GF Machining Solutions
When to EDM™
The first part of this presentation provides a brief educational overview of the Electrical Discharge Machining Process (EDM).

The second half offers a detailed analysis of When, Why and Where EDM can provide a huge benefit in the engineering, design and implementation of the overall tool manufacturing process.
When to EDM™

Wire Cutting

Die-sinking
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.

Mr. & Mrs. Lazarenko at the presentation of the Eleroda D1 at the EMO exhibition in Milan, Italy.

First industrial EDM machine in the world.

Mrs. Lazarenko
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.

Back in 1952, Mr. and Mrs. Lazarenko shown here meeting with Jean Pfau-Physicist at Charmilles who heads up a team of engineers to create a machine that will use the erosive effects of electrical discharges to cut metals.

Mr. Jean Pfau: the “Father of EDM” at Charmilles. (photo taken in 2002)
## Process comparison

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Milling / Turning</th>
<th>EDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Contact</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>• Force</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>• Tool / Workpiece rotation</td>
<td>Yes</td>
<td>Not normally</td>
</tr>
<tr>
<td>• Tool / Workpiece conductive</td>
<td>Not required</td>
<td>Required</td>
</tr>
<tr>
<td>• Material removal method</td>
<td>Shear</td>
<td>Melt / Vaporize</td>
</tr>
</tbody>
</table>
An electrical tension is applied between the piece and the wire. When the voltage becomes high enough, the breakdown of the dielectric occurs and an ionized channel is created. The dielectric becomes locally conductive and the discharge can start.
The controlled discharge

Step 1:
An electrical voltage $V$ is applied. When the voltage becomes high enough, the breakdown of the dielectric occurs.

Step 2:
An electrical current $I$ circulates through the ionized channel and so a discharge is created. It is possible to control the duration and the intensity of the discharge.

Two craters appear on the attachment points of the channel.
Each discharge creates a crater

10µm

+GF+
The plasma

- Bombardment of the cathode by ions
- Plasma
- Pressure (> 40 bar)
- Force onto molten material
- Electrical parameters determine amount of molten material, gap and surface quality
Basics: Material removal phase

- Interruption of electrical current
- Implosion of the plasma
  (= fast pressure release)
- Boiling & evaporation of molten metal
- Ejection of metallic droplets into the gap
- Consolidation of parts of the molten metal on the electrode /part
- Particles can move in the gap
Principle of EDM summary

• Application of an electrical potential between wire and workpiece
• Creation of an ionized channel
• Spark
• Implosion of the plasma channel
• Material ejection

• Temperatures: 10,000 - 20,000 °C
• Pressures app. 40 bars
• Energy density app. $10^{11} - 10^{14}$ W/m$^2$
• Temperature gradients $10^8$ °C/m $10^9$ °C/s
Wire EDM

- Uses water as a dielectric
- Submerged or un-submerged workpiece
- Cuts materials that are conductive
- Uses brass or stratified coated wire
Wire EDM

Generator cabinet
(Fast cutting, 40 Sq.In./hr)

Submerged worktank
(Thermal stability)

Wire supply
(0.004” to 0.013” diam.)

CNC control
(WIN 7, Touch screen)
Wire EDM system

- Wire basket
- Wire spool
- Wire chopper
Wire EDM system

- Wire diameters from: 0.0008” to 0.012”
- Coated or Brass wires specific for either speed, accuracy or tapers

“0” tolerance closed wire guides for accuracy
What is a ROUGH & FINISH cut?

ROUGH CUT:
Rough surface finish
Large particles (chips)

FINISH CUT:
Fine surface finish
Small particles (chips)
First, there are 3 things you must learn about EDM:

1. Flushing
2. Flushing
3. Flushing

“Cut-away view of part being machined”
Corners

Conventional Corner

EDM Corner

Sharp corners are no problem with EDM
Steel extrusion die for fibers

Slot width: 0.002”
Min. inner radii: 0.0001”
Total form diameter: 0.080”
Wire EDM Performance History

Performance vs Price 1978 to 2018
Die Sinking Principle
CNC / Generator
(operator console / spark generator)

Electrode changer
(automatically change electrodes)

Flushing control
(removes particles in the gap)

Die-sinker

Automatic door
(easy access)
Many die-sinking application fields ...
Down & orbiting basics

**Down**
Straight down Z-axis burn using max. power in what is called “roughing” mode. The goal is to remove material quickly. Electrode wear of the Graphite material could be from 0.001 to 0.0015 per side.

**Orbiting 45°**
X/Y axes translation with low power settings in what is called “finishing” mode. Orbiting provides consistent surface finish, even wear, and maintains perfect round geometry or sharp details depending on the orbiting cycle chosen. Electrode wear of the Graphite material could be as low as 0.1%
Machining Cycles

- Down
- Orb
- Angul
- Expan
- Vect
- Helic
- Cone
- Sphere
Hole Drilling EDM

High Speed hole drilling with coreless electrodes

Diameters

Φ0.3 mm  (0.012”)
Φ0.5 mm  (0.020”)
Φ0.8 mm  (0.032”)
Φ1.0 mm  (0.040”)
Φ1.2 mm  (0.048”)
Φ1.5 mm  (0.060”)
Φ1.8mm   (0.072”)
Φ2.0 mm  (0.080”)
Φ2.5 mm  (0.100”)
Φ3.0 mm  (0.120”)
When to EDM by geometry

When?
VERY thin walls

Why?
• No contact
• No force
• No deformation

Examples:
• Surgical tools
• Satellite components
• Inertial guidance
• Microwave horns
• Honeycomb

This satellite structural component was wirecut from solid CAL-4V titanium by Numerical Precision, Inc., Wheeling, Illinois.
Honeycomb

Honeycomb or rib shape: WEDM makes it easy to machine deep and thin walls in copper or graphite.

Complex shapes: Any 4 axes shape can be cut. This reduces the number of electrodes needed for the mold and therefore the time and cost to do it.
When to EDM by **geometry**

**When?**
Internal Radii less than 1/32” parallel to tool axis

**Why?**
Radius is as small as the spark gap. Generally tool is not rotated.

**Examples:**
• Mold & Die components
• Repair work
When to EDM by geometry

When?
High ratios of cavity depth to widths, slots and ribs

Why?
No force means very thin, long electrodes can be used

Examples:
• Flexures
• Collets
• Jet engine blade slots
• Mold cooling ribs
• Reinforcing ribs
When to EDM by geometry

When?
Non-round cavities & openings

Why?
Electrodes don’t have to rotate

Examples:
• Fuel metering valves
• Printer components
• Molds & mold repairs
When to EDM by geometry

When?
Intermittent cuts

Why?
No contact
No force

Examples:
• Engine mounts
• Formula 1 rear housing support
When to EDM by geometry

When?
Very small parts
i.e. 0.25” cube

Why?
Easy to fixture since no force or vibration

Examples:
• Dental fixtures
• Medical claws
• Watch parts
When to EDM *by geometry*

**When?**
**Recessed cuts**

**Why?**
**Cutting tools couldn’t reach cutting area or generate desired shape**

**Examples:**
- **Keyways**
- **Bottling industry**
When to EDM **by geometry**

**When?**
Would have to make a special tool...costly. EDM is a better idea for only 10-20 parts.

**Why?**
**Electrodes are less $ than special cutting tools and easy to machine.**

**Examples:**
- Thin ribs with contoured shape.
- Replace broaching with EDM. For small quantities no need for stamping die.
When to EDM by geometry

When?
Accuracies that are difficult to hold, maintain after heat treating, stress relief, etc.

Why?
Can EDM conductive material of any hardness

Examples:
Mold that needs to be heat treated, rough machined, finished with EDM. Steel-to-steel parting line.

Characteristics of the mold
Hardened Steel 35NDC16, 185 daN/mm², 52 HRc
When to EDM by geometry

When?
Different geometry at top and bottom

Why?
Wire EDM cuts ruled surfaces with simpler program + machine than milling.

Examples:
- Jet engine blades
- Plastic extrusion dies
When to EDM *by geometry*

**When?**
Complex shapes

**Why?**
Easier to program because you are using a tool of constant dimension instead of a variety of different diameter milling cutters.

**Examples:**
Extreme tapers
When to EDM by geometry

When?
Requires multiple component assemblies

Why?
Use taper or recess or depth: diameter capability to make it one piece.

Examples:
Extrusion dies

Wire + Sinker
When to EDM **by geometry**

When?
**Angled cuts**

Why?
**Ability to 3D orbit in space, no force between piece / tool at an angle**

Examples:
**Subgates**
When to EDM by geometry

When?
Requires many different machining processes

Why?
EDM can generate almost any shape in almost any conductive material

Examples:
General mechanics part
Save time and labor to transfer between operations / processes
When to EDM by material

When?
Hardness above RC 38: Hardened steel, stellite, tungsten carbide

Why?
EDM vaporizes material rather than cutting it.

Examples:
• Dies
• Grinding tools

These carbide samples are courtesy of L.H. Carbide located in Fort Wayne Indiana.
When to EDM by material

When?
Toughness: Inconel, monel, hastalloy, nitralloy, waspalloy, nimonic, udimet

Why?
EDM is non-contact; therefore adhesion of workpiece to tool.

Examples:
• Magnetic reader heads
• Artificial joints
• Turbine blades
• Car engine prototypes
When to EDM by material

When?
Tends to leave tough burrs when machined conventionally

Why?
Vaporized material is flushed away leaving “no” burr.

Examples:
• Copper electrode
• Surgical tools

Medical components. Combination small hole EDM (.013 diameter) and wire EDM.

Multi-operation production parts. Copper and stainless steel shown. Any conductive material can be cut burr-free and accurately.
Courtesy of Xact Wire EDM Corporation located in N8w22399 Johnson Dr, Waukesha, WI 53186

Wire + Sinker
Medical

No burrs
0.001" wire slot
When to EDM by material

When?
Frail / Fragile
Can’t take stress of machining

Why?
• No contact
• No force

Examples:
• Printer hammer
• Graphite electrodes
• Honeycomb
• Lead frame die

Wire + Sinker
When to EDM **by material**

**When?**
- Expensive material

**Why?**
- Lower chip: Workpiece mass ratio.
- Slugs are reusable
- Chips are only recyclable.

**EXAMPLES?**
- Dental fixtures
- Endoscopic cutters
- High alloys
When to EDM by material

When?
Explosive or flammable materials

Why?
EDM takes place under water or oil

Examples:
Magnesium
When to EDM by material

When?
Material with hazardous dust particles

Why?
• Particles are flushed away to the filter
• Reduced risk of fumes

Examples:
Beryllium copper
When to EDM by process replaced

When
- Grinding:
  - Form
  - Crush
  - Jig

Why
EDM allows unattended machining, less expensive design and simplified operation

Examples:
Dies, powder metal dies, punches, core pins, dowel holes, etc.

CONVENTIONAL:
- Several steps
- Several tools
- Several machines

EDM:
- Only one operation
- Only one tool
- Only one machine
When to EDM **by process replaced**

**When**
- 2+ axis milling

**Why**
Can slab off large slugs instead of piles of chips.

Example:
When to EDM **by process replaced**

<table>
<thead>
<tr>
<th>When</th>
<th>Why</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid etching or polishing to achieve textured finish</td>
<td>Eliminate etching or polishing therefore reduce # of operations, time, and cost.</td>
</tr>
</tbody>
</table>

**Examples:**
- Containers
  - Beverage
  - Food
  - Perfume
  - Phone mold
<table>
<thead>
<tr>
<th>When</th>
<th>Why</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Short run Stamping (&lt; 5,000 pieces)</td>
<td>No need to make a die set</td>
<td>Sewing machine components, prototypes</td>
</tr>
<tr>
<td>• Broaching (Low volume)</td>
<td>Low cost tooling</td>
<td>Splines Gear teeth</td>
</tr>
<tr>
<td>• Slitting or Slotting</td>
<td>Eliminates burrs and blade wear problems.</td>
<td></td>
</tr>
<tr>
<td>• Parts requiring complex expensive fixturing with conventional machining</td>
<td>No contact no force means simple fixturing</td>
<td></td>
</tr>
</tbody>
</table>
### Characteristic

<table>
<thead>
<tr>
<th></th>
<th>Wire</th>
<th>Sinker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thinnest wall</td>
<td>0.005”</td>
<td>0.002”</td>
</tr>
<tr>
<td>Minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Internal radii</td>
<td>0.0008”</td>
<td>0.001”</td>
</tr>
<tr>
<td>- External radii</td>
<td>sharp</td>
<td>sharp</td>
</tr>
<tr>
<td>- Slot width</td>
<td>0.0016”</td>
<td>0.0004”</td>
</tr>
<tr>
<td>- Hole diameter</td>
<td>0.0016”</td>
<td>0.0006”</td>
</tr>
<tr>
<td>Taper</td>
<td>+/- 45º</td>
<td>N/A</td>
</tr>
<tr>
<td>- Max. angle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Max. height/angle</td>
<td>30º to 16” high</td>
<td>N/A</td>
</tr>
<tr>
<td>Hole depth to diameter ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Conventional</td>
<td>n/a</td>
<td>20:1</td>
</tr>
<tr>
<td>- Spec. Small hole</td>
<td>n/a</td>
<td>900:1</td>
</tr>
<tr>
<td>- Microhole</td>
<td>n/a</td>
<td>10:1</td>
</tr>
<tr>
<td>Recess depth</td>
<td>n/a</td>
<td>1/2 hole diam. - 1/2 electrode shank diam.</td>
</tr>
<tr>
<td>- From round entry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- From straight entry</td>
<td></td>
<td>hole width - electrode shank diam.</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Wire</td>
<td>Sinker</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>--------------------------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>• Workpiece conductivity and fixture max.</td>
<td>Approx. (0.5 - 5) ohm centimeter</td>
<td>Same</td>
</tr>
<tr>
<td>• Accuracy</td>
<td>+/- 0.000040”</td>
<td>+/- 0.0001”</td>
</tr>
<tr>
<td>- Conventional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Microhole</td>
<td>n/a</td>
<td>+/-0.0004”</td>
</tr>
<tr>
<td>• Surface finish</td>
<td>vdi 0</td>
<td>vdi -5</td>
</tr>
<tr>
<td></td>
<td>Microinch 4</td>
<td>microinch 2</td>
</tr>
<tr>
<td>• Texture finish</td>
<td>random, uniform texture only</td>
<td>same</td>
</tr>
<tr>
<td>• Surface integrity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Recast layer thickness</td>
<td>20 millionths</td>
<td>20 millionths</td>
</tr>
<tr>
<td>- Micro crack length</td>
<td>20 millionths</td>
<td>20 millionths</td>
</tr>
</tbody>
</table>
Exact Difficult Machining
The US and World’s Largest Supplier of EDMs for the Tooling & Machining Industries
Q2 of 2017

- **CUT 1000 / CUT 1000 OilTech**
- **CUT 2000S / OilTech**
- **CUT 3000S**
- **AC Progress VP2**
- **AC Progress VP3**
- **CUT P 350**
- **CUT P 550**
- **CUT P 800**
- **CUT E 350**
- **CUT E 600**

**XY travels**
- 220 x 160
- 350 x 220
- 550 x 350
- 800 x 550

**Price / Performance**
- +/-0.0001
- +/-0.0002
- +/-0.0003
Die Sinking portfolio

FORM 1000
FORM 2000 VHP
FORM 3000 VHP

FORM S 350

FORM P 350
FORM P 600
FORM P 900

FORM E 350
FORM E 600
There is a shortage of labor in the trades. We are committed to recruiting the top talent and have created an apprenticeship program to start high school students on the path to work in machining.

Once accepted to the program, GF covers the cost of tuition and books as well as a salary.
Average Student Loan ($37,172) for 10 years at 4% APR

Student Loan Summary

- Monthly Payment: $376
- Payments: 120
- Total of 120 Payments: $45,162
- Total Interest Paid: $7,990

Graph showing payment in dollars over months with categories for Interest, Principal, and Balance.
Training Agenda

YEAR 1
Machining and Manufacturing Basics
- Safety
- Manual Machining
- Prints & Schematics
- Hydraulics & Pneumatics

YEAR 2
Applied Technical Skills
- Intro to Electronics and Mechanical Maintenance
- Intro CNC Programming
- Machining Processes
- Blueprints

YEAR 3
Machine Programming and Service
- Advanced CNC Programming and Computer Aided Mfg.
- Supervised Machine Installation, Diagnosis & Repair

Semester 1-2
- 8 weeks school
- 13 weeks OTJ
- 8 weeks school
- 24 weeks OTJ

Semester 3-4
- 8 weeks school
- 13 weeks OTJ
- 8 weeks school
- 23 weeks OTJ

Semester 5-6
- 8 weeks school

Midpoint Test
Evaluation & Final Exam
Evaluation & Evaluation

Exam & Evaluation

OTJ = on-the-job training
Upon successful completion of their apprenticeship, Apprentices will receive:

• An Associate’s Degree
• Industry Certification(s)
• A Certificate of Completion from the US Department of Labor
• A Certificate of Completion from GF
Glossary of EDM Terms

- **Amperage**: In EDM, the amount of average current measured during the cut.
- **Arc**: A continuous flow of electrical current. This continuous flow causes damage to both the electrode and work piece.
- **Blind hole**: Any cavity that has a bottom surface and that doesn’t connect with any other openings.
- **Capacitor**: An electrode component that stores an electrical charge. In EDM it is used frequently for cutting metals with high melting temperatures and during fine finishing cycles.
- **Carbon**: An abundant, naturally occurring element. Graphite is a form of the element carbon.
- **Core**: The stalagmite caused by EDMing with an electrode drilled with holes for flushing in it.
- **Corner wear**: The measurement of wear on the corners of the electrode.
- **Cubic inches per hour (in 3/hr)**: The unit of measure used to describe the metal removal rate of sinking type EDMs.
Glossary of EDM Terms

- **DC arcing**: Same as ARC.
- **Deionization**: Bringing the dielectric to a non-conductive state.
- **Dielectric fluid**: In EDM, a non-conductive fluid used to control the sparking condition. Also used to cool and remove the cutting debris from the erosion area.
- **Dielectric strength**: Measurement of how resistant the fluid is to current flow.
- **Duty cycle**: The percentage of on-time to the sum of on-time and off-time.
- **EDM (Electrical Discharge Machining)**: A metal removal process using electric sparks to erode conductive materials.
- **Electrode**: The cutting tool in EDM.
- **Electrode growth**: A plating action during certain settings causing material to build up on the electrode, causing an increase in size.
- **End wear**: A measurement of wear on the frontal plane of the electrode.
- **Filtering**: In EDM, a process of removing the cutting debris from the dielectric fluid.
- **Finish**: The surface texture produced.
• **Flush pot:** A multipurpose box-like fixture used to hold the work piece or electrode that allows flushing to pass through. Suction or pressure flushing can be used.

• **Flushing:** The process of removing the cutting debris from the cutting area.

• **Gap (Spark gap):** The distance between the electrode and the work piece where the spark occurs.

• **Gap voltage:** A measurement of voltage during the EDM process.

• **Generator:** A term used to describe the EDM power supply.

• **Injection flushing:** Pressure type flushing where dielectric fluid is forced into the cutting area through various means.

• **Ionization:** The phenomenon by which the dielectric between two points on the electrode and work piece becomes electrically conductive.

• **Microsecond (μs):** One-millionth of a second

• **Off-time:** Length of time that current is off. Measured in microseconds.

• **On-time:** Length of time current is on. Measured in microseconds.

• **Overcut:** Measurement difference between the dimensions of the cavity EDMed and the dimensions of the electrode used to cut the cavity.
Glossary of EDM Terms

- **Peak current**: Maximum current (amperage) available.
- **Average amperage = A**: (On Time + Off Time)
  - e.g. 50 Amp machine 50% On time 50% Off time = 25 average Amps
- **Pulsator**: A mechanical device built into most EDMs for the purpose of moving the electrode in and out of the cavity in timed movements to aid flushing.
- **Reverse polarity**: A process that reverses the flow of current.
- **Vacuum flushing**: A flushing method using suction rather than injection.
- **Undersize**: A term used to describe the difference between the finished cavity size and the electrode size.

*Some definitions were taken from the POCO Graphite Technical Manual*
An example of a product produced because of EDM’s ability to eliminate special cutting tools is this fin deployment actuator housing for a missile. Using EDM eliminated the need for expensive broach tooling to form the through T-slot configuration into this 15-5PH forging.

Part example supplied by Numerical Precision in Wheeling, Illinois
Case study 2

Classic Die, a shop in Grand Rapids, Michigan, produces this injection mold using the fine-grain graphite electrodes above. Ram EDM often provides the only way to produce such intricate mold cavities (this mold has been cross-sectioned to reveal its tapered helical slots), as well as other workpieces which have deep slots or narrow ribs. The components produced in this mold are 2.75 inches long and are used in medical instruments for heart surgery.

Part example supplied by Classic Die in Grand Rapids Michigan.
The surface finish of the fitting surfaces made by WEDM allow air venting during the plastic injection phase. Air can escape but not plastic. This is very useful to help plastic fill the ribs. The reinforcement ribs are complex shapes. They can be machined separately and press fit.

TV mold: Vent hole for reinforcement ribs

The reinforcement ribs of this TV casing are not machined directly on the mold core. They are added (inserted) Open cavities to receive them are WEDM cut.
Case study 4

WEDM makes it easy to machine any kind of gear with high accuracy. No need to use dedicated machine to cut cylindrical or tapered gears. Gear modification is fast and easy. Wire EDM reduce lead time to produce plastic gears.

Plastic gears  Gears for Formula-1 race team
Case Study 5

Gear Wheel machined with Micro WEDM
- Height of structure: 0.240”
- Outer diameter: 0.020”
- Number of teeth: 8
- Wire: 20 µm, (0.00078”) tungsten
- 1 cut
- Material: 1.2343 (X38CrMoVS_1)

Albert-Ludwigs-University
Freiburg
Chair of Process Technology
Faculty of Applied Sciences