

WIRE EDM

“THE FUNDAMENTALS”

BY DONALD B. MOULTON

EDM NETWORK

Sugar Grove, IL

USA

Today, as we embrace the 21st century, there are far greater demands for higher precision in machining, ease of operation, and increased longevity of both the parts, and the machines that make them. CNC Wire EDM can satisfy and meet all these needs. The precision machining of complex geometry's can be easily accomplished with minimal operations.

A B S T R A C T

WIRE EDM FUNDAMENTALS

Today's wire electrical discharge machines have many features and improvements from machines manufactured in the past. This paper is intended to give you a better understanding and basic overview of the fundamentals, features and practical uses of Wire EDM.

HISTORY

The beginning of EDM came during the Second World War, when two Russian physicists B.R. and N.I. Lazarenko published their study on *The Inversion of the Electric Discharge Wear Effect*, which related to the application to manufacturing technology of the capacity of electrical discharges, under controlled distribution, to remove metal.

EDM was being used at that time to remove broken taps and drills. The early “Tap-Busters” disintegrated taps with hand fed electrodes, burning a hole in the center of the tap or drill, leaving the remaining fragments that could be picked out. This saved workpieces and very expensive parts from being scrapped and having to be made over again.

This process opened the birth of Vertical EDM, also called: Sinker, Conventional, Ram, Plunge or Diesinker EDM’s. These machines were, and still are primarily used to make precision cavities in metal primarily for the mold industry.

WIRE EDM

Wire EDM (Vertical EDM's kid brother), is not the new kid on the block. It was introduced in the late 1960s', and has revolutionized the tool and die, mold, and metalworking industries. It is probably the most exciting and diversified machine tool developed for this industry in the last fifty years, and has numerous advantages to offer.

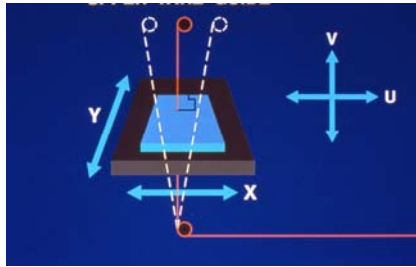
It can machine anything that is electrically conductive regardless of the hardness, from relatively common materials such as tool steel, aluminum, copper, and graphite, to exotic space-age alloys including hastaloy, waspaloy, inconel, titanium, carbide, polycrystalline diamond compacts and conductive ceramics. The wire does not touch the workpiece, so there is no physical pressure imparted on the workpiece compared to grinding wheels and milling cutters. The amount of clamping pressure required to hold small, thin and fragile parts is minimal, preventing damage or distortion to the workpiece.

The accuracy, surface finish and time required to complete a job is extremely predictable, making it much easier to quote. EDM leaves a totally random pattern on the surface as compared to tooling marks left by milling cutters and grinding wheels. The EDM process leaves no residual burrs on the workpiece, which reduces or eliminates the need for subsequent finishing operations.

Wire EDM also gives designers more latitude in designing dies, and management more control of manufacturing, since the machining is completed automatically. Parts that have complex geometry and tolerances don't require you to rely on different skill levels or multiple equipment. Substantial increases in productivity is achieved since the machining is untended, allowing operators to do work in other areas. Most machines run overnight in a "lights-out" environment. Long jobs are cut overnight, or over the weekend, while shorter jobs are scheduled during the day. Most workpieces come off the machine as a finished part, without the need for secondary operations. It's a one-step process.

MACHINE

Wire EDM's are manufactured in various sizes and styles of flush or submerged type machines to fit the needs of the consumer. Large scale EDM's can handle workpieces weighing over ten thousand pounds and can cut over twenty inches thick. Automatic Wire Threaders (AWT) are usually standard equipment on most models. In addition to the X-Y table travels, wire EDM's have U / V travels for providing the movement to cut tapers. Most machines can cut tapers of 20-30 degrees depending on workpiece thickness.



The wire EDM in figure 1 represents current technology. The system consists of a CNC control, power supply with anti-electrolysis circuitry, automatic wire threading, hand held pendant, programmable Z-axis, water chiller and filtration system.



Figure 1

MAJOR COMPONENTS

A Wire EDM system is comprised of four major components.

(1) **Computerized Numerical Control (CNC)**

Think of this as “The Brains.”

(2) **Power Supply**

Provides energy to the spark.

Think of this as “The Muscle.”

(3) **Mechanical Section**

Worktable, workstand, taper unit, and wire drive mechanism.

(This is the actual machine tool.)

Think of this as “The Body.”

(4) **Dielectric System**

The water reservoir where filtration, condition of the water (resistivity/conductivity) and temperature of the water is provided and maintained.

Think of this as “The Nourishment.”

We'll look at each of these components in more detail, but first lets look at how wire EDM works.

PRINCIPLE OF WIRE ELECTRICAL DISCHARGE MACHINING

The Spark Theory on a wire EDM is basically the same as that of the vertical EDM process. In wire EDM, the conductive materials are machined with a series of electrical discharges (sparks) that are produced between an accurately positioned moving wire (the electrode) and the workpiece. High frequency pulses of alternating or direct current is discharged from the wire to the workpiece with a very small spark gap through an insulated dielectric fluid (water).

Many sparks can be observed at one time. This is because actual discharges can occur more than one hundred thousand times per second, with discharge sparks lasting in the range of 1/1,000,000 of a second or less. The volume of metal removed during this short period of spark discharge depends on the desired cutting speed and the surface finish required.

The heat of each electrical spark, estimated at around 15,000° to 21,000° Fahrenheit, erodes away a tiny bit of material that is vaporized and melted from the workpiece. (Some of the wire material is also eroded away) These particles (chips) are flushed away from the cut with a stream of de-ionized water through the top and bottom flushing nozzles. The water also prevents heat build-up in the workpiece. Without this cooling, thermal expansion of the part would affect size and positional accuracy. Keep in mind that it is the ON and OFF time of the spark that is repeated over and over that removes material, not just the flow of electric current.

COMPUTER NUMERICAL CONTROL (CNC)

Today's numerical control is produced with the needs of the operator in mind. Programs, machine coordinates, cutting speeds, graphics and relevant information is displayed on a color monitor, with easy to use menu's.

The control unit displays menu's that are designed to give top priority to operability. Characters and commands are input using the keyboard. The system is very easy to use, allowing the operator to quickly become familiar with it, resulting in his/her learning curve being drastically reduced.

Besides executing NC data for positioning movement of the axes, the control amends these movements when using offsets, tapering, scaling, rotation, mirror images, or axis exchange. The control also compensates for any pitch error compensation or backlash error in the axes drives, to ensure high accuracy positioning. The machine has multiple coordinate systems, and jobs can be programmed in absolute or incremental modes saving valuable programming time. For example, multiple jobs can be set-up on the worktable, while storing the separate reference points or locations of these jobs in specific coordinate registers.

The numerical control offers the capabilities of scaling, mirror imaging, rotation, axis exchange and assist programs. This enables an operator to produce an entire family of parts from a single program without the need to edit the program. Mirror imaging is great for left and right handed parts. Scaling is useful when working with "shrink factors" for plastic cavities or extrusion dies. Assist programs find the edge of parts, vertically align the wire, and perform centering routines that are very useful to the operator when setting up jobs.

Other features include technology to aid in the prevention of wire breaks, background editing and graphic display of programs while the machine is running.



Programs are input through the RS232C, 3.5" floppy disk unit, or keyboard.

One of the most important features that the control handles is offset. Programs are created and written for the center of the tool (wire) to follow the outline of the part. Lets say you are using a .010" diameter wire and it cuts a .012" slot with the power settings provided for the particular material. A .006" offset would be needed to put the part "on-size". Which side of the part (left or right) we apply the offset is determined by two factors.

1. Is the part we are saving, the male (slug), or the female (opening)?
2. Are we cutting the part in a clockwise or counterclockwise direction?

Using a die as an example, the same program can be used to cut the die block, punch pad, stripper, and even the die shoe. By changing the offset amount, the sizes and clearances required are maintained on all the parts.

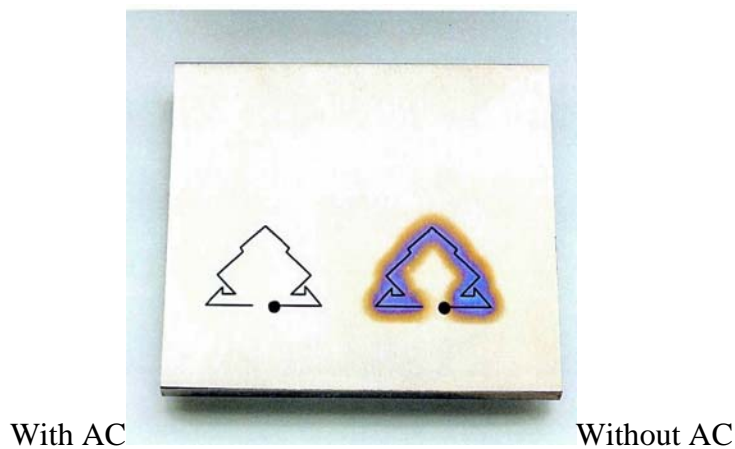
Power Supply

When wire EDM machines were first introduced in the United States, they were equipped with power supplies that could achieve less than one square inch per hour.

Today, most machines are rated to cut over twenty square inches per hour and faster. Faster or slower speeds are obtained depending on the workpiece material, part thickness, wire diameter, type of wire, nozzle position, flushing condition and required part accuracy. .

Adaptive Control is yet another improvement where high speed circuitry has improved the spark gap sensitivity, reaction time of the servo motors, and changes to the power. With these improved capabilities, wire breakage is reduced to a minimum, making today's machines far more "forgiving" than in the past.

Another feature is the anti-electrolysis circuitry that prevents the risk of electrolysis while cutting workpieces that are in the machine for extended periods. This AC circuit also eliminates the blue discoloration that appears when cutting titanium alloys with DC circuits and is a beneficial feature when cutting aluminum.

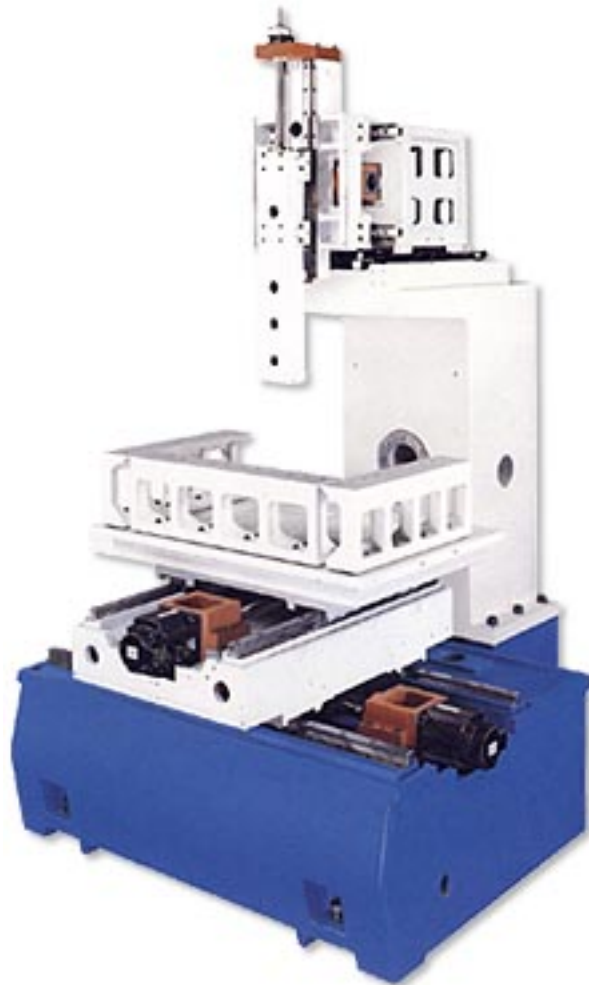


Surface finishes on steel parts today are around sixty RMS for the roughing operations and surface finishes better than $0.5 \mu R_{max}$ can be achieved with multiple skim passes. In many cases, this eliminates or minimizes "benching", hand polishing, or lapping of parts that have fine finish requirements.

MECHANICAL SECTION

Table movement

Machine movement is accomplished with precision lead screws with recirculating ball bearings on all axes that are driven by AC motors. Before shipping, the machine's position is checked and any errors or backlash are corrected by pitch error compensation that is permanently stored in the computers memory.



WIRE PATH

When wire EDM was first introduced, copper wire was used on the machines because it conducted electricity the best. But as speeds increased, its limitations were soon discovered. The low tensile strength of copper wire made it subject to wire breaks when too much tension was applied. Poor flushability was another problem, due to copper's high thermal conductivity. A good portion of the heat from the EDM spark was transferred to the wire and carried away from the workzone instead of using that heat to melt and vaporize the workpiece. There is a vast array of wires to choose from with brass wire normally being used however, molybdenum, graphitized, and thick and thin layered composite wires are available for different applications.

Needs for various wires include: optimizing for maximum cutting speeds, (coated or layered wire) cutting large tapers, (soft brass) or cutting thick workpieces (high tensile strength with good flushability).

Wire diameters range from .004" through .014" with .010" being the most commonly used. The wire originates from a supply spool, then passes through a tension device (different diameter wires require different amounts of tension to keep it straight). It then comes in contact with power feed contacts where the electric current is applied. The wire then passes through a set of precision, round diamond guides, and is then transported into a waste bin. The wire can only be used once, due to it being eroded from the EDM process. (The used brass wire is sold to the scrap dealer for recycling)

AUTOMATIC WIRE THREADING (AWT)

The demand for automatic wire threading (AWT) and dependent reliability has been met with new and improved designs. This feature allows multiple openings to be cut in die blocks, progressive dies, production, and prototype workpieces automatically and unattended without the intervention of an operator, resulting in higher productivity. With the addition of the programmable "Z" axis, workpieces of different thickness, can also be machined. For example, the die openings and dowel pin holes can be machined on a one inch thick die block, then the machine can be programmed to move to another location and machine the punches on a two or three inch thick workpiece.

Cutting and threading of the wire are controlled by codes in the program. If there is a wire break during machining, the machine returns to the start point of that opening, re-threads the wire and move through the program path to the position where it broke, powers up, and continues cutting as if the wire had never broken. Some EDM's can also rethread the wire through the slot. The threading process of the automatic wire threader takes place automatically if there is a broken wire or by a command in the program. In a wire break situation, the end of the wire is clamped while the supply wire is drawn back, annealing and separating the wire, while leaving a sharp point on the end of the supply wire. The wire tip segment that was clamped is disposed of in a wire tip disposal unit. The supply wire is then directed into the lower guide. The wire then proceeds to the back of the machine where it is discarded in a scrap wire bin. AWT offers the ability to cut multiple openings in a workpiece without operator intervention. Parts with multiple openings or even several jobs are cut overnight while many jobs can be cut over the weekend without operator intervention.

Advancements in Taper Cutting

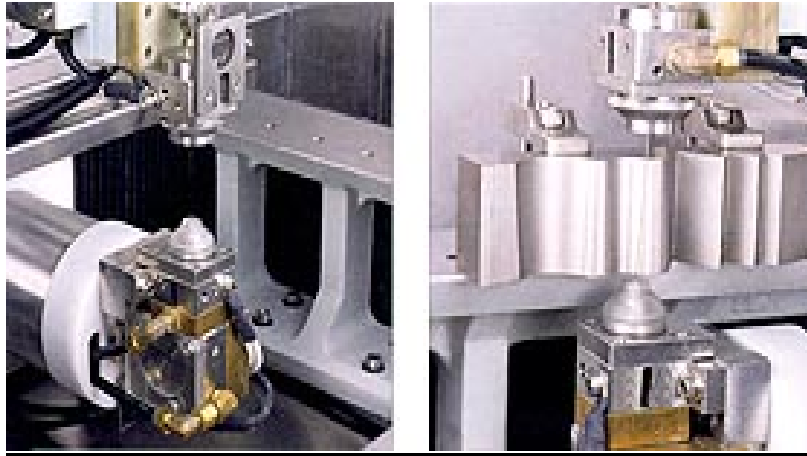
Most Wire EDM's are equipped with a programmable "Z" axis giving precise control of the upper guide assembly to ensure accurate tapers. The rigid U and V axis is positioned away from the work area to avoid moisture, contamination and deflection from the high pressure flush. These axes provide movement to the top portion of the wire to produce taper angles of up to +/- 30 degrees. Both conical and oblique cylindrical radii can be programmed, and the size of the top and bottom radii of the part can also be programmed.

Tapering values can be changed within the program. This is useful for mold applications or form tools that have different side and frontal taper relief angles. Die blocks are normally machined first with their taper relief, then straight cut for their die land.

The machine control knows where the upper and lower guide are in relation to the worktable. The amount of taper angle, and direction the wire is tilted in relation to the program path is in the program. The operator only needs to input where the taper should intercept the workpiece in relation to the work table surface.

For small production runs, parts are made by cutting laminated stacks of material, this is also great for cutting prototype parts. Independent programming of the U & V axes is for workpieces that have a different shape on the top and bottom. The independent, simultaneous movement of all four axes (X, Y, U, V) makes machining extrusion dies, airfoil shapes, and "squircles" (a square shape on the top, and a circle on bottom of the workpiece) quite easy.

TAPERING EXAMPLES



DIELECTRIC SYSTEM

Wire EDM uses deionized water as the dielectric compared to Vertical EDM's that use oil. The dielectric system includes the water reservoir, filtration system, deionization system, and water chiller unit. During cutting, the dirty water is drained into the unfiltered side of the dielectric reservoir where the water is then pumped and filtered through a paper filter, and returned to the clean side of the dielectric tank.

Following filtration, the clean water is measured for conductivity, and if required passes through a vessel that contains a mixed bed of anion and cation beads. This mixed bed resin (the ion exchange unit) controls the resistivity of the water to set values automatically.

The clean water fills the clean side of the dielectric reservoir and proceeds to the cutting area. Used water is drained and returned to the unfiltered side of the dielectric reservoir to complete the cycle. A water chiller is provided as standard equipment to keep the dielectric, workpiece, worktable, control arms, and fixtures thermally stable.

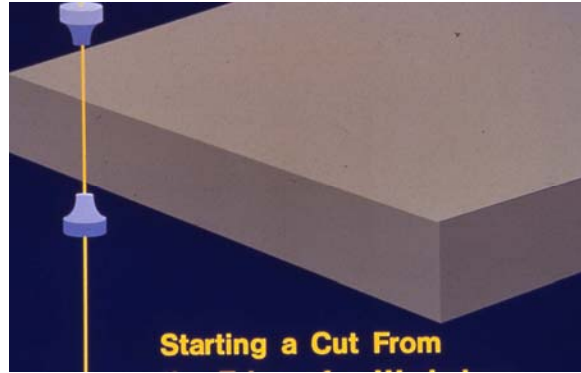
During the cutting process the chips from the material that is being eroded, gradually changes the water conductivity level. Resistivity levels of the water are set according to the cutting requirements of the workpiece material being machined.

Submerged Machining

Submerged machining is extremely useful for applications that generally have poor flushing conditions. Some applications and examples where submerged machining is more practical would be cutting large taper angles, tall workpieces, laminations, tubes, irregular shaped parts, workpieces with undercuts and cutting very close to the edge of the workpiece. Applications where poor flushing conditions exist are numerous. The following examples might exist on any given job.

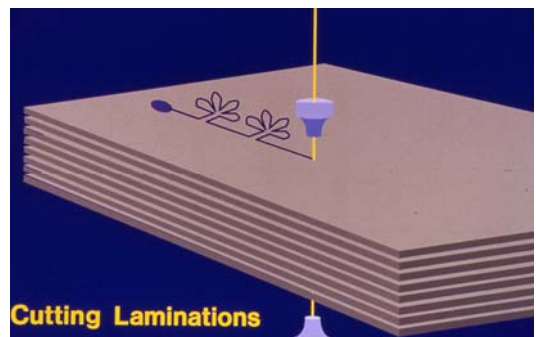
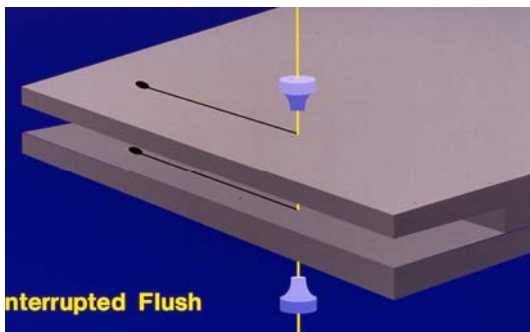
STARTING A CUT FROM THE EDGE OF A WORKPIECE

When starting a cut from the edge of a workpiece, cutting a form tool, slicing a tube or bar stock, or starting a cut from a large diameter start hole, is a slower process without submerged machining capabilities. There is a greater risk of breaking a wire if the flush is not set properly or if too much power is used. This condition is greatly reduced when cutting the part submerged.



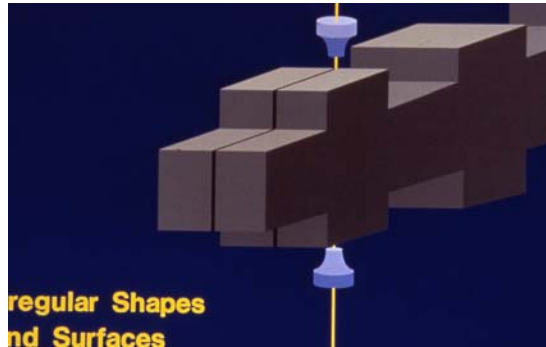
Interrupted Flush

When parts with existing openings, slots or cross holes in them must be cut, conventional flushing produces air pockets and results in reduced performance or wire breaks. Submerged machining provides stable cutting of these parts.



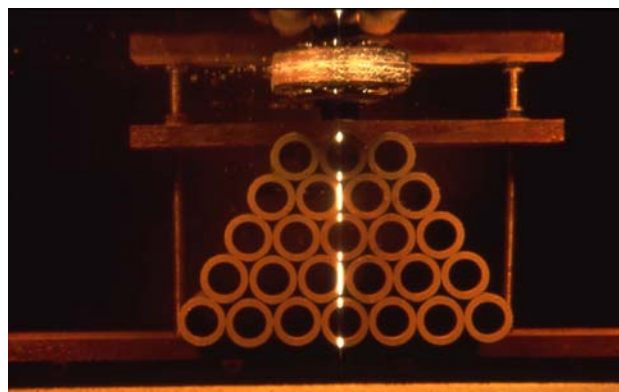
IRREGULAR SHAPES AND SURFACES

When it is not possible to have the flushing nozzles close to the top or bottom of the workpiece, splash flush machines may require constant adjustment of the top and bottom flush. When machining submerged, you can adjust the flush once and forget it.



CUTTING ROUNDS

Cutting round stock or tubing presents a combination of adverse effects. Submerged cutting can efficiently cut these jobs without the flush being impaired. Thermal stability of the entire set-up is enhanced when submerged cutting, thus producing more accurate skin cuts, better surface finishes, and improved part accuracy.



PREVENTIVE MAINTENANCE

You wouldn't drive your car five years or more without changing the oil. You wouldn't let ten or more years pass without painting your house. Well, EDM machines need some tender, loving care too. But, it's not as bad as you might think! Preventive maintenance on your house (painting) takes twenty hours or more; maintenance on your EDM usually consumes twenty to thirty minutes a week or less. Like rotating your tires, conductivity pieces need rotating or indexing, resin need changing, lubricate the system, clean the rollers, check the cables and the AWT.

No matter whose EDM system you own, the lack of maintenance will lead to slower cutting speeds, size inaccuracy, lines in the part, wire breaks, a rougher surface finish, and (eventually) a service call.

Every EDM manufacturer provides comprehensive documentation with their machines. Included with these documents are precise maintenance instructions. These instructions should include: (A) a list of items requiring maintenance; (B) directions for performing each routine; (C) drawings and/or pictures showing locations, exploded views, etc.; (D) the recommended time interval for each preventive routine.

CONCLUSION

WIRE EDM HAS A BROAD RANGE OF APPLICATIONS THAT ARE CONTINUING TO GROW

- . Parts with complex geometry's
- . Parts requiring "tenths" tolerances
- . Parts where burrs can't be tolerated
- . Thin or delicate parts that are susceptible to tool pressure
- . Progressive, blanking and trim dies
- . Extrusion dies
 - Precious metals
- . Narrow slots and keyways
- . Mold components
- . Tooling for forging, or injection molding operations.
- . Medical and dental instrumentation
- . Cutting hardened materials such as carbide, C.B.N. and P.C.D.
 - Cutting difficult to machine materials like hastaloy, inconel and titanium
- . Aerospace, defense and electronic parts
- . Prototypes parts
 - Production parts
 - Form tools and inserts
 - Electrodes (graphite or copper) for vertical EDM

The above list of application represent only a fraction of areas where wire EDM is being used. "The wire EDM process is only limited by your imagination!"

ABOUT THE AUTHOR

Don Moulton is the sales manager for EDM Network, headquartered in Sugar Grove, Illinois. His experiences over the last quarter of a century include many facets of EDM including applications, management, marketing, sales, and over 15 years working directly for EDM manufactures while promoting EDM throughout the United States and Canada

He has authored white papers, publications and has participated in numerous major and local seminars for SME, SPE, NMTBA and served on the EDM steering committee for Gardner Publications (Modern Machine Shop.)