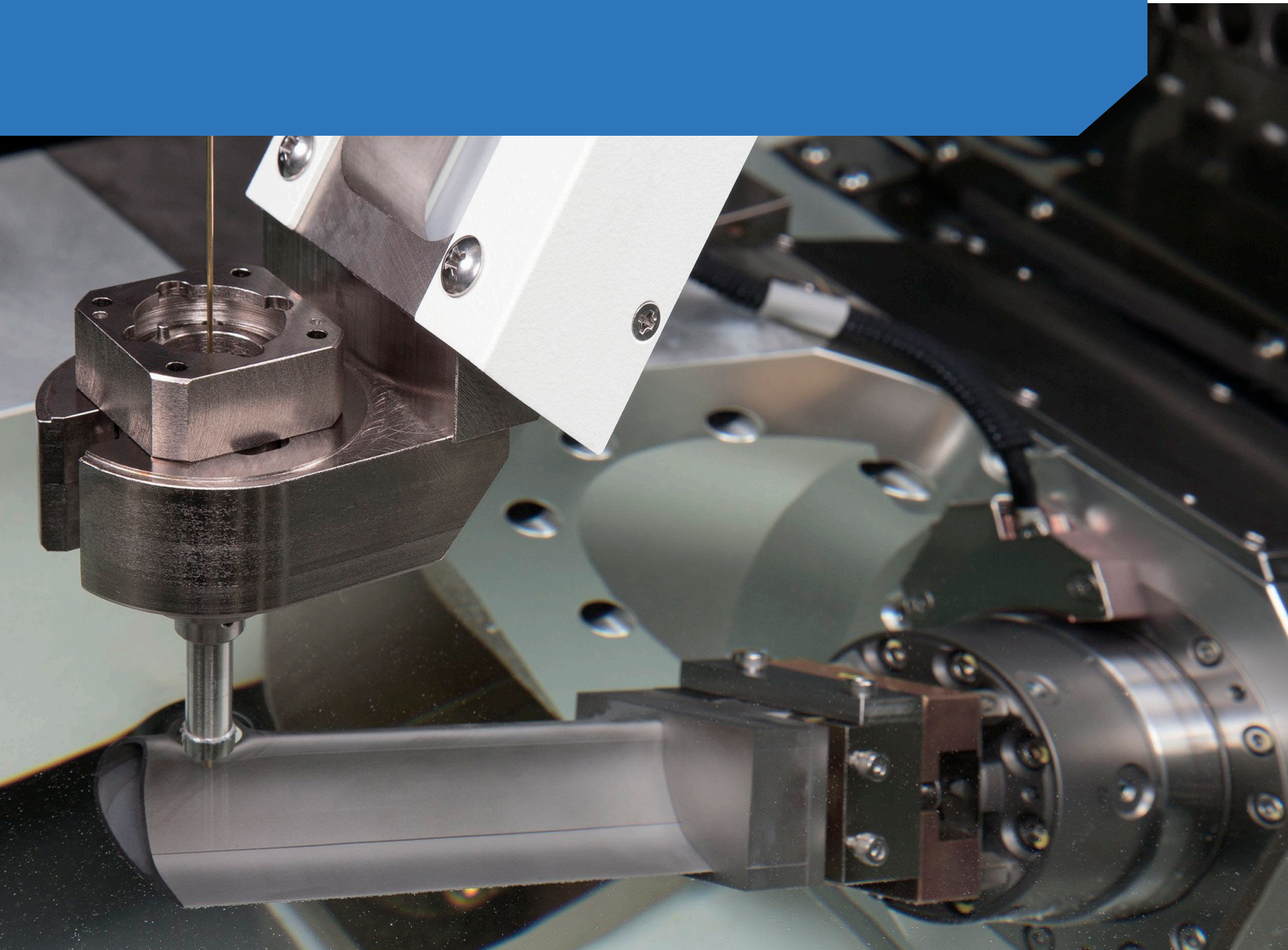


SELECTING THE APPROPRIATE EDM TECHNOLOGY FOR HOLE-DRILLING APPLICATIONS



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SELECTING THE APPROPRIATE EDM TECHNOLOGY FOR HOLE-DRILLING APPLICATIONS

ADVANCEMENTS IN EDM HOLE DRILLING

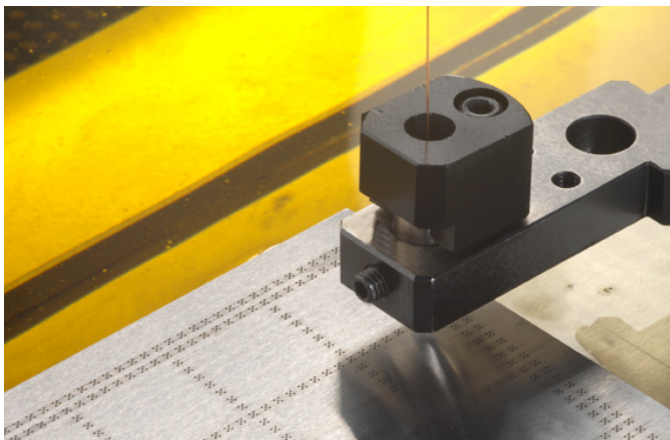
Changes in market demand are frequently the catalyst for advancements in machining technologies; such is the case for modern EDM hole-drilling machines. While traditional hole features have typically afforded manufacturers the flexibility to use a variety of manufacturing approaches, modern product designs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

AT A GLANCE

- CHANGING MARKET DEMANDS
- OIL VS. WATER DIELECTRIC
- PROCESS ENGINEERING CONSIDERATIONS
- AUTOMATION FOR EDM HOLE DRILLING
- CONCLUSION

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 requirements of accuracy, quality and production volume for various applications. These advancements in EDM technologies offer several advantages over traditional manufacturing methods. In many cases, the EDM drilling process can reduce lead-times by eliminating the need for secondary post-machine operations by producing burr-free hole features with greater precision. When compared to conventional processing methods, such as mechanical drilling, the small hole diameters and often contoured part designs will typically bend or break conventional 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.

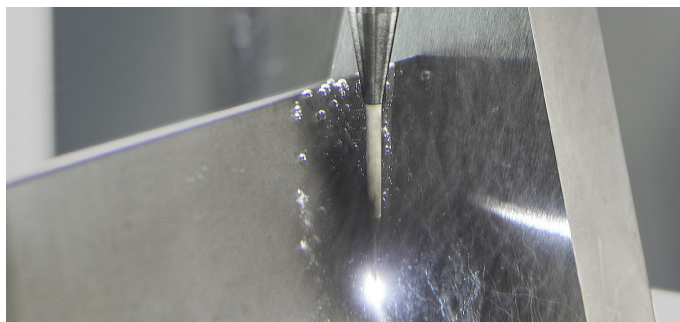


In the medical market, design engineers are pursuing a higher degree of complexity surrounding hole sizes and quality. Applications such as surgical tooling and implantable devices are being designed with

extremely small hole diameters, hereto 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 its own unique blend of hole-production requirements. The most common hole features seen in modern aerospace applications are known as 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 as well as shaped hole features known as diffuser shapes.

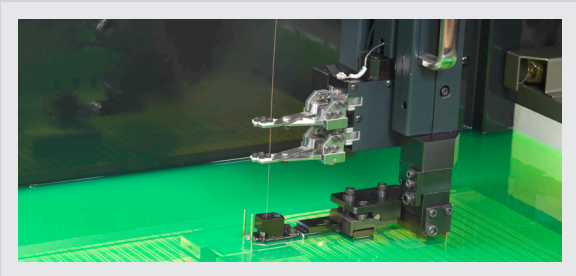
Production requirements for these holes typically range in diameter from 0.5 mm to 1.5 mm, with average accuracy tolerances of ± 0.050 mm. Since EDM drilling is a thermal process, attention must be paid to the impact of the process on the metallurgical quality of the workpiece. The heat affected zone (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 development of several new EDM hole-drilling technologies that emphasize speed over precision, such as multi-sided part positioning and back-strike prevention.

OIL **VS.** WATER

ADDRESSING THE DIFFERENCE BETWEEN DIELECTRIC EDMs

Despite the growing variety of EDM hole-drilling technologies available on the market, there exist two primary machine platforms, oil dielectric and water dielectric, which offer very distinct performance characteristics. Key points of differentiations 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 that is best suited for their applications.

OIL DIELECTRIC 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 also allowing standard sinker EDM operations and orbiting and finish machining operations all on the same machine.

WATER DIELECTRIC EDMs



WHY WATER?

Water, typically deionized to control conductivity, is an effective and inexpensive dielectric fluid that is the most commonly used in EDM drilling machines. In order to maintain consistent water quality for the most controlled burn, these machines use filtration and deionization systems. Water is an excellent choice when the workflow calls for a dedicated process machine, one that drills only holes, and requires the fastest possible machining speeds. A sweet-zone balance between electrode, machining discharge power and dielectric characteristics exists at typical hole sizes (0.5-1.5 mm) and yields the best speed.

OIL DIELECTRIC EDMs

Dielectric Properties

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.

Processing Methods

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. Oil-based machine platforms typically use copper and tungsten electrodes, depending on hole requirements.

Machining Characteristics

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 typically more consistent than those of water-based systems, producing highly accurate hole location, straightness, roundness and surface quality. Finishing operations on the machine are possible to improve part accuracy, quality and surface finish. The produced accuracy and surface quality from the roughing hole-drilling operation in oil is substantially enhanced when 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 are oftentimes used for both hole drilling and standard sinker EDM operations.

WATER DIELECTRIC EDMs

Dielectric Properties

The speed of water-based EDM drilling is attributable in large part 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.

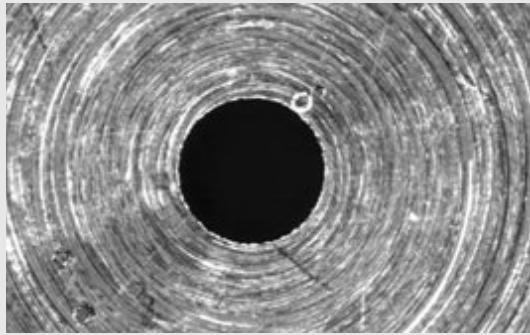
Processing Methods

Water-based systems can perform machining operations 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 design.

Machining Characteristics

In water EDM drilling, L:D ratios upwards of 300:1 are possible with 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 see 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.

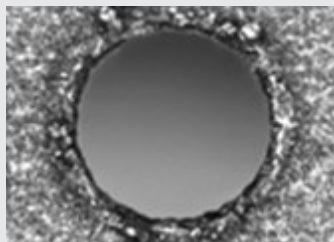
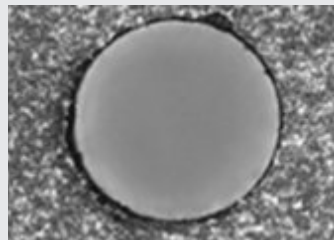
OIL DIELECTRIC EDMs



Example

MACHINE: MAKINO EDAF2-FINE HOLE
WORK: INCONEL
ELECTRODE: COPPER PIPE - 0.43 MM DIAMETER
HOLE DIAMETER: 0.50 MM (± 0.005 ")
THICKNESS: 2.0 MM (L/D 4:1)
CYCLE TIME: 80 SECONDS PER HOLE

WATER DIELECTRIC EDMs



Example

MACHINE: MAKINO EDBV3
WORK MATERIAL: INCONEL
ELECTRODE: BRASS MULTICHANNEL - 1.24 MM DIAMETER
HOLE DIAMETER: 1.44 MM DIAMETER ± 0.050 MM
THICKNESS: 0.075" (L/D 4:1)
CYCLE TIME: 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:

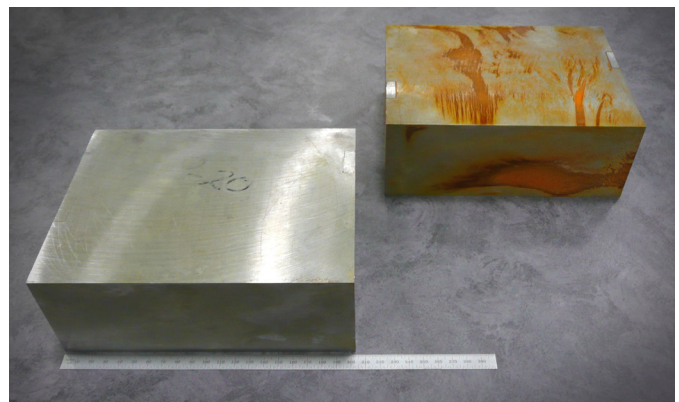
- CAPACITY FOR FINE-HOLE EDM DRILLING AND STANDARD SINKER EDM OPERATION ON A SINGLE MACHINE
- THE ABILITY TO QUICKLY CHANGE FROM ONE EDM METHOD TO ANOTHER
- ACCURACY CAPABILITY
- TOOL-CHANGE CAPABILITY
- FLUSH PRESSURE CAPABILITY
- SMALLEST HOLE SIZE CAPABILITY

Other important features include speed, automatic guide change and whether or not 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, the machine should also contain its own deionization system (water only) and dielectric chilling unit (oil and water configurations) to precisely control the dielectric fluid's characteristics. Machine construction rigidity and thermal stability are other factors that should be evaluated for long-term reliability and upkeep.

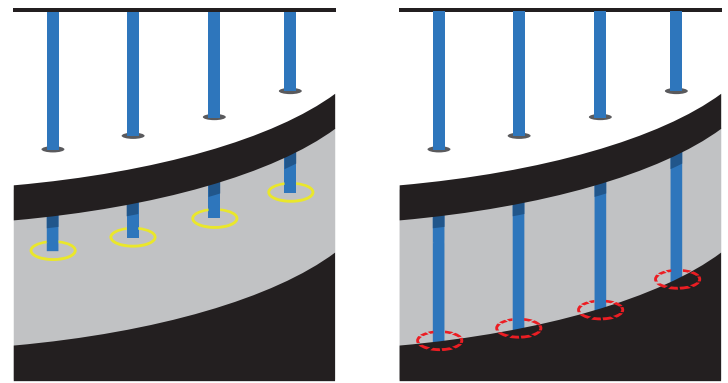
RUST

Rust should be considered when evaluating process considerations. In the die/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, and it is also important to evaluate the machine tool's work-tank area, as any components that are exposed to water will be susceptible to rusting.



BREAKTHROUGH DETECTION

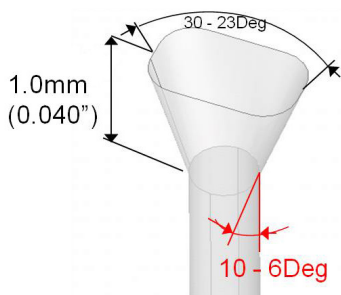
Breakthrough detection is another important machine feature that is needed in 90 percent of aerospace applications. When machining hollow parts, such as blades and vanes for turbine engines, the EDM drilled hole typically breaks into an internal hollow cavity. It is critical for the machine to control 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. If back-striking occurs, it can alter part quality and component cooling efficiency by altering airflow. This change in component airflow and cooling efficient as a result of back-striking can create an internal hot spot during engine operation, which can lead to premature wear or component failure. To prevent back-striking, advanced generator pulse detection is a necessary machine feature.



With piercing detection function

Without piercing detection function

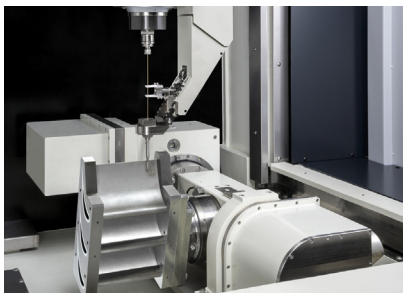
The machine generator monitors the effective discharge pulse count, spark-gap voltage and machining speeds. Upon breakthrough, these values change in a predictable way that can be detected. Being able to detect these variables quickly with ultra-sensitive technology, while also machining at maximum speed,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



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 2 mm 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 upon 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 both single- and 2-axis configurations, and can vary in size, accuracy and weight-limit capabilities. The preferred method is to have the rotary table completely integrated into the machine control, meaning that programming and positioning of the rotary table are controlled by the machine controller and contained in one all-inclusive program. For 2-axis rotary table applications, it is important to pay close attention to weight-limit capacity, and also determine a “moment of inertia” for your application. Proper sizing of a 2-axis rotary table is important, as the size, weight and distribution of that weight (moment of inertia) may impose limitations.

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 also 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 be used to 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, which represents a significant saving of time and labor while also helping to improve accuracy.

AUTOMATION FOR EDM HOLE DRILLING

Almost all industries that perform EDM hole drilling can automate their operation, if needed. To consider automation, one must know part production volumes and have a target unattended production time. It must be decided if the operator will load parts multiple times per shift, or once per shift, and what workholding and electrode requirements are necessary for a desired time of unattended operation. The size of a machine required to maximize unattended operations should also be considered. Is access needed to multiple sides of the part, and can a fixture be used for multiple parts at one time?

SOME TYPES OF MACHINE FEATURES THAT SUPPORT EDM HOLE-DRILLING AUTOMATION ARE NOTED BELOW:

- ROTARY TABLES
- TOOL CHANGES
- GUIDE CHANGES
- WORKPIECE CHANGE (ROBOT)
- ELECTRODE PALLET CHANGE (ROBOT)



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 include robust tool and guide exchange design, ease of realignment and reliable tooling for the desired application. Having automatic tool change and guide change capabilities enables automatically changing of the hole size and provides the best machining performance while maximizing unattended operations. For example, the electrode wear characteristics differ between oil and water, and more holes can be machine per electrode with oil than water.



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.

WHEN TO USE 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 being typically used. Proper diligence in assessing the needs for a particular workflow can ensure tiny holes are drilled to perfection.

WHEN TO USE 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

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