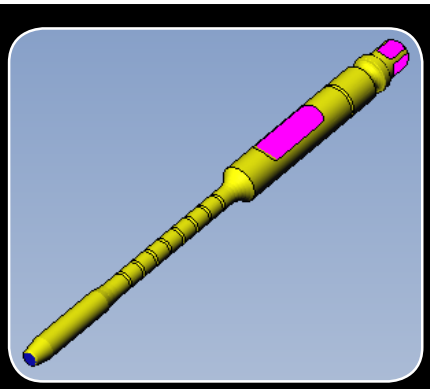
Putting it all together

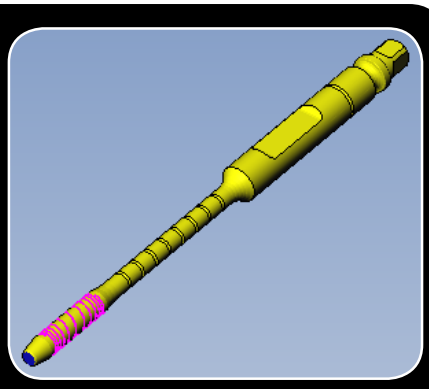
Three types of rotary machining have been discussed. Any of these EDM technologies can be used alone, in combination, or combined with other machining processes like turning and milling.



Use Spin-and-Burn to rough and finish outer profiles.



Use Turn-and-Burn to cut contours or pockets on different sides of a workpiece



Use Turn-while-Burn to cut complex shapes and slots that require synchronized motion of multiple axes.

The convergence of rotary axis technology developed by machine tool builders, rotary table builders, and developers of CAM software make this the perfect time to explore the full potential of rotary EDM capabilities.

Thanks to rotary technology, manufacturers can achieve superior accuracy and surface finish on extremely complex parts and geometry that could only be imagined a few years ago.

The only question is which technology will provide the greatest benefit and complement the current capabilities of your shop.

Stand-alone indexers save time and improve accuracy by reducing set-ups. Spinners expand capabilities to include turning and micro-turning applications. An integrated rotary axis moves the capabilities of a single machine into a whole new realm of part-making capabilities. One shop could use any or all of these technologies.

Increasing the flexibility of existing machines in the shop is both practical and necessary to turn the current situation into a long-term competitive edge.

ESPRIT
The Right Choice

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