TECHCOMMENTARY

ELECTRICAL DISCHARGE MACHINING

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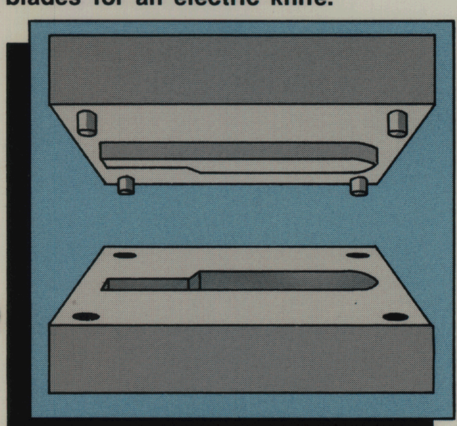
EDM: The Metal-Removal Problem Solver

Today machine shops are being asked to machine hard materials into intricate and unusual shapes. In many cases traditional machining methods just don't measure up. Electrical Discharge Machining (EDM) fills this gap and produces high quality products.

While the basic EDM process has been around for over 40 years, only recently have advances in power supplies and computer control made it practical for many applications. An increasing number of companies find that they can save money and manpower by using EDM. For example, tools used in the manufacture of dies and punches previously took skilled craftsmen endless hours to produce by hand. Now they can be machined automatically—faster, more accurately, in a single piece, in hardened metal, and at a fraction of the cost. For many other companies EDM is the only way to get a job done, because EDM can create burr-free, intricate and precise shapes in materials that otherwise cannot be machined. In fact, the EDM process is so versatile that the shapes it creates are limited only by a designer's imagination. These shapes include workpieces with high length-to-diameter ratios, extrusion dies where difficult angles are required, and gears where repeatability of critical specifications is a necessity.

Figure 1. **A punch and die that stamps blades for an electric knife.**



Applications

Because EDM is able to create this wide variety of difficult shapes, it has become popular for many different applications. EDM has found widespread use not only in the manufacture of punches and dies, but also in moldmaking, aerospace applications, making extrusion dies, and the production of small holes (larger than 0.015 inch) and micro-holes (0.015 inch and smaller). Creating small and/or deep slots is another important EDM application. However, its most popular application is in the making of blanking dies.

EDM can be used to advantage in many situations, and a few examples are given below. While none of the examples may exactly fit your type of work, they may give you ideas on how to use EDM to solve some of your more difficult machining problems.

- In 1973, a punch and die set used to stamp blades for an electric knife was made of carbide, without EDM, at a cost of $12,900. In 1984, it was produced in-house by wire-cut EDM at a cost of $4,000. The set was made of CPM-10V and has stamped more than 100,000 parts. (See Figure 1).
- A three-gang punch and die set took about 1,000 hours to manufacture using conventional methods and required sectionalization. Using EDM took 1/5 the time and the die was manufactured in a single piece. Machining with a solid die is more accurate because the die is more rigid than a die made in sections and bolted together. (See Figure 2).
- EDM was selected as the method to produce holes in a stainless steel medical cannula where no burrs could be tolerated. (See Figure 3).

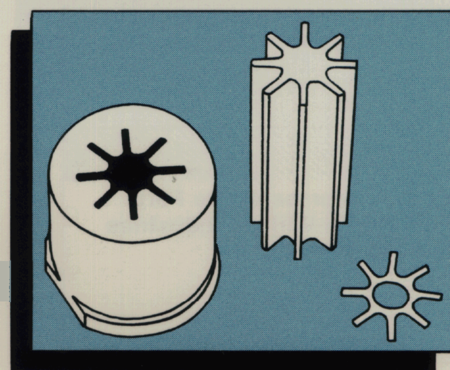


Figure 2. **A punch and die that punches the small star-shaped fiber part in the lower right.**

A summary of representative parts produced by different industries is given in Table 1.

Advantages and Limitations

EDM is selected for a job because of the advantages it offers over conventional methods. The

Industry	Part
Tool and Die	Plastic molds Form tools Extrusion dies Blanking dies Punches
Automotive	Die shoes Trim dies Fuel injector nozzles Carburetors
Aerospace	Cooling holes in turbine blades Turbine blade root sections Combustor liners Turbine nozzle bands
Medical Supplies	Cannula tubes

***Table 1.* Representative Parts Produced in Various Industries by EDM**

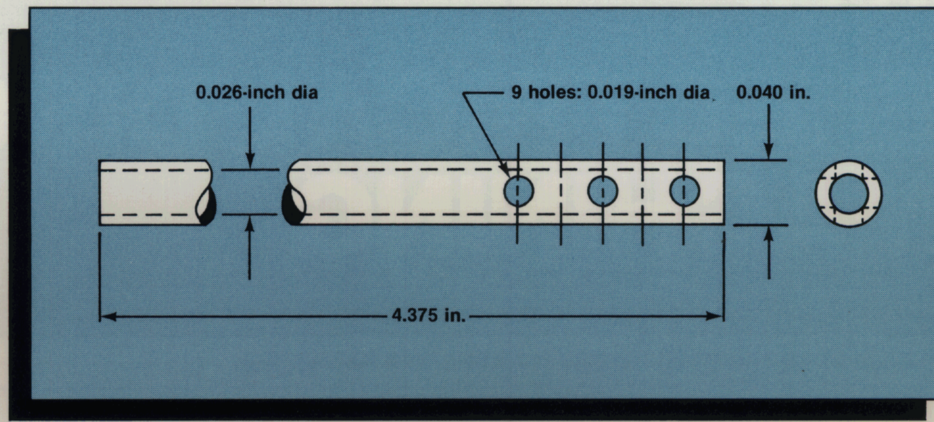


Figure 3.* This medical cannula was drilled by EDM. *Nine burr-free 0.019-inch-diameter holes were drilled in 304 stainless steel tubing.

advantages and the limitations of EDM are listed in Table 2.

To overcome its limitations, EDM is often used in conjunction with other processes. For example, the bulk of the material may be removed by conventional means before EDMing.

EDM Variations

Any material that conducts electricity can be EDMed, and the speed of the process is not affected by the hardness of the material. This makes EDM an ideal process for machining hard materials like hardened steel and carbides. EDM also is perfect for soft or delicate materials since EDM does not use force to remove the material, and there is no risk of mechanical distortion or damage by cutting tools.

There are two basic types of EDM machines, vertical and wire-cut. In both types material is removed from a workpiece by steadily bombarding it with controlled sparks of electricity. The workpiece never comes in contact with the electrode and thus no machining forces distort its shape.

Vertical EDM—It sometimes is called ram-type, plunge-type, sink, cavity, or conventional EDM. Despite its many names, the process is the same. An electrode is moved towards a workpiece submersed in a tank containing a dielectric. Electric sparks erode the workpiece so that eventually a mirror image of the electrode is formed. The shape of the electrode thus determines the shape of the cavity; for example, a star-shaped electrode creates a star-shaped cavity.

What has contributed greatly to the versatility of vertical EDM is the ability to program and move the electrode in three axes of motion, X, Y, and Z, plus rotation. In many cases the table holding the workpiece also can move in both the X and Y directions. These combinations of movements together with different shaped electrodes make possible the creation of virtually any shape; the machining method is not limited to surfaces of revolution as with conventional machining methods.

A vertical EDM system is composed of a pulse power supply, an electrode, a dielectric coolant, and ancillary equipment. Technological advances are improving the system capabilities —cutting rates are increasing and improvements are being made in other values.

A significant feature of EDM is electrode wear. Since some material is blasted off both the workpiece and the electrode with each pulse, the EDM tool wears—even though there is no cutting force or contact between it and the workpiece. There is considerable variation of electrode

***Table 2.* Advantages and Limitations of EDM**

Advantages	Limitations
Can EDM anything that conducts electricity	Workpiece must be conductive
Can create intricate and unusual shapes	Slower material removal rate
No tool force on machine, electrode, or workpiece	Electrode wear may require use of several tools
Easily automated	Electrode wear can produce inaccuracies
Great precision	Cavities may be slightly tapered
Repeatability	Undesirable recast layer may need to be removed
Can create solid dies eliminating sectionalizing and grinding	Leaves a very shallow, highly stressed surface layer
Frees skilled craftsmen for more productive work	Equipment is expensive
May eliminate secondary operations	
Drilling at shallow angles possible	

wear depending on the application. Several electrodes may be necessary to complete one job or a single electrode may be used for quite a few operations. Often, a partially worn electrode may be used to start a job and then a new one brought in to finish it. Fortunately, an electrode's wear is not related to its hardness, so that electrodes can be made of materials that are easily machinable such as graphite.

Wire-Cut EDM—Because it uses a constantly-moving wire as the cutting tool, it is also called traveling-wire EDM. The wire is threaded around the machine and through the material. This means wire-cut EDM cannot be used to machine blind shapes since the wire must go completely through the workpiece.

In wire-cut EDM the side of the wire acts like a bandsaw to cut through the workpiece material. Once the machine starts, the wire is in continuous motion so that the cutting is actually being done by a new electrode all the time, thus solving the problem of electrode wear. The used wire is then discarded. Wire-cut EDM is used with computer numerical control (CNC), and machines frequently work unattended throughout the night or weekend.

Numerical control has always been a part of wire-cut EDM. Today computers with sophisticated software packages have cut programming time and extended geometric capabilities. There have been hardware developments in the machines as well. Especially important is automatic rethreading which is vital for machines that work unattended.

A wire-cut EDM system is composed of a power supply, an electrode, a dielectric coolant and ancillary equipment. Like vertical EDM, technology is rapidly improving the systems' capabilities. Some of today's CNC wire EDM equipment can cut at speeds in excess of 20 square inches per hour (0.33 in.^{2}/min).

The workpiece typically is mounted on a table with two degrees of freedom. The movement of the table often is controlled by a computer which may be able to compensate for overcut, wire thickness, and known errors in the workpiece. By angling the workpiece with respect to the wire, conical shapes can be formed.

Wire-cut EDM is efficient because the wire erodes a thin line around the perimeter of the required cut rather than eroding the full volume of the cavity as with vertical EDM.

The dielectric fluid used with wire-cut EDM is usually deionized water. It is forced by pressure and/or vacuum into the cavity around the wire and is collected on the other side of the workpiece.

Other Types—Another form of EDM which should be mentioned is Electrical Discharge Grinding (EDG). A graphite wheel is used as a rotating electrode. This nonabrasive grinding eliminates costly diamond wheels and does not distort delicate parts.

Overview

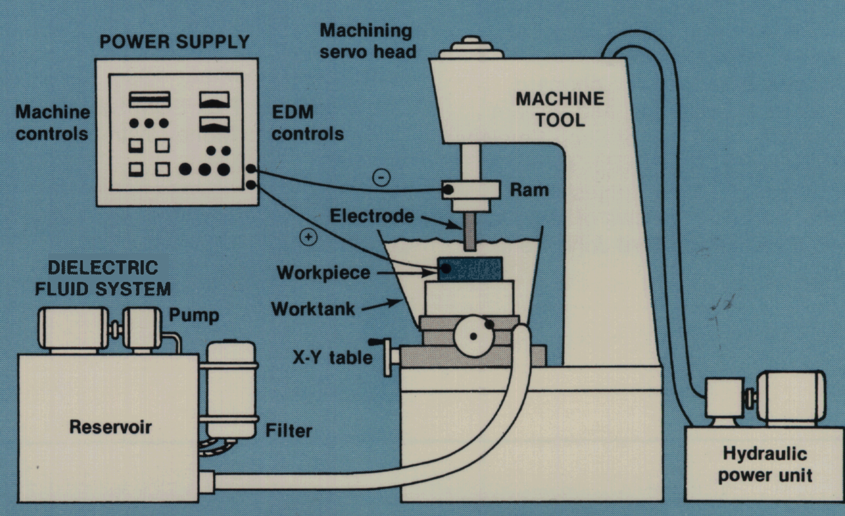
Process Description

In both vertical EDM and wire-cut, the actual [redacted] process is similar. The workpiece and the electrode are immersed in a dielectric fluid such as oil or deionized water. The electrode and workpiece are separated by a small gap and voltage is applied. When there is enough voltage, the dielectric breaks down. A spark jumps the gap, striking the workpiece and vaporizing part of the material. The intense heat also melts a small portion of the material. The current then is pulsed off, and the dielectric flows into the area carrying away most of the melted material in the form of small chips or cinders. The current is pulsed on and off at a rapid rate, typically at frequencies of from 500 to 1,000,000 pulses per second.

The chips absorb most of the heat produced by the sparks. The dielectric fluid that flushes away these particles also dissipates the heat enabling the tool and workpiece to remain relatively cool despite the very high, localized temperatures produced by the spark discharges.

The shape of the electrode creates a correspondingly shaped cavity in the workpiece that is always slightly larger than the dimensions of the electrode. This overcut reflects the size of the gap and can be as small as 0.001 inch with low cutting rates.

A small portion of the melted material is redeposited on the workpiece. The amount redeposited can be minimized by carefully controlling the pulsing of the current and the flow of the dielectric. In most applications this redeposited material is not a problem and can even be beneficial. In other applications, a finishing step is required to remove it. Other than the redeposits, EDM is a completely burr-free machining method.



Schematic of the EDM process

Power Supplies—These provide a train of unipolar pulses of adjustable width, height and repetition rate.

Advances in power supplies have improved the consistency and control of the pulses as well as increasing the power, and have greatly improved EDM operations. Fortunately, new power supplies are compatible with most systems, so older EDM systems can be upgraded by replacing the power supply.

In Summary

Electrical Discharge Machining has become a valuable tool for tool manufacturers and throughout the metalworking industry. As with other nontraditional processes, its specialized characteristics have enabled it to have a major impact on the manufacturing industry. Recent advances in controls and automation have secured EDM's position in today's factories. As with all processes, there are limits and drawbacks. However, EDM can be used to advantage in many applications, and shops which ignore EDM may find themselves no longer in a competitive position.

The information discussed in this issue of TechCommentary is an overview and intended only to familiarize you with the basic aspects of EDM. If you are interested in more detailed background, please contact CMF or an EDM equipment builder or supplier.

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The Center's mission is to assist industry in implementing cost- and energy-efficient, electric-based technologies in metals fabrication and related fields. TechCommentary is one communication vehicle that the Center uses to transfer technology to industry. The Center also conducts research in metal heating, metal removal and finishing, and fabrication.

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