LearnCNC Electrical Discharge Machining (EDM)

This course in an introduction to EDM Wire and Sinker machining technology theory and application.

Module 1: Electrical Discharge Machining (EDM) Introduction

This course is designed to introduce the learner to electric discharge machining.

Electrical Discharge Machining or EDM is a type of machining that uses electricity to erode material away from a part.

EDM is considered a non-traditional machining method, meaning the material does not come off with a traditional chip, like it would with milling or turning.

This course is designed to be used in parallel with the instruction of a subject matter expert.

- Lesson 1: EDM Fundamentals
- Lesson 2: How EDM Works

Module 2: Wire EDM Concepts

This module explains basic wire EDM concepts.

- Lesson 1: The Machine
- Lesson 2: The Wire
- Lesson 3: Applications
- Lesson 4: Machine Setup
- Lesson 5: Production
- Lesson 6: Flushing
- Lesson 7: Filtration

Module 3: Wire EDM Operation

Wire EDM Operation provides easy to understand Wire EDM machine operation through project based learning. This module includes: Overview Setup Operation

- Lesson 1: Wire EDM Overview
- Lesson 2: Wire EDM Programming
- Lesson 3: Wire EDM Job Setup
- Lesson 4: Wire EDM During Cutting
- Lesson 5: Wire EDM Auto Thread and Alignment

Module 4: Sinker EDM Concepts

This module explains the basic sinker EDM concepts.

- Lesson 1: How it works
- Lesson 2: Electrodes
- Lesson 3: C-Axis

- Lesson 4: Setup
- Lesson 5: Flushing
- Lesson 6: Fluid

Module 5: Sinker EDM Operation

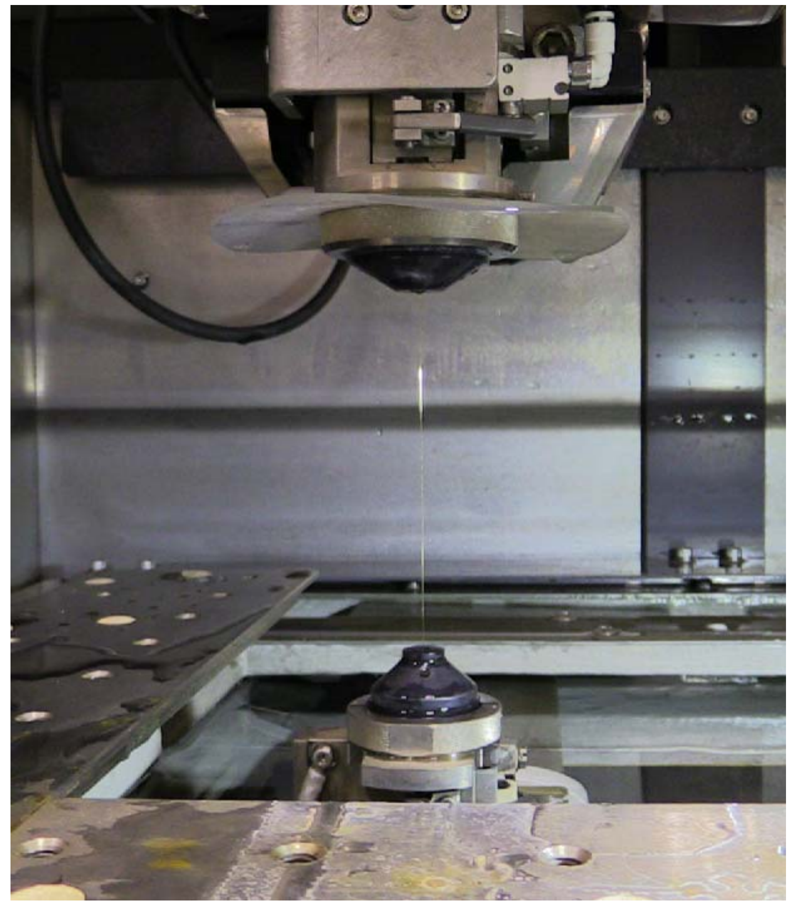
Plunge EDM Machine Operation provides easy to understand Plunge EDM machine operation through project-based learning. This module includes: Overview Setup Operation

- Lesson 1: Sinker EDM Overview
- Lesson 2: Starting up the Machine and Basic Operations
- Lesson 3: Screen Operations
- Lesson 4: Sinker EDM Job Setup
- Lesson 5: Sinker EDM Programming
- Lesson 6: Sinker EDM Before and During Burn

EDM

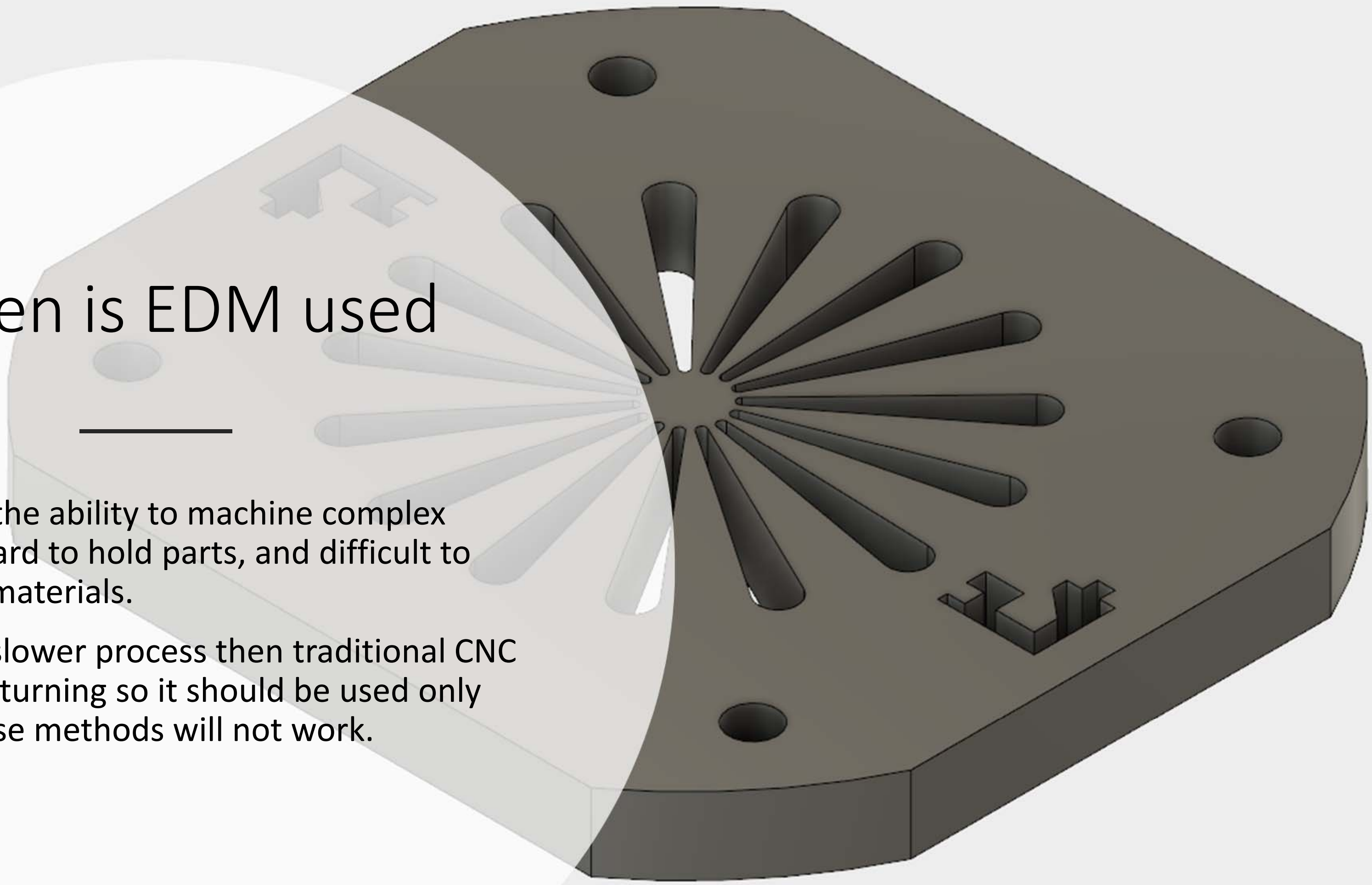
Electrical Discharge Machining

- Electrical Discharge Machining or EDM is a type of machining that uses electricity to erode material away from a part.
- EDM is considered a non-traditional machining method, meaning the material does not come off with a traditional chip, like it would with milling or turning.



When is EDM used

- EDM has the ability to machine complex shapes, hard to hold parts, and difficult to machine materials.
- EDM is a slower process then traditional CNC milling or turning so it should be used only when these methods will not work.



Types of EDM

- There are three major types of EDM machines:
  - Wire EDM
  - Sinker/RAM EDM
  - Small Hole EDM

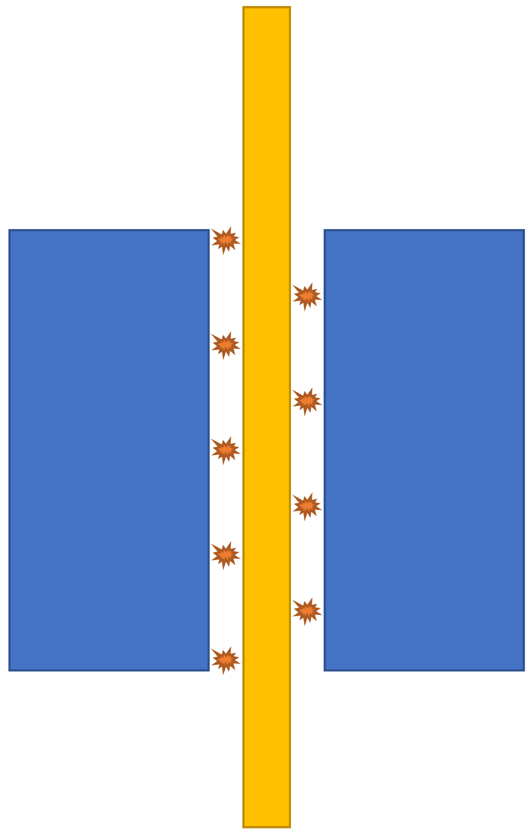
- Each type of EDM has their own unique features for eroding material away from the workpiece.

Materials that can be EDMed

- Any material that conducts electricity can be EDMed.
- The following are examples of material that can be EDMed:
  - Aluminum
  - Steel
  - Inconel
  - Stainless Steel
  - Titanium
  - Copper
  - Brass
  - Tool Steels
  - Graphite
- EDM is a process in which material hardness or machinability have little affect on the cut. Unlike milling or turning where great consideration must be taken in selecting a process based on the material being cut, the EDM process is virtually the same for most materials.

Wire EDM

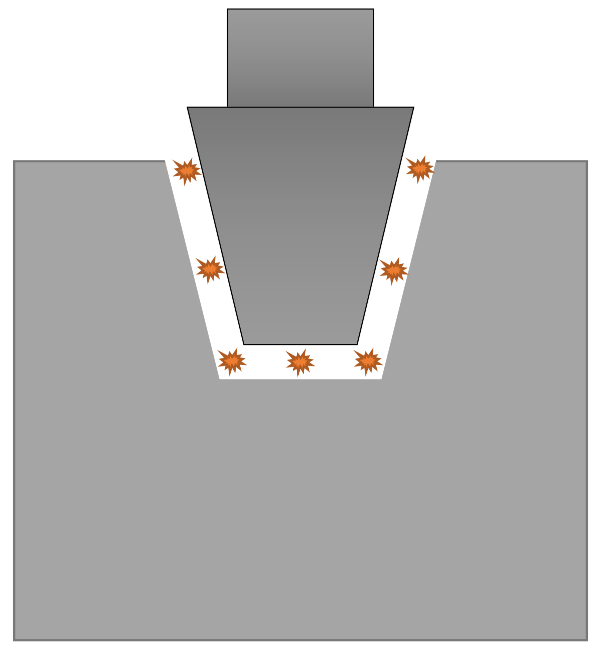
- Wire EDM uses small diameter wire, usually .002”-.012” in diameter, that travels through the workpiece to erode the material.
- Wire EDM can do very intricate shapes but the shapes must go through the part. This is because the wire passes through an upper and lower guide on the machine so that it can cut.



Sinker EDM

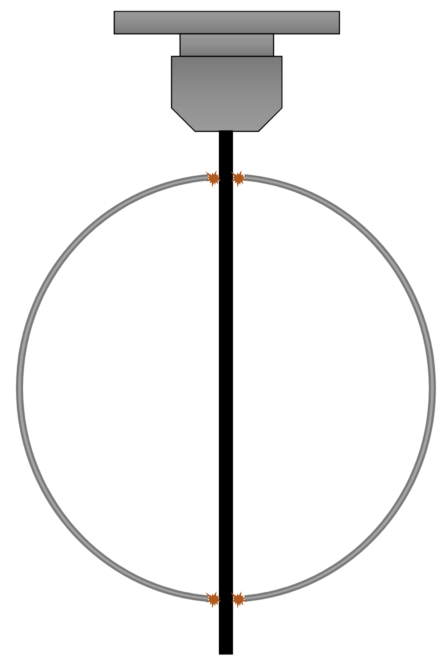
- Sinker EDM, also referred to as Ram or Plunge EDM, can produce blind cavities in a part. This is done by using an electrode that advances toward the part and burns away the material.

- The electrodes are usually brought to shape using a CNC milling center. Once the electrode is shaped, it can then be used in the sinker EDM to burn the material away.



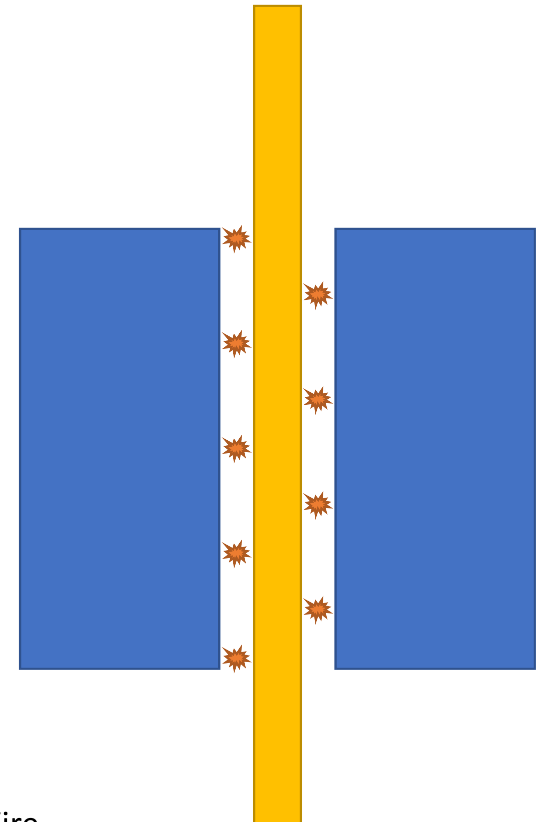
Small Hole EDM

- Small Hole EDM also referred to as hole poppers or fast hole drilling use a small round rotating electrode to drill through the part. The electrodes can be as small as .020" in diameter and drill up 12 inches in depth.



How EDM works

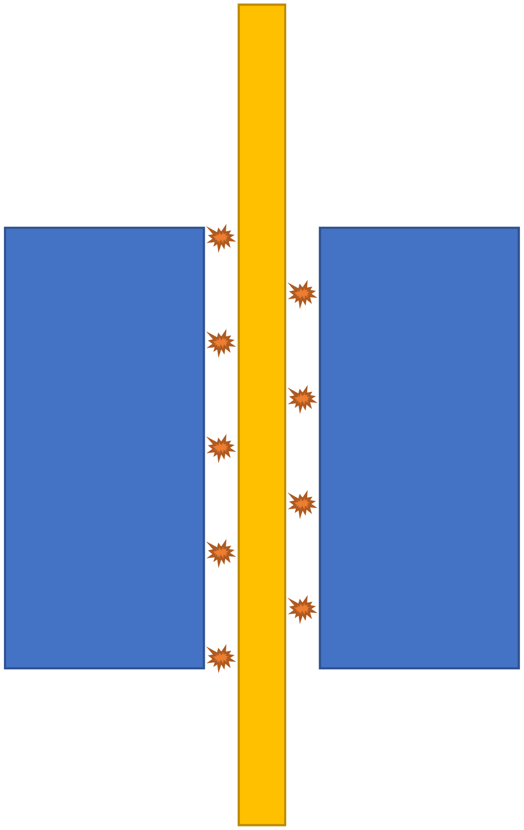
- EDM uses electricity to burn the material away. The process needs three things to work:
  - A positive charge, this is normally the workpiece
  - A negative charge, this is normally the electrode
  - Dielectric fluid, a non-conductive fluid. This acts as a resister, coolant, and flushes the eroded material away



1. Wire
2. DC electrical pulses
3. Polarity
4. Workpiece

Non-Contact

- EDM is a unique process in the fact that the electrode, weather is be wire, sinker or small hole, never comes in contact with the work piece. The electrode simply comes close enough for the spark to happen.
- This means there is no cutting pressure from the EDM process.
- This makes EDM ideal for parts that are delicate or hard to hold.



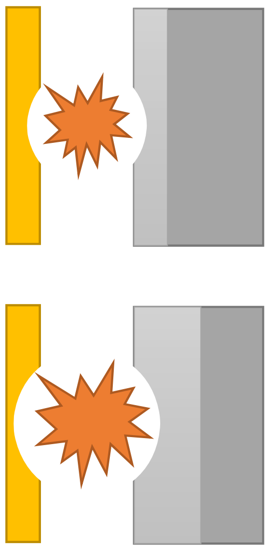
How EDM works

As the machine runs, dielectric fluid insulates the electrode from the part. The surrounding dielectric fluid ionizes and becomes more conductive as the machine runs. This allows controlled sparks to jump from the wire to the workpiece, eroding them both.

- The electrode never touches the workpiece, as sparks erode the material in the way of the toolpath.
- Servos maintain a small gap as the metal is eroded. This prevents short circuits and allows dielectric to flush particles away from the cut.

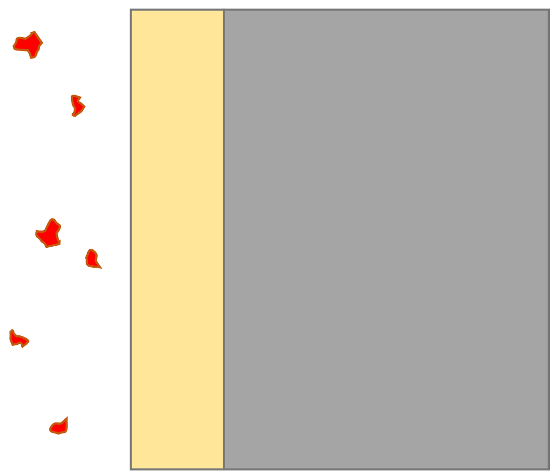
Spark Gap

- The more power that is applied to the cut, the earlier the spark leaves the wire. The spark will also be larger, this means that each spark will remove more material. It also means that the surface finish will be rough.
- To speed up the process rough and finish cuts are often used. The roughing pass quickly removes the material. After roughing a semi-finish and finish pass can be taken to improve the surface finish and accuracy of the cut.



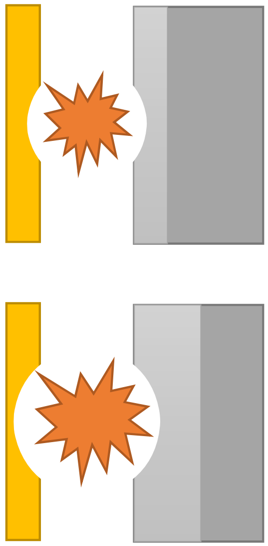
Recast

- As the spark erodes material there is a high amount of heat applied to the work piece, enough to heat the material and burn it away.
- During the eroding process there are multiple layers of material that are created.
  - The first is the material that gets hot enough to vaporize and leave the work piece
  - The second is the layer of material that is heated, but does not get hot enough to leave the part. This is called recast. The properties of this resolidified material changes as a result.
  - The third layer is the unaffected work piece.



Recast

- The more power that is applied to the cut the larger the spark will be. This also means more heat. The spark will cut more but it will also heat the part more. This makes the recast on the part thicker.
- Many parts that require EDM work will specify the amount of recast that a part can have.
- For parts with a recast callout, an appropriate power setting will need to be selected to acquire the needed results.



Hazards

- Dangerous fumes are emitted when cutting, mostly during plunge EDM cutting.
- Ventilation systems should be used during plunge EDM cycles.
- All cutting must be submerged in dielectric, otherwise sparks can cause fires.

Wire EDM

Basic Wire EDM Concepts

- A wire is feed from a spool, through an upper guide, then the workpiece, a lower guide, and into a wire bin.
- This style of EDM is often compared to a bandsaw. A cutting edge runs through a machine, which in turn cuts through the part.
- Wire EDM machines are different from other styles of EDM in that they cut intact shapes out of material. The material cut from the workpiece is a “slug”, which is cut from a “punch”.
- There are two methods of dielectric use:
  - Dry – A stream of dielectric fluid surrounds the wire.
  - Submersed – A housing contains the dielectric fluid, which the workpiece is submerged in.

Machine Layout

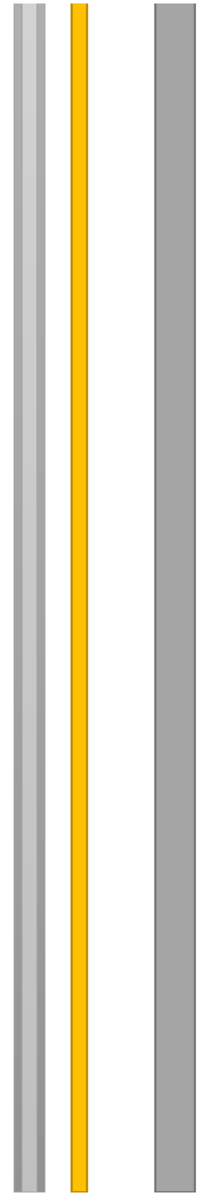
- The spool of wire is located in the head of the machine, it feeds through a series of tensioning pulleys, and then a draw tube. This is were the wire can be cut and annealed for the auto threading process. After the draw tube is the upper guide, once the wire passes through the upper guide it can go through the work piece and onto the lower guide. After the lower guide, the wire is feed into the recycling bin in the rear of the machine.

The Wire EDM Process

- The power supply generates a set voltage and amperage to regulate sparks between the part and electrode.
- A pressurized stream of dielectric insulates the part and electrode until sparks travel between the two. This erodes the material away from the workpiece with great precision.
- After a spark, the dielectric flushes and cools the eroded particles. This spark and off time cycle happens thousands of times a second. No two sparks happen in the exact same place
- The dielectric is filtered through a resin tank to remove impurities and maintain it’s low level of conductivity.

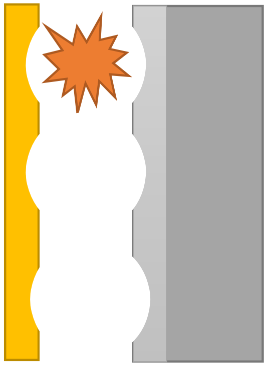
The Wire

- The wire that is used in often made from brass or brass and zinc. There are other variations of wire composition. The material that is being cut effects the type of wire that is used.
- Wire can also be run in different sizes. .002” to .012” wire can be used. The type of material being cut, the height of the part and the details in the part all play a part in choosing wire size.



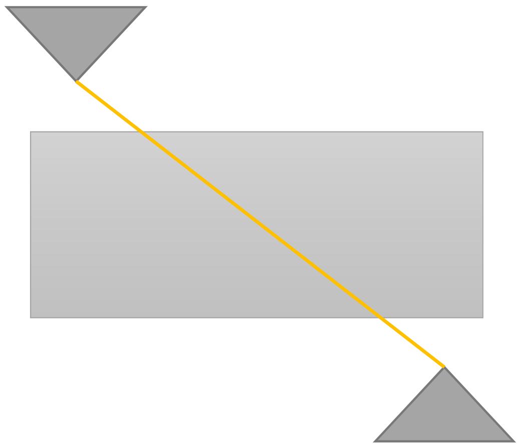
The Wire

- The spark that erodes material from the work piece also erodes material from the wire. The spark leaves pits or impurities in the wire. This means the wire is only good for a single pass and then has to be discarded.
- Many machines have a used wire bin in the back of the machine. To keep the wire from balling up into a mess, production wire EDM machines have an add-on feature that cuts the wire to a set length. This keeps the wire neat and eliminates the chance of balling.



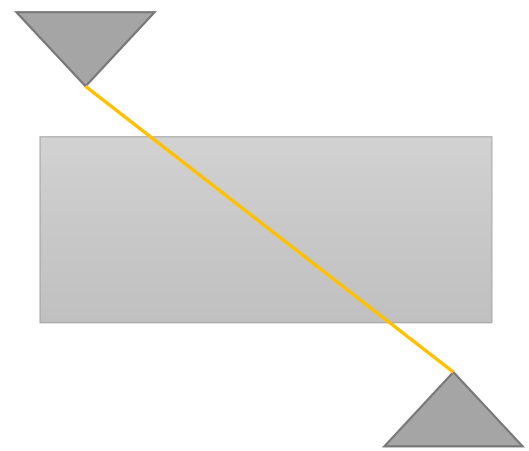
Upper and Lower Guides

- The wire passes through and upper guide. This is in the head of machine were the spool of wire is located.
- After passing through the work piece the wire goes through the lower guide. This guide is located just under the workpiece.
- The upper and lower guides can move independently of each other. This gives the machine the ability to cut tapers.



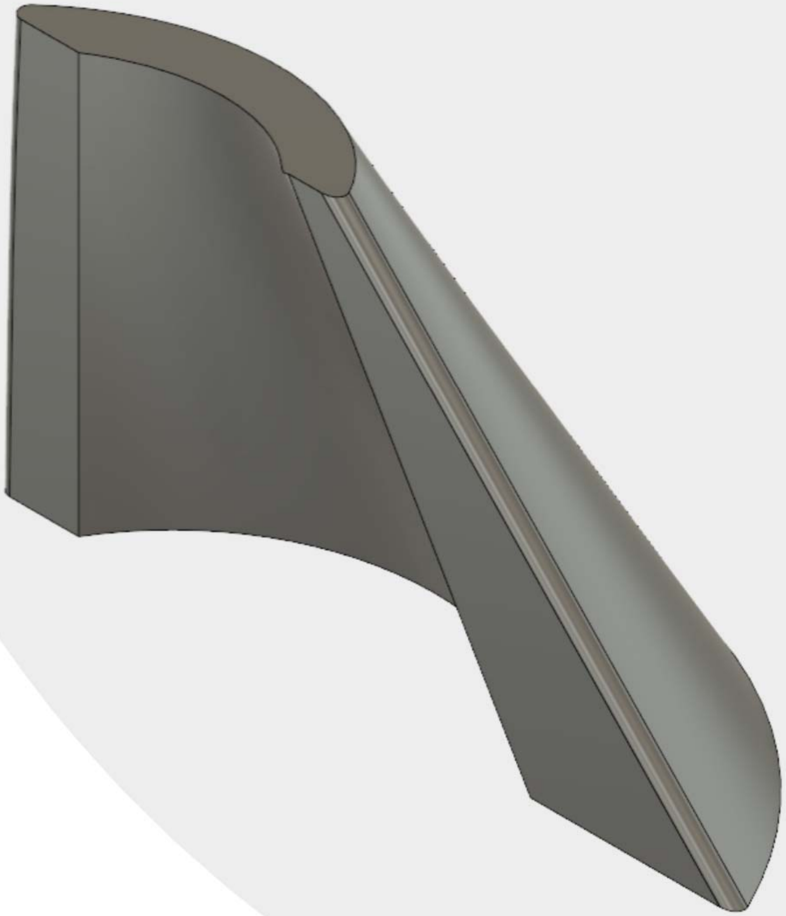
Controlling the Upper and Lower guides

- The upper guide can be moved by X,Y and Z moves in the program.
- The lower guide is controlled by U and V.
  - U is a secondary X axis move.
  - V is a secondary Y axis move
  - W is a secondary Z axis move but is not needed because the lower guide stays at a fixed Z level below the part.



Taper Cutting

- One of the greatest aspects of wire EDM is its capability to cut complex designs at an angle.
- The upper and lower guides the wire passes through can offset with a max wire angle of 45°.
  - The greater the angle that is applied to the wire the more stress that is created on the wire.
- This greatly increases the potential for complex parts.



Submerged cutting

- Submerged cutting is a form if wire cutting where a tank is filled with dielectric.
- The work piece is submerged in the dielectric during cutting operations.
- Care should be taken that particles are being flushed away from the wire.

Applications

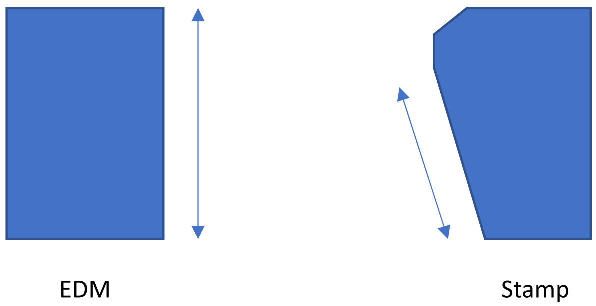
- Many parts are designed with complex geometry that go beyond conventional machine abilities.
- Wire EDMs are great at getting into small spaces, around confined corners, and angled contours that turning or mill turn tools aren’t capable of.

Applications

- Wire EDMs are often used to cut tall parts, especially if the tall part has intricate designs.
- The first wire EDMs were not capable of cutting parts taller than a few inches, now there are machines capable of cutting 60”+ tall parts.

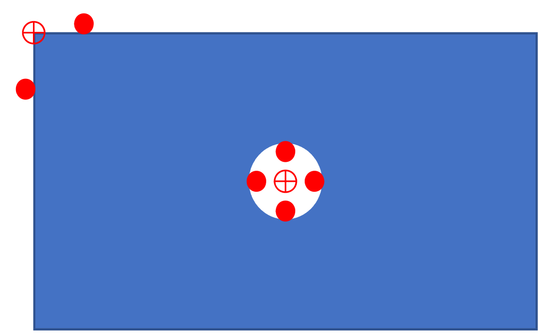
Applications

- Wire EDMs produce great surface finishes, this allows slip fits that are almost indistinguishable from solid parts.
- Since the wire is pulled taut between two guides, the cuts are flat. This is just one advantage EDM has over stamping.



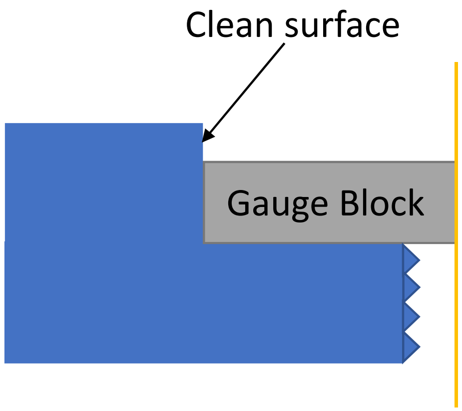
Edge Finding

- Just like with conventional machining, part origins need to be found before running a program.
- Corners & holes are common origins.
- The wire is touched of a part surface and offset to compensate for the wire thickness.
- Corners require two points of contact, while holes require four.



Edge Finding

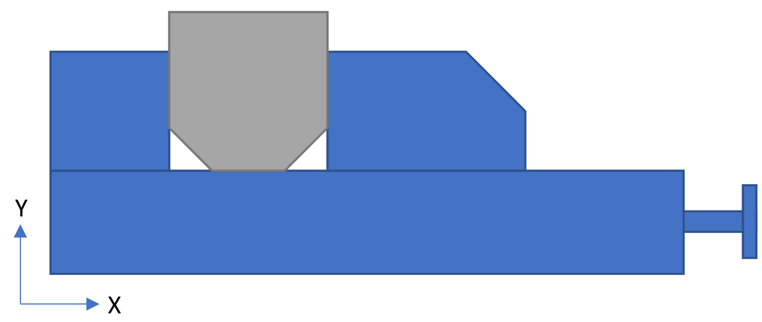
- Make sure contact surfaces are clean and square.
- If a surface has imperfections, gauge blocks and other reference tools can be used to extend accurate surfaces.



This demonstrates touching off a gauge block of a known length.

Workpiece Holding

- Over the years many forms of wire EDM workholding has emerged such as clamps, vises, and chucks.
- These fixtures have clearance in Z for the wire to pass through without interfering with the fixture.
- There are varying levels of technology, from small vises turned on their side, to magnetic chucks that interface with only one face of the part.
- The use of magnets is made possible by the fact that there is no cutting pressure during the cutting process.

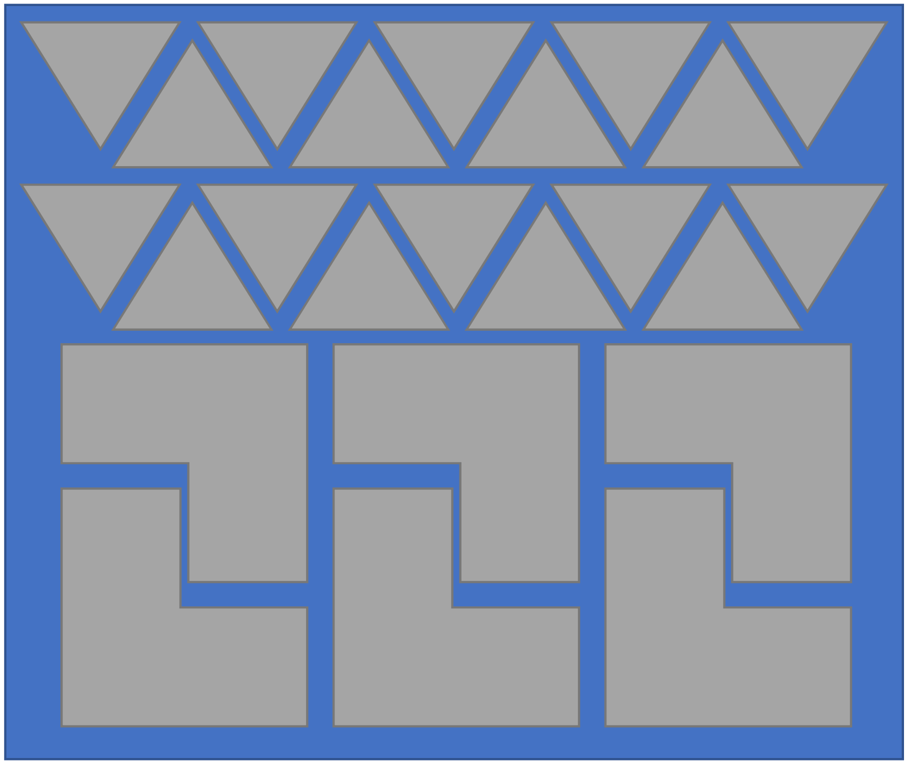


Production Wire EDM

- In the 70s, most EDMs cut at a rate of 2" per hour. There are reports of modern machines exceeding 50" per hour.
- Large diameter coated wires are often used to maximize speed.
- To further maximize production, companies can buy addons such as pallet or tool changers, robots, and many types of software to streamline production.
- Machining costs are often based off machine time, but other factors include:
  - Toolpath length
  - Material
  - Setup time and difficulty

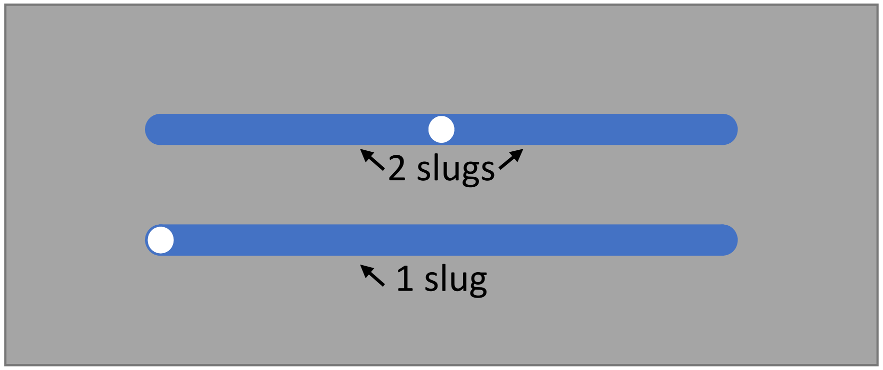
Nesting

- One good practice in machining is to be as efficient with material usage as possible. Therefore, parts should be aligned to get the most parts per workpiece.
- In a sheet part positions can be moved and rotated to reduce waste.



Starter Holes

- The wire cannot simply cut through material axially. So, starter holes must be made if the wire starts in the material boundary.
- These can be made by either drilling or using a hole popper.
- Starter holes should be between 1/8” and 1/4” offset from the desired surface to cut.
- In confined areas, starter holes should be positioned with the intent to reduce the number of slugs produced.
  - Corners are the ideal location.

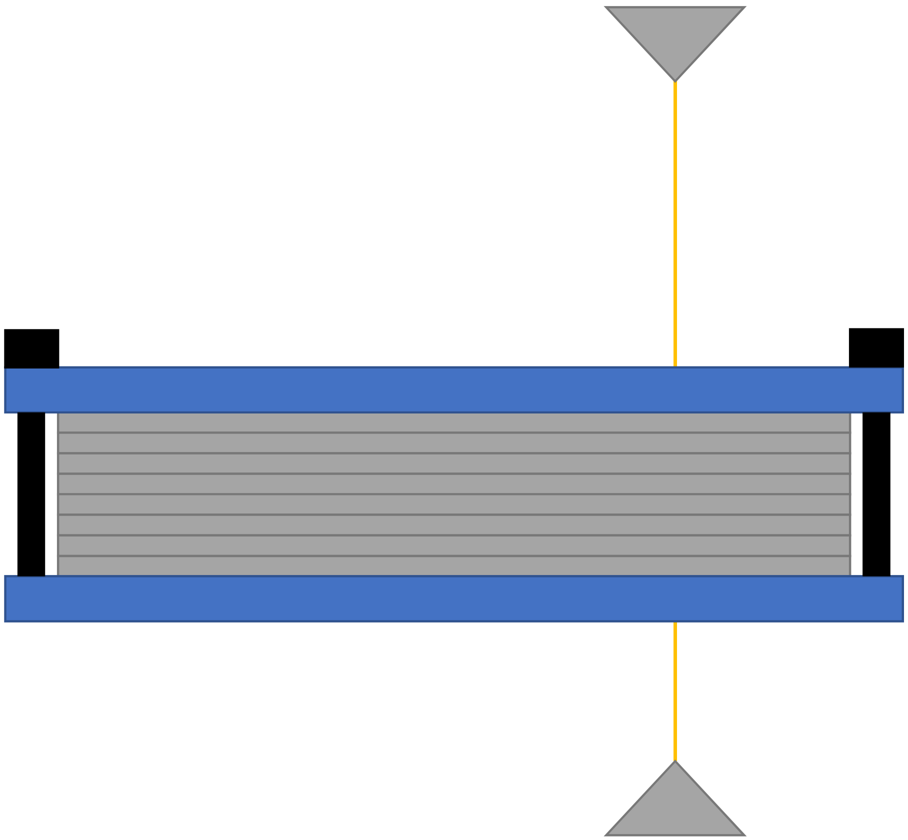


Auto Re-threading

- For many parts, multiple cuts are needed for completion.
- In order to save time, machines have the ability to cut the wire after an operation, then thread the wire through the next starter hole and continue cutting.
- During the threading process, the wire is feed through a stream of water, which keeps it accurately aligned.

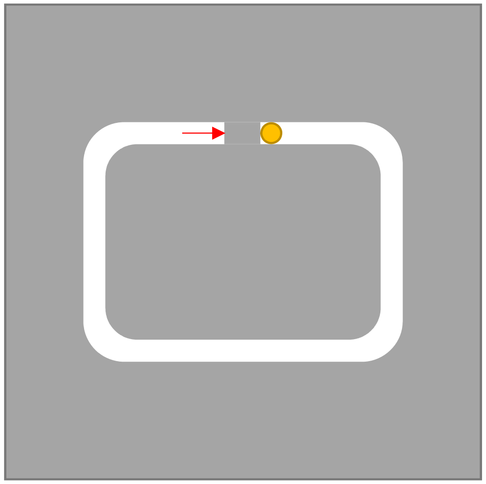
Stacking Parts

- Material can be stacked to cut multiple parts at once.
- A top and bottom plate can be bolted together, sandwiching the workpieces.
- Low quantity work can also be welded together on the outside edges.



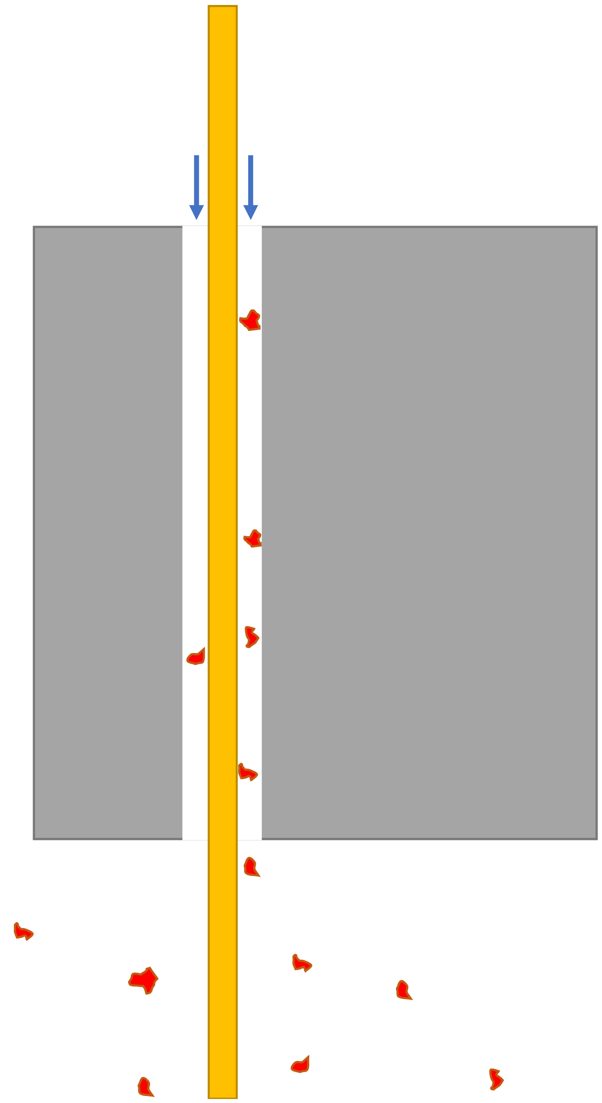
Tabs

- Cutting slugs out of punches introduces a problem. Once a slug is loose it falls, this can interfere with the wire, workpiece, and the EDM machine itself.
- To fix this, tiny tabs of material can be left to hold a slug in place until it's ready to be cut free.
- Standard tab sizes range from 1/8" to 1/4".
- Tabs allow for roughing and finishing passes before the part is cut off.



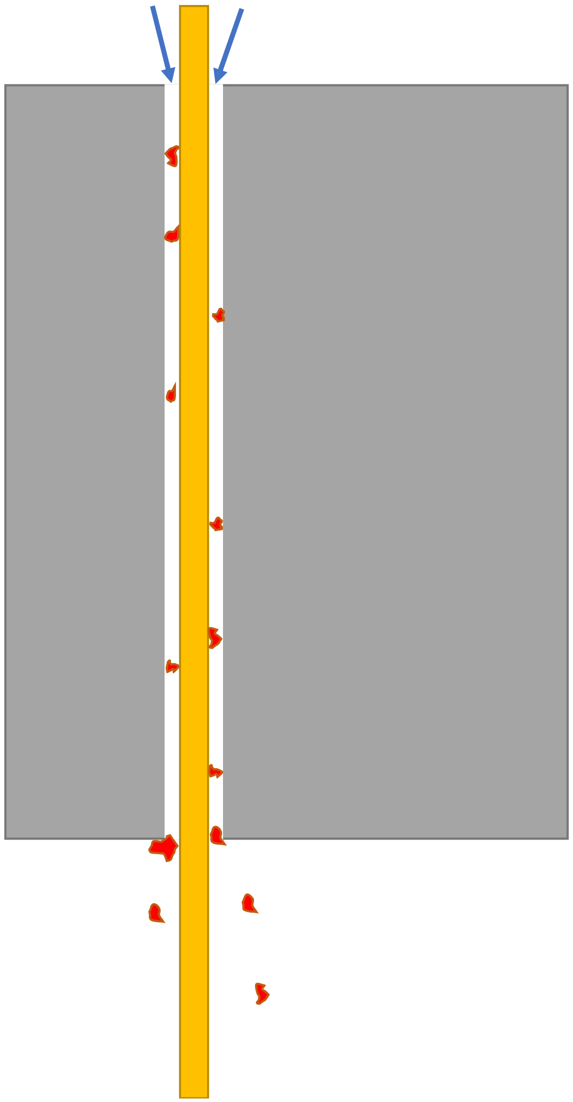
Flushing

- Flushing is added to the wire process to help clean the cut area of particles that appear during the eroding process.
- Flushing happens from the top and bottom heads.
- Each of these have independent pressure adjustment that can used to dial in the cutting process.



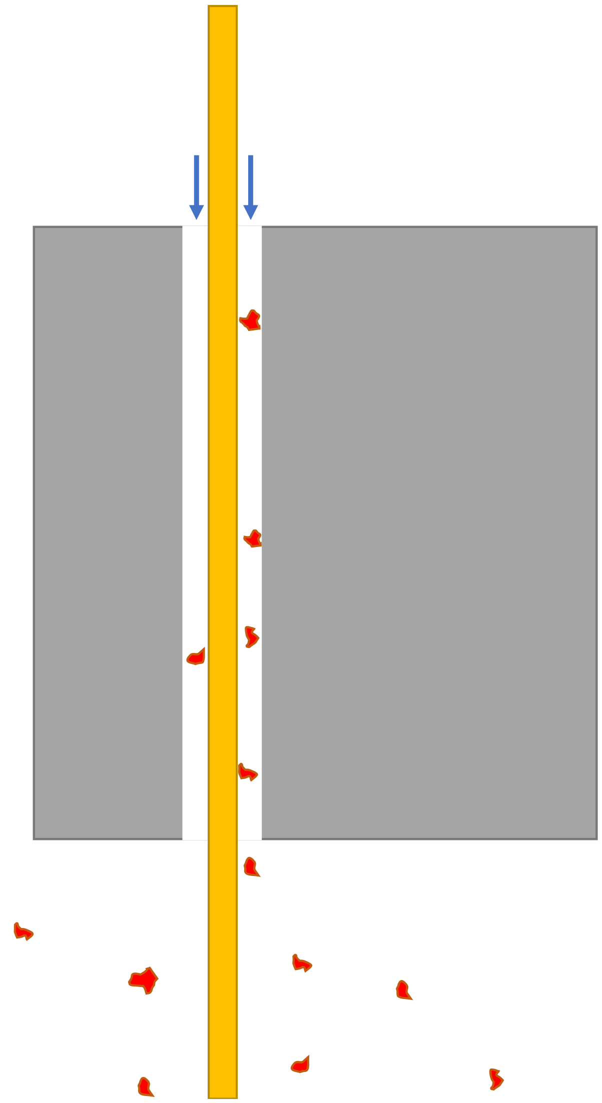
Poor Flushing Conditions

- While flushing helps the eroding process there are a few factors that can effect flushing:
  - Work piece material
    - Some materials cause more contamination while being cut
  - Work piece height
    - The taller the work piece the harder it is to get flushing to the center of the work piece
  - Cavities
    - If the part has an opening or pocket in it, the flushing will be effected by the relief. Once the higher pressure fluid reaches the opening the pressure will be lost because of the cavity or pocket.



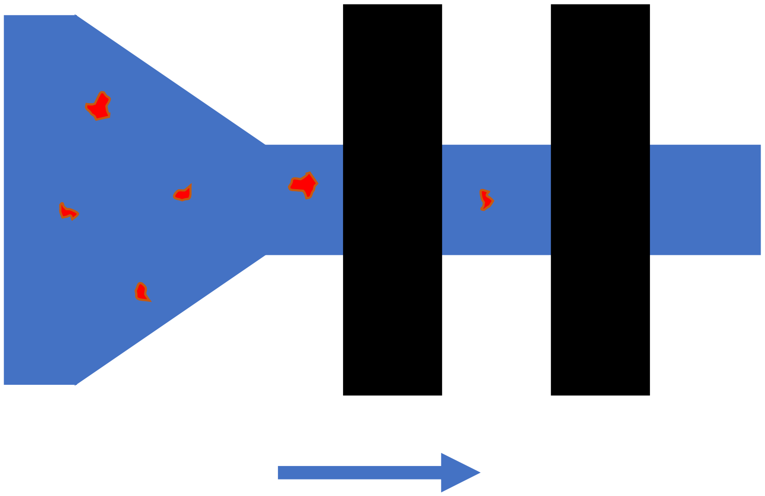
Flushing

- Flushing is using a current in the dielectric to expel eroded particles. It is possibly the most important factor for efficient EDMing.
- The machine should be setup so that the cutting area constantly has fresh dielectric.
- Inadequate flushing can cause eroded particles to reattach to the workpiece, this will likely cause arcs that will damage the part.



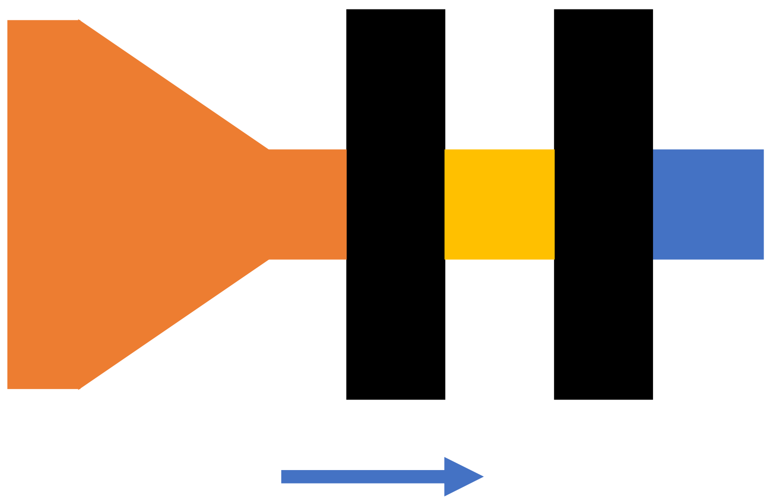
Filtration

- The EDM process causes a large amount of contamination to enter the dielectric fluid. In the case of wire EMD the fluid is deionized water.
- If the particulates are not removed from the fluid they will build up and effect the wires ability to cut.
- To prevent this the fluid is run through a series of filters to remove particles, then it is run through a resin tank to purify the water before returning to the fluid storage tank.



Chilling Dielectric

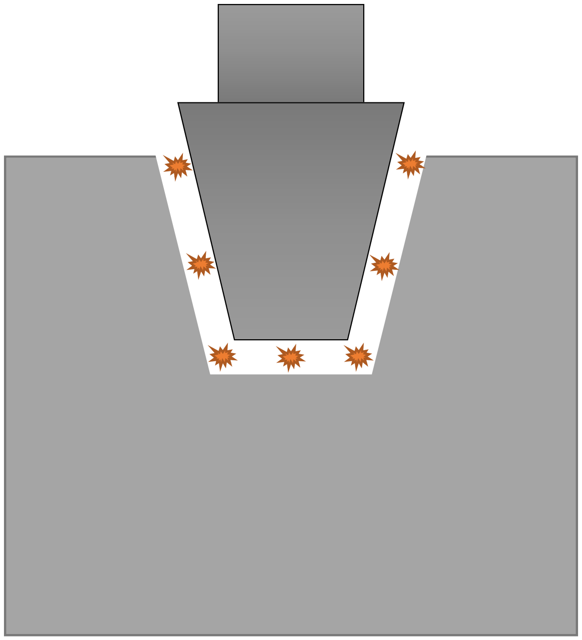
- The EDM process creates heat as material is eroded away. Over time this will heat the dielectric fluid. In production EDM it is important to have a chiller for the fluid.
- The chiller helps to maintain a consistent temperature of the fluid while the eroding process takes place.



Plunge EDM

Basic Plunge EDM Concepts

- A shaping tool is plunged into the workpiece. This erodes a shape into the workpiece.
- Sparks erode material along the whole tool.

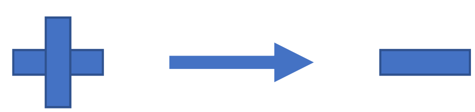


The Plunge EDM Process

- The power supply generates a set voltage and amperage to regulate sparks between the part and electrode.
- A pressurized stream of dielectric insulates the part and electrode until sparks travel between the two. This erodes the material away from the workpiece with great precision.
- After a spark, the dielectric flushes and cools the eroded particles. This spark and off time cycle happens thousands of times a second. No two sparks happen in the exact same place.
- The dielectric is filtered to remove impurities and maintain it's low level of conductivity.

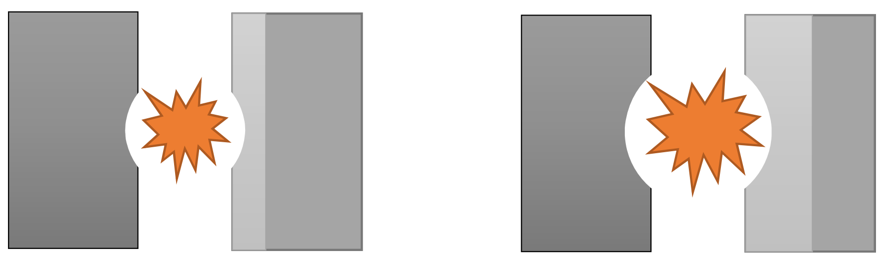
Polarity

- Polarity is the direction of current flow.
- Polarity has more of an impact on plunge EDM than wire EDM.
- Generally, electrodes with negative polarity cut faster, but wear better with positive polarity.
- While cutting carbide, copper, and titanium, negative polarity is generally used.
- Some machines can change the polarity to best suit the situation. This is called polarity changing.



Power Settings

- Amperage affects overburn, the distance between the electrode and the workpiece on one side.
- Higher amps produce more of an overburn, which results in a faster cut but worse finish.
- Lower amps produce slower but better finishes.
- Overburn can often very from .0008” to .025”.
- With consistent power, machines can maintain accuracy of plus or minus .0001”.

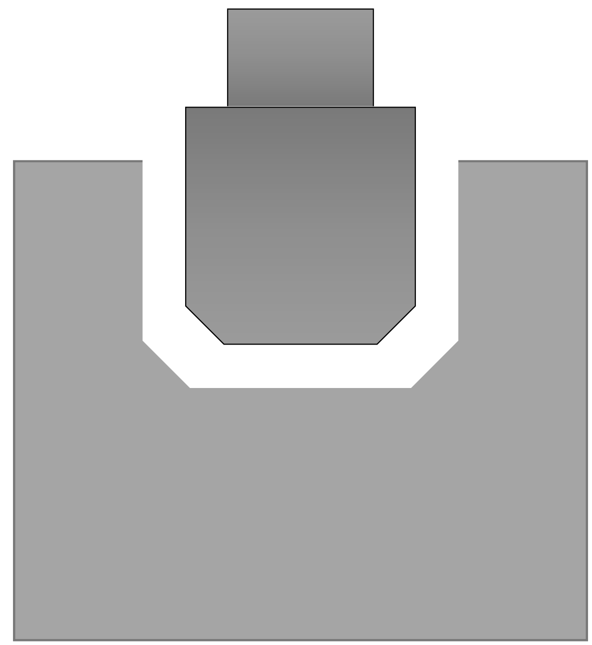


Electrodes

- Electrodes are the tools that erode the workpiece. They can be machined to any desired shape.
- There are two main groups of electrode, metallic and graphite.
- Most metallic electrodes are made of brass, copper, tungsten, and zinc. Combinations of metal are combined for more efficient cutting.
- Graphite and tungsten hold up well because of their high resistance to heat.
- In most cases:
  - Graphite electrodes for high temp. alloys.
  - Metallic electrodes for low temp. alloys.

Electrodes

- Electrodes need to be designed as a mirror image of the cavity being cut. What needs to be removed in the cavity will be the shape of the electrode being made.
- Graphite is a common electrode material when detailed electrodes need to be made.

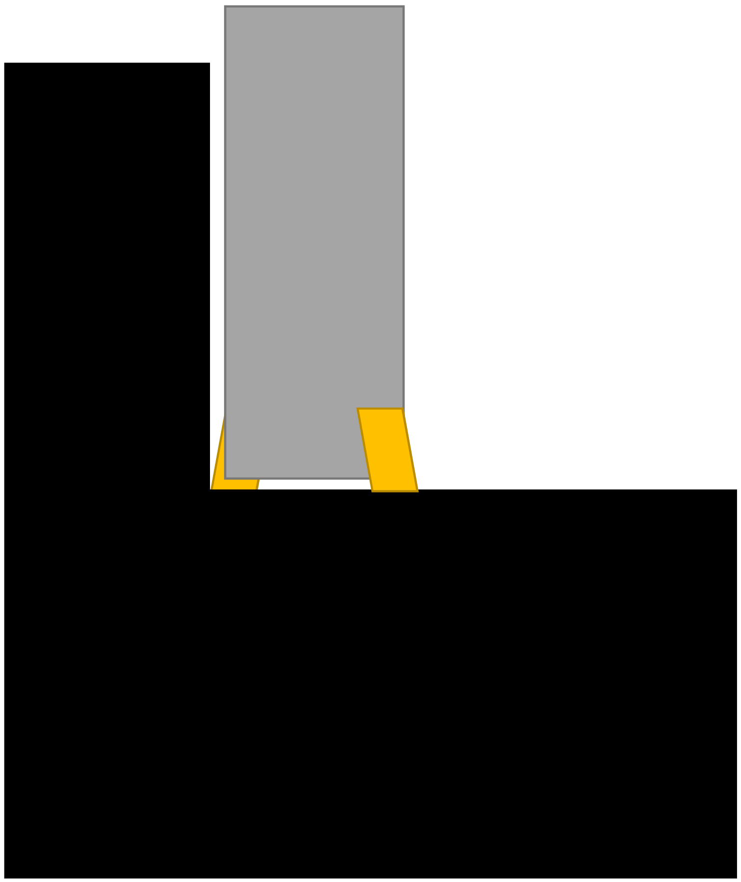


Electrodes

- Graphite is the easiest electrode material to machine. It is relatively soft, but due to its abrasiveness, carbide tools should be used.
- Graphite is extremely messy to machine. When cut, it forms a fine powder that easily spreads, and can cause premature machine wear.
- Use sharp tools with positive rakes for graphite.
- Graphite is porous, so it acquires imperfections the more it is submerged. These imperfections can be fixed by putting the electrode in the oven for an hour at 250°F.

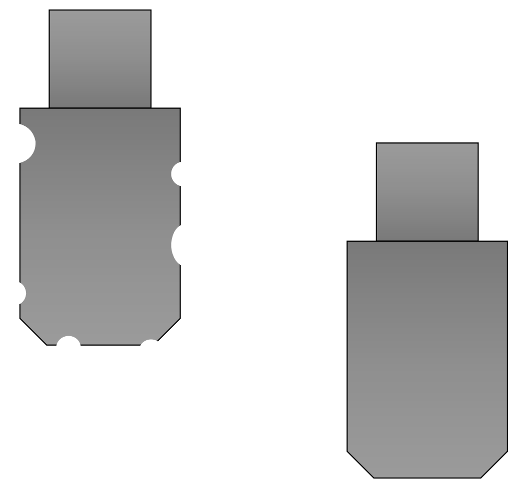
Machining Electrodes

- Electrodes need to be machined to be brought to size. Most electrodes are machined in a CNC mill or lathe.
- The electrode must be rough cut from a block, machined in the CNC and then put into the sinker to cut the part.
- In shops with multiple sinker EDMs, there is often a CNC mill dedicated to machining electrodes.



Rough and Finish Electrodes

- Most companies using EDM sinkers have multiple electrodes for the same process. This is done for efficiency.
- The electrodes are made the same. The newest electrode is used as the finish electrode, once it is no longer acceptable as a finish electrode is becomes the roughing electrode. After the electrode has wear from roughing it goes to be machined. It will be machined down until the wear is completely removed.

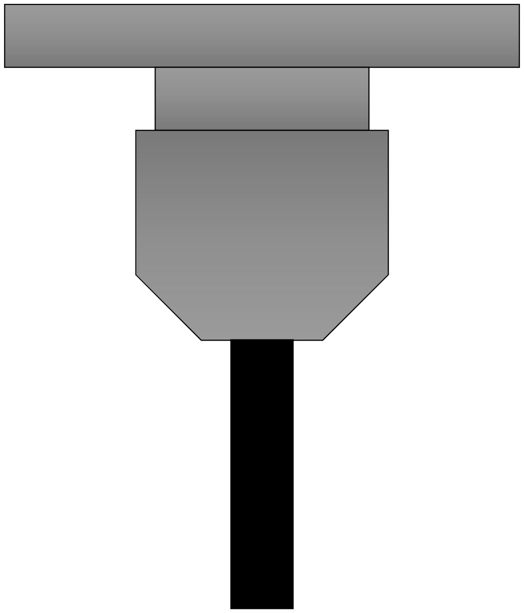


No-Wear

- If an electrode has less than 1% wear it is considered to be in a no-wear cycle.
- No-wear cycles happen when the electrode is positively charged and the off time is longer than the on time.
- While electrodes don’t noticeably wear during these cycles, there is the danger of the part plating the electrode, which would then swell and deform.

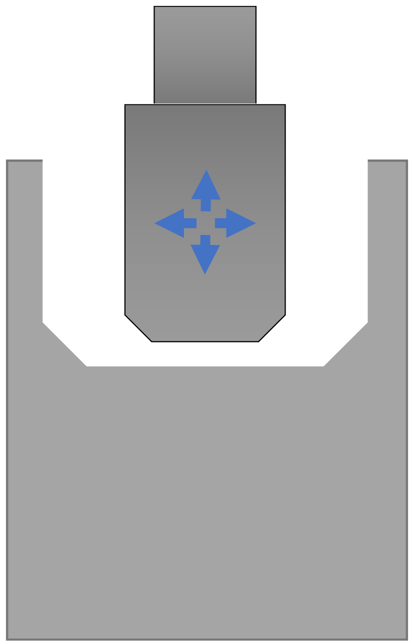
Electrode Holding Systems

- Because electrodes are taken in and out of the sinker and machining centers frequently, quick change holding systems have been developed. These systems accurately and quickly locate and tighten the electrode in place with high repeatability.
- The systems include a chuck and pallet. The pallet is fixed to the electrode. The chuck is permanently fastened in the sinker as well as the machine preforming the electrode machining.



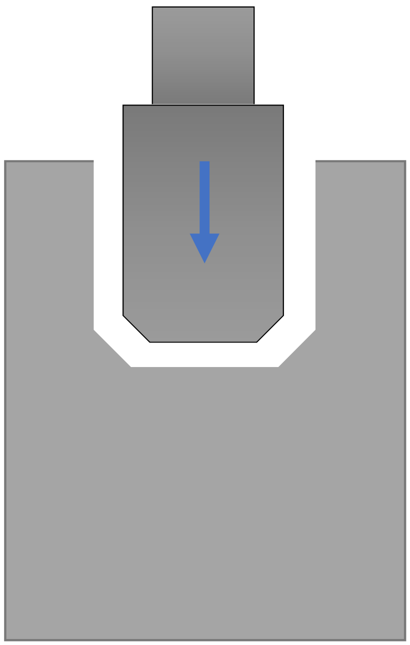
CNC Sinker

- CNC sinker EDMs have the ability to be programmed. This means that the feature positions on the part can be programmed into the machine.
- The electrode can move into position, the power setting can be called up and then the electrode can burn to programmed depth.



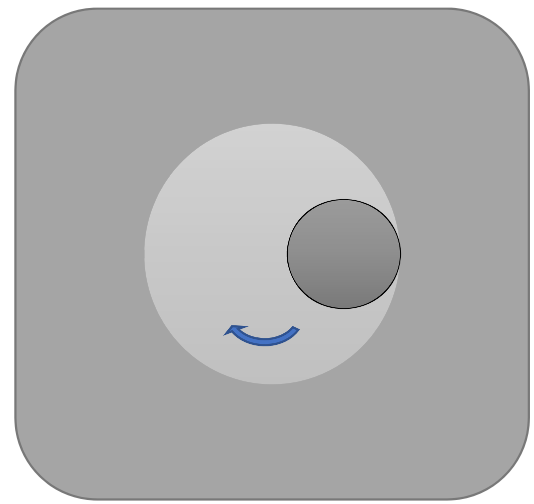
Conventional Sinker and Electrodes

- Sinker EDM's were in use before CNC technology came out. This means sinker EDM could not orbit to bring a cavity to size. As power settings changed for rough and finish passes, special electrodes had to be made to account for the overburn of each power setting. This means if there was a rough, semi-finish, and finish pass, there had to be three different size electrodes made.



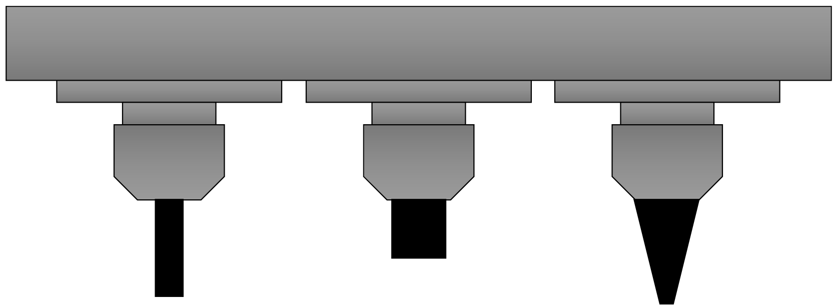
Orbiting

- CNC sinker EDM have the ability to orbit. Orbiting is the ability for the electrode to move in the X and Y axis to bring the feature in the part to size.
- Orbiting can be done in square and circular patterns.
- Orbiting eliminates the need for having multiple size electrodes to finish a feature on a part.



Tool changers

- To better automate CNC sinker EDMs, tool changers can be added to the machines. Tool changers allow for multiple electrodes to be loaded in the machine.
- This means that multiple features can be finished on the part without operator intervention.

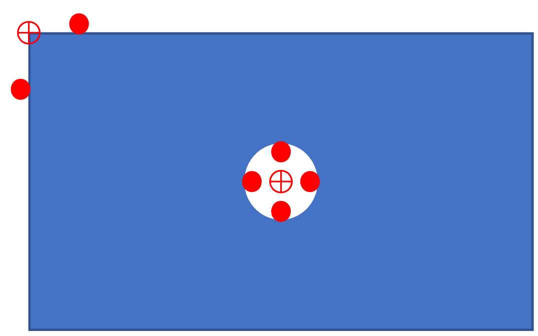


C Axis

- The C axis is rotation around the Z axis, much like spindle rotation on a mill.
- It is mainly used to orient the spindle, but it can also be used to cut threads or other slanted surfaces.
- Advanced machines can use the C axis with other axis at the same time.

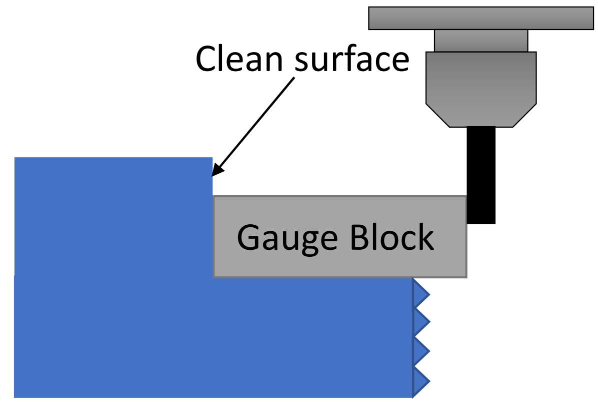
Edge Finding

- Just like with conventional machining, part origins need to be found before running a program.
- Corners & holes are common origins.
- The electrode is touched of the appropriate part surface. once electrical contact is sensed the machine knows where the edge of the part is.
- Corners require two points of contact, while holes require four.



Edge Finding

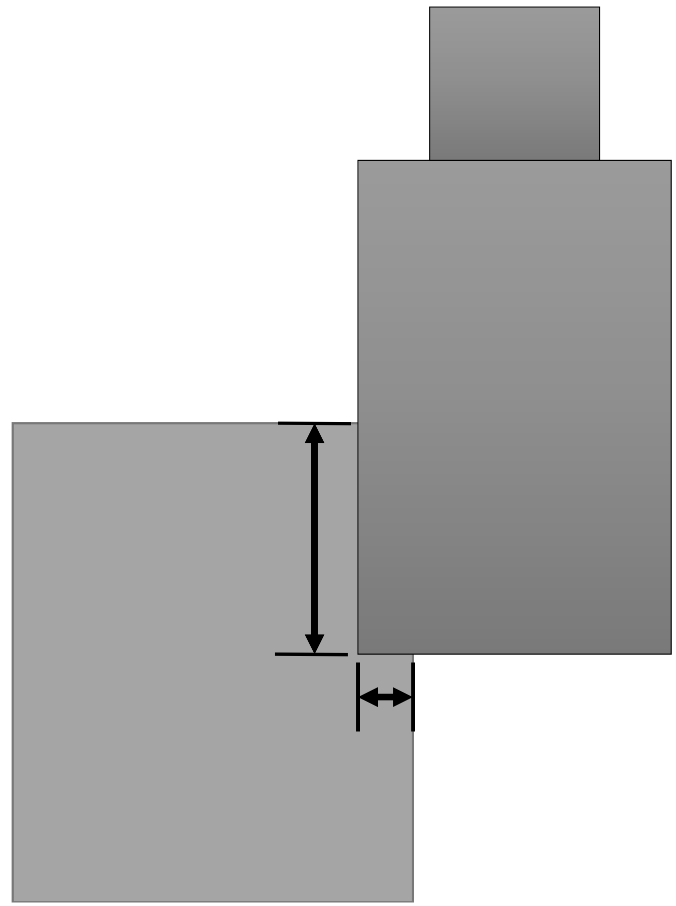
- Make sure contact surfaces are clean and square.
- If a surface has imperfections, gauge blocks and other reference tools can be used to extend accurate surfaces.



This demonstrates touching off a gauge block of a known length.

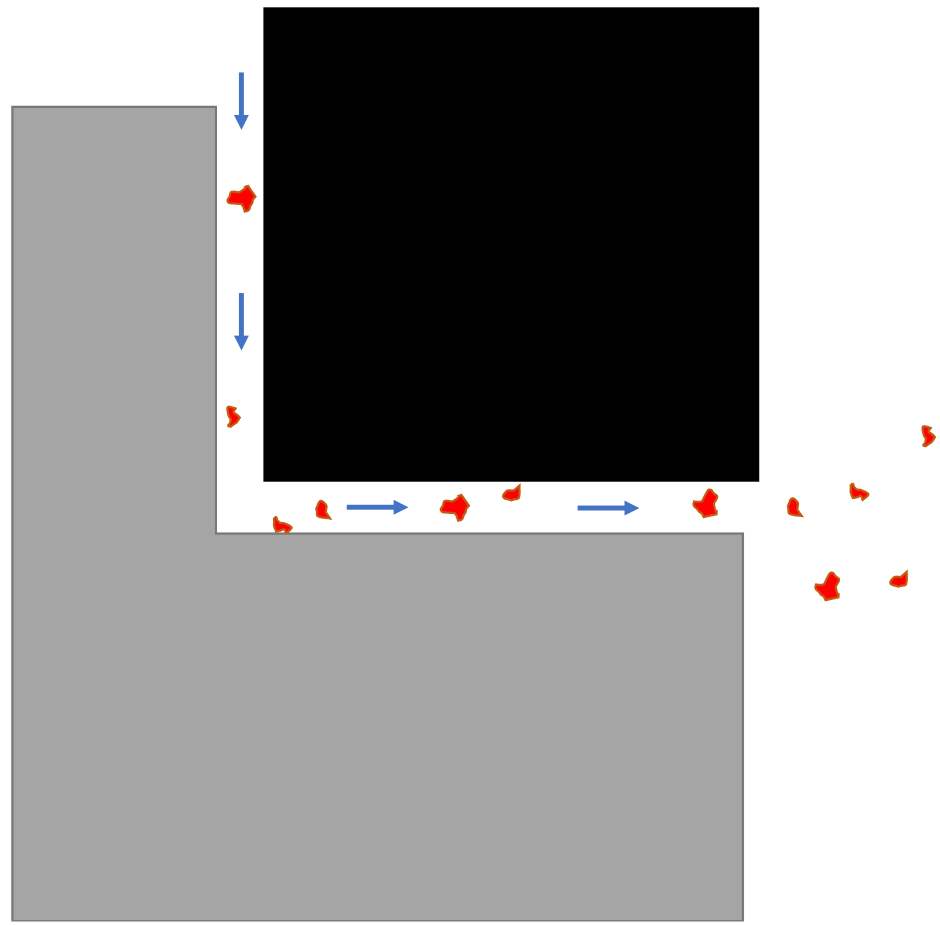
Calculating Power for an Electrode

- The size of the electrode determines the amount of power that can be applied to the cut. The power setting is chosen by the amount of square inches contained in the cutting area of the electrode.
- This is important to note because a 2"x2" electrode can not have 4 square inches of power applied if it is only taking a cut 1/8" wide around the perimeter.
- The power setting needs to selected based of the amount of electrode in the cut. Having to much power running through the electrode will cause an arc-out, or crack the electrode.



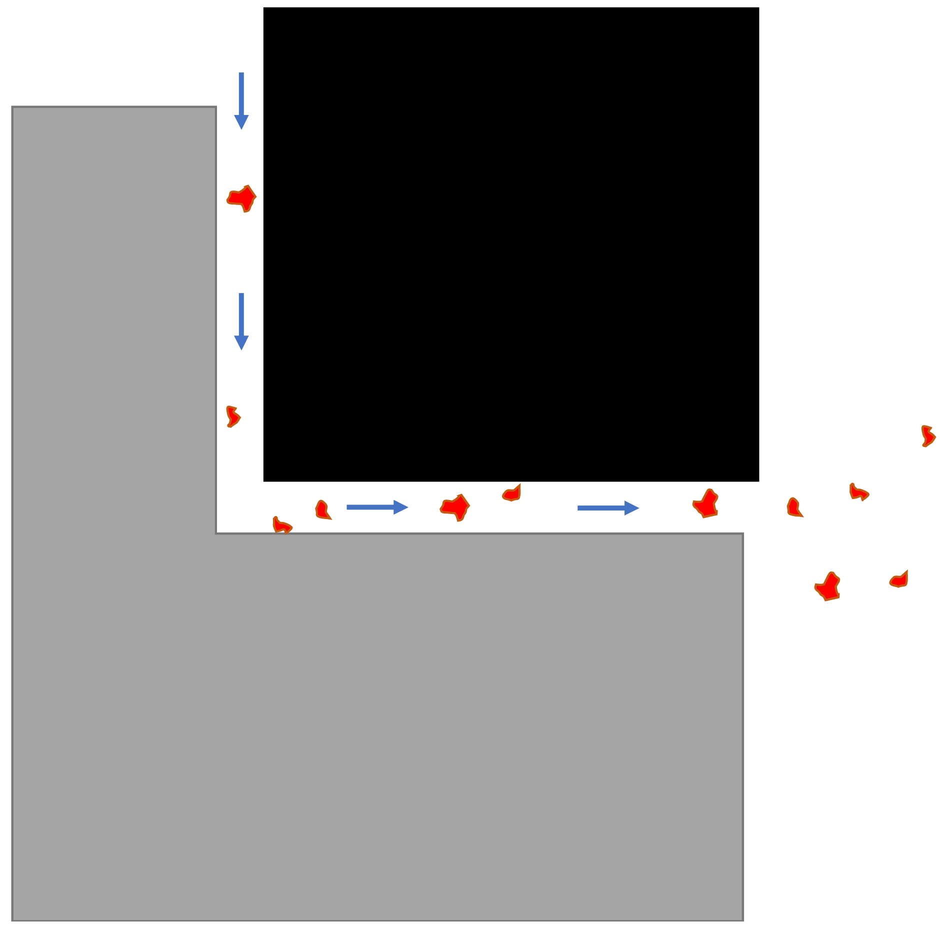
Flushing

- Flushing is using a current in the dielectric to expel eroded particles. It is possibly the most important factor for efficient EDMing.
- The machine should be setup so that the cutting area constantly has fresh dielectric.
- Inadequate flushing can cause eroded particles to reattach to the workpiece, this will likely cause arcs that will damage the part.



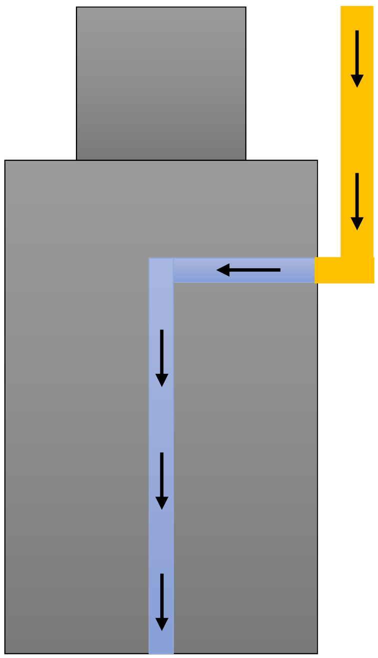
Flushing

- Volume is more important than pressure. Too much pressure can cause electrode wear and bounce particles around the burn area.
- With a high volume of dielectric with good flow encourages particle evacuation. Depending on whether it’s a roughing or finishing operation, a good pressure is around three to five psi.



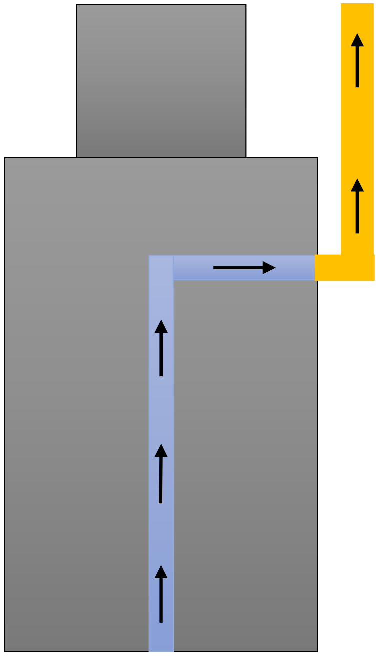
Building Flushing into Electrodes

- Basic flushing can be done using coolant lines. They can be adjusted and pointed into the cavity during the cut. During the Z retracts the flushing helps remove the particulates that have been burned away during the eroding process.
- When the cavity in the feature is deep or basic flushing can not be used electrodes can have flushing holes built into the electrode. The flushing line can be connected to the electrode and when turned on will provide flushing to the area being eroded.



Suction

- Suction is the opposite of flushing. Most sinker EDM machines have the ability to suction. This means the line or holes in the electrode act as a vacuum and can pull fluid and particulates out of the cut.
- As the fluid and waste is pulled out fresh oil is drawn in.

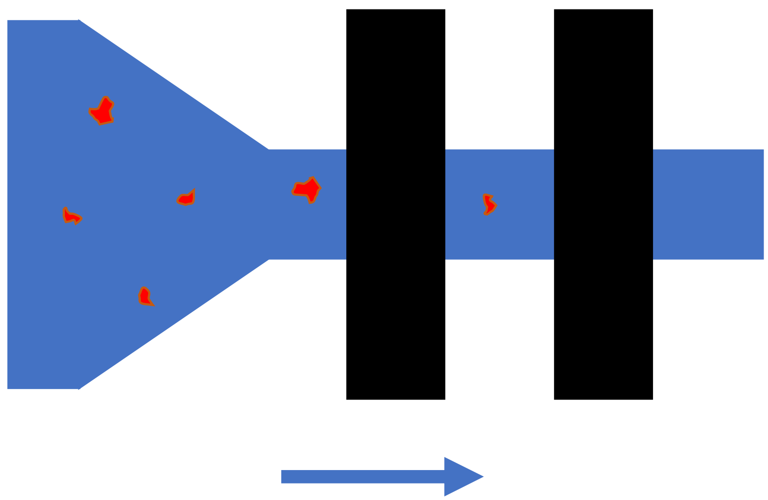


Dielectric Fluid

- Dielectric fluid is a non-conductive fluid. It acts as a resister, coolant, and flushes eroded material away.
- Water or oil is used.
- Oil has a flash point of 200°F, but 165°F is still unsafe. During roughing operations, therefore, the temperature must be monitored.

Filtration

- The EDM process causes a large amount of contamination to enter the dielectric fluid. In the case of sinker EMD the fluid is usually an oil.
- If the particulates are not removed from the fluid they will build up and effect the electrodes ability to cut.
- To prevent this the fluid is run through a series of filters to remove particulates before returning to the fluid storage tank.



Chilling Dielectric

- The EDM process creates heat as material is eroded away. Over time this will heat the dielectric fluid. In production EDM it is important to have a chiller for the fluid.
- The chiller helps to maintain a consistent temperature of the fluid while the eroding process takes place.