11 Ram EDM Electrodes and Finishing

Electrodes

Electrode selection and machining are important factors in operating ram EDM. With wire EDM there is a constant supply of new wire, or electode material; with ram EDM the electrodes wear. So knowing about electrodes is important in doing ram EDM. See Figure 11:1.

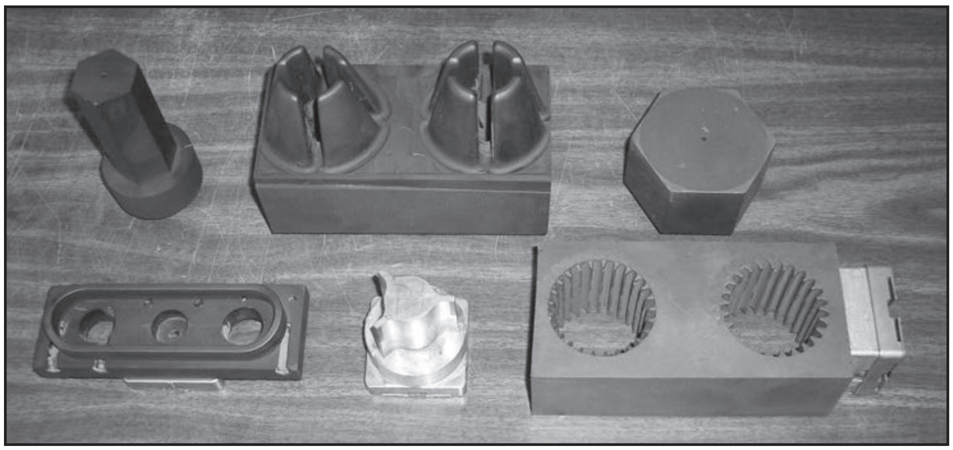


Figure 11:1

Various Electrodes for Ram EDM

A. Function of the Electrode

The purpose of an electrode is to transmit the electrical charges and to erode the workpiece to a desired shape. Different electrode materials greatly affect machining. Some will remove metal efficiently but have great wear; other electrode materials will have slight wear but remove metal slowly.

B. Electrode Selection

When selecting an electrode and its fabrication, these factors need to be evaluated:

1. Cost of electrode material.
2. Ease or difficulty of making an electrode.
3. Type of finish desired.
4. Amount of electrode wear.
5. Number of electrodes required to finish the job.
6. Type of electrode best suited for the work.
7. Number of flushing holes, if required for the electrode.

C. Type of Electrode Materials

Electrodes fall into two main groups: metallic and graphite. There are five commonly used electrodes: brass, copper, tungsten, zinc, and graphite. In addition, some electrode materials are combined with other metals in order to cut more efficiently.

Studies show that graphite electrodes have a greater rate of metal removal in relation to its wear. Graphite does not melt in the spark gap; rather, at approximately 6062° F (3350° C), it changes from a solid to a gas. Because of graphite's relatively high resistance to heat in the spark gap (as compared to copper), for most jobs it is a more efficient electrode material. See Figure 11:2. Tungsten has a melting point similar to graphite, but tungsten is extremely difficult to machine. Tungsten is used as “preforms," usually as tubing and rods for holes and small hole drilling.

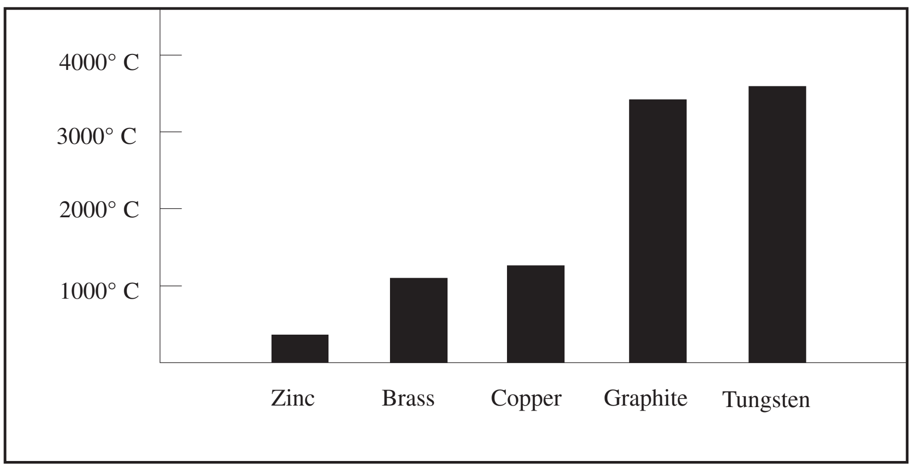


Figure 11:2

Electrode Melting Points

Metallic electrodes usually work best for EDMing materials which have low melting points as aluminum, copper, and brass. As for steel and its alloys, graphite is preferred. The general rule is:

Metallic electrodes for low temperature alloys.
Graphite electrodes for high temperature alloys.

However, exceptions exist. For instance, despite higher melting points for tungsten, cobalt, and molybdenum, metallic electrodes like copper are recommended due to the higher frequencies needed to EDM these materials.

Copper has a distinct advantage over graphite because it performs better in “discharge-dressing." During unsupervised CNC cutting, the copper electrode can be sized automatically by using a sizing plate. The copper electrode can then be reused for a finishing cut or used to produce another part.

D. Galvano Process for Metallic Electrodes

Sometimes large solid electrodes are too heavy for the servo and too costly to fabricate. In such cases, the Galvano process can be used to fabricate the mold. A mold is electrolytically deposited with copper up to .200" (5 mm) thick. The inside of the copper shell is partially filled with an epoxy, and wires are attached to the copper electrode. The formed electrode is then mounted on the EDM machine.

E. Custom Molded Metallic Electrodes

Where multiple electrodes are constantly required, a 70/30 mixture of tungsten and copper powder is pressure molded and sintered in a furnace. This process can produce close tolerance electrodes.

F. Graphite Electrodes

In America, approximately 85 percent of the electrodes used are graphite. Graphite machines and grinds easily compared to metal electrodes. Burrs usually occur when machining metal electrodes; however, burrs are absent when machining graphite. Copper tends to clog grinding wheels. To avoid wheel clogging, some use an open grain wheel and beeswax, or a similar product.

However, graphite has a major problem: it's “dirty." Many shops rather use job shops that specialize in ram EDM because graphite dust coats everything in the building. Generally, such shops come equipped with an adequate filter system to handle the graphite dust.

Unlike metal when it's machined, graphite does not create chips—it creates black dust. If graphite dust is not removed while being machined, it will blanket the shop. Although certain graphites are used for lubricants, the graphite in electrodes is synthetic and very abrasive. Getting graphite into the machine-ways can cause premature wear. Because of the abrasive characteristics of graphite, machinists are advised to use carbide cutting tools. When grinding graphite electrodes, they should use a vacuum system. See Figure 11:3.

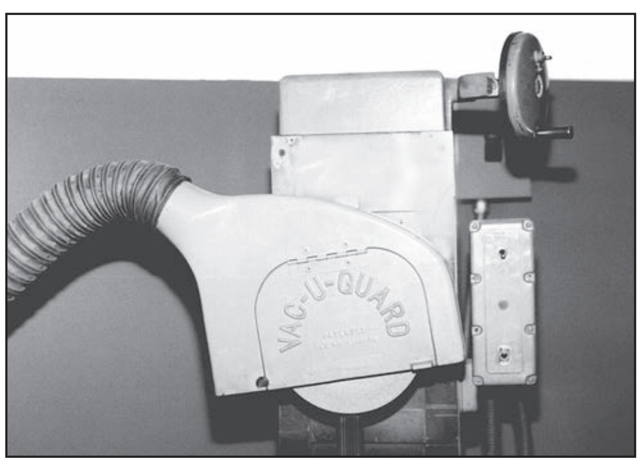


Figure 11:3

A Surface Grinder Equipped with a Vacuum System for Grinding Graphite

A vacuum system also can be installed when milling graphite. Some mills use a liquid shield around the cutter to remove graphite dust. There are also special designed, totally enclosed CNC milling machines that are used to machine graphite.

Graphite is porous so liquids can penetrate and introduce problem-causing impurities. The larger the graphite grain structure, the greater the danger for impurities. However, dense graphite, even after being soaked in fluid for several hours, shows little fluid penetration.

One way to remove impurities is to put the electrode in an oven for one hour at 250° F (121° C). Electrodes can also be air dried. It is recommended that graphite electrodes should never be placed in a microwave oven.

If porous electrodes are used, they should contain no moisture. Trapped moisture can create steam when cutting, and thereby damage the electrode.

When machining, graphite tends to chip when exiting a cut. To prevent chipping, machinists should use sharp tools, and a positive rake. A method to prevent chipping is to make a precut into the graphite where the cutting tool will exit. Different grades and porosities of graphite are shown in Figure 11:4

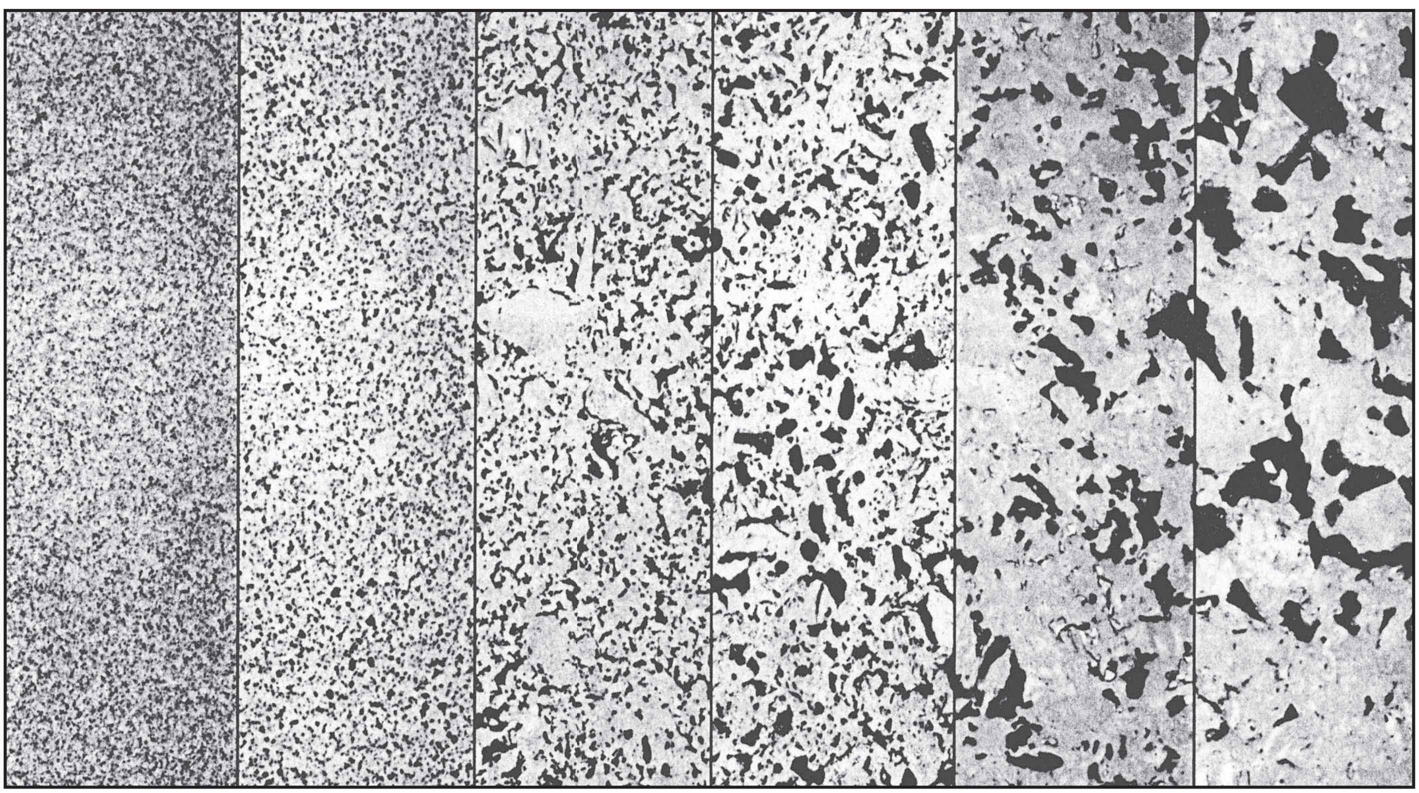
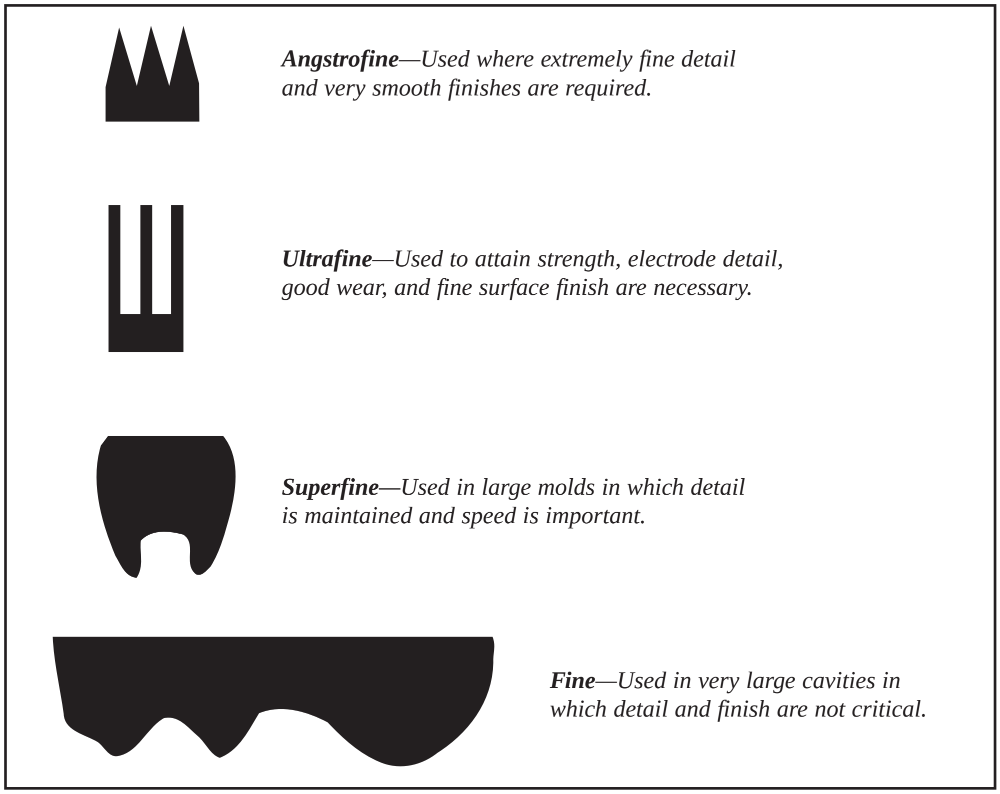


Figure 11:4

Graphite Grain Size Magnified 100 X

G. Determining Factors for Choosing the Proper Graphite

Grain size and density of graphite determine its cost and cutting efficiency. Remember, the electrode produces the mirror image into the workpiece. See Figure 11:5.



Courtesy Poco Graphite

Figure 11:5

Typical Electrode Shapes for Various Classifications of Graphite

The General Rule for Determining Graphite

A. Choose a finer grain size graphite for fine detail, good finish, and high wear resistance.

B. Choose a less costly, coarser electrode when there is no concern for small detail or fine finish.

H. Electrode Wear

Except in the no-wear cycle, electrodes have considerable wear. If the portion of the electrode that did not wear retains its shape, the electrode can be redressed and reused. For example: A long hex graphite is machined for blind hex cavities. When the lower portion of the hex electrode wears, its worn portion is removed and the electrode is reused.

On some formed electrodes, an electrode cannot be remachined. In such cases, sufficient electrodes need to be fabricated.

Heaviest electrode wear appears in the corners. This wear occurs because the electrode corner must EDM a larger area than other surfaces. See Figure 11:6.

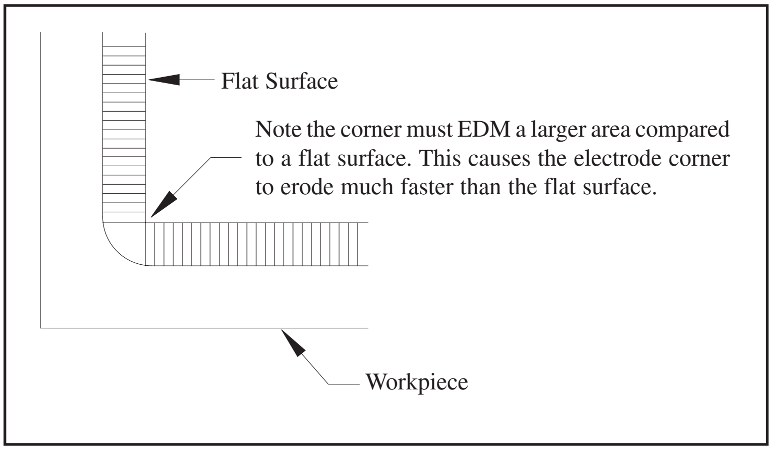


Figure 11:6

Corner Electrode Wear

I. Abrading Graphite Electrodes

The abrading process is an efficient method of producing complex and large electrodes for production and redressing purposes. A pattern is first made for the desired shape. Then, an epoxy inverted form is made from the pattern and charged with a carbide grit coating. This carbide-grit form becomes the abrading tool. See Figure 11:7.

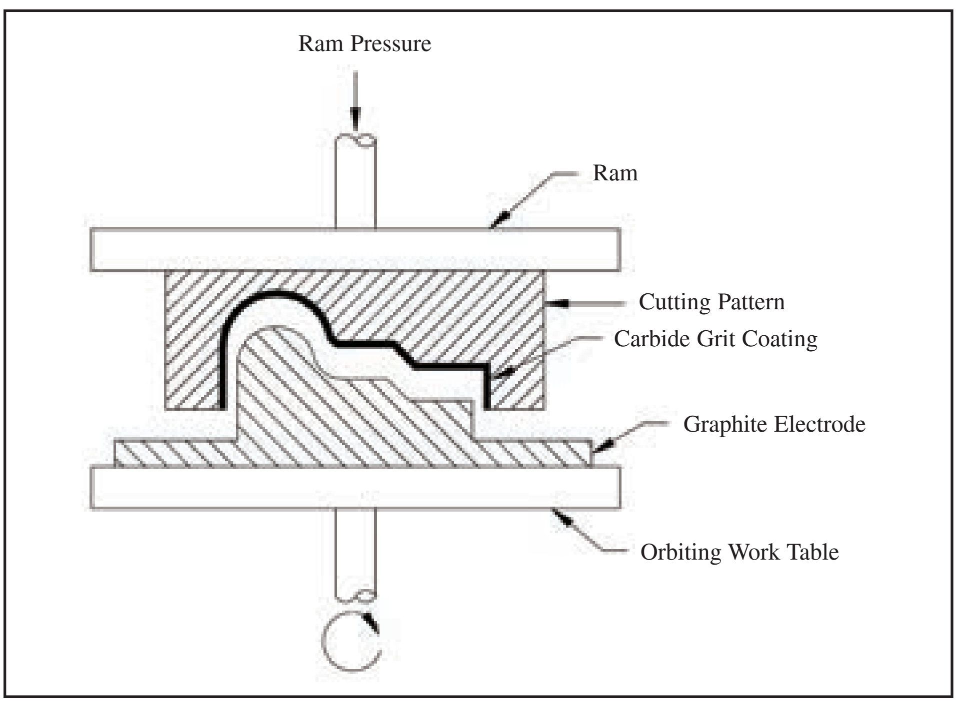
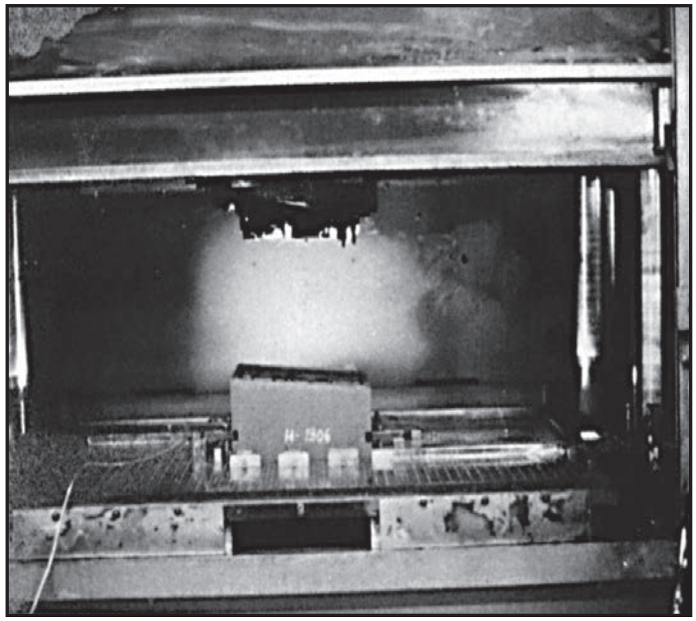


Figure 11:7

Abrading Graphite Electrodes

The machine orbits from .020" to .200" (.51 mm to 5 mm). As the machine vibrates in a circular motion within a bath of oil, the impregnated pattern forms the graphite electrode. See Figure 11:8.

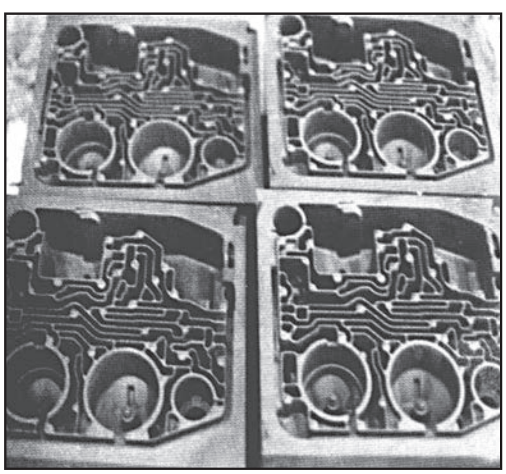


Courtesy Hausermann

Figure 11:8

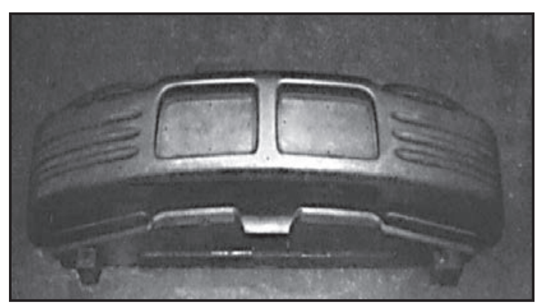
Abrading Machine

The abrading tool produces a very fine finish on the electrode. Multiple electrodes can be produced from the same pattern without any secondary benchwork. This process is used for large electrodes with many details, such as crankshaft forging dies and transmission housing molds. See Figure 11:9.



Courtesy Hausermann

Abraded Valve Body Electrodes for Automatic Transmission



Courtesy Hausermann

Large Abraded Electrode for Plastic Mold for Bumper Fascia

Figure 11:9

Abrading Electrodes

J. Ultrasonic Machining for Graphite Electrodes

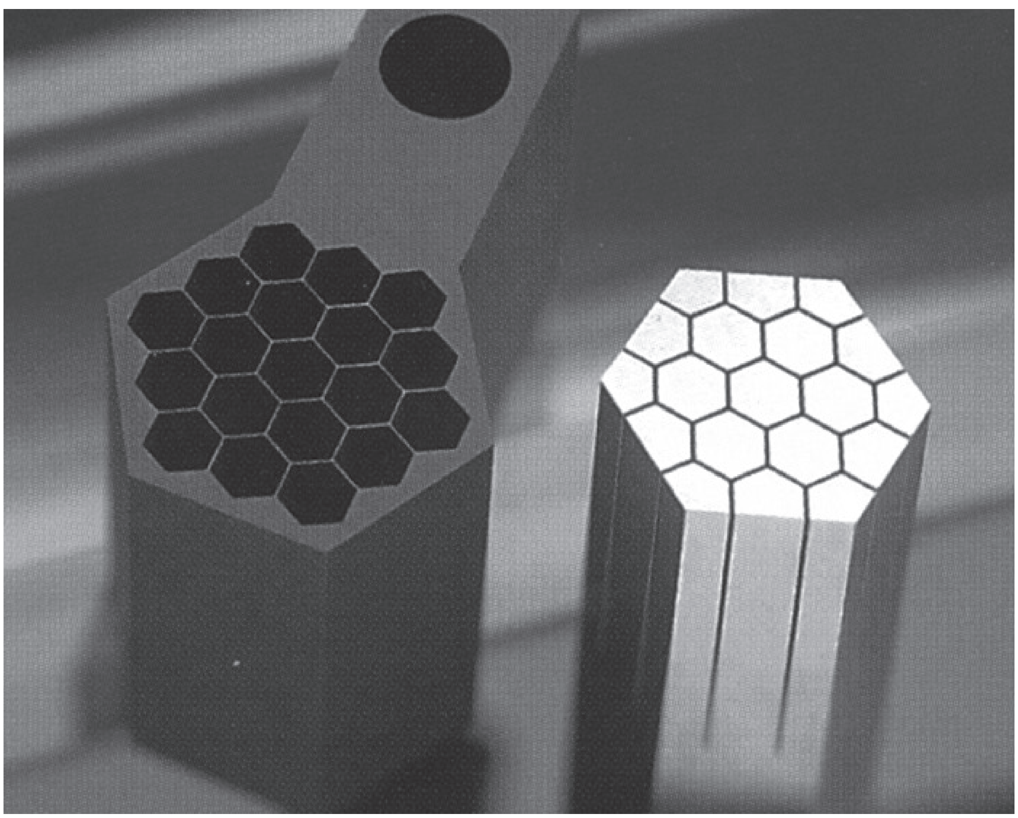
As in abrading, ultrasonic machining also cuts by vibration. It uses a metal form tool and an abrasive slurry flow between the form tool and the electrode. The electrode is formed as the workpiece vibrates. This process is predominantly used for shallow cavities, such as coining and embossing dies.

K. Wire EDMing Metallic and Graphite Electrodes

Some believe wire EDMing metallic electrodes is efficient, whereas wire EDMing graphite electrodes is inefficient. However, in recent years the cutting speeds of wire EDM have increased, making it in some cases to be economical for machining graphite electrodes.

In addition, when electrodes containing fine details are wire EDMed, the fine details add no significant costs to electrode fabrication. Also, the dust problem associated with machining graphite electrodes is eliminated because deionized water in wire EDM washes the eroded particles away. See Figure 11:10.

The densely-structured Angstrofine graphite cuts nearly twice as fast as all other graphites. Zinc coated wires have also increased the speed of wire EDMing graphite electrodes. Some studies show that using zinc coated wires have significantly increased cutting speeds of graphite.



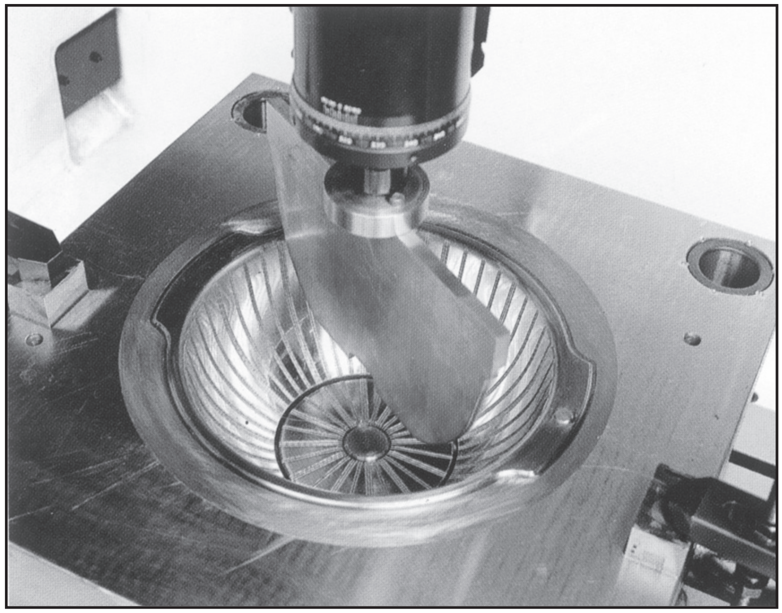
Courtesy Sodick

Figure 11:10

Wire EDMed Electrode and Finished Part

L. Electrodes and C Axis

One of the unique features on some ram EDM machines is the capability of the C axis to rotate. This allows for easy lining up the electrode to the workpiece, and it also allows a single electrode to rotate and cut multiple cavities, as shown in Figure 11:11



Courtesy Sodick

Figure 11:11
Single Electrode and C Axis

M. Electrode Overcut

The EDMed cavity will always be larger than the electrode. The difference between the electrode and the workpiece gap is called the "overcut," or "overburn," as shown in Figure 11:12. The amount of overcut will vary according to the amount of current, "on times," type of electrode, and workpiece material.

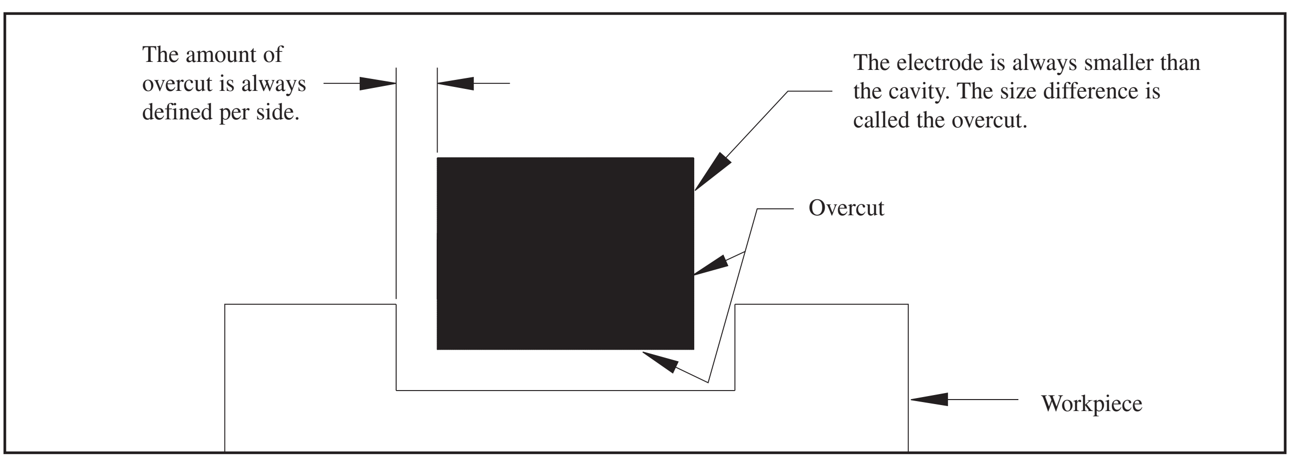


Figure 11:12
The Overcut

The primary factor affecting the overcut is the amount of electrical current in the gap. The overcut is always measured per side. Overcuts can range from a low of .0008" (.020 mm) to a high of .025" (.63 mm). The high overcuts are the results of cutting with high amperages. Most manufacturers have charts showing the amount of overcut operators can expect with certain power settings.

During a roughing cut, greater current is applied to the electrode, causing a greater overcut. A finishing cut, however, uses less current and produces a much smaller overcut.

Given the same power settings and material, the overcut remains constant. For this reason, tolerances to +/- .0001 (.0025 mm) can be achieved with ram EDM. However, when such tolerances are called for, the cost increases because machining time increases.

Recast and Heat-Affected Zone

The EDM process creates three types of surfaces. The top surface contains a thin layer of spattered material that has been formed from the molten metal and the small amounts of electrode material. This surface layer of spattered EDM residue is easily removed.

Underneath the spattered material is the recast (white) layer. When the current from the EDM process melts the material, it heats up the underlying surface and alters the metallurgical structure.

This recast layer is formed because some of the molten metal has not been expelled and has instead been rapidly quenched by the dielectric oil. Depending on the material, the recast layer surface can be altered to such an extent that it becomes a hardened brittle surface where microcracks can appear. This layer can be reduced substantially by finishing operations.

The next layer is the heat-affected zone. This area is affected by the amount of current applied in the roughing and finishing operations. The material has been heated but not melted as in the recast layer. The heat-affected zone may alter the performance of the material.

There can be significant differences between wire and ram EDM heat-affected zones. When roughing with ram EDM, much more energy can be supplied than with wire EDM. This greatly increases the heat-affected zone with ram EDM. On thin webs it can create serious problems because the material will be heat treated and quenched in the dielectric oil. This can cause thin webs to become brittle.

When dielectric oil is heated, the hydrocarbon in the oil breaks down and creates an enriched carbon area in the cutting zone. This carbon becomes impregnated into the surface and alters the parent material. Often, this surface becomes hard and makes polishing more difficult. To avoid heat problems when EDMing thin webs, parts should be premachined and EDMed with lower power settings.

Today's newer power supplies create about half the depth of heat-affected zones as older machines. This shallower depth reduces the need for removing more material to reach base metal.

The depth of the altered metal zone changes according to the amount of current applied, as shown in Figure 11:13. A careful finishing operation can greatly reduce these three layers of the heat-affected zones.

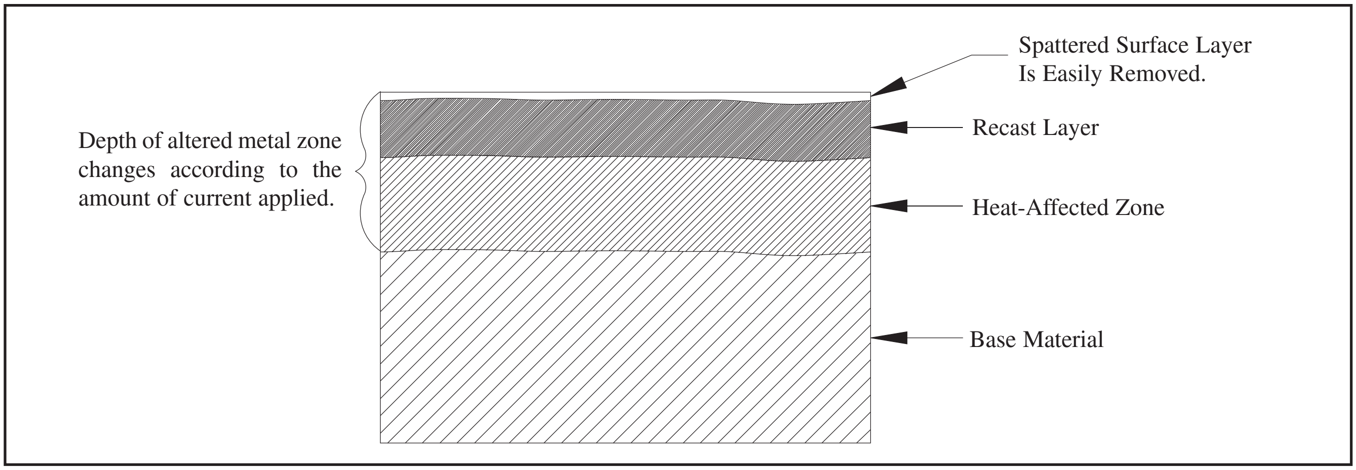


Figure 11:13

Metal Zones Altered by EDM

Finishing

Knowing the principle of the overcut is important to understand the resulting surface finish. When high current is applied to the workpiece, it produces large sparks and large workpiece craters. This results in a rough finish, as illustrated in Figure 11:14.

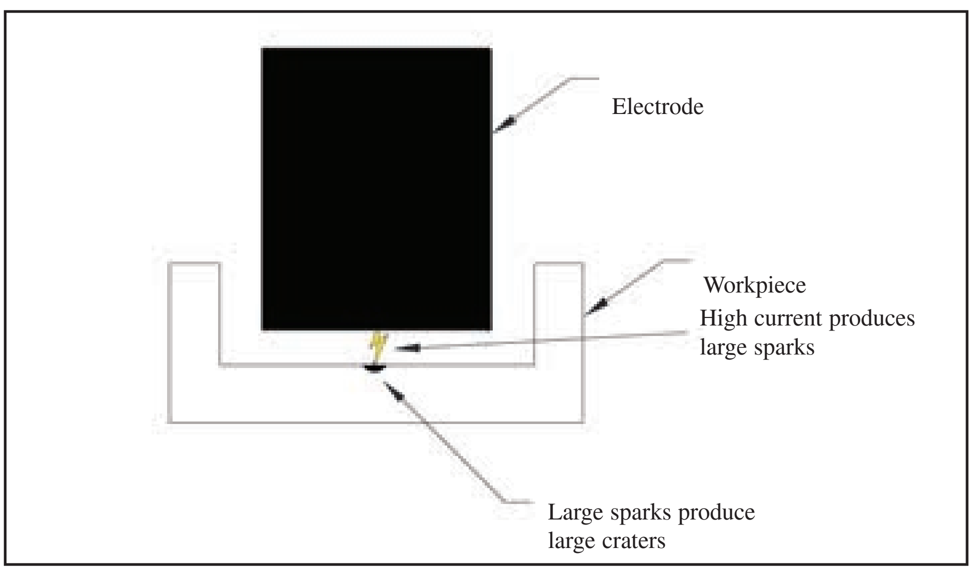


Figure 11:14

Roughing Cut Produces a Coarse Finish

When a slight amount of current is applied to the workpiece, small sparks are produced which create small craters. Applying low current slows the machining process, but it produces a fine finish, as shown in Figure 11:15.

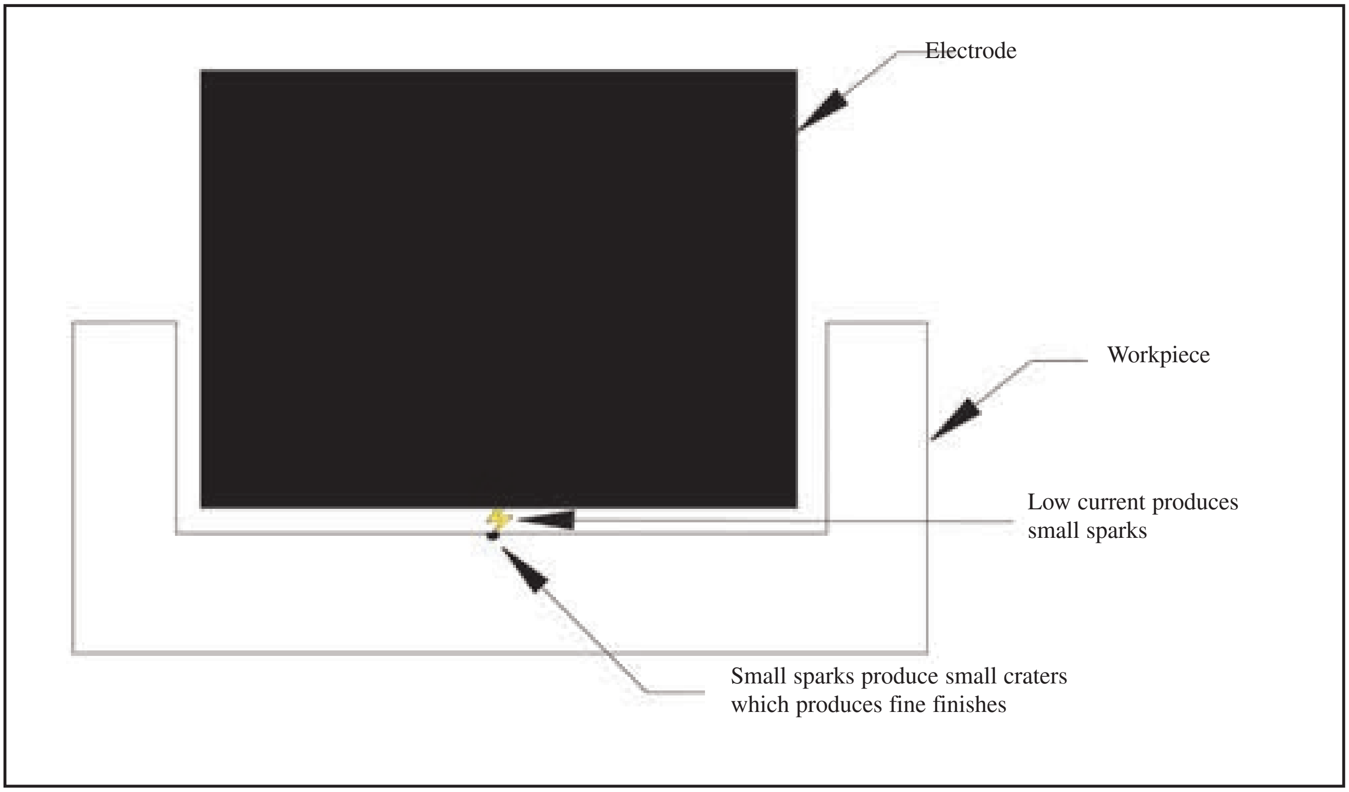


Figure 11:15

Finishing Cut with Low Current Produces a Fine Finish

When a very small amount of current is applied (short on times and low peak current) to the surface of the workpiece, machines are capable of producing mirror-like finishes. Machines equipped with orbiting abilities can also help to produce a fine finish by orbiting the electrode. Certain orbiting machines can be programmed so that the current is gradually reduced until a mirror-like finish occurs.

The workpiece finish will be a mirror image of the electrode. If the electrode is imperfect or pitted, the finish will be imperfect or pitted. A coarse electrode produces a coarse finish. The finer the electrode grain structure, the finer the finish.

Mirror Finishing and Diffused Discharge Machining

Advances in the controls and the dielectric fluid have dramatically improved surface finish. Some machines use a specially formulated dielectric fluid for finishing operations that produces mirror finishes of less than 1.5 Rmax p17µm. Some machines contain two dielectric fluid tanks, one for conventional roughing and semi-finishing and the other for producing mirror finishes.

Manufacturers have discovered that after adding silicon, graphite, or aluminum powder to the dielectric fluid, excellent surface finishes are produced. This process is called Diffused Discharge Machining (DDM). What transpires in DDM is the electrical discharges from the electrode do not first strike the workpiece, but strike the silicon or other particles and generate micro discharges. These micro electrical discharges result in craters so small that they produce a mirror finish. See Figure 11:16.

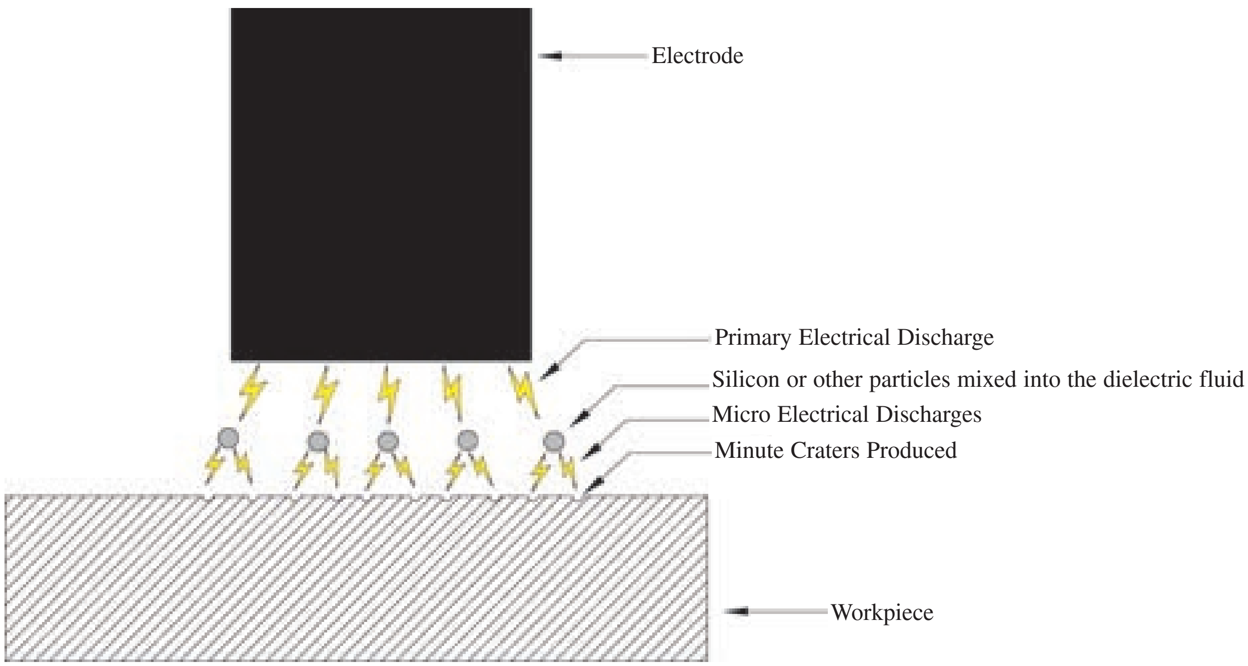


Figure 11:16

Mirror Finishes with Diffused Discharge Machining

The specially formulated dielectric fluid allows the gap distance between the electrode and the workpiece to increase from .0008" to .004" (.020 mm to .1 mm) and more. This larger gap greatly improves the flushing and results in a much more stable cut. Also, the current is distributed more evenly, greater surface areas can be machined, and higher spark energy can be used. The basic rule in finishing is the smaller the spark, the finer the finish. Any method therefore which decreases the intensity of the spark produces a finer finish. In addition, DDM produces a much smaller heat-affected zone.

Micro-Machining

Micro-machining with EDM is being done with electrodes as small as .0004" (.01 mm). Micro-machining uses specialized machines using low power and equipped with microscopes for viewing and inspection.

Micro-stamping is being explored at the University of Tokyo with punches as small as .0012" (.03 mm). They use a wire electrode to EDM the micro punch. The front end of the punch is used to EDM the die section. After the die section is EDMed, the front end of the punch is removed by EDMing the thin section off. They use the micro punch to stamp .002" (.05 mm) phosphor bronze material in the EDM machine. Obviously, this procedure is not for volume production. See Figures 11:17-20.

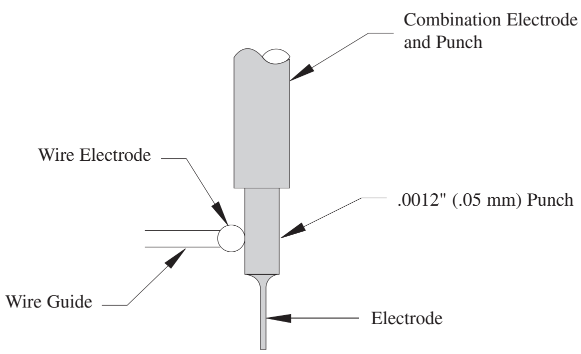


Figure 11:17

Step 1. A wire electrode is EDMing the micro punch.

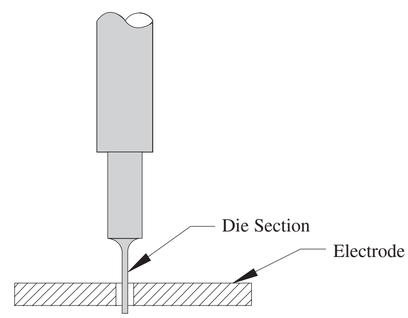


Figure 11:18

Step 2. The front end of the punch is used as an electrode to EDM the die section.

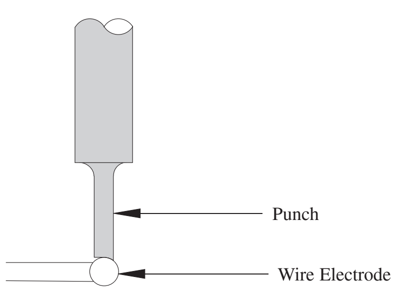


Figure 11:19

Step 3. The front end of the electrode is removed by the wire electrode.

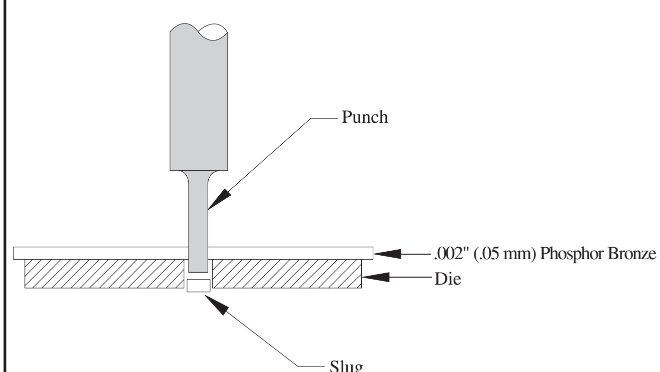


Figure 11:20

Step 4. The material is stamped in the EDM machine.

Figures 11:17-20

Micro-Machining

For small holes and slots, lasers have been the instrument of choice. However, sometimes the edges of the laser holes or slots have poor edge definition. With micro EDM, the edges of the holes and slots are square. This capability is particularly useful for items such as optical apertures and guides, ink-jet printer nozzles, audio-visual components, and computer peripherals. See Figure 11:21.

Courtesy Panasonic

Figure 11:21

Micro EDM Machine

Ram EDM has many exciting possibilities. The next section covers the function of the dielectric oil and the various ways of flushing.