Mercatech, Inc.

Electrical Discharge Machining Services

EDM Tutorial and Design Guide

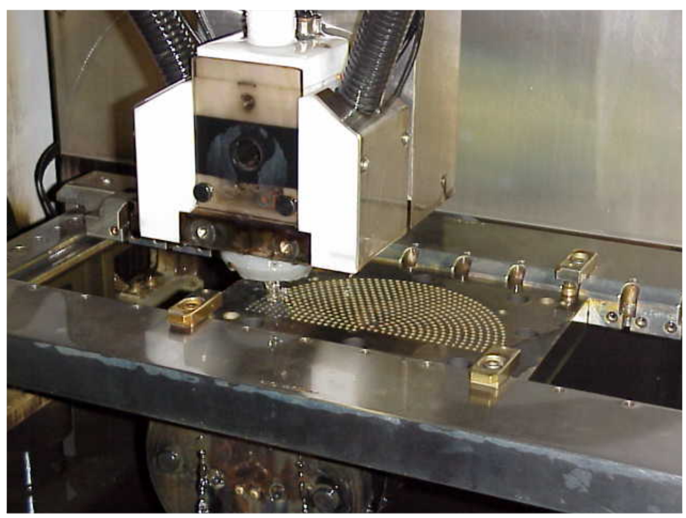
EDM 101: What is EDM?

EDM stands for electrical discharge machining, the applications best suited for this metal removal process are those characterized by extremely exacting tolerances and situations that would be extremely difficult or impossible to handle with any other method of machining.

An Overview Of EDM

The origin of electrical discharge machining goes back to 1770, when English scientist Joseph Priestly discovered the erosive effect of electrical discharges. In 1943, Soviet scientists B. Lazarenko and N. Lazarenko had the idea of exploiting the destructive effect of an electrical discharge and developing a controlled process for machining materials that are conductors of electricity.

With that idea, the EDM process was born. The Lazarenkos perfected the electrical discharge process, which consisted of a succession of discharges made to take place between two conductors separated from each other by a film of non-conducting liquid, called a dielectric. The Lazarenkos achieved a form of immortality with this circuit, which today bears their name. Today, many EDMs use an advanced version of the Lazarenko circuit.



How It Works

During the EDM process, a series of non-stationary, timed electrical pulses remove material from a workpiece. The electrode and the workpiece are held by the machine tool, which also contains the dielectric. A power supply controls the timing and intensity of the electrical charges and the movement of the electrode in relation to the workpiece.

At the spot where the electric field is strongest, a discharge is initiated. Under the effect of this field, electrons and positive free ions are accelerated to high velocities and rapidly form an ionized channel that conducts electricity. At this stage current can flow and the spark forms between the electrode and workpiece, causing a great number of collisions between the particles.

During this process a bubble of gas develops and its pressure rises very steadily until a plasma zone is formed. The plasma zone quickly reaches very high temperatures, in the region of 8,000 to 12,000' Centigrade, due to the effect of the ever-increasing number of collisions. This causes instantaneous local melting of a certain amount of the material at the surface of the two conductors. When the current is cut off, the sudden reduction in temperature causes the bubble to implode, which projects the melted material away from the workpiece, leaving a tiny crater.

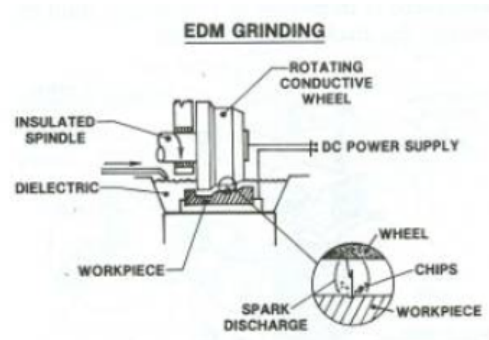
The eroded material then resolidifies in the dielectric in the form of small spheres and is removed by the dielectric. All this without the electrode ever touching the workpiece!

Making EDM a no-contact machining process allowing you to achieve tighter tolerances and better finishes in a wide range of materials that are otherwise difficult or impossible to machine with traditional processes.

Growth of EDM

EDM has rapidly earned its place alongside milling and grinding equipment as a proactive, mainstream technology. EDM is best known for its ability to machine complex shapes in very hard metals. The most common use of EDM is machining dies, tools and molds made of hardened steel, tungsten carbide, high-speed steel and other workpiece materials that are difficult to machine by "traditional" methods.
The process has also solved a number of problems related to the machining of "exotic" materials such as Hastelloy, Nitralloy, Waspaloy and Nimonic, which are used on a large scale in the aeronautical and aerospace industries.
With the reduction in electrode wear and increased sophistication of EDM controls in rams, new EDM processes use simple-shaped electrodes to 3D mill complex shapes. EDM also is being used for polishing small, intricate surfaces.
Since EDM does not involve workpiece/tool forces like a mill or grinder, it is possible to EDM shapes that would break conventional cutting tools or be broken by them.

Different Types of EDM



RAM EDM

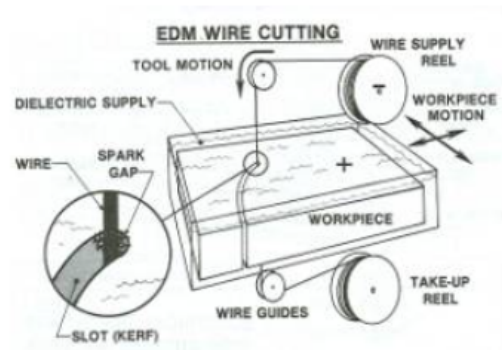
RAM EDM, also known as plunge EDM or standard EDM, is the oldest form of EDM machining. It generally consists of an electrode usually made out of graphite that is plunged into a workpiece in order to create a blind-shaped cavity. It can also be used to generate through holes and geometry but these are not the primary uses of the process.

Drill EDM

Drill EDM uses rotating concentric electrodes to drill through a workpiece and basically performs the same functions as a drill press, except that the material hardness is not a factor and the accuracy of the finished hole is far superior than what any drill press can produce. It is best used to drill start holes for the wire EDM in already hardened material as well as accurate very small holes for industries like aerospace and medical equipment. For reference, our electrode diameters range from .006” to .250”.

Wire EDM

Wire EDM uses a traveling wire electrode (usually .010” diameter or smaller) that goes through the workpiece. The wire, in this case, is controlled by computer following the assigned geometry for the part to be produced. At Mercatech, Inc., with the help of our fully programmable 4 axis EDM equipment, we can produce larger components faster and with greater precision, as well as a higher degree of economy and flexibility for all your EDM machining needs. Our non-traditional integrated approach, as well as technological advantages, can provide you with the best and most profitable solutions. By helping you make the right decisions up front... before machining... your work will be done faster and more cost-effectively than you ever thought possible.



When Should You EDM?

This question can be answered either by looking at geometries produced or materials machined. Hereafter, are two summary tables to help you determine the benefits of EDM for your applications.

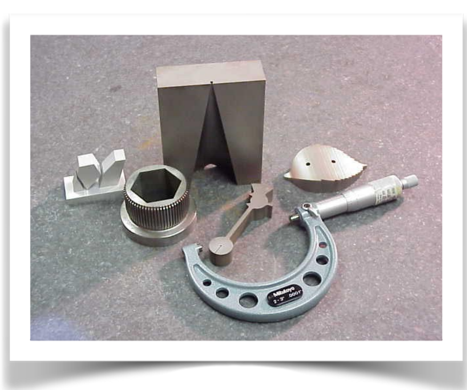


Table I - When To EDM By Geometry	
When	**Why**
Very thin walls	No contact, no force, no deformation
Internal radii equal to or less than 1/32 inch parallel to tool axis	Radius is as small as the spark gap. Generally, tool is not rotated.
High ratios of cavity depth to width, for example, slots and ribs	No force means very think, long elecrodes can be used.
Non-round cavitites/openings	Electrodes don't have to rotate.
Intermittent cuts	No contact, no force
Very small parts (fit in a 0.25-inch cube)	Easy to fixture since no force or vibration is involved
Recessed cuts	Cutting tools couldn't reach cutting area or generate desired shape.
Requires special/unique cutting tools	Electrodes often less costly than special cutting tools. Electrode is easy to machine, unlike carbide. Wire is available standard.
Accuracies that are difficult to hold, maintain after heat treating (stress relieving, and so on)	Can EDM conductive materials of any hardness
Different geometry at top and bottom	Wire EDM cuts ruled surfaces with a simpler program and machine than milling.
Complex shapes	Easier to program because you are using a tool of constant dimension instead of a variety of different diameter milling cutters.
Requires multiple component assemblies	Use taper or recess or depth: diameter capability to make it one piece.
Angled cuts	Ability to 3D orbit in space.

Table II - When To EDM By Material	
When	**Why**
Hardness above Rc 38:hardened steel, Stellite, tungsten carbide	EDM vaporizes material rather than cutting it.
Toughness: Inconel, Monel, Hastelloy, Nitralloy, Waspaloy, Nimoric, Udimet	EDM is non-contact, therefore no adhesion of workpiece to tool.
Tends to leave tough burrs when machined conventionally	Vaporized material is flushed away leaving no burr.
Frail/fragile (can't take stress of machining)	No contact, no force
Expensive material	Lower chip/workpiece mass ratio. Slugs from wire EDM may be reusable whereas chips from conventional machining are recyclable at best.
Certain explosive or flammable materials	EDM takes place under water.
Material with hazardous dust particles	Particles are flushed away to the filter. Reduced risk of fumes.
Note: Workpiece material must be electrically conductive or semi-conductive with no non-conductive cutting zones.	

EDM for tooling applications

When a part requires special/unique conventional cutting tools. Electrodes are easy to machine, unlike carbide. Equally important, the wire used by a wire EDM is available as a standard, off-the-shelf component. EDM is a low cost tooling option when you need short run stamping (under 5,000 pieces) and low volume broaching. With EDM, there's no need to make a die set. That's why EDM is used to make sewing machine components and prototypes. Instead of using expensive broaches, EDM is a very attractive form of low-cost tooling. This is a reason companies use EDM to produce splines and gear teeth along with all their metal stamping & mold making needs.

Limitations of EDM

Clearly, the benefits of EDM are considerable, and it is often appropriate to EDM instead of using conventional manufacturing processes. But not always. What are some of the restrictions of EDM?

- Wire EDM tapering: The maximum taper angle is ±45 degrees.The maximum height/angle is 30 degrees at 16 inches high. in The maximum electrical resistance for workpiece and fixture is approximately 0.5-5.0 ohm centimeter for both wire and sinker EDMs.
- The accuracy of an EDM is limited to about ±0.0001 inch for wire and ram EDMs.
- Surface finish is about VDI of 0 (4 microinch) for wire and VDI of -5(2 microinch) for sinkers.
- Surface integrity is 20 millionths of an inch recast layer thickness for wire and ram EDMs and 20 millionths microcrack length for wire and ram EDMs. The result can be as good or better than a ground surface.

To get the most out of wire EDM capabilities, thorough preparation is essential. Careful attention to items such as, starter hole location, pickup hole or edge preparation, minimum radius and other requirements will simplify your job, reduce time and money in wire burning, and will insure finished part integrity.

The following items are suggestions we came up with. They are the product of experience and *should not be seen as requirements in any way*. Not every job will fit into an "ideal" wire EDM situation. But by using as many of the tips presented hereafter you will reduce the time and money needed in wire burning.

We want to make EDM work for you!

Material Preparation

All material should be clear of burrs and shavings.

All steels should be demagnetized.

Draw an outline of what is to be burnt on top of the material with a marker or a paint pen for easy profile identification. Take this opportunity to write some needed engineering notes where needed. Scribing on blue die chemical is also a valid option if surface finish is not an issue.

Wherever possible try to grind at least two sides, top and bottom parallel to each other.

Drawings

If you have CAD drawings available, please provide them to us.

Include all pertinent manufacturing information like clearances, shrink factors, etc. with your prints or CAD files.

Starter Hole Location

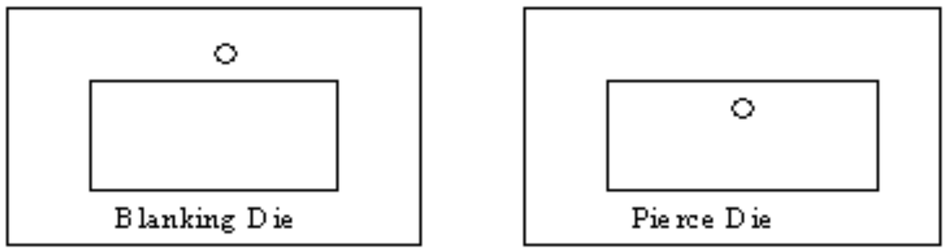
Wire EDM requires a starter hole. We can drill it when you send us the material or you can include it yourself. It is completely up to you.

When possible, the starter hole should be located:

A On a symmetrical centerline or a place that is easy to dimension
B .150 to the inside for dies or die-like profiles
C .150 to the outside for punches or punch-like profiles
D In a common relationship with the punch and the die

E On “One cut punch & die” applications, the starter hole should be placed so as to allow the entry line for blanking and piercing operations as follows: Outside the profile for blanking dies Inside the profile for piercing dies

F Where the “glitch” or wire starting point can be easily dressed or stoned



“Slug the punch” start hole illustration

Starter Hole Condition

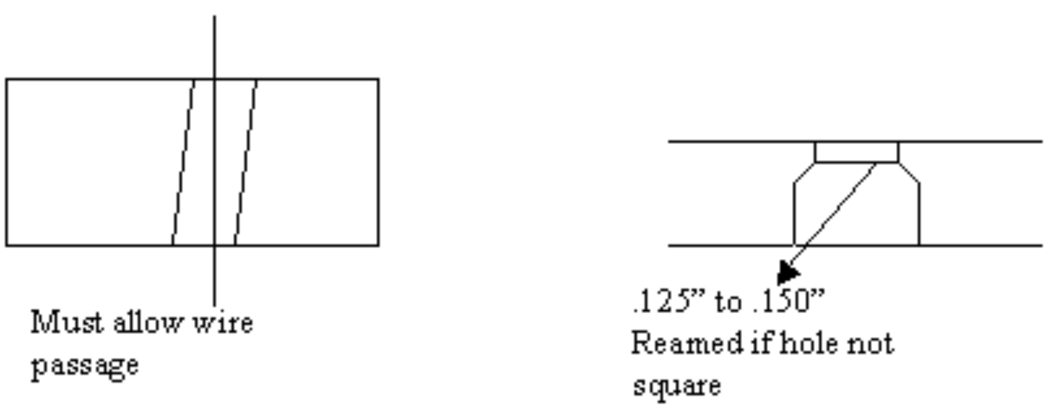
If used for datum location, the starter hole must be round and, either be absolutely square to surface or relieved to present only a small land.

If size is a constraint, the hole must be square enough to allow passage of the taut wire. Note that the most economical and widely used wire diameter is .010”.

Any scale or residue should be cleaned from the hole.

No matter how large the opening is to be cut, the optimum hole size should be no bigger than .125”.

The additional material around the starter hole in the drop area aids in the wire EDM process by keeping the wire in the material.

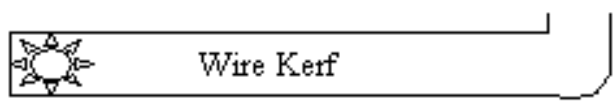


Datum Accuracy

Wire EDM machines use the wire to gain location to a workpiece in a similar way a center and edge finder is used on a milling machine. Except that the wire is way more sensitive than the edge finder. The wire has to go completely through the whole surface of the piece when picking up a hole or past an edge, and will pick up any burr or imperfection causing mis-location. The three typical EDM pick up stations are: a through hole, an edge, a combination of the two.

Minimum Radius Consideration

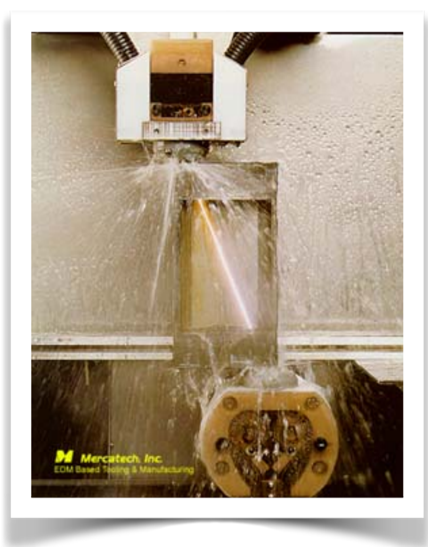
The minimum radius that can be put on an inside corner is equal to half of the kerf on a single pass cut. The kerf being defined as the wire plus the spark gap. In order to get a smaller radius, you must either do several skim cuts, or use smaller diameter wire. Keep in mind that both these options are more expensive due to the increased burning time of multiple passes and the slower cutting speed of smaller wire. Our standard burning wire is .010" in diameter*. It is important for you to consider what inside radius you consider acceptable for your project.*

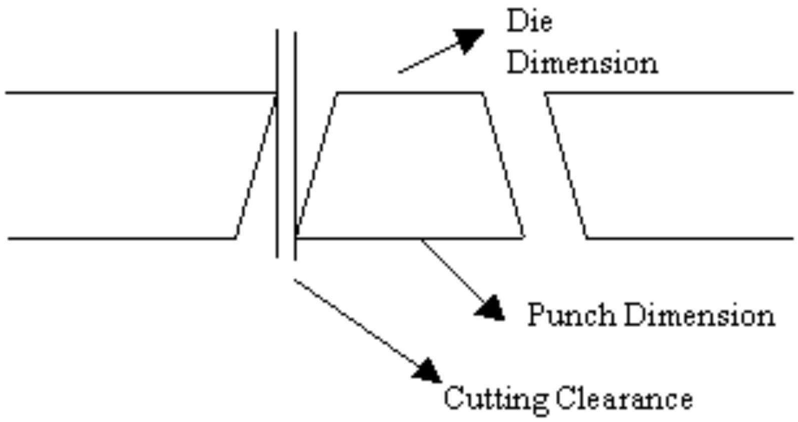


Kerf = wire diameter + (2 X spark gap)

Punch From Die Technique

This technique works very well for short-to-medium run tooling. A punch can be pulled from the die with great economy. This is possible because the small kerf inherent to wire EDM. The angle at which the wire burns is adjusted to produce the required clearance between punch and die. Another advantage of this technique is that the punch and die can be pre-located for perfect alignment before burning.





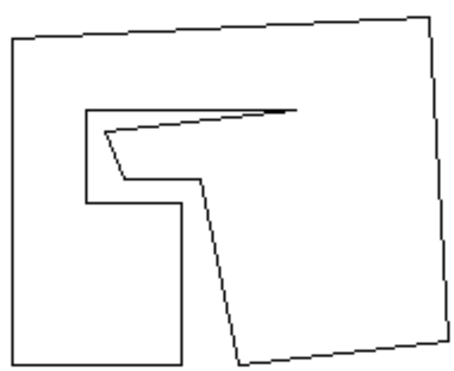
Taper Relief

In the past taper relieving was a less-than-perfect technique, any kind of relief behind a parallel cutting land was acceptable. With wire EDM, accurate tapering is possible on all cut-outs. Current practice calls for relief between ¼ degree and ½ degree with no parallel land. The amount of dimensional change due to regrinding is negligible and is normally acceptable. If required, land and taper relief are possible with additional wire passes.

Accuracy

Generally speaking, +/- .001" is achievable in one cut. Tighter tolerances are possible by making a rough cut and doing multiple skims.

When cutting a punch or punch-like geometry out of a block, it is always better to use a starter hole than cut in from outside of the block, as the stress in the material will find in the lead line a place to relieve itself.



Cutting in from outside of block is to be avoided because of material relief

Whenever possible, it is best to leave between ½” and ¾” of material around all edges to allow for clamping and frame strength while cutting. Even though the frame is usually discarded after cutting, it is a rigid frame which insures finished part integrity.

Design

Because of the increased strength of one piece dies as opposed to split and ground construction, die designed for wire EDM can frequently be made more compact and with fewer stations. Keep in mind when designing components such as feeder plates that with our four axis wire EDM, one component can often take the place of previously several components. Examine your design to ensure that you have taken full advantage of all the numerous benefits of wire EDM machining.

Part-Specific Tips

Punches Plan for your punch blocks to have multiple punches nested in them. One starter hole can go along way in a well nested punch block.

Die Plates We do not have any problem burning dowel holes in die plates, they do, however, add some EDM time to your plate. Convenience and accuracy vs wire time is something worth debating.

Mold Pockets The usual way to construct those pockets is to locate them off the center of the mold base. The best way to pick them up with wire EDM is to provide a starter hole near the center of the mold base. It eliminates extensive and costly four-sided edge pick-ups from all four sides of the base.

Sub Plates & Die Shoes It is preferable not to rough out a sub plate prior to wire EDM. Should you want or have to do it for reasons like handling weight. Please keep in mind to leave between ½” and ¾” material to allow for the wire to be inside the material at all times. Let the wire burn the clearance for you.

Surface Finishes

Surface finishes are measured by instruments known as roughness meters.

Experience proves that measurement of surface finishes by visual and tactile comparison with a standard results in errors not exceeding 2 CH classes.

The roughness criteria are Ra (Europe) CLA (UK) AA (USA)

Mercatech uses the Charmilles scale of roughness. Here is how it relates to the standards.

VDI	Ra		Rt	Class	VDI	Ra		Rt	Class
3400	CLA		Appro		3400	CLA		Appro	
	AA		8*Ra			AA		8*Ra	
CH	Micro mm	Micro inch		ISO 1302	CH	Micro mm	Micro inch		ISO 1302
0	0.1	4	0.8	N3	23	1.4	56	11.2	
1	0.11	4.4	0.88		24	1.62	63	12.96	
2	0.12	4.8	0.96		25	1.8	72	14.4	N7
3	0.14	5.6	1.12		26	2	80	16	
4	0.16	6.4	1.28		27	2.2	88	17.6	
5	0.18	7.2	1.44		28	2.5	100	20	
6	0.2	8	1.6	N4	29	2.8	112	22.4	
7	0.22	8.8	1.76		30	3.2	125	25.6	N8
8	0.25	10	2		31	3.5	140	28	
9	0.28	11.2	2.24		32	4	160	32	
10	0.32	12.8	2.56		33	4.5	180	36	
11	0.35	14	2.8		34	5	200	40	
12	0.4	16	3.2	N5	35	5.6	224	44.8	
13	0.45	18	3.6		36	6.3	250	50.4	N9
14	0.5	20	4		37	7	280	56	
15	0.56	22.4	4.48		38	8	320	64	
16	0.63	25.2	5.04		39	9	360	72	
17	0.7	28	5.6		40	10	400	80	
18	0.8	32	6.4		41	11.2	448	89.6	
19	0.9	36	7.2	N6	42	12.6	500	100.8	N10
20	1	40	8		43	14	560	112	
21	1.12	44.8	8.96		44	16	640	128	
22	1.26	50.4	10.08		45	18	760	144	

Definition of roughness criteria No. CH = 20 log (10 Ra) (micro mm)

Mercatech as a general rule allows a tolerance of +/- 2 CH for surface finish measurement.

Recast Layers

EDM is a burning process that causes the melting away of the metal surface generating a new hardened layer of martensite on the cut surface, this layer is an unstable structure that needs tempering.

This “recast”appears as a thin white layer measuring from .0002” to .003” and is composed of metal that was molten during the EDM burn and resolidified when flushed by the dielectric fluid. It can, therefore, possess a higher carbon contents.

Tests have been performed on such surfaces and have discovered that the hardness of this new layer often measure to a 70 Rc or higher. This explains why tools made with EDM generally will wear slower than tools made by traditional processes. The main problem encountered by some industries is that this layer is always full of minute cracks.

Under this first recast layer we can find a second white layer that will usually measure a hardness of 65 Rc.

A third layer can be found under these, it is a gradient layer of metal that has been overtempered, drawing down the actual hardness level. This layer gets harder as it goes deeper in the metal away from the first 2 layers.

These layers have received many names over the years. The main ones are recast, white layer, heat affected zone (HAZE).

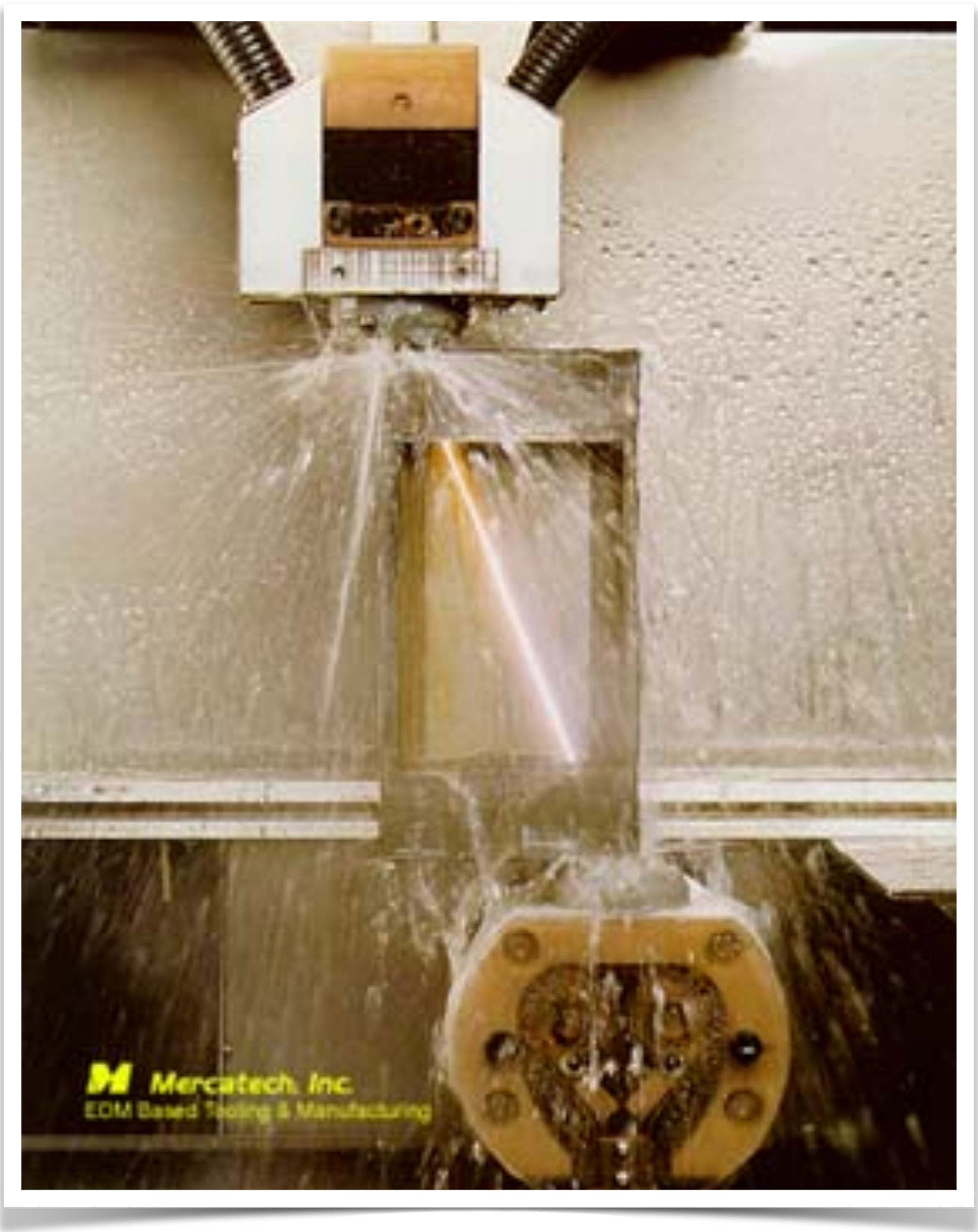
Now what to do with those layers? The answer depends on the application the tool is needed for.

If you want to use the EDMed tool in a wear application such as a stamping die for example. It is then recommended to immediately perform a 250 to 300 degree Farenheit temper to stabilize the fresh martensite layer. After this a very light stoning of the cutting edge will provide you with a long lasting tool.

For high pressure applications like extrusion and injection molding. Both white layers need to be removed either by grinding or lapping. If this is not done the cracks in the outer white layer will cause the tool to fail prematurely.

For all aerospace applications another way of removing the layers may be through the use of chemicals.

Recommended reading on the topic would be: “Heat Treatment, Selection and Application of Tool Steels” by Bill Bryson. ISBN 1-56990-238-0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