Selecting the Appropriate EDM Technology for Hole-Drilling Applications

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Advancements in EDM Hole Drilling

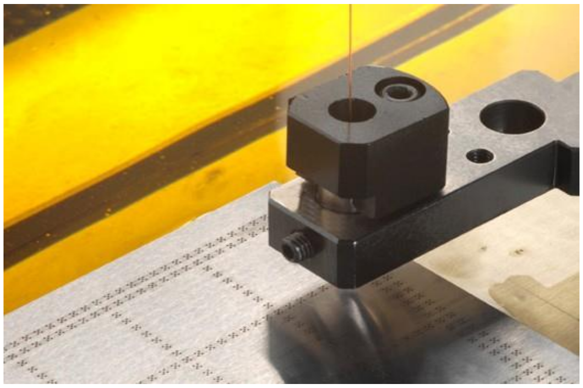
Changes in market demand are frequently the catalyst for advancements in machining technologies; such is the case for modern EDM hole-drilling machines. While traditional hole features have typically afforded manufacturers the flexibility to use a variety of manufacturing approaches, modern product designs and production requirements have spurred new manufacturing challenges and innovations.

Compared to alternative hole-production technologies such as lasers and mechanical drilling, EDM technologies have advanced rapidly to become the fastest and most economical means of hole manufacturing. In fact, for some modern applications, the EDM process may be the only viable method for meeting complex hole requirements. This evolution in hole features can be attributed to the changing demands of several key market segments, particularly medical and aerospace.

Within these industries, manufacturers are encountering increasingly complex hole designs and specifications that demand unique and specialized EDM hole-drilling technologies. Selecting the appropriate EDM technology for modern hole-drilling applications is critical to achieving the highest production throughput, best part quality and accuracy, and lowest manufacturing cost. This white paper addresses the varying EDM hole-drilling technologies available, their advantages and disadvantages and ideal production requirements.

At a Glance

Changing Market Demands



While improved speed and precision are desirable performance attributes for any manufacturing process, the growing demand for exotic materials and improved production capacity has significantly raised customer expectations for hole-drilling capabilities within the general production market. In response to this demand, EDM hole-drilling technologies have diversified and matured to meet specific accuracy, quality and production volume requirements for various applications. These advancements in EDM technologies offer several advantages compared to traditional manufacturing methods. In many cases, the EDM drilling process can reduce lead times by eliminating the need for secondary post-machining operations by producing burr-free hole features with greater precision. Compared to conventional processing methods, such as mechanical drilling, the small hole diameters and often contoured part designs will typically bend or break traditional drilling tools. In addition, EDM processes are unaffected by the hardness of workpiece materials, making it an effective solution for a wider variety of applications.

Design engineers are pursuing a higher degree of complexity in hole sizes and quality in the medical market. Applications such as surgical tooling and implantable devices are being

designed with extremely small hole diameters, referred to as "fine hole diameters," that require exacting tolerances (often ±0.005 mm) and hole diameters as small as 0.010 mm. Hole quality at the entrance and exit of these hole features are critical to workpiece acceptance, requiring identical sizes and characteristics with no tooling marks or burrs on the surface of the parts. These challenges have driven the development of several highly specialized EDM hole-drilling technologies, which emphasize precision over speed.

Similarly, the aerospace market encounters a unique blend of hole production requirements. The most common hole features seen in modern aerospace applications are film cooling holes. These hole features are machined directly into the leading and trailing edges of blade and vane segments used within jet engines and serve a critical role in providing cool airflow through the hollowed center of these parts.

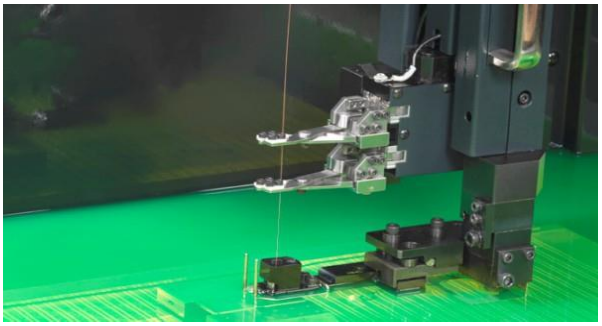
Aircraft blade and vane components commonly feature high volumes of film cooling holes and shaped hole features known as diffuser shapes.

Production requirements for these holes typically range in diameter from 0.5 mm to 1.5 mm, with average accuracy tolerances of ±0.050 mm. Since EDM drilling is a thermal process, attention must be paid to the impact of the process on the metallurgical quality of the workpiece. The heat-affected zone (HAZ) and recast in the material around the drilled hole typically have a maximum allowable value under 0.050 mm. These characteristics have led to the development of several new EDM hole-drilling technologies that emphasize speed over precision, such as multisided part positioning and back-strike prevention.

Oil vs. Water

Despite the growing variety of EDM hole-drilling technologies available, there are two primary machine platforms, oil dielectric and water dielectric; they offer distinct performance characteristics. Key points of differentiation include speed, quality, hole size, machine features and maintenance. By evaluating applications based on these attributes and the requirements necessary to meet production demands, manufacturers can identify an EDM hole-drilling technology best suited for their applications.

Oil Electric EDMs

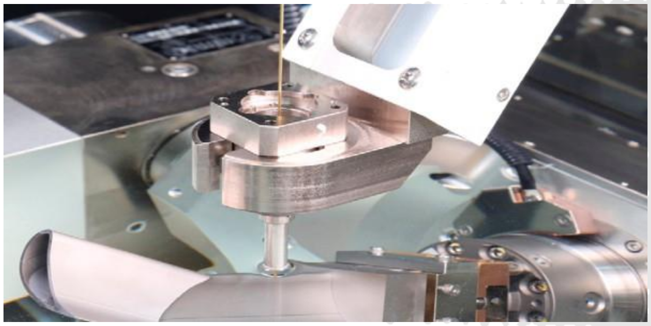


Why Oil?

Simply put, oil is used to provide the highest accuracy and best surface-quality holes.

It is typically reserved for precision machining or special applications not possible with the tolerances and surface finish of water machines. In addition, using an oil-based machine enhances the overall workflow by allowing standard sinker EDM operations and orbiting and finish machining operations all on the same machine.

Water Electric EDMs



Why Water?

Deionized water to control conductivity is an effective and inexpensive dielectric fluid commonly used in EDM drilling machines. These machines use filtration and deionization systems to maintain consistent water quality for the most controlled burn.

Water is an excellent choice when the workflow calls for a dedicated process machine that only drills holes and requires the fastest possible machining speeds. A sweet-zone balance between the electrode, machining discharge power and dielectric characteristics exists at typical hole sizes (0.5~1.5 mm) and yields the best speed.

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Oil vs. Water

Dielectric Properties

Oil Electric EDMs

As opposed to the conductive properties of water, oil is an insulator and therefore provides both a smaller spark gap and much more precise control over the spark during machining. These factors lead to slower processing times and provide stable control over low-power finishing processes for improved overall accuracy and surface finish. With lower power sparks, the resulting HAZ and recast characteristics are dramatically improved (minimized), and smaller diameter holes can be reliably produced.

Water Electric EDMs

The speed of water-based EDM drilling is largely attributable to the conductive nature of the water, allowing for both stable high-power EDM discharge and a large spark-gap area that increases flushing ability during machining. Additionally, the light viscosity of water provides for efficient cooling and debris evacuation in flushing. Most water-based machines use di-resin to control the water conductivity.

Processing Methods

Oil Dielectric EDMs

Most oil EDM drilling machines are based on standard sinker EDM platforms and provide automatic tool change (ATC) capabilities. Unlike water dielectric, all oil-based machining operations are performed completely submerged. Depending on hole requirements, oil-based machine platforms typically use copper and tungsten electrodes.

Water Dielectric EDMs

Water-based systems can perform submerged and non-submerged by using through-electrode flushing and an external flush hose. The stable high-power discharge and flush properties of water dielectric offer the fastest possible machining speeds with the deepest L:D ratios using brass electrodes, either simple hollow tubes or multiple internal channel designs.

Machining Characteristics

Oil Dielectric EDMs

Oil dielectric drilling operations are typically limited to L:D ratios of 150:1 but can produce accuracy tolerances of ±0.005 mm or finer. Entry and exit holes made via oil-based systems are generally more consistent than water-based systems, delivering highly accurate hole location, straightness, roundness and surface quality. Finishing operations on the machine can improve part accuracy, quality and surface finish. The produced accuracy and surface quality from the roughing hole-drilling operation in oil is substantially enhanced compared to water-based systems. Given the higher viscosity of oil combined with the smaller spark gap, machining speed can be up to five times slower than water. As a result, oil-based EDM drilling is typically reserved for hole diameters under 0.5 mm. Oil-based systems are also highly versatile and often used for hole drilling and standard sinker EDM operations.

Water Dielectric EDMs

In water EDM drilling, L:D ratios upwards of 300:1 are possible with an accuracy usually held to ±0.050 mm or greater. The size, shape and quality of entry and exit holes produced via water-based processes tend to have greater variance than oil dielectric processes. Water dielectric machines are typically designed for one process and do not provide any ability for finish operations; the final surface finish is what is possible with the high-power rough machine setting only.

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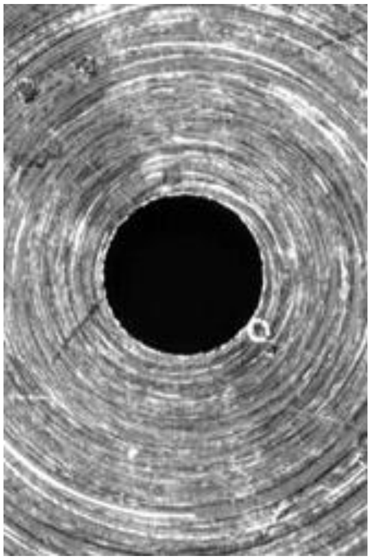
Oil vs. Water

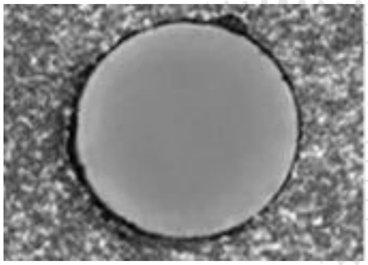
Oil Electric EDMs

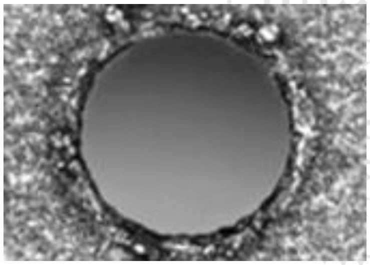


Machine: Work:
Electrode: Hole
Diameter:
Thickness:
Cycle Time:

Makino EDAF2-Fine Hole
Inconel
Copper pipe Æ0.43mm
0.50mm (± 0.005")
2.0mm (L/D 4:1)
80 seconds per hole

Water Electric EDMs





Machine:
Material:
Electrode:
Hole
Diameter:
Thickness:
Cycle Time:

Makino EDBV3
Inconel
Brass multichannel Æ1.24mm
1.44mm (±0.050)
0.075" (L/D 4:1)
5 seconds per hole

Process Engineering Considerations

When choosing the right machine to buy (whether oil or water-based), below are the key features to look for:

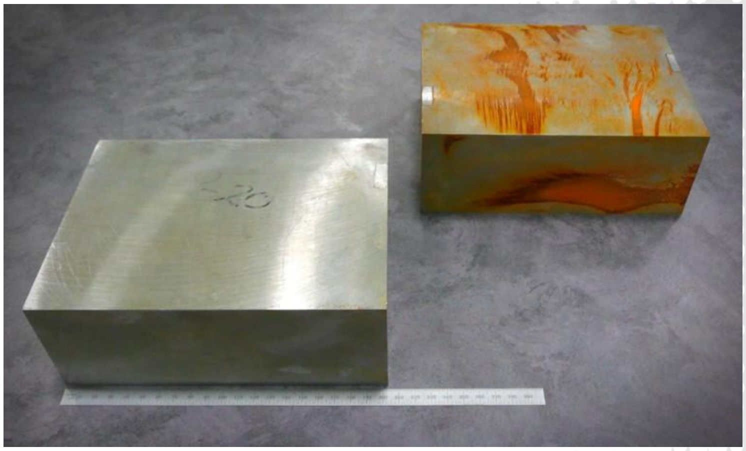
- Capacity for fine-hole EDM drilling and standard sinker EDM operation on a single machine
- Machining speed/process time
- Accuracy capability/edge quality
- Tool change capability
- Flush pressure capability
- Smallest hole size capability
- Metallurgical quality
- Unattended operation/ automation

Other important features include speed, automatic guide change and whether the machine offers submerged operations, which produces less splashing.

The build of the EDM machine can certainly impact performance. When purchasing an EDM machine for hole drilling, pay close attention to the on-machine water quality control systems. Most water-based machines use simple filtration, and some don't use any. For stable and reliable results, water-based machines should contain their own deionization system. Both oil- and water-based machines should also have a dielectric chilling unit. Machine construction rigidity and thermal stability are additional factors that should be evaluated for long-term reliability and upkeep.

Oxidation

Oxidation, also known as rust, should be part of the process evaluation. In the Die and Mold industry, parts are typically made from A2, D2, H13 and M4 tool steels. Tool steels and low carbon steels are perhaps most prone to rust, which can destroy the part or degrade the accuracy and edge quality. Rust may also create additional secondary cleaning operations depending on the critical features of the part. Rust issues are only a concern on water-based EDM drilling machines. It is also important to evaluate the machine tool's work-tank area, as any components exposed to water will be susceptible to rusting.

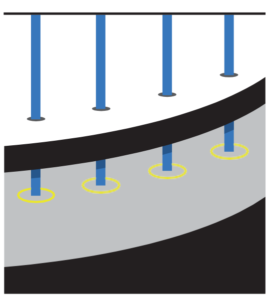


Breakthrough Detection

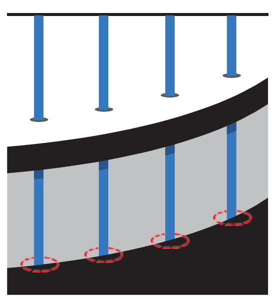
Breakthrough detection is another important machine feature needed in 90 percent of aerospace applications. When machining hollow parts, such as blades and vanes for turbine engines, the EDM drilled hole typically breaks into an internal cavity. It is critical for the machine to control the depth and position of the electrode during breakthrough, as the electrode cannot machine or back-strike (impinge or violate) the back rear wall of the inner cavity.

Back-striking can alter part quality, impact component cooling efficiency by altering airflow. This change in component airflow and cooling efficiency can create an internal hot spot during engine operation, which can lead to premature wear or component failure. Advanced generator pulse detection is a necessary machine feature to prevent back-striking.

The machine generator monitors the effective discharge pulse count, spark-gap voltage and machining speeds. Upon breakthrough, these values change in a predictable way that can be detected. Being able to detect these variables quickly with ultra-sensitive technology while also machining at maximum speed is imperative and critical for reliable processing.



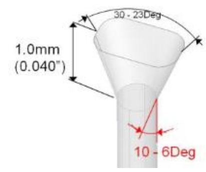
With Piercing Detection Function



Without Piercing Detection Function

Contour Machining

Contour machining is used primarily in aerospace applications for producing diffuser cooling film holes. These details are typically a square or rectangular shape that taper down and blend into a final through hole. The size and depth of these features can vary, but their depth is typically 2mm or under. Processing of a diffuser cavity is very similar to conventional milling, wherein the electrode is used with multiple X/Y/Z axis G-code program data to produce the 3D shape. Based on the workpiece configuration and diffuser variations, special programming software may be required to minimize NC code creation.



Rotary Tables

Rotary tables are another important item to review for EDM drilling. They are available in single- and two-axis configurations and can vary in size, accuracy and weight-limit capabilities.

The rotary table should be fully integrated into the machine control. This allows for complete control of the programming and positioning of the rotary table by the machine controller in one all-inclusive program. For two-axis rotary table applications, it is important to pay close attention to weight-limit capacity and determine a "moment of inertia" for your application. Proper sizing of a two-axis rotary table is important, as the size, weight and distribution of that weight (moment of inertia) may impose limitations.

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Electrode Redressing

Electrode redressing should also be considered. This function and feature will allow the worn area of an electrode, such as tapering or bullet-nosing of the electrode tip, to be "dressed" and machined off in an automatic cycle within the machine. Electrode redressing helps improve part accuracy and ensures consistent hole-to-hole cycle time, and provides consistent breakthrough by enabling more even and predictable electrode wear. These functions can also be used to automatically size or shape the electrode to any required diameter but at the cost of additional cycle time. Some manufacturers offer a wire dressing attachment that can be used to "dress" off the worn tip of the electrode after the completion of a hole for an even faster process. This wire dressing attachment can also produce small-shaped features on the electrode for standard sinker EDM operations. For example, the wire dressing attachment has been used to automatically manufacture small rectangular electrodes on the machine, significantly saving time and labor while also helping to improve accuracy.

High-precision holes are typically smaller in diameter, so automatic tool and guide change capabilities are key features to look for and are critical for unattended operation. Look for machine features and qualities that ensure reliable tool and guide changes and easy realignment for the desired application. For example, the electrode wear characteristics differ between oil and water, and more holes can be machined per electrode with oil than water.

Almost every industry that performs EDM hole drilling can automate its operation. To consider automation, one must know part production volumes and have a target for unattended production time. Other considerations include:

- How often an operator will load parts per shift
- What workholding and electrode requirements are necessary for the desired time of unattended operation
- What size of a machine is required to maximize unattended production
- How many sides of a part might need to be accessed
- If a fixture can be used for multiple parts at one time

Some types of machine features that support EDM hole-drilling automation are noted below:

Conclusion

The right tool is needed for the job, and both water- and oil-based EDM hole-drilling machines certainly offer attractive capabilities for producing small holes. The imperative is to accurately determine the needs and choose the machine with the performance and characteristics best suited for the work for maximum productivity and process efficiency.

Why Oil?

When accuracy, surface finish and hole-size requirements are the key factors driving the process, oil-based EDM drilling can provide finished parts with the tightest tolerances. By eliminating post-EDM processing, a one-machine process is possible whereby a single oil-based machine replaces both a water-based EDM rough drilling machine followed by a wire EDM finishing/ sizing process. Here are some of the types of applications that benefit from this slower processing method:

- Aero-engine fuel delivery nozzles
- Medical tooling and implantable device parts
- Die/mold features that require secondary finishing operations

Oil-based EDM drilling may offer greater flexibility in a job-shop environment by allowing EDM drilling and sinker EDM machining on a single platform.

As is often the case, workpiece requirements ultimately drive which machine type is chosen, with the most productive machine for the job is typically used. Proper diligence in assessing the needs for a particular workflow can ensure tiny holes are drilled to perfection.

Why Water?

When production of quality holes is needed, with minimal per-hole cycle time and tolerance requirements that allow some entry/exit hole diameter variation and edge rounding, water-based EDM drilling will almost always yield the fastest machining speeds possible. The finished part may require post-machine finishing operations, but in this type of workflow, that may be preferable to the increased cycle time required for higher quality oil-based EDM drilling.

Water-based EDM drilling machines are dedicated to hole-drilling operations, which is perfect for high-volume production operations. Because time is money, the faster holes can be produced to the required tolerances of more productive, efficient operations. Below are some of the types of applications that benefit from this faster processing method:

- Aerospace cooling film holes
- Medical tooling
- Start holes for wire EDM
- Die/mold

Resources

Learn About Makino EDM Hole-drilling Technologies
www.makino.com/edm-hole-drilling

Watch These Online Seminars:
A New Approach to Aerospace Blade and Vane Cooling Hole Machining >>>
High-Quality, High-Precision Production of Ultra-Small Holes by EDM >>>
Unique Solutions for Shaped Fine-Hole Machining
>>> The Fine Art of Micro-Hole Machining

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