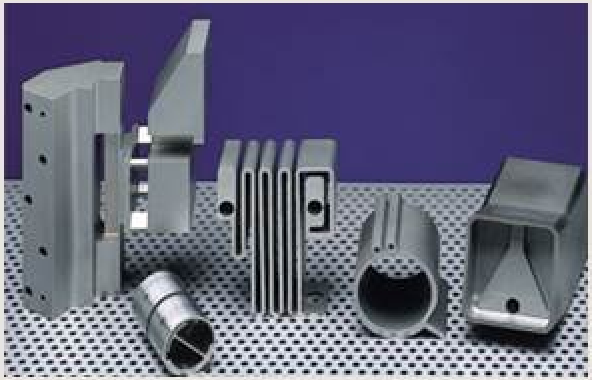
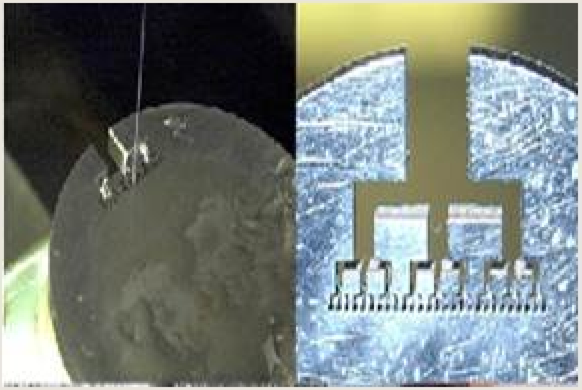
Micro ELECTRICAL DISCHARGE MACHINING (μEDM)

Introduction

- With the recent developments in material technology, as well as the increase in demand for more complex and economic machining processes, the conventional method of machining is unable to cater to the need of the industries



- Non-traditional machining has started to play an important role in processing of advanced materials.



- One such popularly employed non-traditional machining techniques is Electrical Discharge Machining (EDM) and μEDM in micro manufacturing domain

Need for μEDM Process

- To machine high hardness and high strength material (above 50 HRC).

(HRC 55–66:- Very hard steel - chisels, quality knife blades,

Hardened High Speed Carbon and Tool Steels, Stainless Steels, newer powder metallurgy parts)

- To machine work piece which are too flexible or slender to support the cutting or grinding forces.

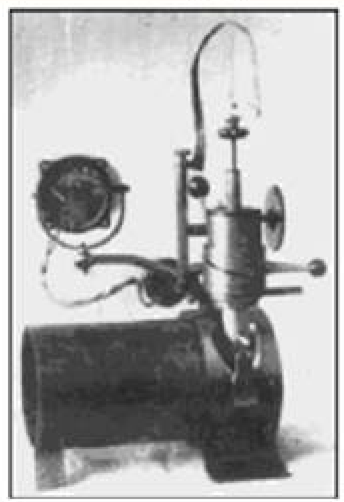
- To machine parts with complex shapes, such as internal and external profiles, or small diameter holes.

- When surface finish or tolerances required are better than those obtainable by conventional process.

- When Temperature rise or residual stress in the work piece are undesirable.

History of EDM process

- During World War II physicists **B.R. and N.I. Lazarenko** in Moscow conducted studies on the minimization of wear on electric power contacts.
- They tested different materials with discharges of defined energy, generated by a capacitor.
- B.R. Lazarenko published the paper “To invert the effect of wear on electric power contacts”, in 1943.
- This idea started the development of Electrical Discharge Machining (EDM), using controlled discharge conditions, for achieving precision machining.



B.R. Lazarenko in the laboratory: a scene from the movie of 1950. Device for removing broken instruments from the shells of Katyusha projectiles (the early 1940s). Author’s certificate of invention of the method of machining metals and other conducting materials no. 700010 dated April 3, 1943, issued to N.I. Lazarenko and B.R. Lazarenko.

History of n EDM process….

- Attempts were made for the first time to machine metals and diamonds with electrical discharge. **V.E. Matulaitis and H.V. Harding** of **Elox** US developed "Disintegrators" to remove broken taps from valuable work piece materials such as cemented carbide and high speed steel (During the 1930s itself).
- Erosion was caused by intermittent arc discharges occurring in air between the tool electrode and work piece connected to a DC power supply.
- Since then, EDM technology has developed rapidly and become indispensable in manufacturing **applications** such as **die and mold making, micro-machining, prototyping**, etc.

Advantages of EDM process

- Any material that is electrically conductive can be cut using the EDM process.
- Hardened workpieces can be machined eliminating the deformation caused by heat treatment.
- A relatively soft graphite or metallic electrode can easily machine hardened tool steels or tungsten carbide
- Can achieve extremely high accuracies (0.0004 mm) and close tolerances.
- The EDM process is burr-free

MICRO – ELECTRICAL DISCHARGE MACHINING (EDM)

- Micro-EDM is the application of EDM on micro field. Micro-EDM has similar characteristics as EDM except that the size of the tool, discharge energy and axes movement resolutions are in micron level.

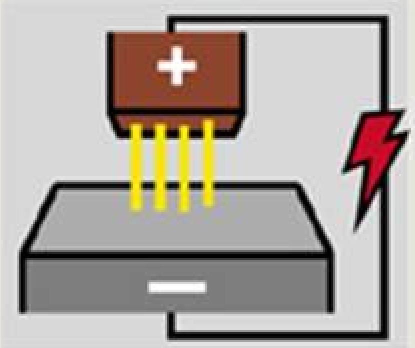
- At the present time, micro-EDM is a widespread technique used in industry for high-precision machining of all types of conductive materials such as: metals, metallic alloys, graphite, or even some ceramic materials, of whatsoever hardness.

- Micro-EDM provides such advantages as the ability to manufacture complicated shapes with high accuracy, and can process any conductive materials regardless of hardness, it has become one of the most important methods for manufacturing micro-features and parts with sub-micrometer order size.

- In recent years micro-EDM has been used extensively in the field of micro-mould making, production of dies, cavities and even complex 3D structures.

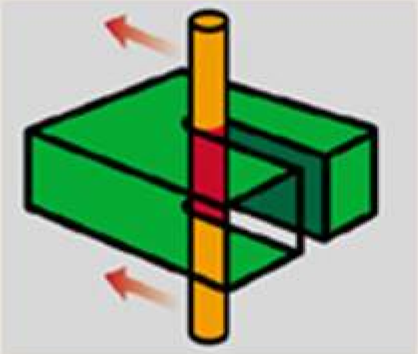
Variations of EDM

- Basic Process: Electric discharge machining (**EDM**), sometimes referred to as **spark erosion machining**, spark eroding, burning, die sinking, wire burning or wire erosion, is a manufacturing **process** whereby a desired shape is obtained using electrical discharges (sparks).



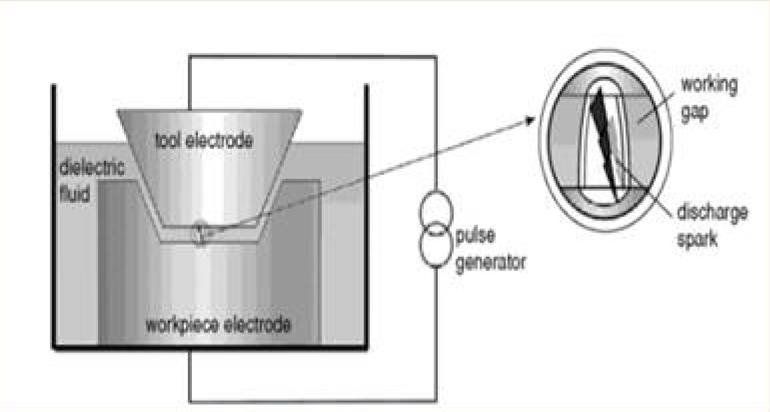
Wire Cutting

- EDM wire cutting uses a metallic wire to cut a programmed contour in a workpiece.
- Extrusion dies and blanking punches are very often machined by wire cutting

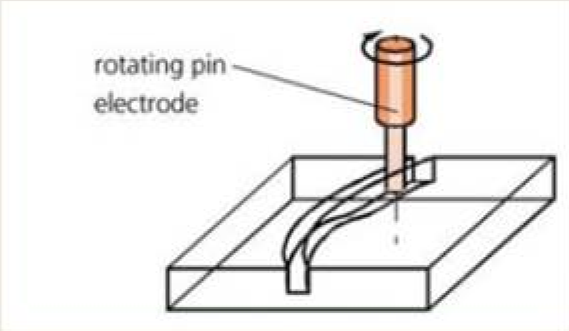


Types of Micro EDM process

Micro EDM



Micro ED Milling (μED-milling)



Micro ED Drilling (μEDD)

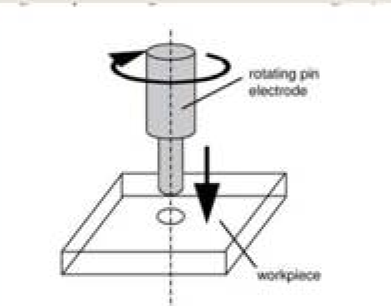


FIGURE 3-15 Illustration of the micro-electrical discharge drilling process.

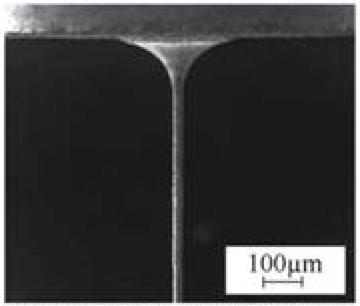
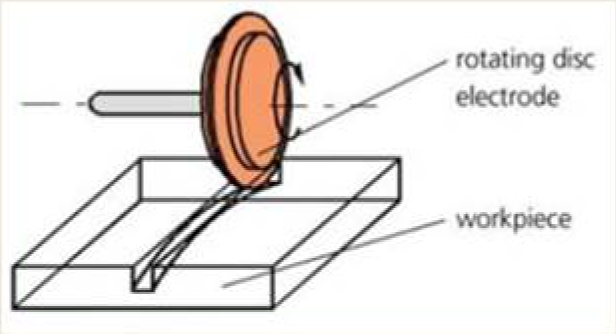


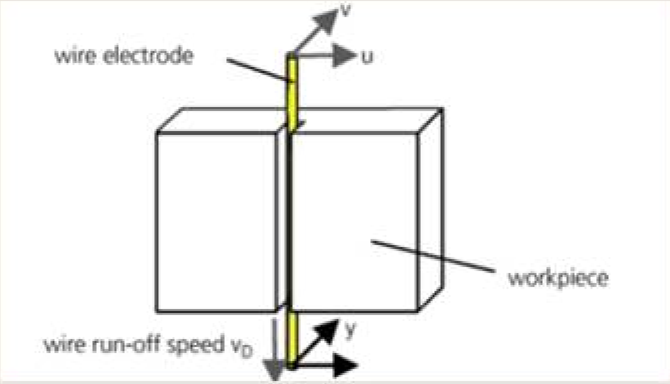
FIGURE 3-16 Electrode for μ-ED drilling made of cemented carbide.

Micro ED Grinding (μEDG)

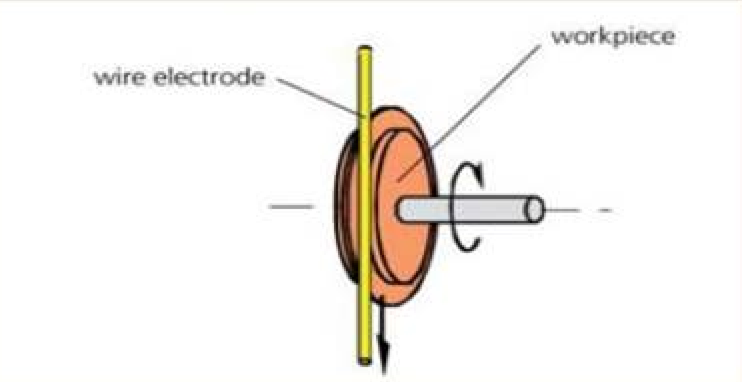


Variants in Micro Wire EDM

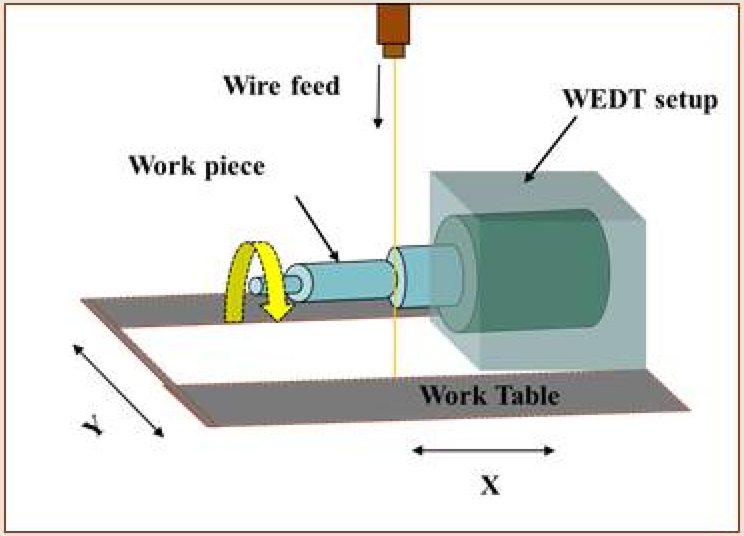
Micro Wire EDM



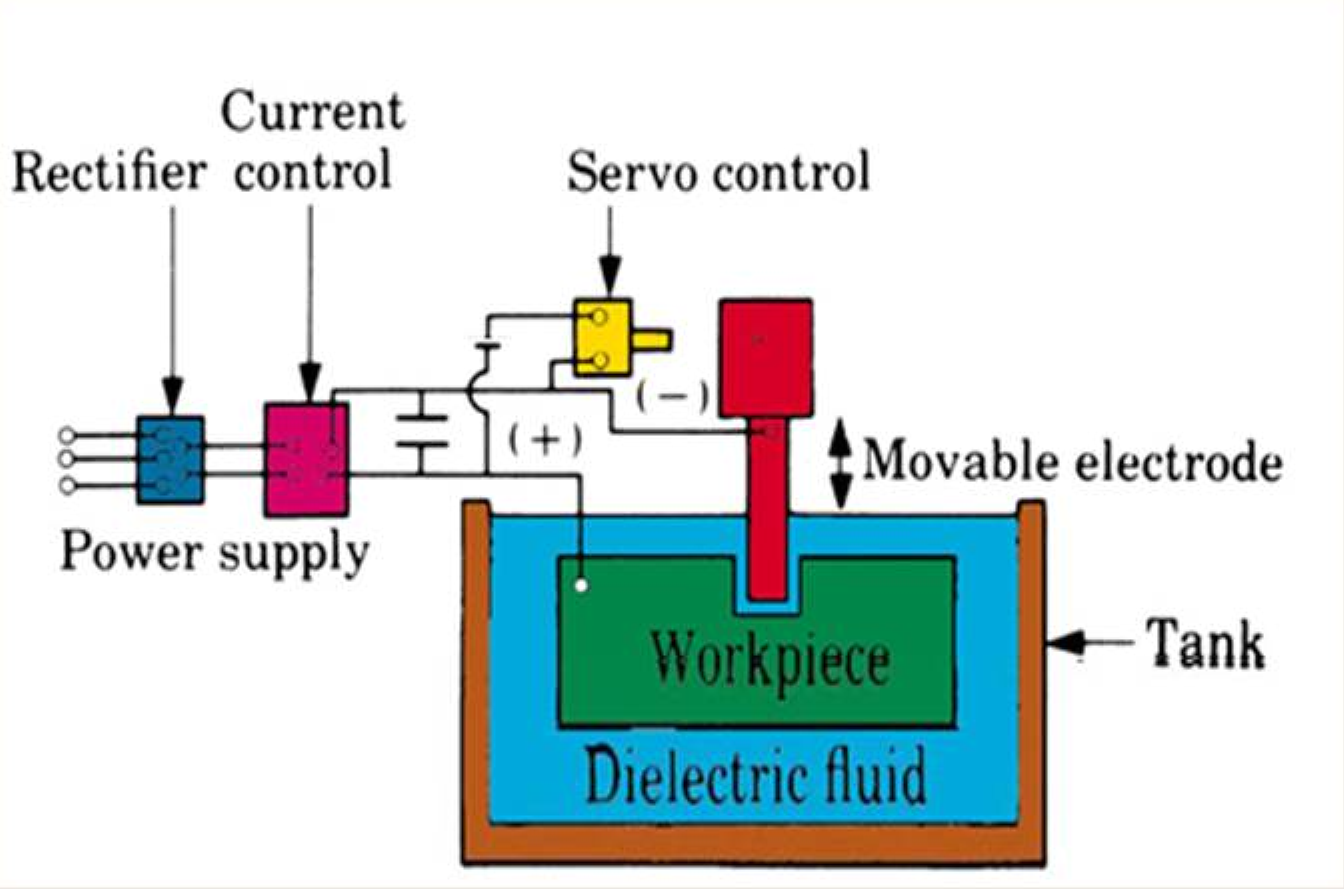
Micro Wire ED Grinding (µWEDG)



Micro Wire EDM Turning (µWEDT)

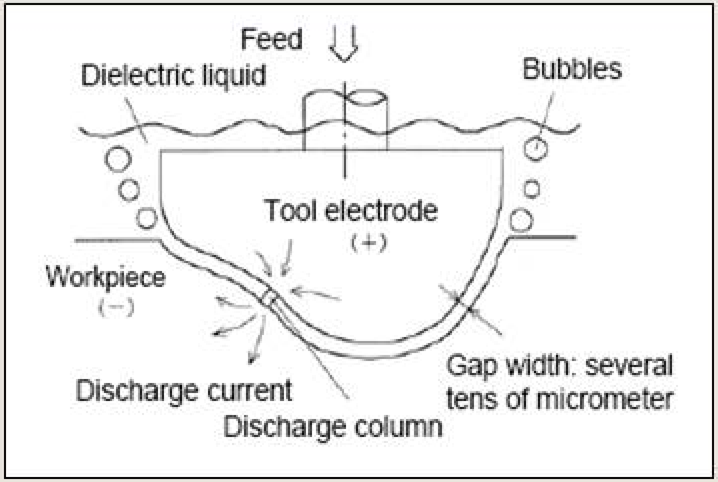


Schematic of EDM process



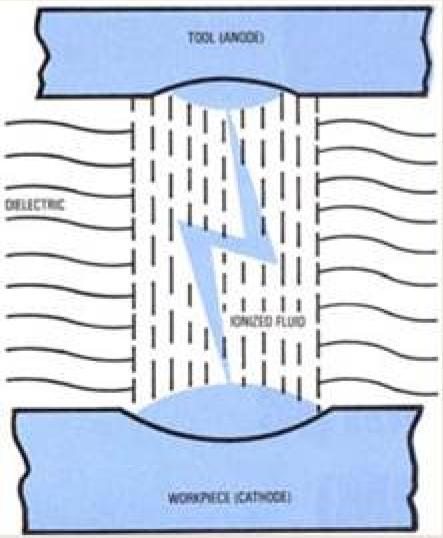
Mechanics of EDM Process

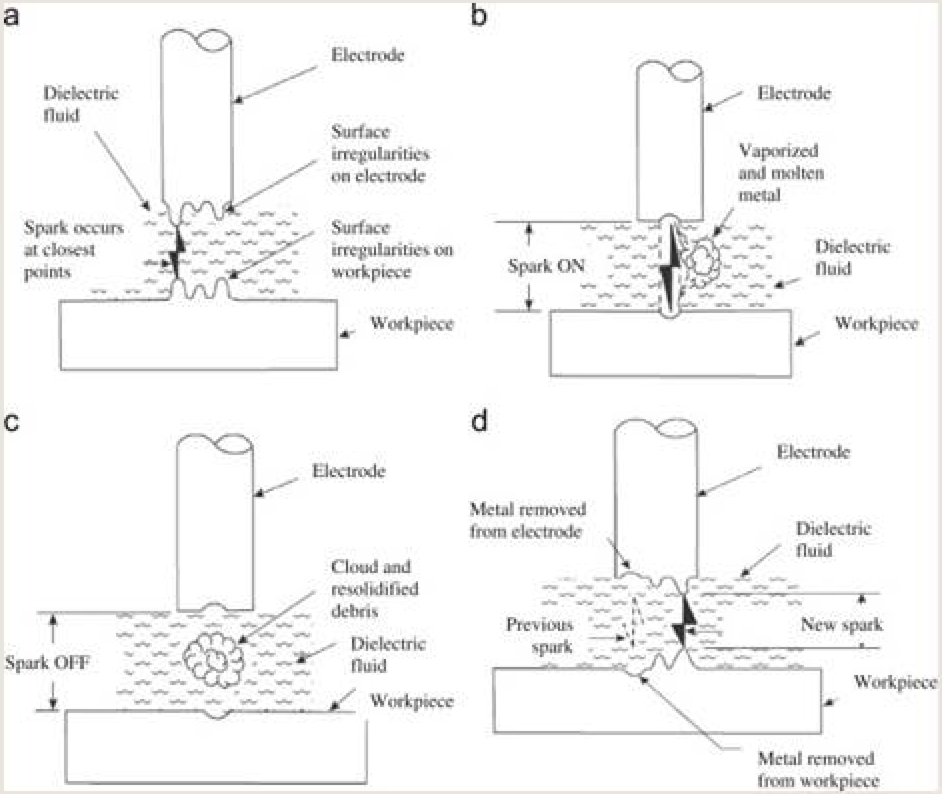
- Electrical Discharge Machining (EDM) is an electro-thermal non-traditional machining process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark.
- Both the **tool and the work material are to be conductors of electricity**.
- A **potential difference is applied between the tool and work piece**.
- The tool and the work material are **immersed** in a **dielectric medium**. Generally **hydrocarbon dielectrics, mineral oil, kerosene, deionized water or distilled water** is used as the dielectric medium.
- A gap is maintained between the tool and the work piece



Role of the dielectric fluid

- acts as a **insulator** until the potential is sufficiently high.
- depending upon the applied potential difference and the gap between the tool and work piece, an **electric field would be established if the voltage is increased over break-down voltage,** that results in spark machining as illustrated in following slides
- acts as a **flushing medium** and carries away the debris.
- also acts as a **cooling medium**.





Steps in EDM process:

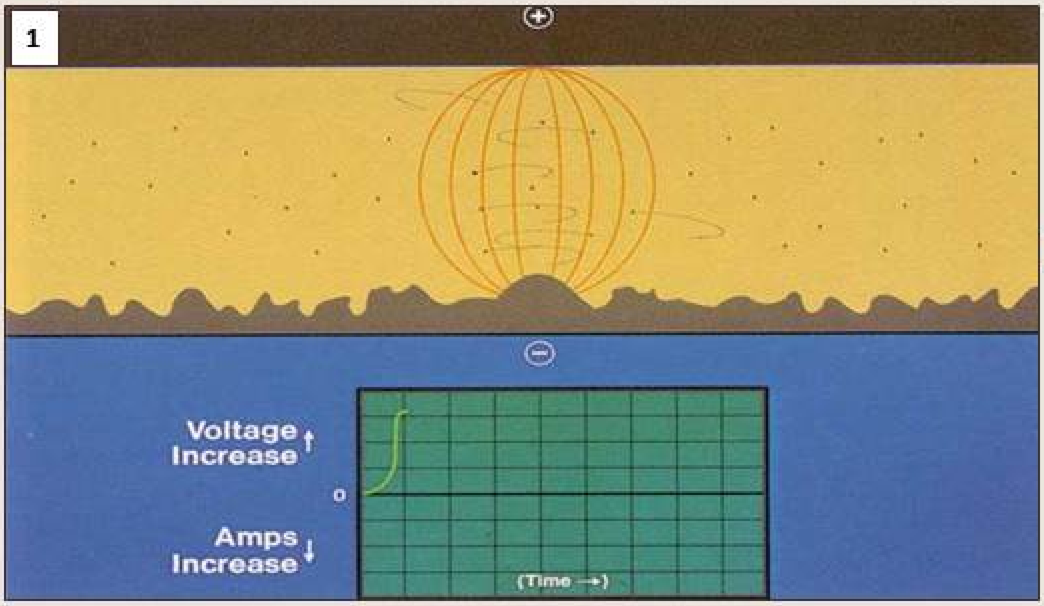
(a) occurrence of spark at the closest point between workpiece and electrode,

(b) melting and vaporization of workpiece and electrode materials during spark on-time,

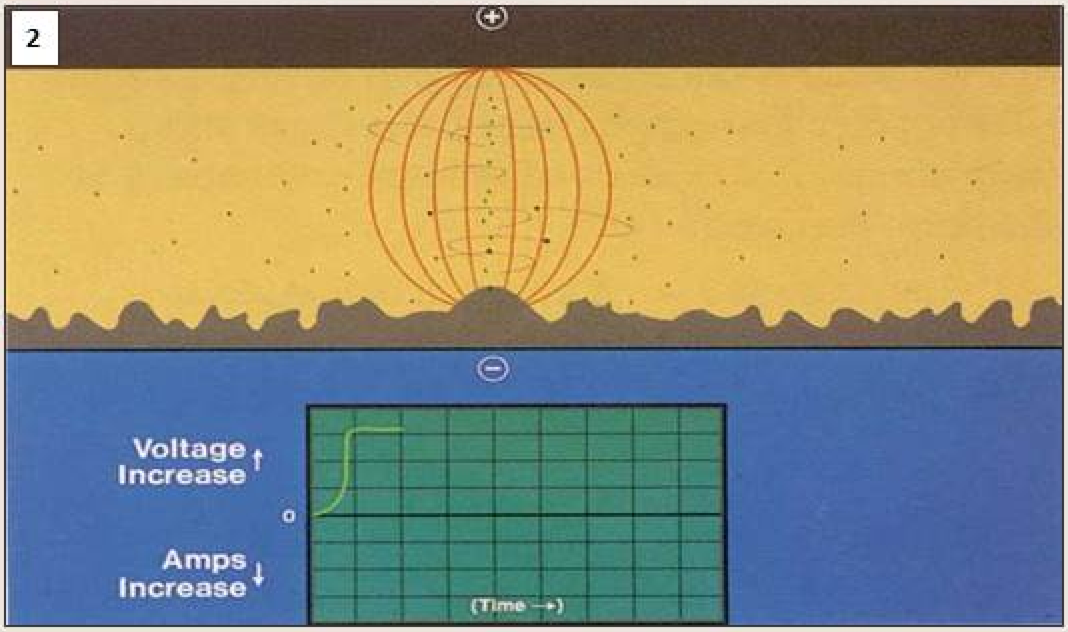
(c) vaporized cloud of materials suspended in dielectric fluid, and

(d) removal of molten metal and occurrence of next spark

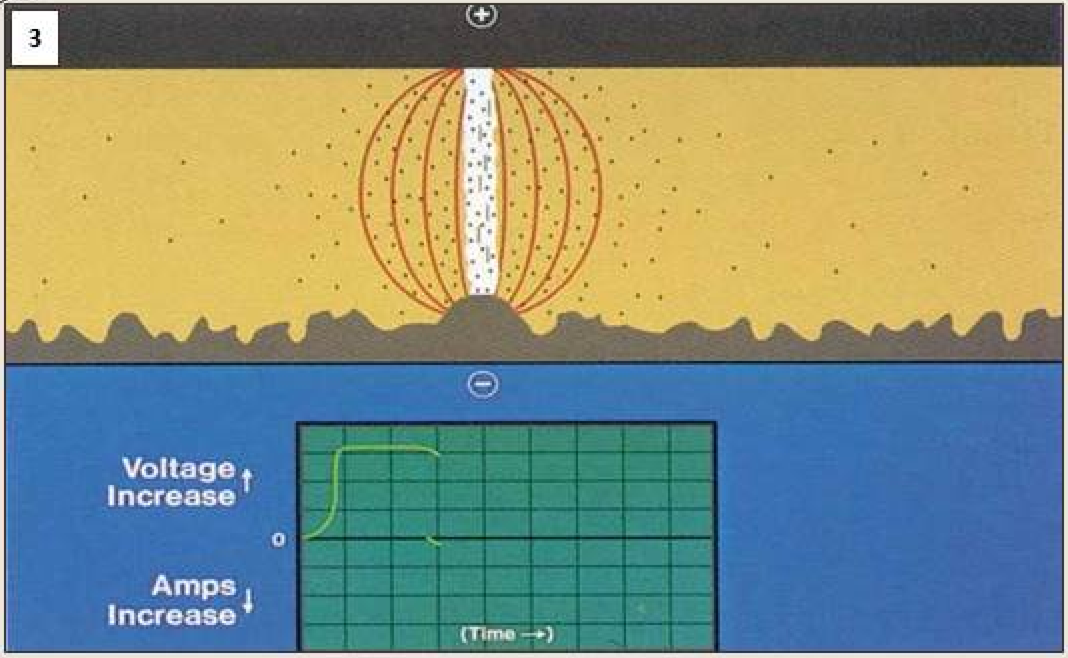
Details of mechanics of material removal during EDM process



- The electrical field is strongest at the point where the distance between the electrode and work piece is least, such as the high point shown.
- The graph in the illustration shows that the potential (voltage) is increasing, but current is zero.

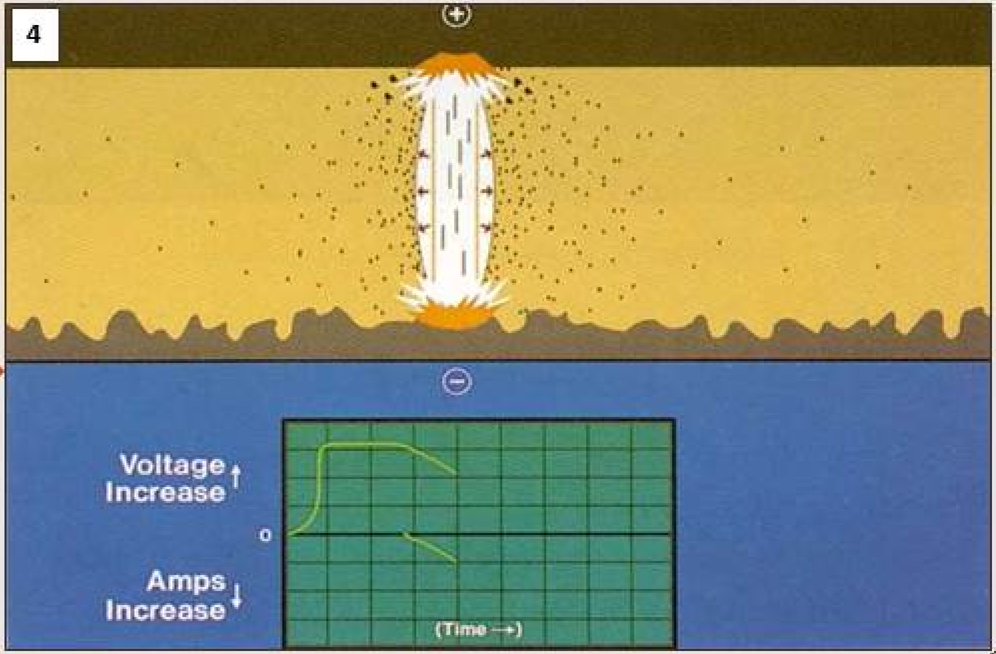


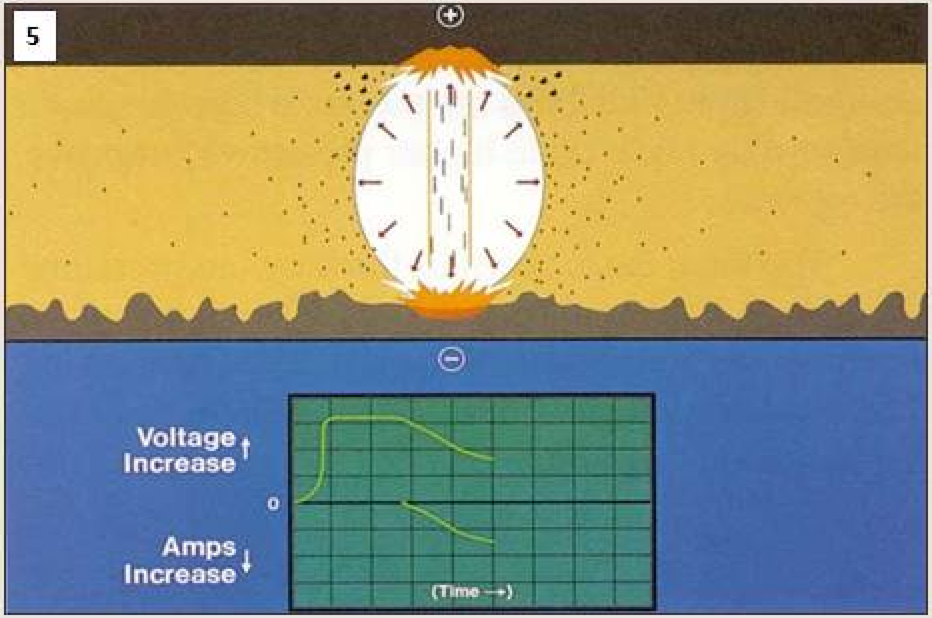
- As the number of ionic (charged) particles increases, the insulating properties of the dielectric fluid begin to decrease along a narrow channel centered in the strongest part of the field.
- Voltage has reached its peak, but current is still zero.



- A current is established as the fluid becomes less of an insulator.
- Voltage begins to decrease.

- Heat builds up rapidly as current increases, and the voltage continues to drop.
- The heat vaporizes some of the fluid, work piece, and electrode, and a discharge channel begins to form between the electrode and work piece.





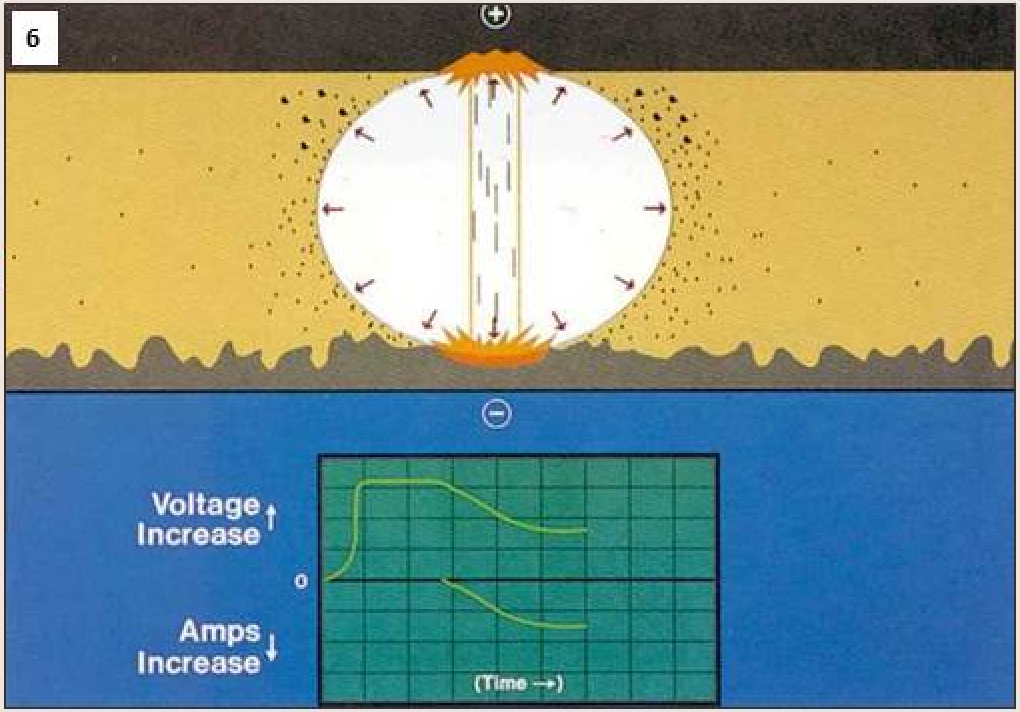
- A vapour bubble tries to expand outward, but its expansion is limited by a rush of ions towards the discharge channel.

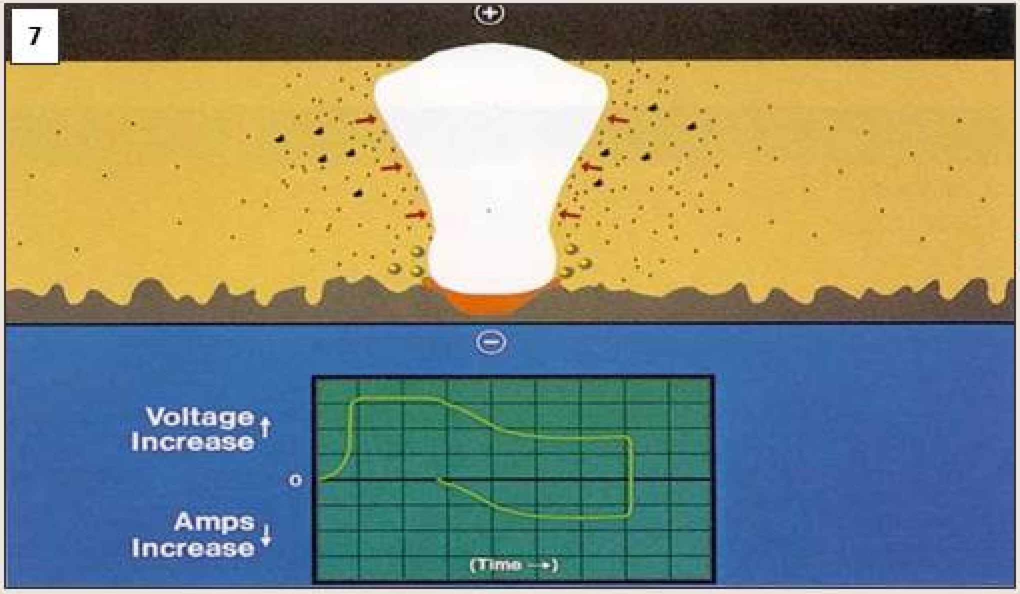
- These ions are attracted by the extremely intense electro-magnetic field that has built up. Current continues to rise, voltage drops.

- Near the end of the on-time, current and voltage have stabilized, heat and pressure within the vapour bubble have reached their maximum, and some metal is being removed.

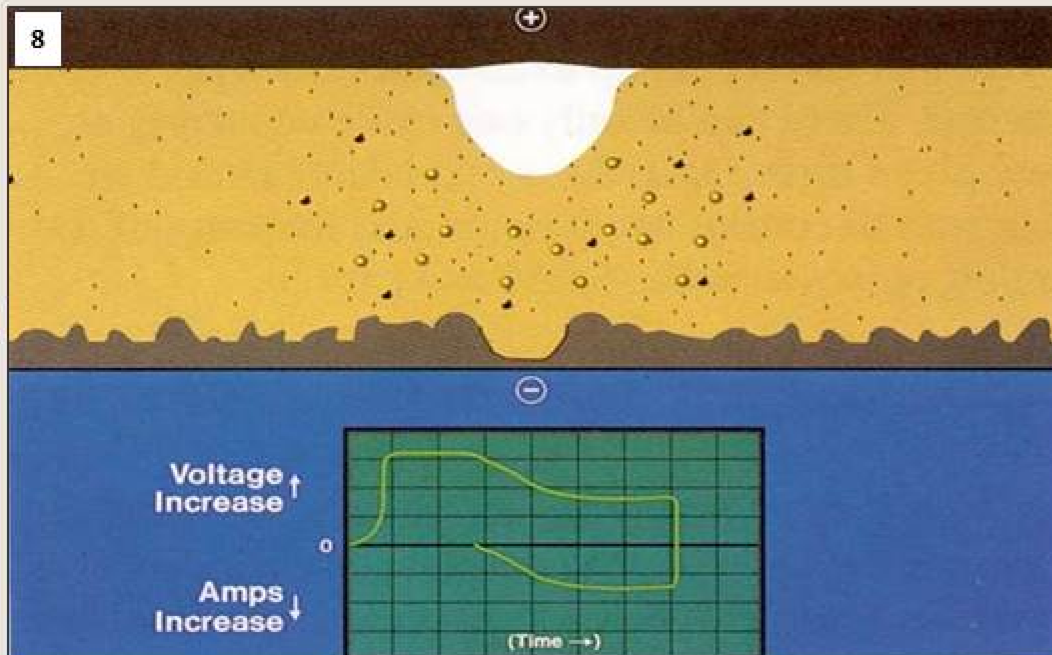
- The layer of metal directly under the discharge column is in molten state, but is held in place by the pressure of the vapour bubble.

- The discharge channel consists now of a superheated plasma made up of vaporized metal, dielectric oil, and carbon with an intense current passing through it.

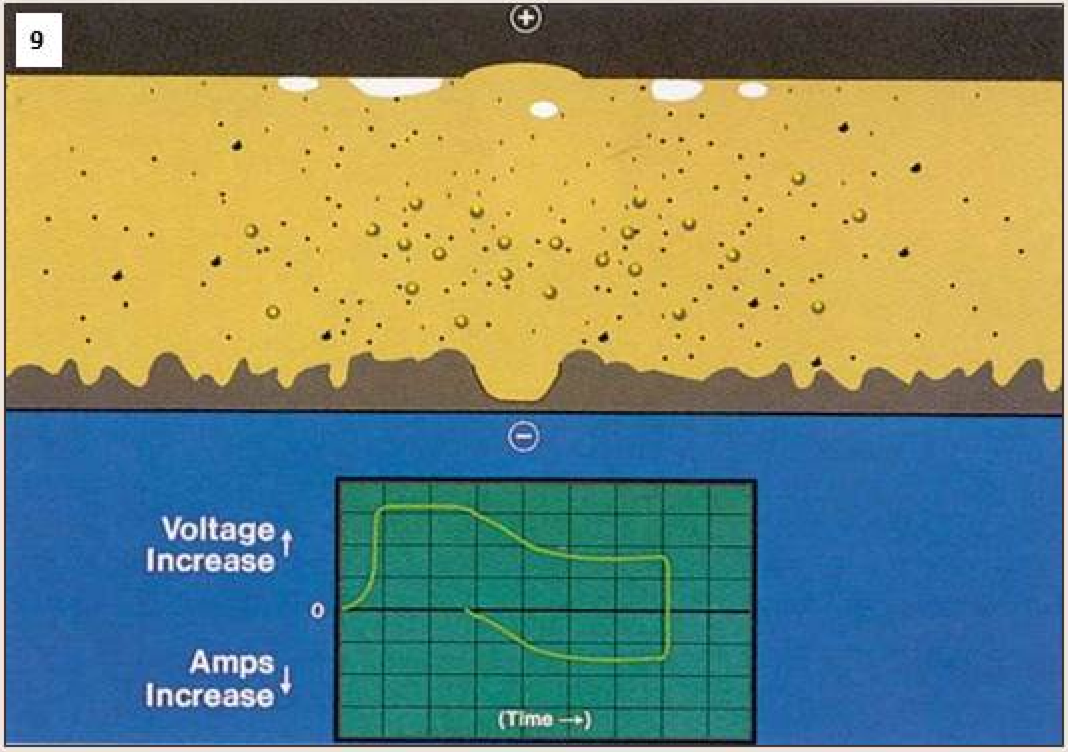




- At the beginning of the off-time, current and voltage drop to zero.
- The temperature decreases rapidly, collapsing the vapor bubble and causing the molten metal to be expelled from the work piece.



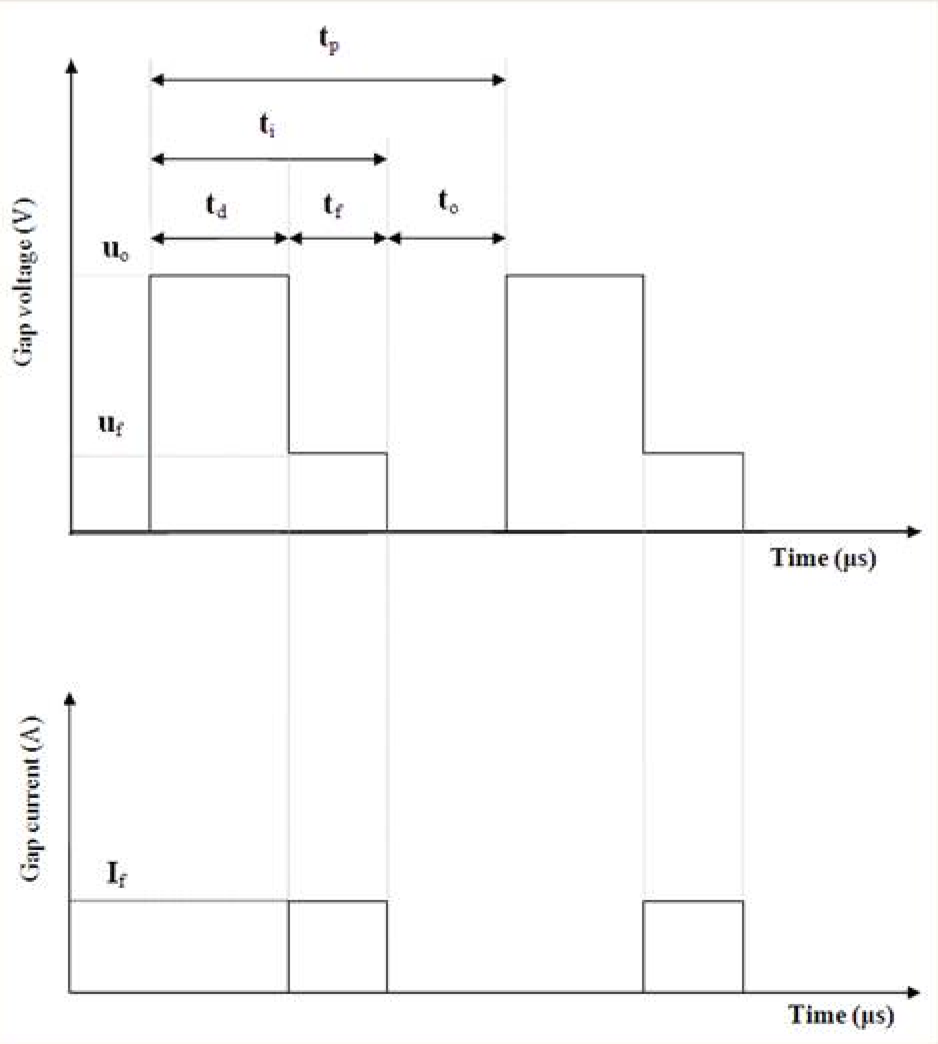
- Fresh dielectric fluid rushes in, flushing the debris away and quenching the surface of the work piece.
- Unexpelled molten metal solidifies to form what is known as the recast layer.



- The expelled metal solidifies into tiny spheres dispersed in the dielectric oil along with bits of carbon from the electrode.
- The remaining vapor rises to the surface.
- Without a sufficient off-time, debris would collect making the spark unstable. This situation could create a DC arc which can damage the electrode and the work piece.

- This on/off sequence represents one EDM cycle that can repeat up to 250,000 times per second.
- There can be only one cycle occurring at any given time.
- Once this cycle is understood we can start to control the duration and intensity of the on/off pulses to make EDM work for us.

Ideal EDM Pulse Cycle



t_d - Ignition delay time

t_f - Active pulse time or discharge duration

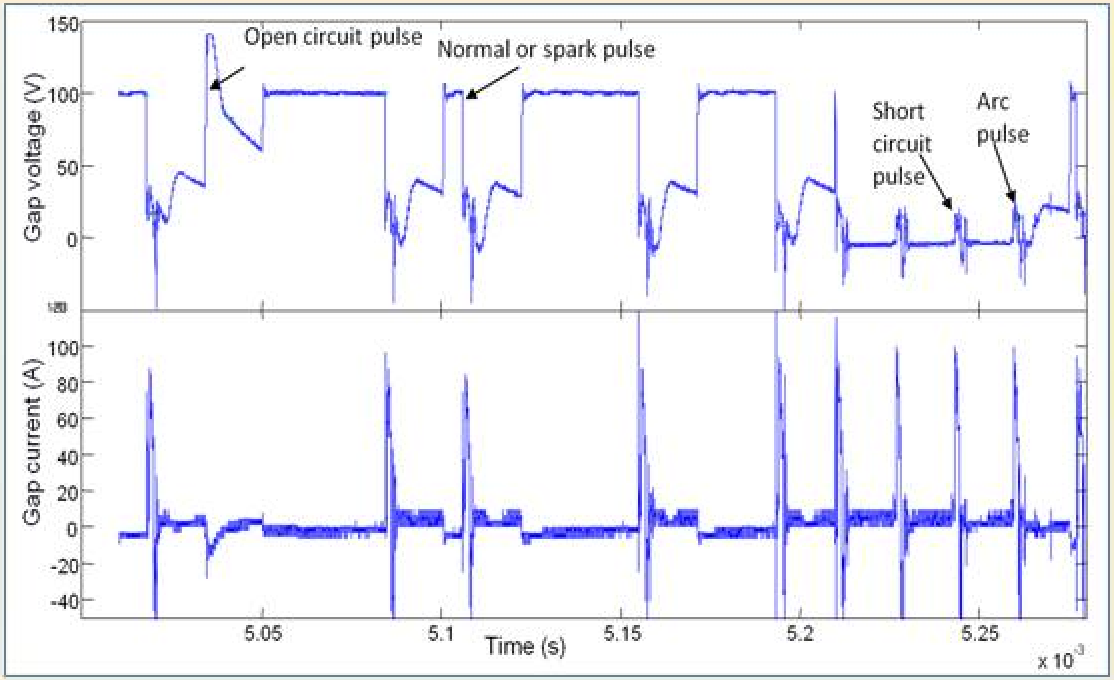
t_i - Voltage pulse time (or) pulse on time

t_o - Pulse off time

t_p - Voltage pulse cycle time

Actual Pulse Trains

Different types of discharge pulses in spark erosion machining processes

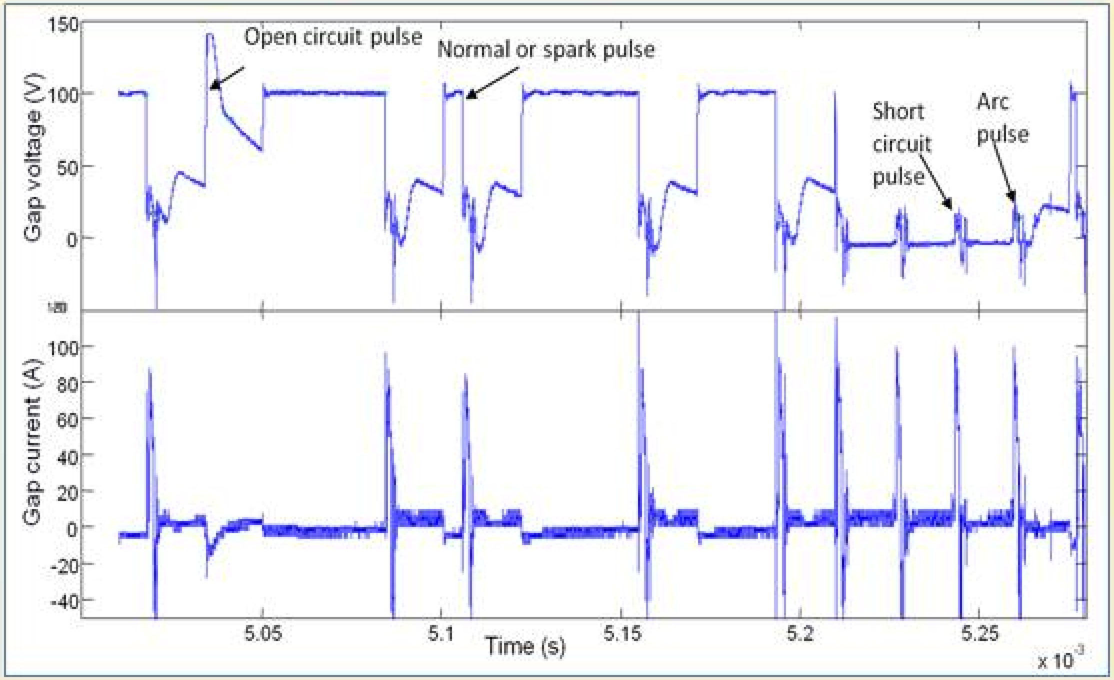


Open circuit pulse: Open circuit pulse is an inefficient pulse during which there is no discharge current and machining does not occur. This type of discharge occurs when the distance between two electrodes is far.

Normal or spark pulse:

A normal pulse is an effective pulse which is always is associated with an ignition delay. In this case discharge occurs after the ignition delay.

Different types of discharge pulses in spark erosion machining processes…



Arc pulse:

In case of arc pulse ignition delay is negligible or zero. In this case discharge occurs before the voltage reaches its peak. Occurrence of arc pulse is due to poor flushing condition, gap contamination which depends on the concentration of debris at the spark gap. If the pulse off time is not sufficient to deionise all the charge carriers formed during the previous discharge. Arcs damage the surface finish.

Short circuit pulse

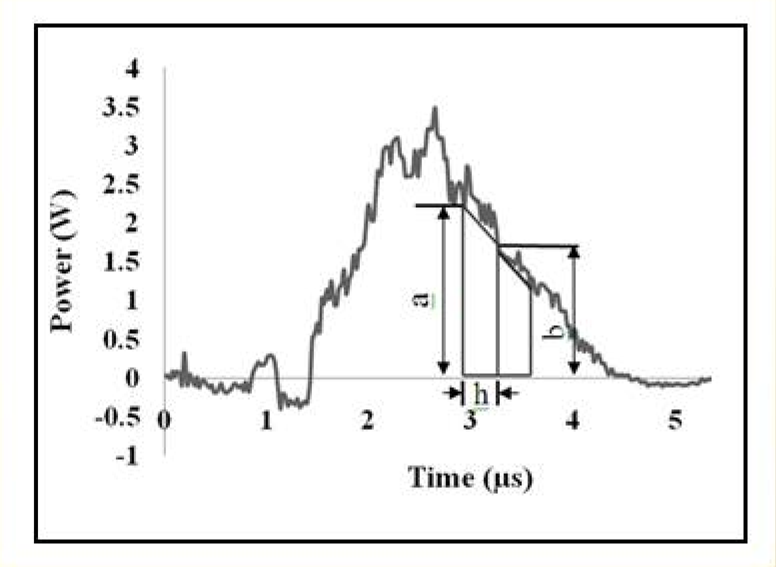
Short circuit pulse almost resembles an arc pulse. It is difficult to distinguish between short and arc pulse. A short circuit is differentiated from the arc pulse by the discharge voltage. The discharge voltage of short circuit pulse is lower than that of arc pulse. The occurrence of short circuit pulse is due to the contact between the electrodes and bridging of gap between the electrodes by debris.

Energy Consumption

- Energy (E) is calculated using power pulse train by integrating the power pulse with respect to time.
- When P(t) is the power in watts, t_1 and t_2 are the time intervals, the energy is given by the equation

$$E = \int_{t_1}^{t_2} P(t)\,dt$$

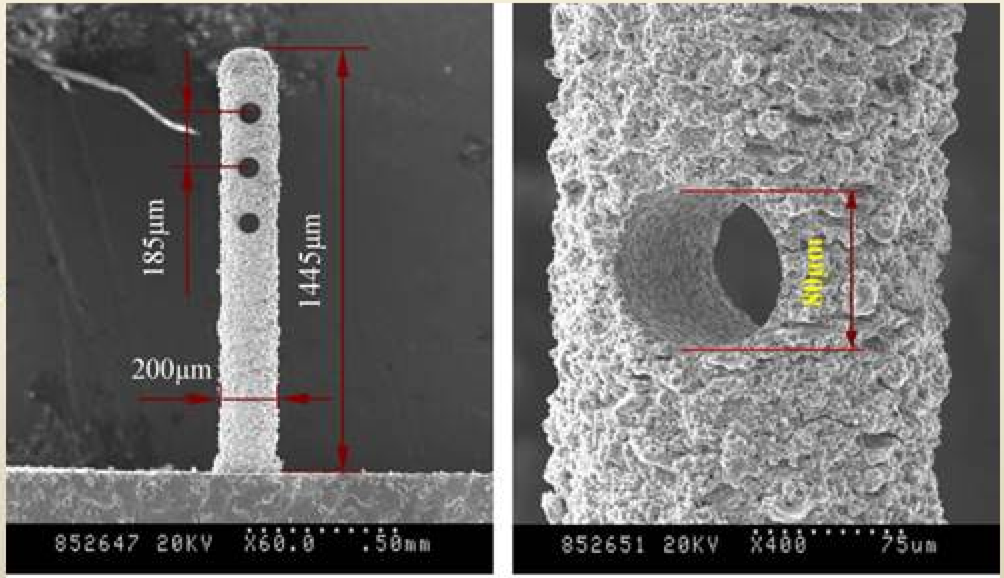
The energy (E) is represented as the area under the power pulse train by dividing the area bound between the curve and the axis into small trapezium and adding their areas, as shown.



MICRO EDM DRILLING

- In micro-EDM drilling process, the purpose of machining is to remove material from the work piece, so the machining polarity should be set as follows: the tool electrode is cathode and the work piece (deposited material) is anode.
- The micro-steel cylinder (Ø200μm) deposited and micro-holes with 80μm in diameter are drilled in the radial direction using micro-EDM drilling is shown in Figure.

Selective removal of micro-EDM drilling:
(a) Steel cylinder with holes
(b) 80μm micro-hole



(a) Steel cylinder with holes (b) 80μm Micro hole

MICRO-EDM MILLING

- Micro-EDM milling is a useful process for the fabrication of micro-3D structure using a simply shape tool electrode machining layer by layer with proper path planning.

- Using the end discharge of a tool electrode scanning in each layer has special advantages in machining 3D micro-structures with high aspect ratio or made of high-performance materials.

- Then the tool electrode feeds vertically a distance of layer thickness to compensate the tool electrode wear for the next layer machining.

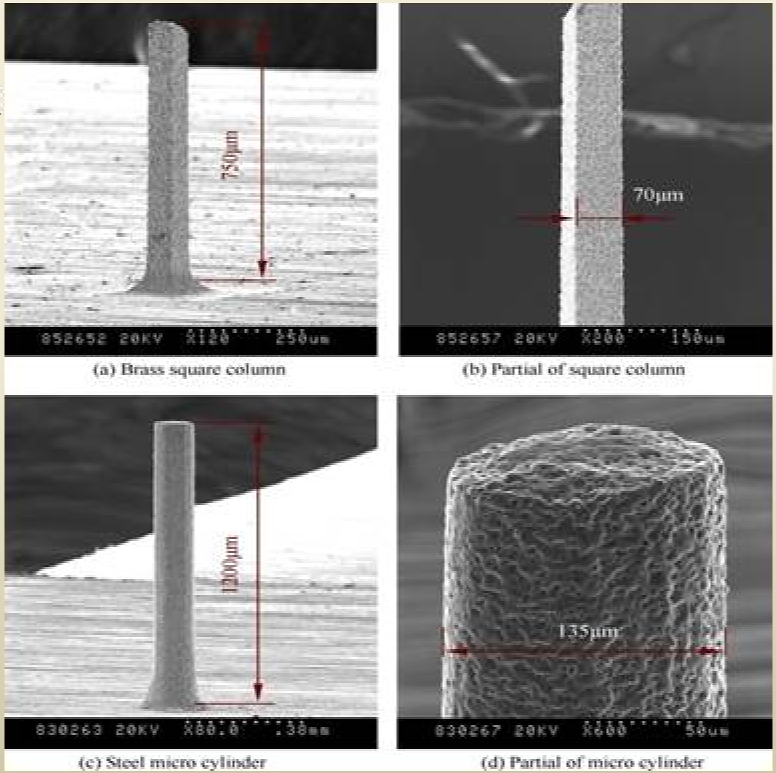
- The tool electrode is set as cathode and the kerosene is applied as the working medium.

- The diameter of tool electrode is 200μm with the revolution velocity of 2000 rpm. The thickness of each layer is selected as 10μm, which is just little than the discharge gap of the micro-EDM.

- As a result, micro-structures with fine surface quality and high dimensional precision were fabricated.

- A micro-square column with 70μm in side length and 750μm in height is fabricated from a micro-brass cylinder (Ø200m) deposited above
- It can be seen that the side walls of the micro-square column are smooth and the edges of regression between the side walls are very straight, which proves the high shape accuracy of the machining.
- The selective removal process of deposited material by using micro-EDM milling has good repeatability
- Figure shows a micro-steel cylinder with 135μm in diameter and 1200μm in height from a deposited micro-steel cylinder

Selective removal of micro-EDM milling
(a) brass square column
(b) partial of square column
(c) steel micro-cylinder
(d) partial of micro-cylinder

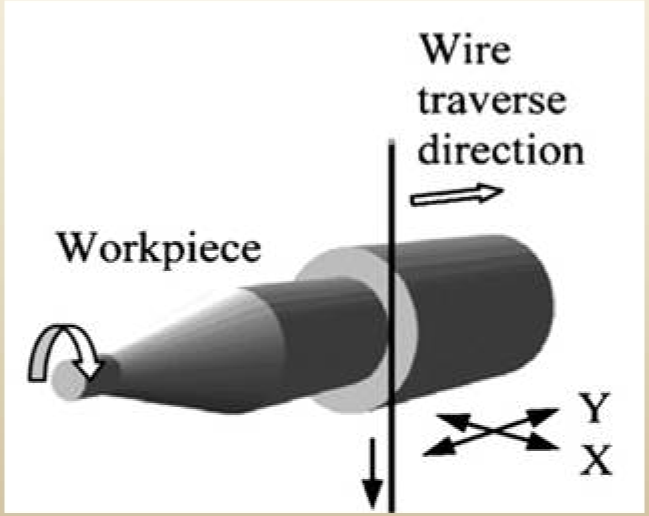


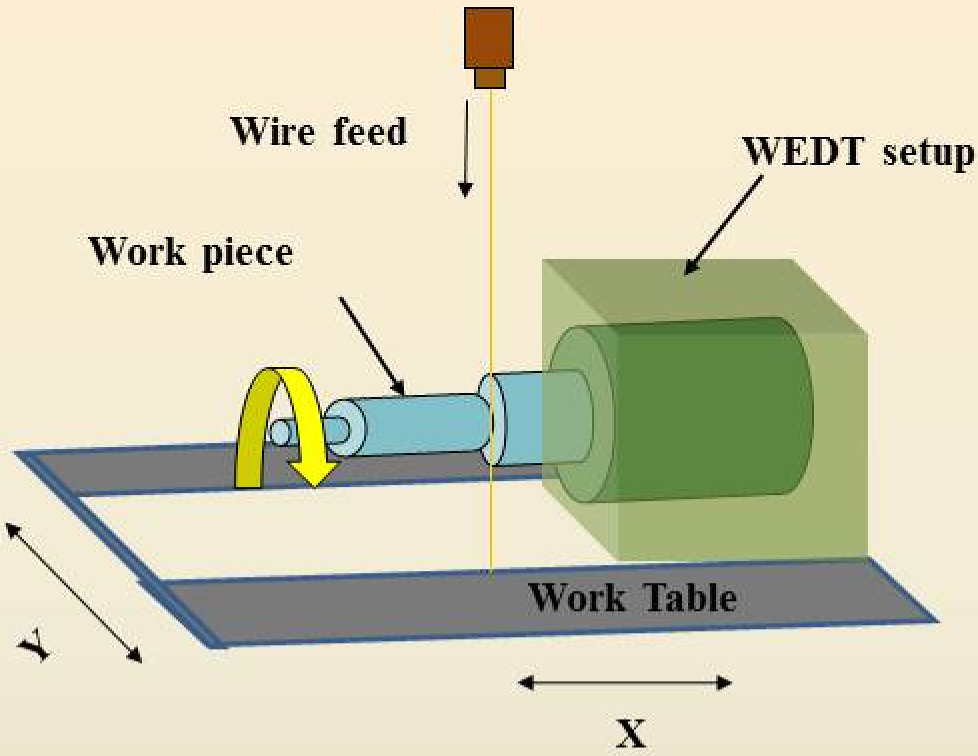
(a) Brass square column
(b) Partial of square column
(c) Steel micro cylinder
(d) Partial of micro cylinder

WIRE ELECTRICAL DISCHARGE TURNING (WEDT) PROCESS

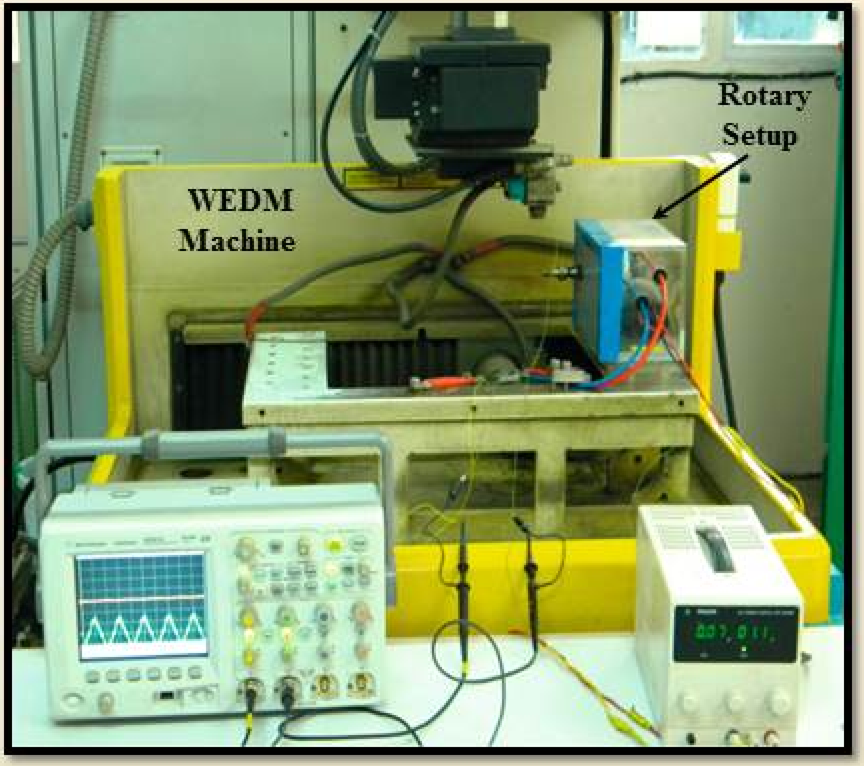
- One of the configurations of WEDM is Wire Electrical Discharge Turning (WEDT) process .
- In 1997, Masuzawa and Tonshoff presented a keynote Paper at the Scientific Technical Committee Paper Discussion Sessions and reported turning of small diameter pins of size 5µm using WEDM.
- Turning with WEDM is one of the emerging areas, developed to generate cylindrical form on hard and difficult to machine materials by adding a rotary axis to WEDM as shown in figure.
- The electrically charged wire is controlled by the X and Y slides to remove the work material and to generate desired cylindrical form on the work piece.

- A rotary axis is added to wire EDM machine in order to produce axisymmetric parts.
- The initial shape of the part needs not to be a cylindrical form.





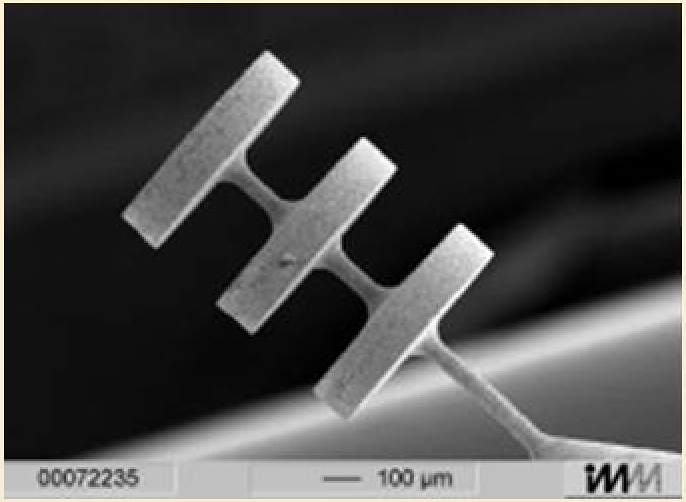
Schematic illustration of the wire EDT process



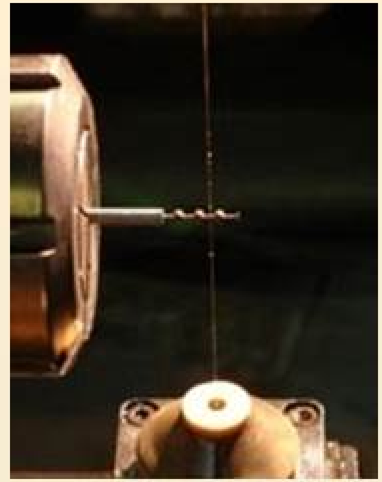
Wire EDM machine with rotary setup
(Janardhan and Samuel, 2010)

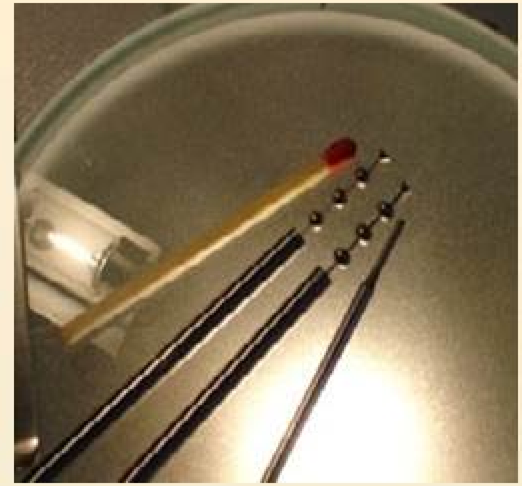
Characteristics features of WEDM turning

- Smallest diameters can be produced
- Very high surface quality
- Several production steps can be put together to EDM Turning
- Reduction of Set Up Time
- No shape grinding wheels anymore
- Contour stability
- Can be modified for a production solution
- Surface quality as grinded

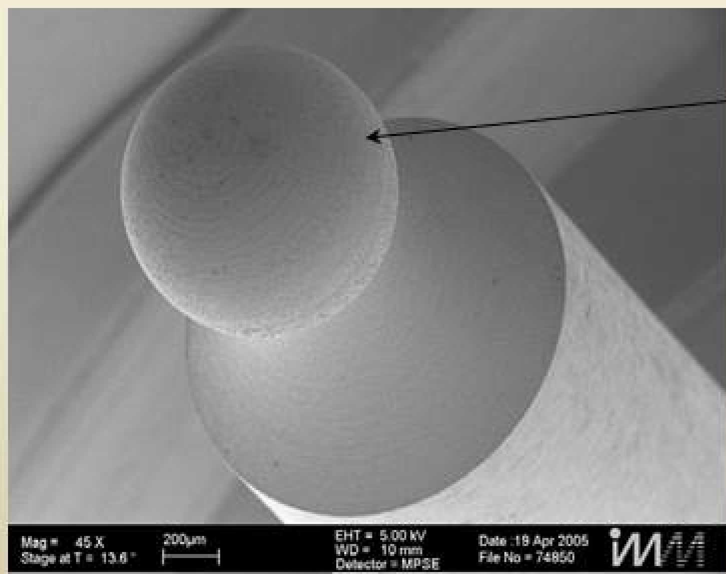


Electrode for die-sinking applications

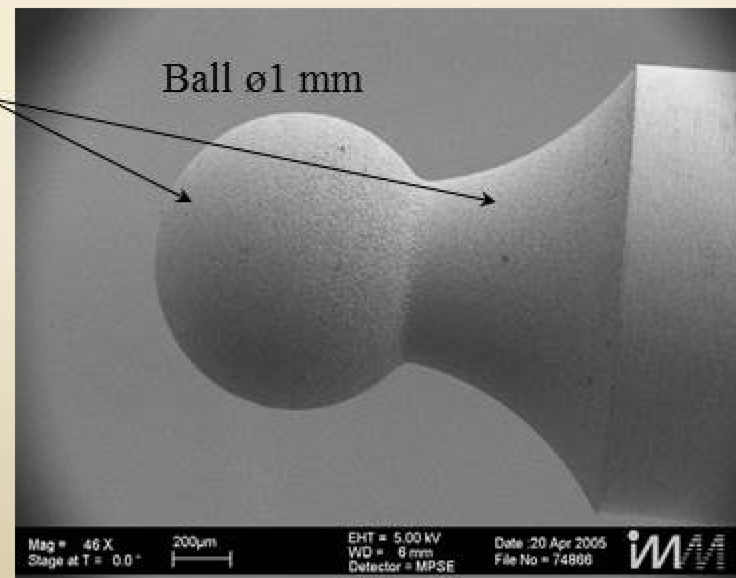




Production of discharging stamps

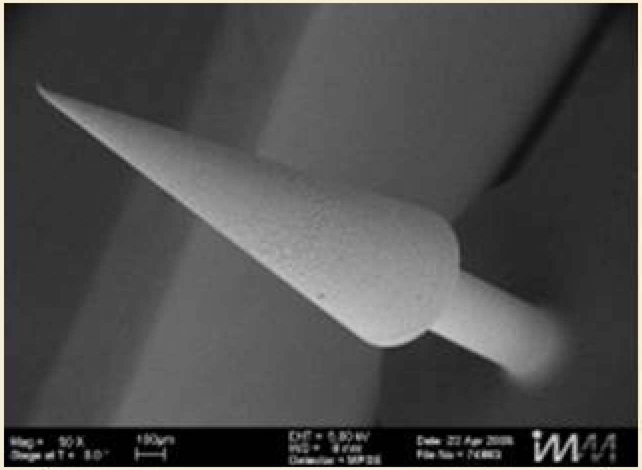


EDM turned region

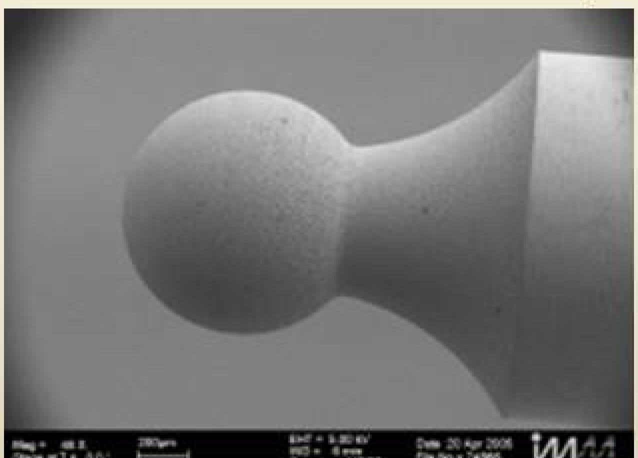


Plunger for a micro pump

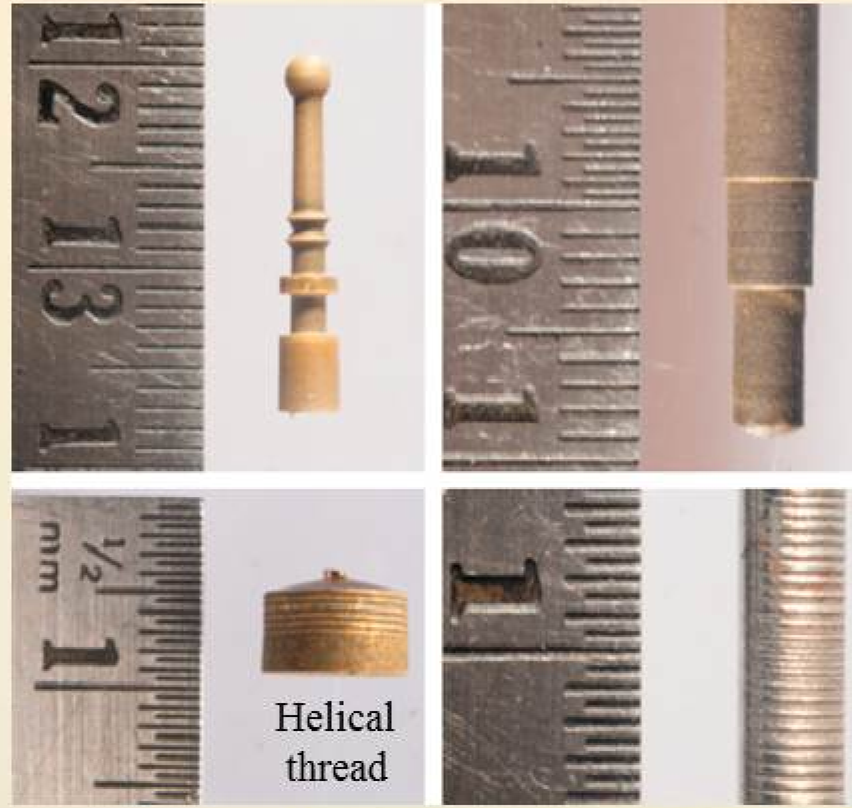
Components machined using WEDT process



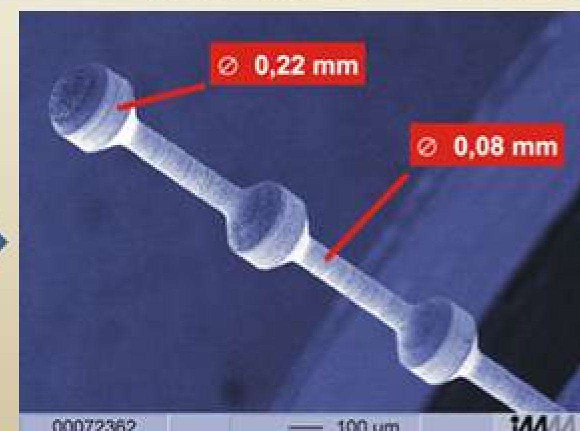
Micro needle tip for medical application, Tip ø 3 µm



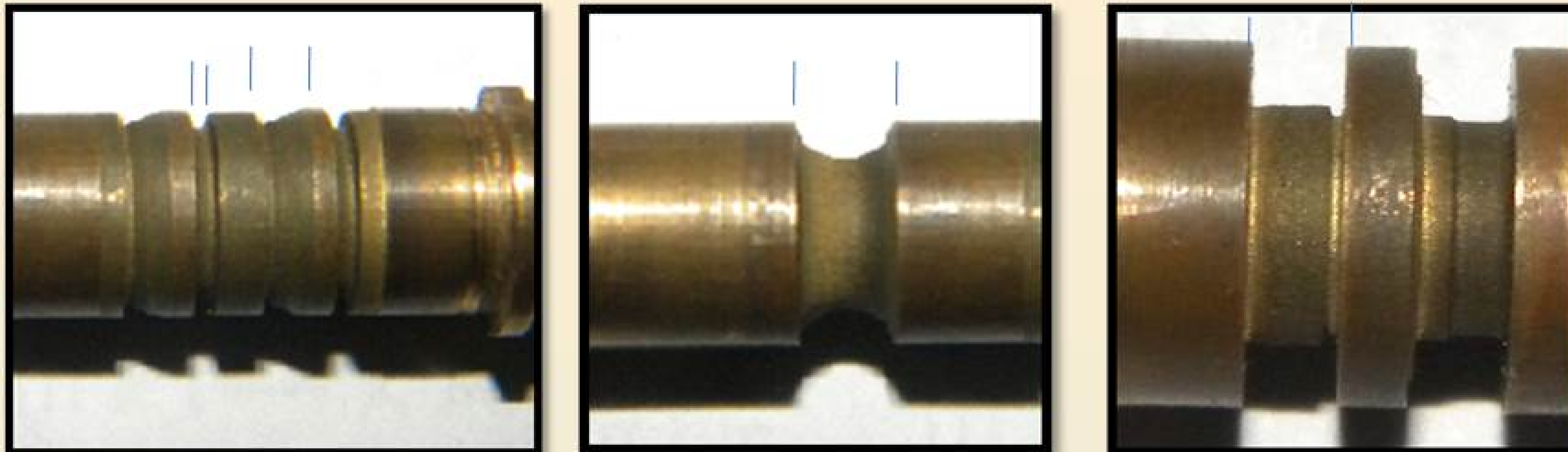
Micro driving rod with ball end ø 0.8 µm



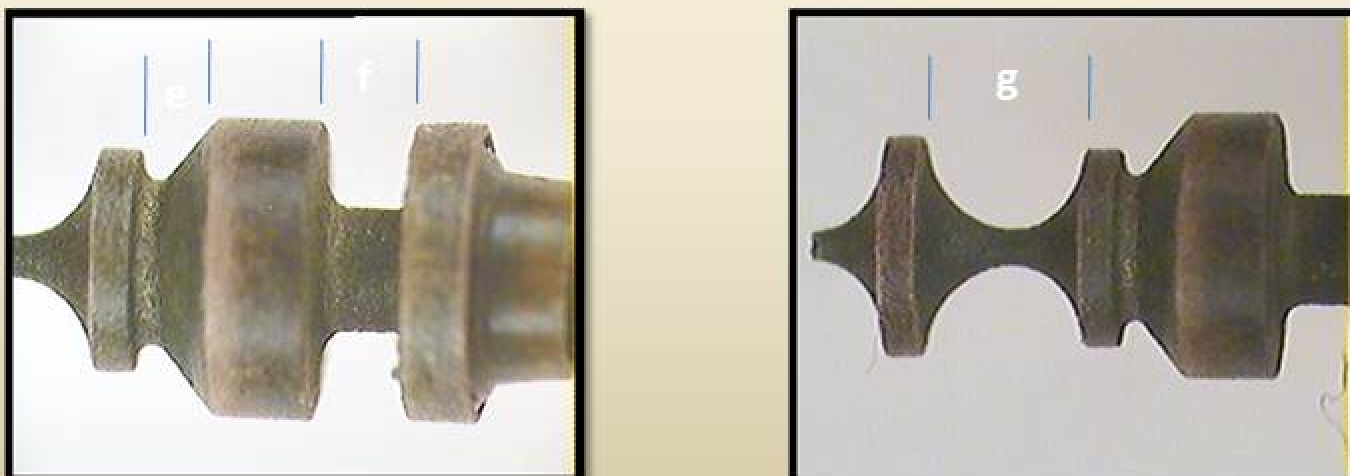
EDM turning of microstructures



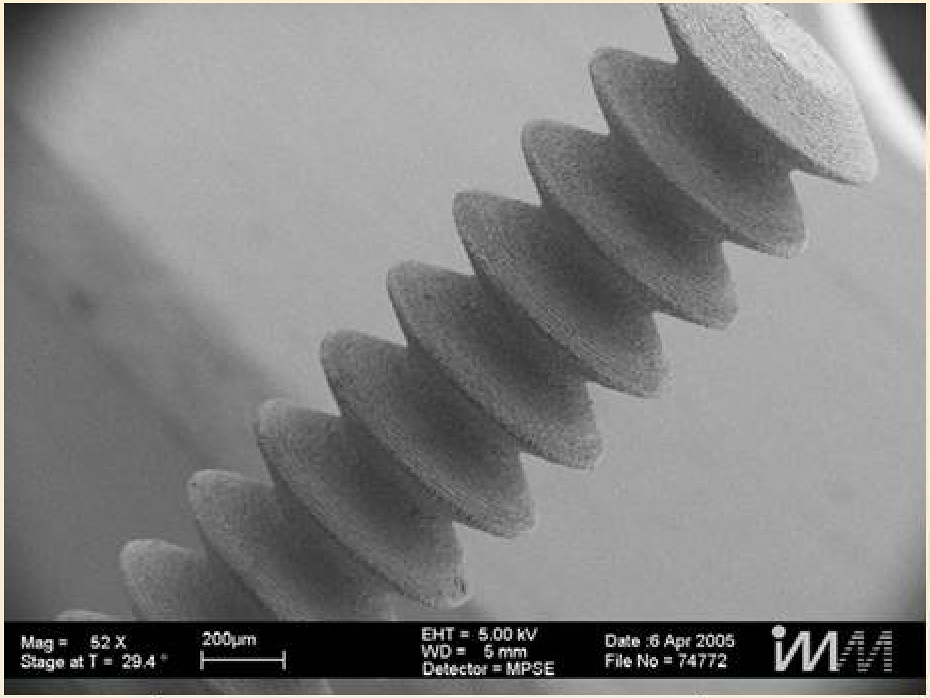
Components Machined

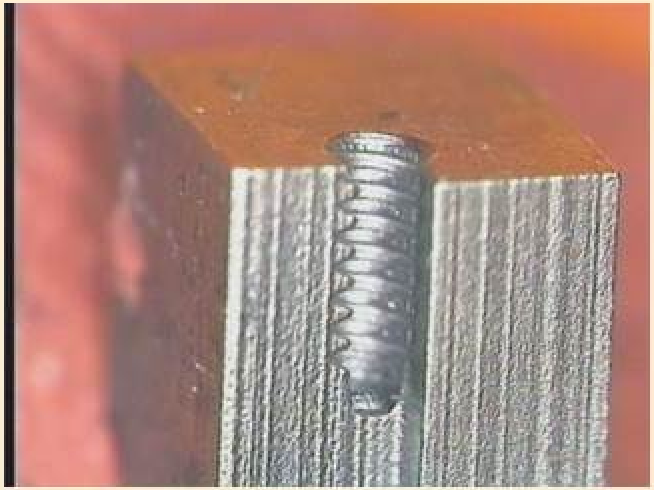


Different axi-symmetric shape machined (10 mm dia. Work piece)



Axisymmetric form on 3 mm diameter specimen(optical microscope image)

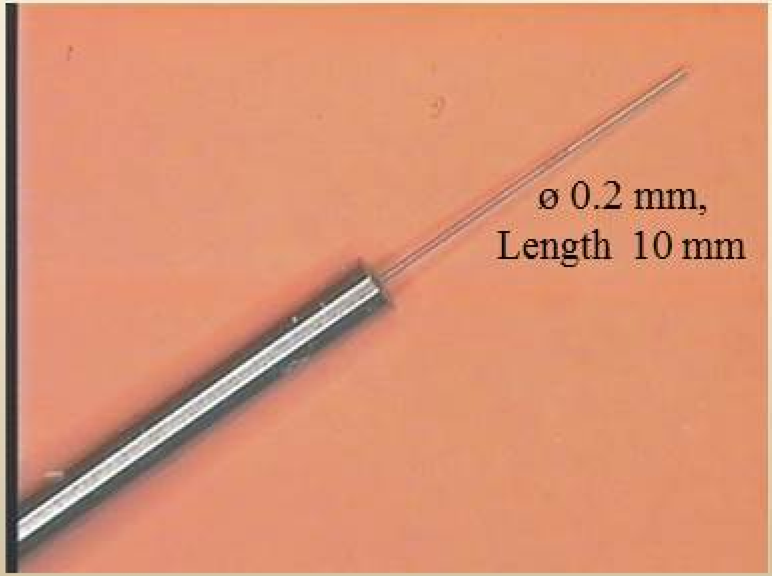




Screw Thread M1
ø 0.7 mm and Lead 0.25mm

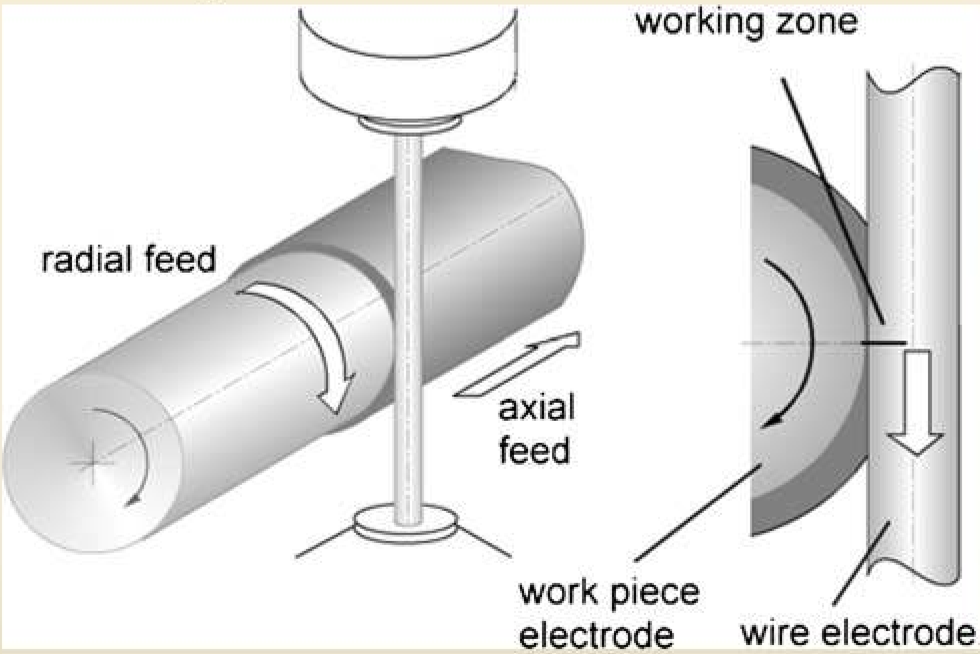
Pocket hole Screw Thread M1 produced by sinking EDM on a hardened steel using this electrode

EDM turned Discharging stamps for Micro injection moulds



WIRE ELECTRICAL DISCHARGE GRINDING (WEDG)

- Using a wire electrode traveling along the groove of a wire guide, a micro rod can be machined like in a turning process to achieve high surface finish.

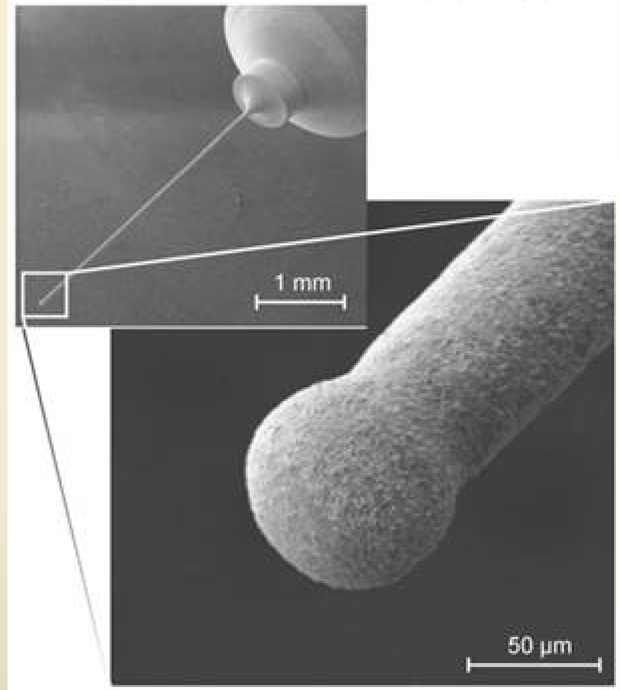


Kinematical conditions of WEDG

- In WEDG, there is no problem of wear, because a renewable wire is used as tool electrode. Since the wire is guided by the groove of the wire guide, machining accuracy is not deteriorated by the wire vibration unlike the WEDM process.

process parameters:

wire electrode :	MicroCut, d_D = 0,07 mm,
work piece:	cylinder, WC, d_w = 3 mm, l = 5 mm
machining strategy:	radial infeed, axial feed
	rotational speed n_w = 100 min^{-1},
technology:	4-cut technology regarding tab. 2



geometrie element	nominal	measured
shank diameter base point	80 µm	78,0 µm
shank diameter tip end	80 µm	69,5 µm
sphere diameter	100 µm	89,8 µm

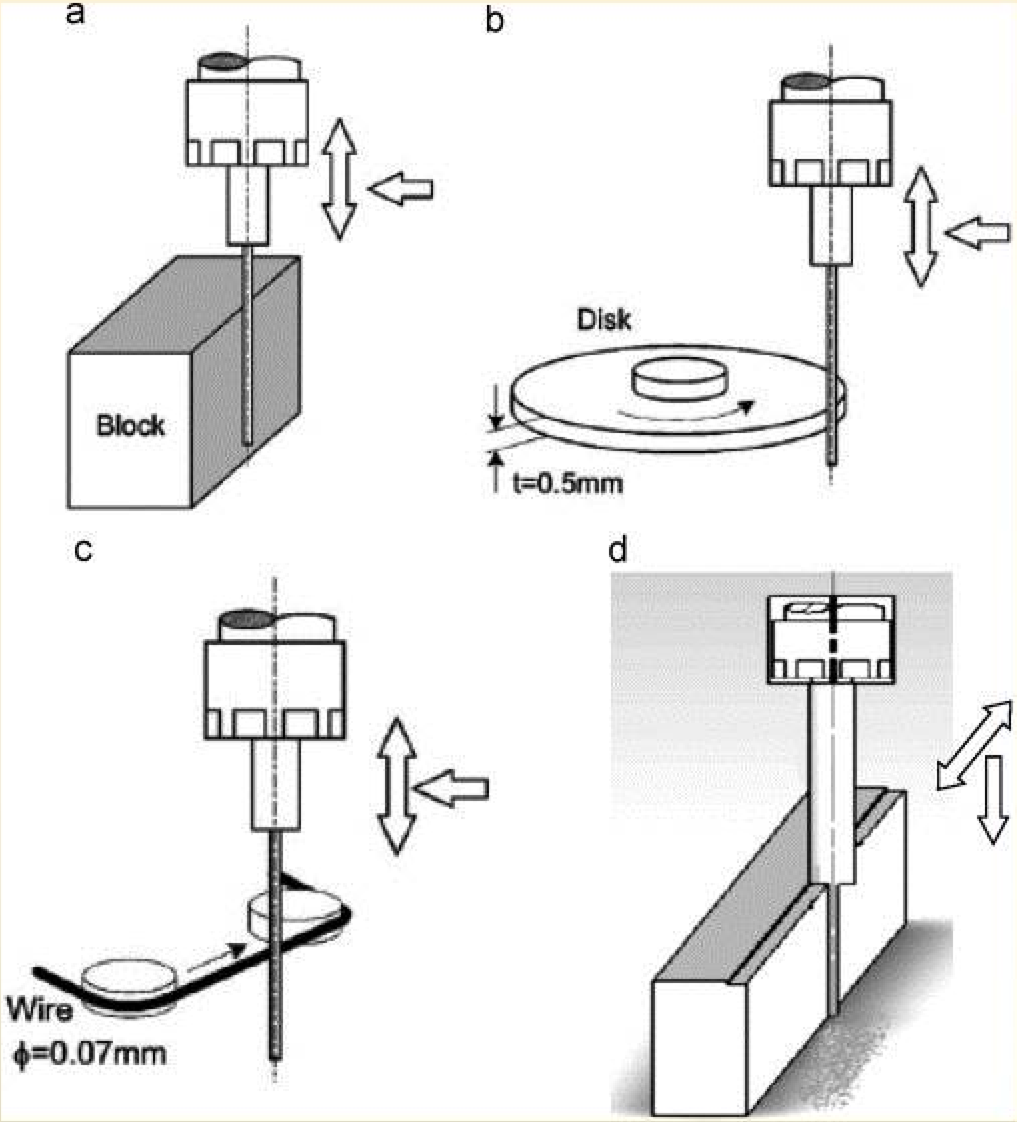


Fig. 4. Different types of micro-EDG process using (a) stationary sacrificial block, (b) rotating sacrificial disc, (c) wire-EDG, and (d) moving BEDG process [33].

Principle of Powder Mixed EDM (PMEDM)

- Chain like structures, inter locking, bridging, series discharges, enlarged and widened plasma channel.
- Improvement of MRR and SR

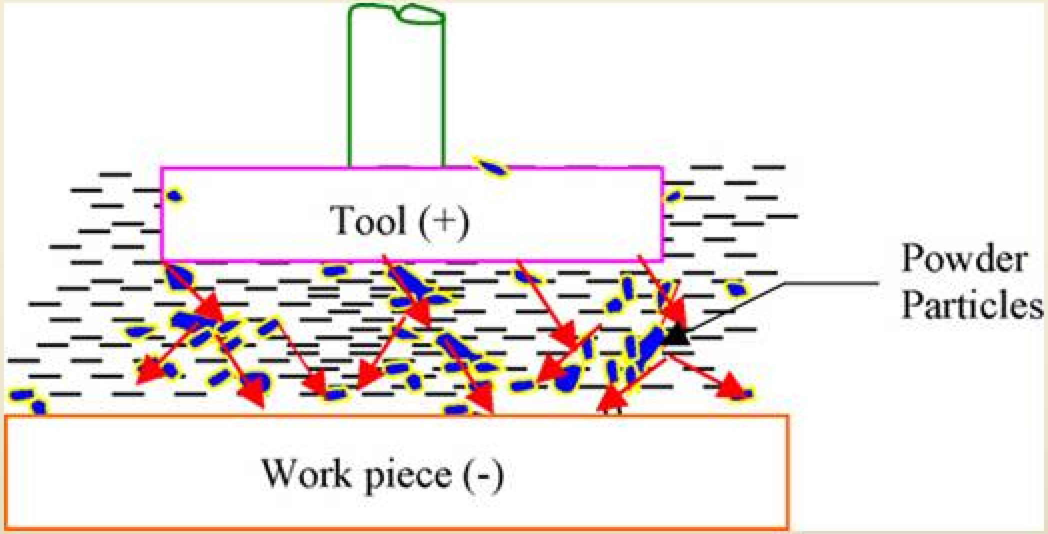


Fig.2 Mechanism of PMEDM
Khansal H.K et al (2007)

ABRASION-ASSISTED WEDM

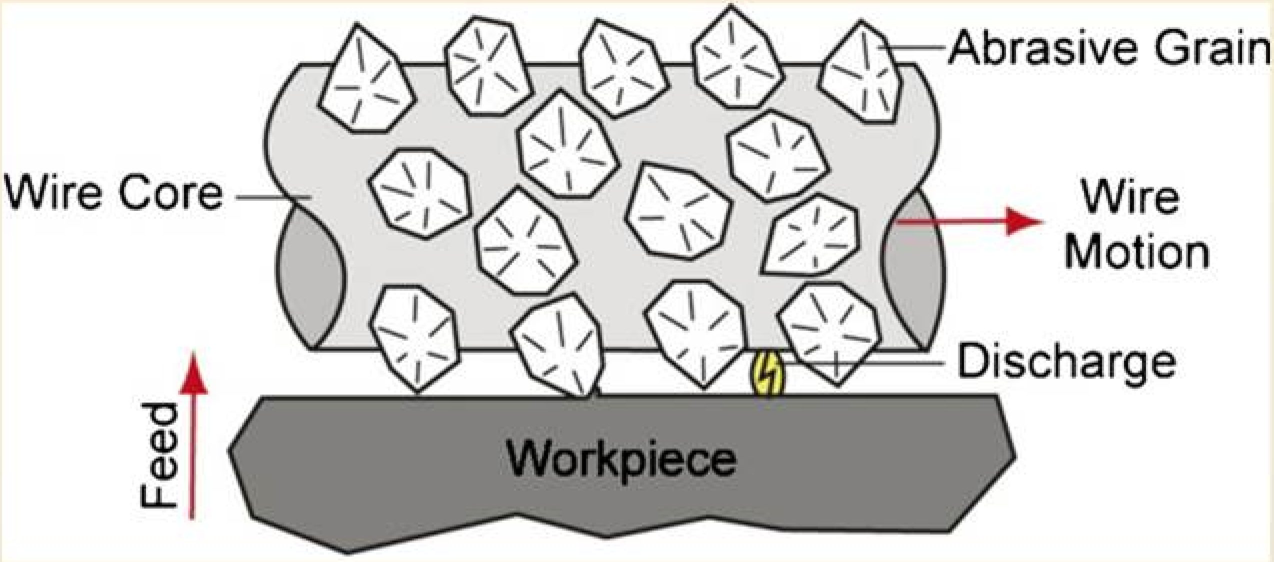
- The concept of integrating abrasion into electrical discharge machining for processing electrically conducting hard materials seems to have been first proposed by Grodzinskii and zubotava in the early eighties.

- AWEDM is helpful in productive machining of advanced engineering materials that are difficult to machine, in plunge grinding and drilling configurations.

- This combination can be viewed in terms of the electrical spark discharges augmenting grinding performance through effective in-process dressing/declogging of the grinding wheel and thermal softening of the workpiece material, alternatively, the abrasive action can be considered to enhance electrical erosion through in situ removal of the molten/recast workpiece material.

- AWEDM is realized by replacing the wire used in WEDM by a fixed-abrasive wire, and can therefore be considered to be a combination of WEDM and a wire sawing process at relatively low wire speed.

- The process kinematics in AWEDM is similar to that of WEDM: the wire translates along its axis lateral to the machined surface while being simultaneously fed relative to the wire axis under servo control, such that a dielectric filled gap of several mm is maintained between the work piece surface and the wire core.



Schematic of AWEDM

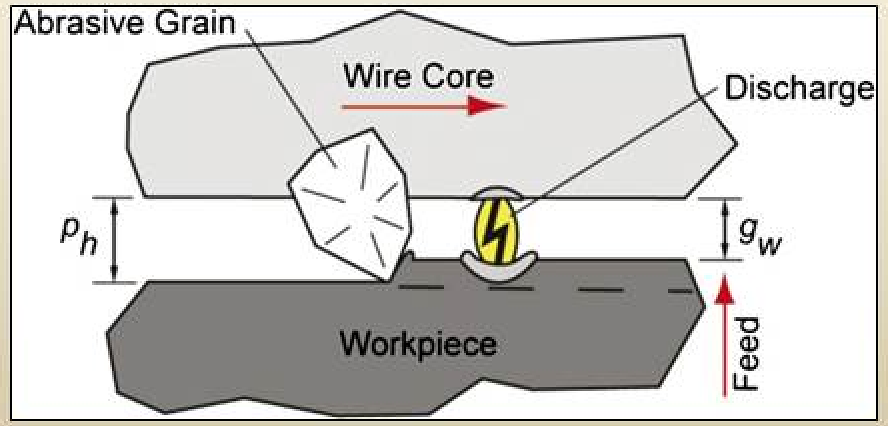
- As the gap width is sensed and controlled electrically, it is essential that the wire core is electrically conductive and the abrasive is electrically non-conductive.

- Under conditions that the abrasive protrusion height ph is greater than the working gap width g_w (ref. figure below), electrical discharges occur between the wire core and the workpiece to remove material by spark erosion, while the abrasives simultaneously abrade the workpiece.

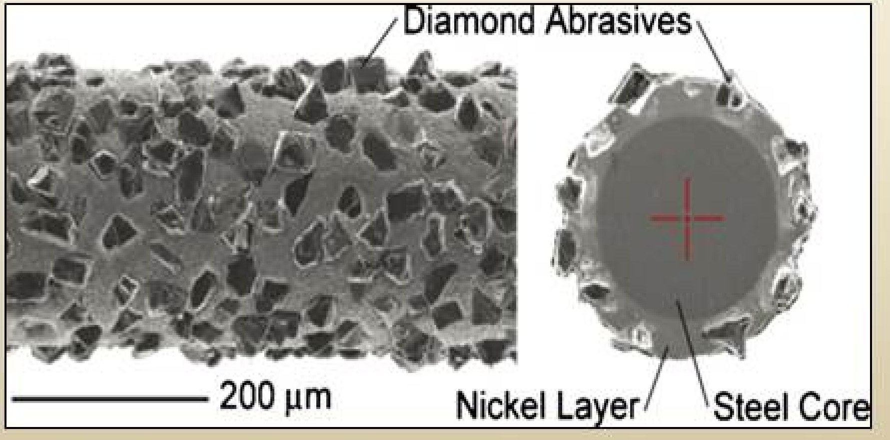
- For a particular servo reference voltage setting, g_w is dependent on the dielectric strength of the working fluid in the gap; ph is primarily determined by the size of the abrasives used in the wire.

- The extent of material removal by abrasion in AWEDM is controlled by the relative magnitudes of g_w and p_h, both of which are random variables that are characterized by their distributions.

- At a certain location in the working gap, an active abrasive (ref. figure below) tends to remove an uncut thickness (p_h -g_w) work piece material that could be molten, thermally softened or recast, depending on the time interval between the occurrence of a discharge along the path of the abrasive and the abrasive engagement.

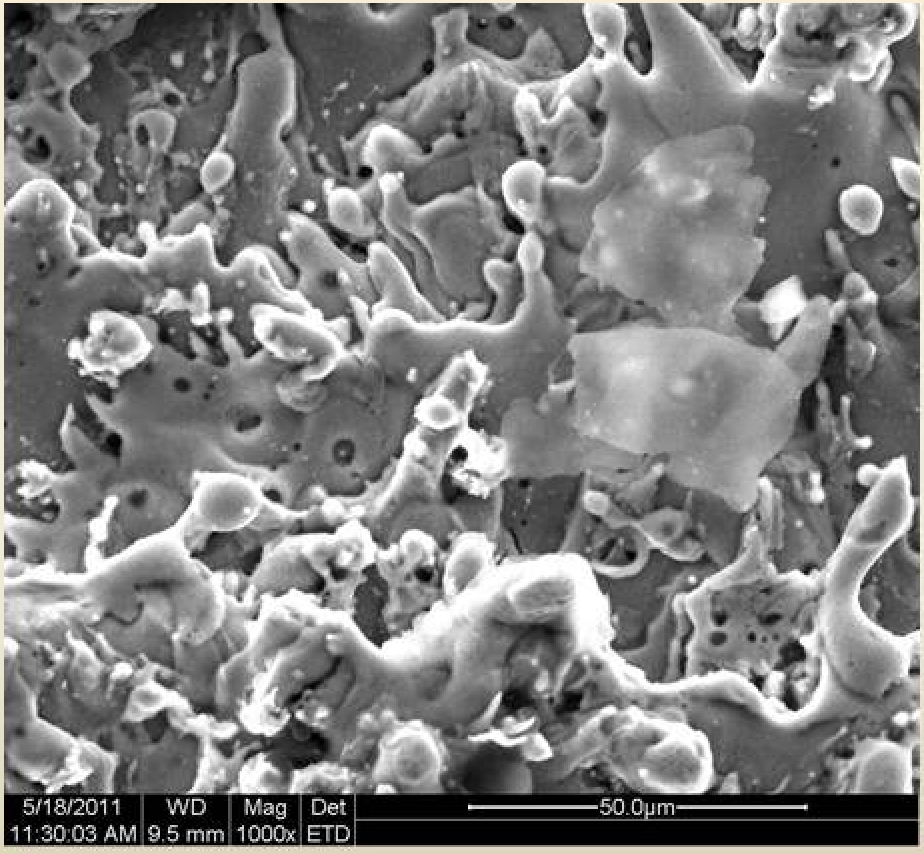


The inter electrode gap in AWEDM



Surface and section of diamond wire

Typical EDMed surface

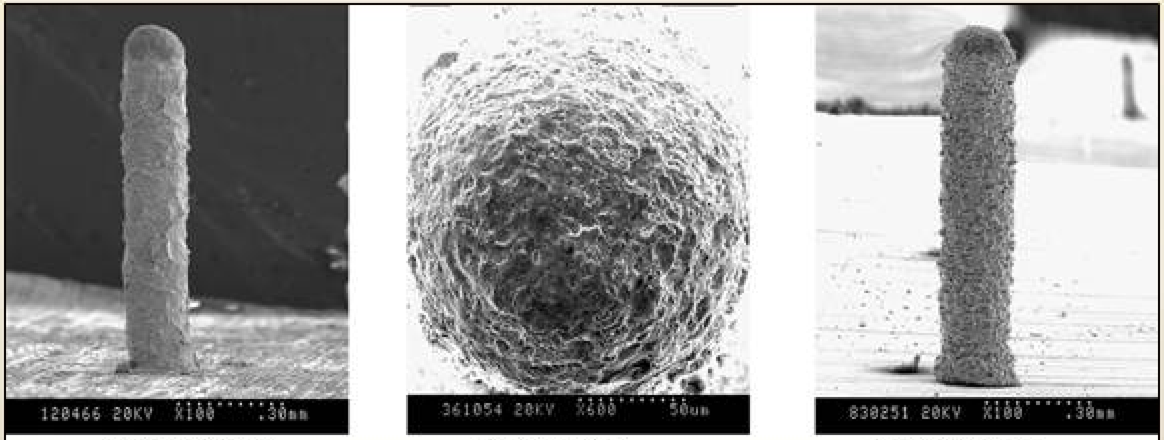


MICRO –EDM DEPOSITION PROCESS

- The process of EDM deposition can be described as follows
  - Medium ionization and forming of a discharge channel
  - Tool electrode material melting or gasifying removal
  - Removed tool electrode material depositing on the cathode and deionization.
- Repeating the above mentioned steps, metal material from the tool electrode will be deposited on the work piece surface.
- The tool electrode material can be deposited on the work piece to form the micro-cylinders using micro-EDM deposition process.
- However, in deposition process, the removed tool electrode material that has been melted or gasified will adhere to the side surface of the deposited cylinders.
- The dimension accuracy and surface quality of the deposited micro-features will be unsatisfied with the desired needs of application. So a selective removal process of the deposited material has to be carried out.
- Selective removal experiments like micro-EDM drilling in radial direction and micro-EDM milling can be used.

SELECTIVE REMOVAL OF THE DEPOSITED MATERIAL

- Micro-EDM deposition process can be used to fabricate micro features by depositing tool electrode material on to the work piece material.
- However, in deposition process, the removed tool electrode material that has been melted or gasified will adhere to the side surface of the deposited feature.
- The dimension accuracy and surface quality of the deposited micro-feature will be unsatisfied with the desired needs of application.



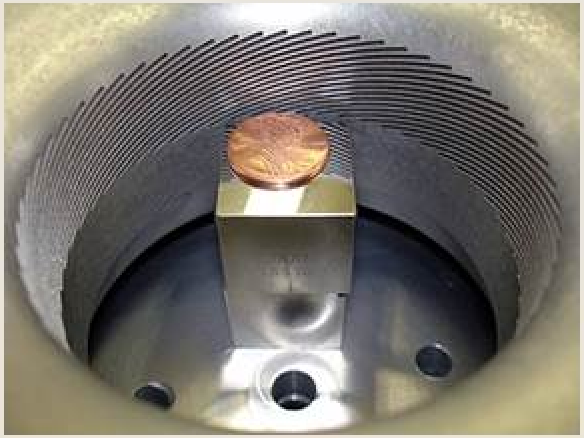
(a) Brass cylinder (b) End surface (c) Steel cylinder

Micro-cylinders fabricated by EDM deposition process
(a) brass cylinder (b) end surface (c) steel cylinder

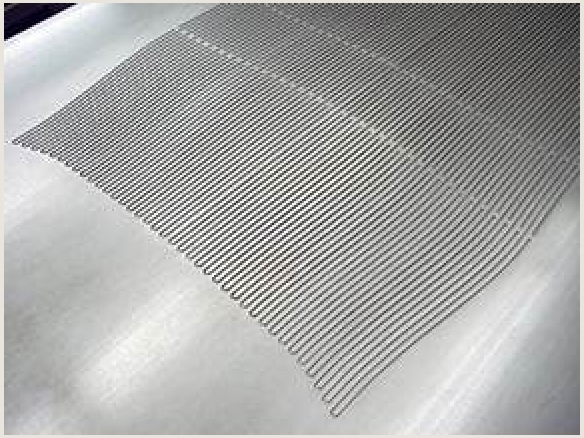
- So a selective removal process of the deposited material is to be carried out. Several removal strategies including micro-EDM drilling and micro-EDM can be used.

Applications of EDM and Micro EDM

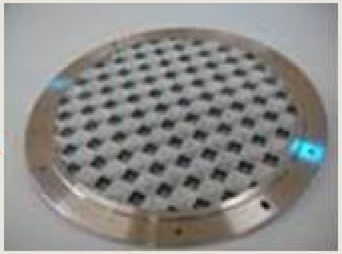
- Complex dies sections and molds can be produced accurately, faster, and at lower costs.
- Thin fragile sections such as webs or fins can be easily machined without deforming the part.



EDM machined components

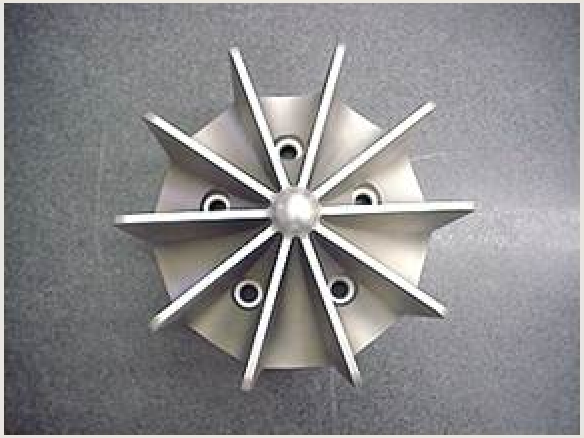


Optical reflector made by EDM

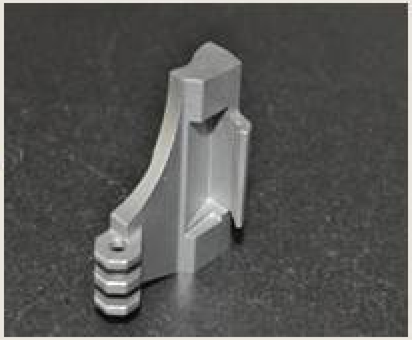


EDM in manufacture of Aircraft components

Manufacturer of **complex EDM micro, miniature and small parts for aerospace and aircraft parts on all hard and tough materials.**



- These precision Inconel Cargo Latches are manufactured completely using EDM and is used in an Aerospace application
- The final cargo latches measured 2.00 inches thick, and manufactured with +/- .0005 of an inch tolerance.



EDM in manufacture of Satellite components

- Manufacturing of complex satellite parts on the hardest and toughest materials to close tolerance.
- **Machining EDM Parts for application of miniature, small, large and giant parts and components for satellite, defense, rocket applications.**

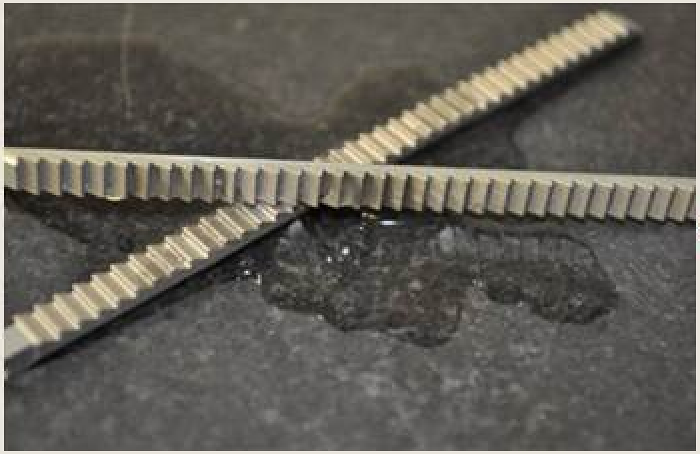


Surface illumination of "filler nozzle." Approximately 20° of angle from center line of pattern.

EDM in manufacture of Medical components

- Some of the materials used for the most part in the surgical and medical EDM applications are Tungsten, Molybdenum & Titanium.

Pieces are EDM machined to minimum lengths as small as .300” and widths of .100”, with material thickness as thin as .024”.



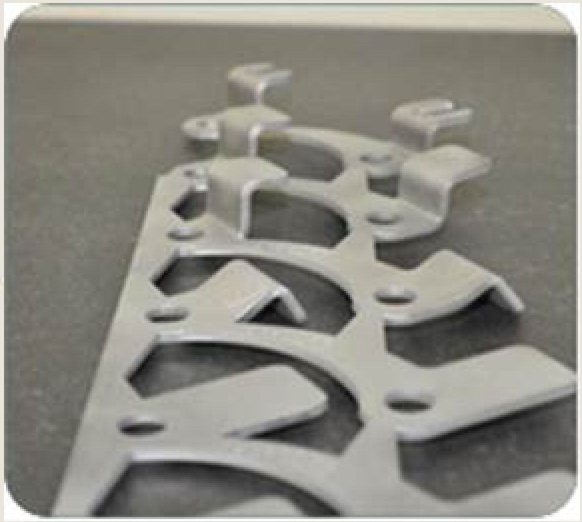
- These precision machined Stainless Steel Ratchets are used within a medical device (Medical device ratchet).
- The final ratchets measured 5.500 inches long, .180 inches wide, .200 inches thick, and featured a .004 inch maximum internal radius with a surface finish of 32 RMS.

EDM in Tooling & Die manufacturing

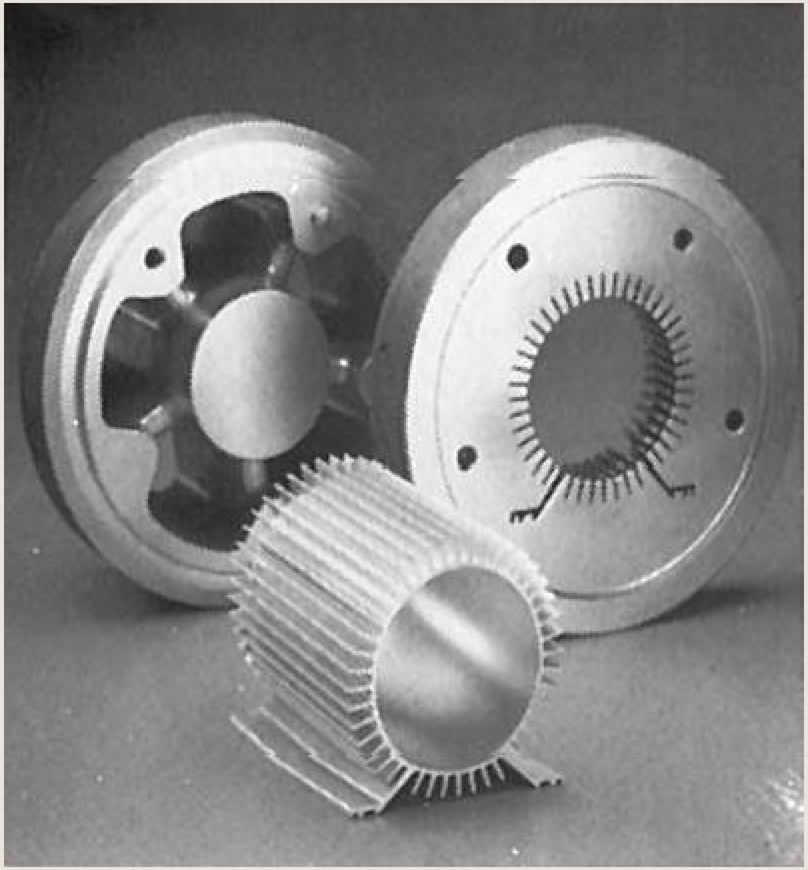
- Applications include producing die cavity for large components, deep small holes, complicated internal cavities.
- Dimensional accuracy of ± 0.0005” is achievable.

These precision machined Progressive Dies made of D2 steel are used to manufacture a push rod guide plate for high performance automotive engines

The final dies measured 1.5 inches in thickness with a bend angle of 90 degrees, and featured a Rockwell Hardness value of 58-62.



Components Manufactured using EDM



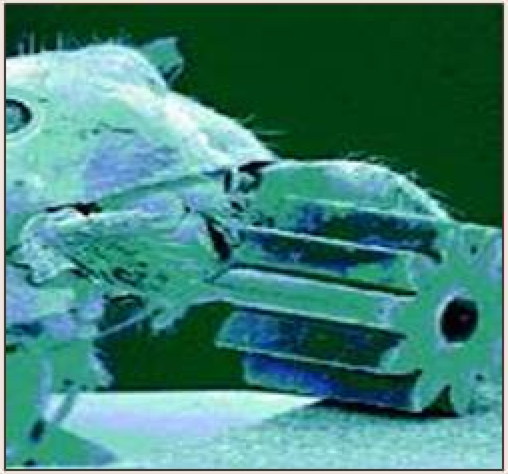
Examples of cavities produced by the EDM process, using shaped electrodes. Two round parts (rear) are the set of dies for extruding the aluminum the aluminum piece shown in front.

Stepped cavities produced with a square electrode by the EDM process. The work piece moves in the two principal horizontal directions (x-y), and its motion is synchronized with the downward movement of the electrode to produce these cavities. Also shown is a round electrode capable of producing round or elliptical cavities.

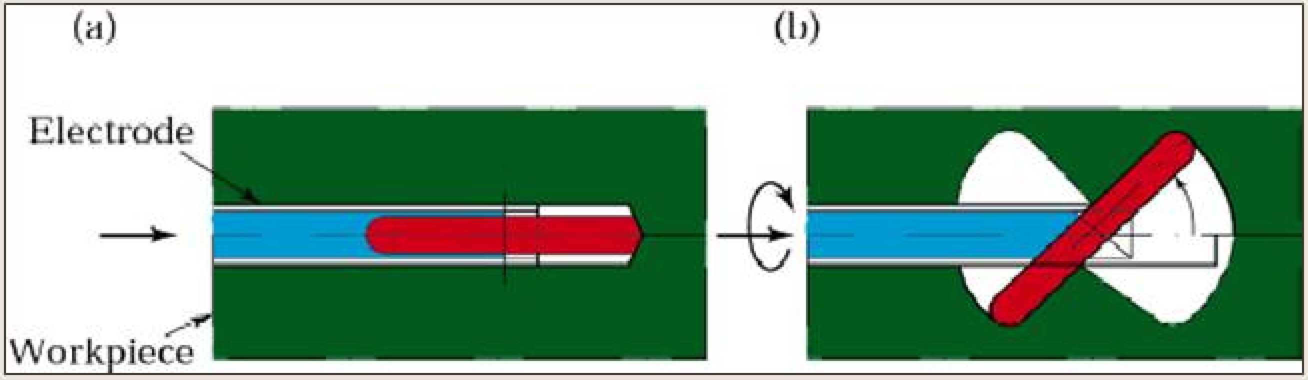
7075-T6 aluminum back plate latch, EDM cost is less than half the milling cost.

Intricately detailed automobile part

Small parts made using EDM



Small gear (with insect for scale) shows a capability of EDM micromachining.

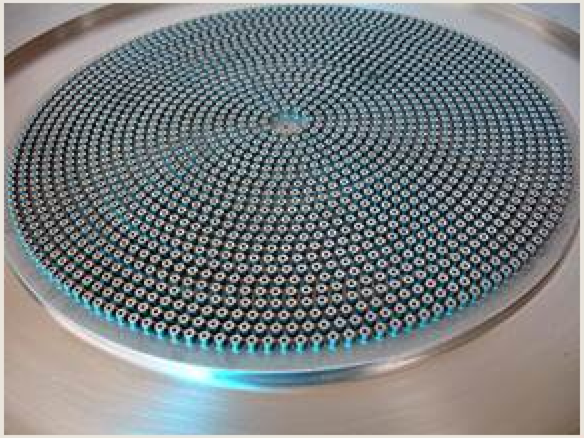


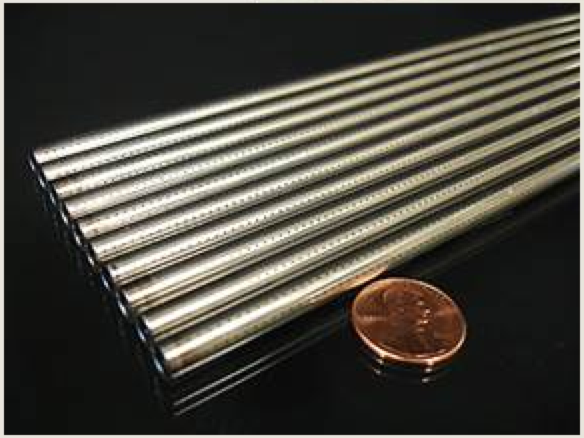
Schematic illustration of producing an inner cavity by EDM, using a specially designed electrode with a hinged tip, which is slowly opened and rotated to produce the large cavity

Micro features/Components

Micro Hole Drilling

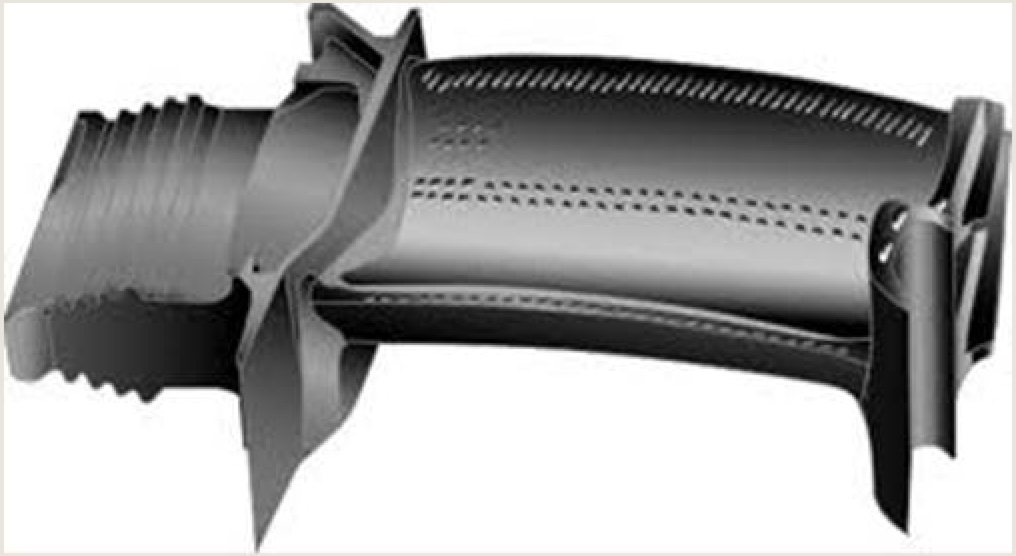
Difficult profiles are easily drilled with Small hole EDM. 0.040" diameter hole on center of .5000" diameter ball bearing





Angle EDM Hole Drilling
We can help with machining of wire safety holes or starter holes in parts where the hole is at an angle or on a curved surface and conventional drilling would be exceptionally difficult. Variety of burn hole patterns can be machined per specification.

Micro holes for cooling in Turbine Blades



WIRE ELECTRICAL DISCHARGE MACHINING (WEDM) PROCESS

- Wire electrical discharge machining (WEDM) is a widely accepted non-traditional material removal process used to manufacture components with intricate shapes and profiles. It is considered as a **unique adaptation of the conventional EDM process**, which uses an electrode to initialize the sparking process.

- WEDM was first introduced to the manufacturing industry in the late 1960s. The development of the process was the result of seeking a technique to replace the machined electrode used in EDM. In 1974, D.H. Dulebohn applied the optical-line follower system to automatically control the shape of the component to be machined by the WEDM process.

- By 1975, its popularity was rapidly increasing, as the process and its capabilities were better understood by the industry. It was only towards the end of the 1970s, when computer numerical control (CNC) system was initiated into WEDM that brought about a major evolution of the machining process. As a result, the broad capabilities of the WEDM process were extensively exploited for any through-hole machining owing to the wire, which has to pass through the part to be machined.

- Wire-electro discharge machining is a process of **material removal of electrically conductive materials by the thermoelectric source of energy**. The material removal is by controlled **erosion through a series of repetitive sparks** between electrodes, i.e. work piece and tool

- WEDM **utilizes a continuously travelling wire electrode** made of thin **copper, brass or tungsten of diameter 0.05–0.3 mm**, which is capable of **achieving very small corner radii.**

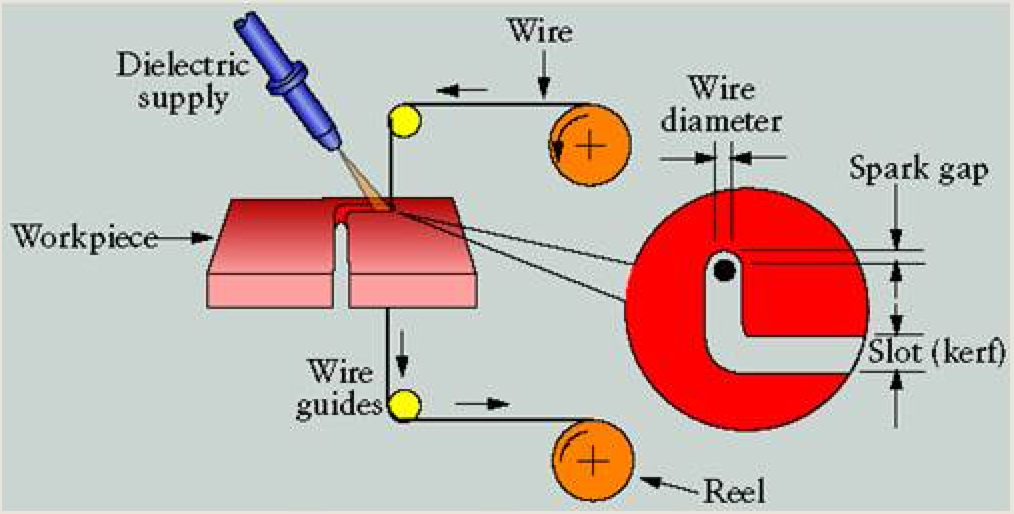
- The wire is **kept in tension using a mechanical tensioning device** reducing the tendency of producing inaccurate parts.

- During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining.

- In addition, the WEDM process is **able to machine exotic and high strength and temperature resistive (HSTR) materials** and eliminate the geometrical changes occurring in the machining of heat-treated steels.

- Figure shows the basic features of the Wire-EDM process. The electrode is a thin wire and it is pulled through the work piece from a supply spool onto a take up mechanism.

- On application of a proper voltage, discharge occurs between the wire electrode and the work piece in the presence of a flood of deionized water of high insulation resistance.



Schematic illustration of the wire EDM process

Wire EDM Machine (SODICK)

Advantages of WEDM

- Wire cut EDM machine is **able to machine material, with high hardness, high strength, high fragility and high tenacity, which is not easy to be or can't be machined by conventional method,** even some semi-conductive materials are also can be processed by wire cut EDM machine.

- Thanks to tiny size of electrode wire, wire EDM **can machine small abnormal shape holes**, small gap or job with complicated shape.

- There is **very little heat impact on the surface of work piece**, suitable to process some heat sensitive material; at the same time, as impulse energy concentrate on very small area, machining accuracy is higher.

- As the **cutting path is very small**, there is very less removal ratio of material, so **use ratio of material is pretty high.**

- Comparing to EDM spark erosion machine, electrode wire replaced formed electrode, saving a lot of cost of designing and making electrode and prepared period is shortened obviously.

- Using **water-based working solution**, clean and safe, especially **environment-friendly.**

Limitations and Applications of WEDM

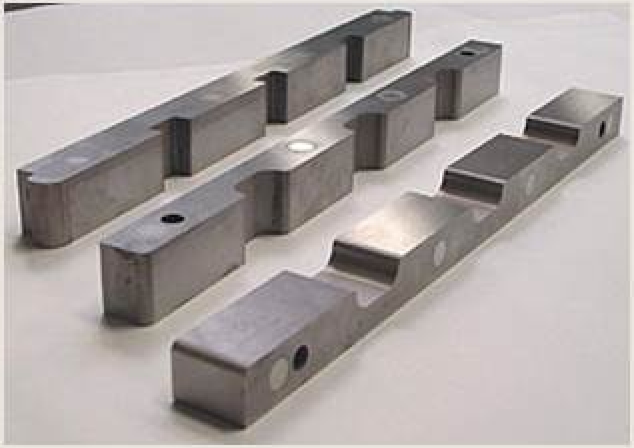
- As the electrode needs to go through work piece, so it can't machine blame hole kind or step plane kind work piece, besides, machining efficiency of wire cut EDM machine is compare to other conventional metal processing equipments.

- The common applications of WEDM include the fabrication of the **stamping and extrusion tools and dies, fixtures and gauges, prototypes, aircraft and medical parts, and grinding wheel form tools.**

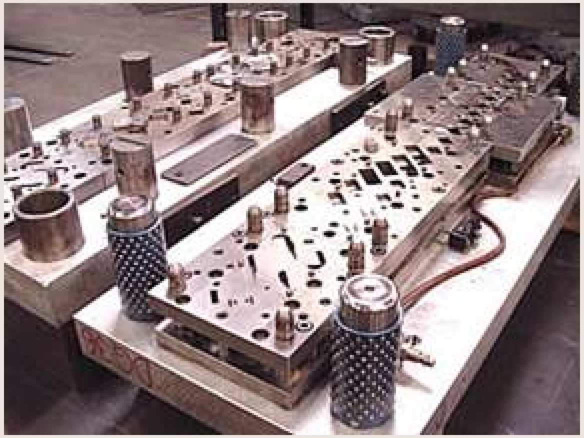
- Wire cut EDM is widely used to machine **various molds, such as punch die, squeezing die, powder metallurgy mold, bend mold, plastic mold**. Among these different kind molds, **cutting punch die take a great share**, to precious punch die machining, wire cut EDM is a indispensable technology. By adjusting different compensation value while programming, wire cut EDM can **cut terrace die, punch plate, stripper plate** and etc, it is easy to meet the requirement of mold fitting clearance and machining accuracy.

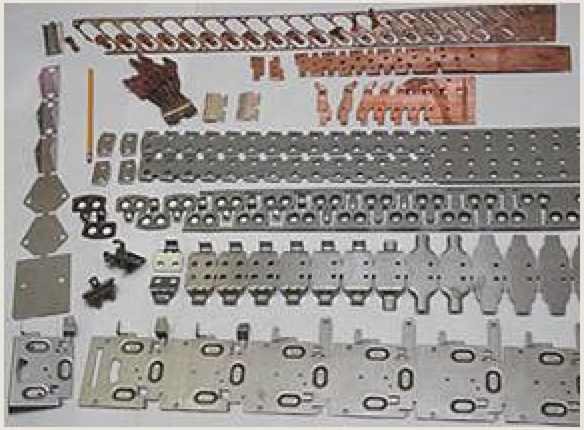
- WEDM is used in manufacture of **Engine components, Turbine components**, Hydraulic components, **Turbo machinery components**, construction equipment, Shafts, forgings, Jewelry, **Valves, Pins, Thread rod, Fasteners, spindles sockets**, bushings, Spacers, Fittings, Standoffs, extrusion dies, Fixtures, **Form Tools**, **Injection Mold components**.

WEDM used in Tooling and Die manufacturing



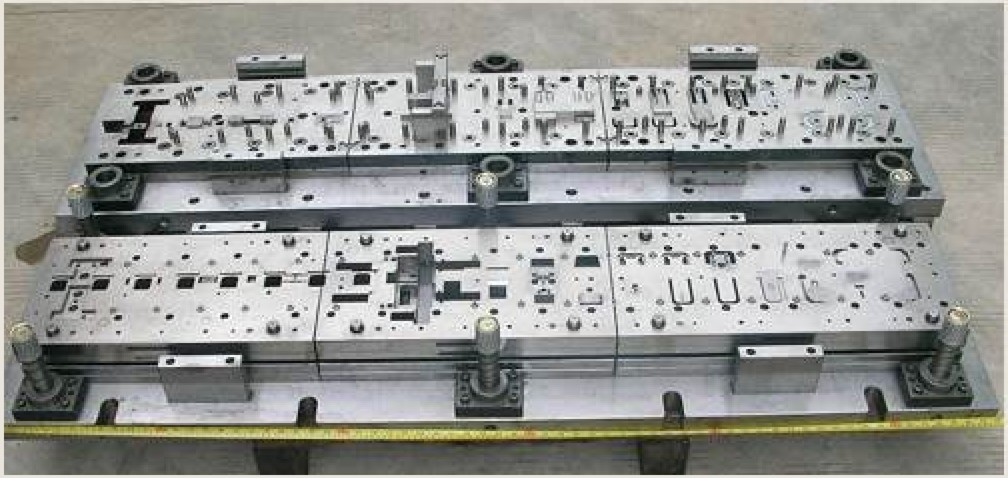
Carbide Dies and Components





Short and long run metal stampings Prototypes Value added stampings **Stamping Dies and Tooling**

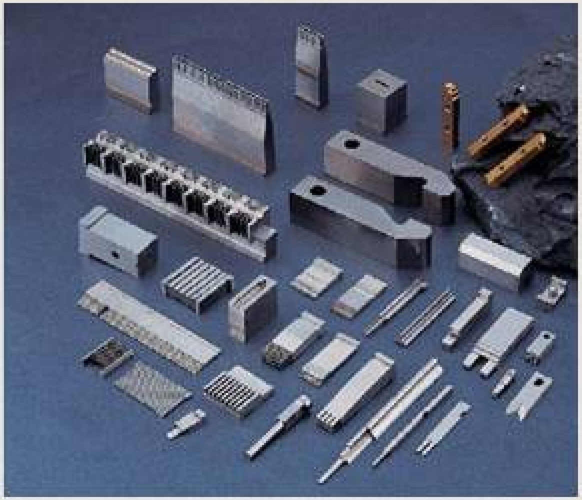
Class A Progressive Die for electrical components (terminal leads)



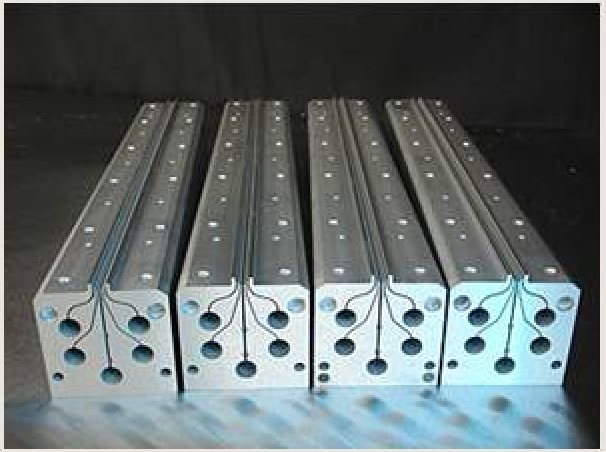
Advanced punch dies have characteristics of complicated structure

WEDM in manufacture of automotive parts

- Possessing a large taper cutting capacity, of wire EDM technology allows to form more intricate contours out of difficult-to-machine metal materials, such as stainless steel, tool steel, high temperature alloys, stainless alloys, and titanium.



Automobile connector mould component

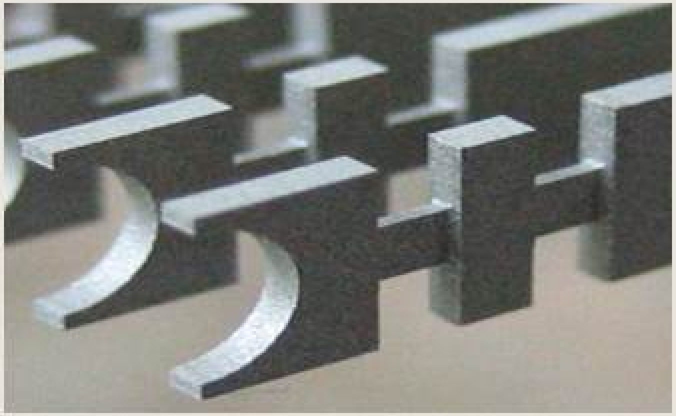


Monoblock made using WEDM

Automobile parts with tiny gap, narrow slit and complex shape machined using WEDM

- Specializing in the manufacturing of medical devices, surgical tools, missile and aerospace components

Tiny detailed machining to precision surgical specifications and diameters so small only EDM machining

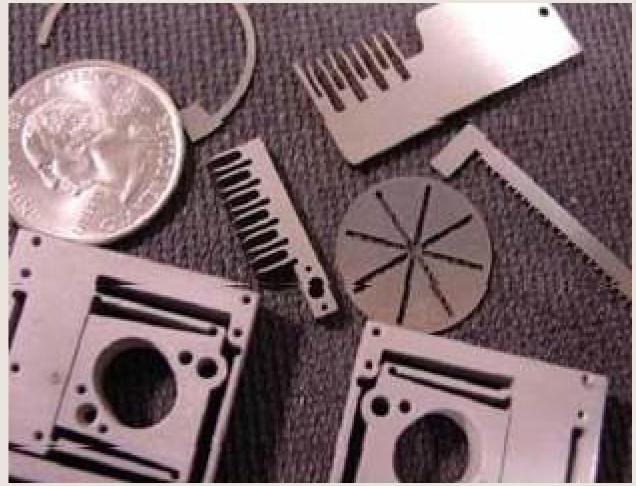


Electro optical component for military application

Difficult internal parts made using WEDM

Machining-centre Components

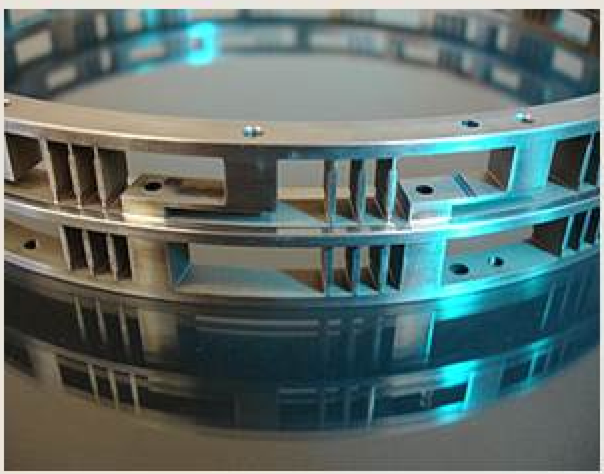
Parts machined using WEDM



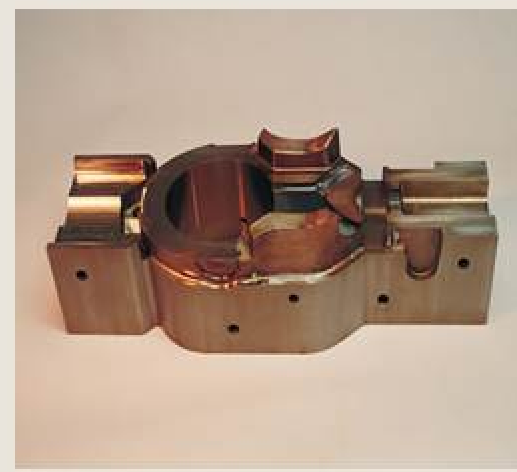
Special gears, forming cutting tools, various shape holes

Ball valve. Wire cutting internal spline for shaft mating.

Components Wire Cut - die blocks, strippers, holders, punches, forms.



Complex shapes machined using WEDM

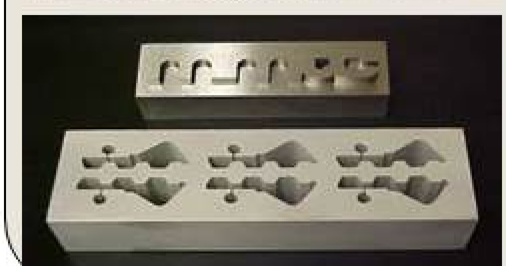


Marine industry mold approximately 30" wide

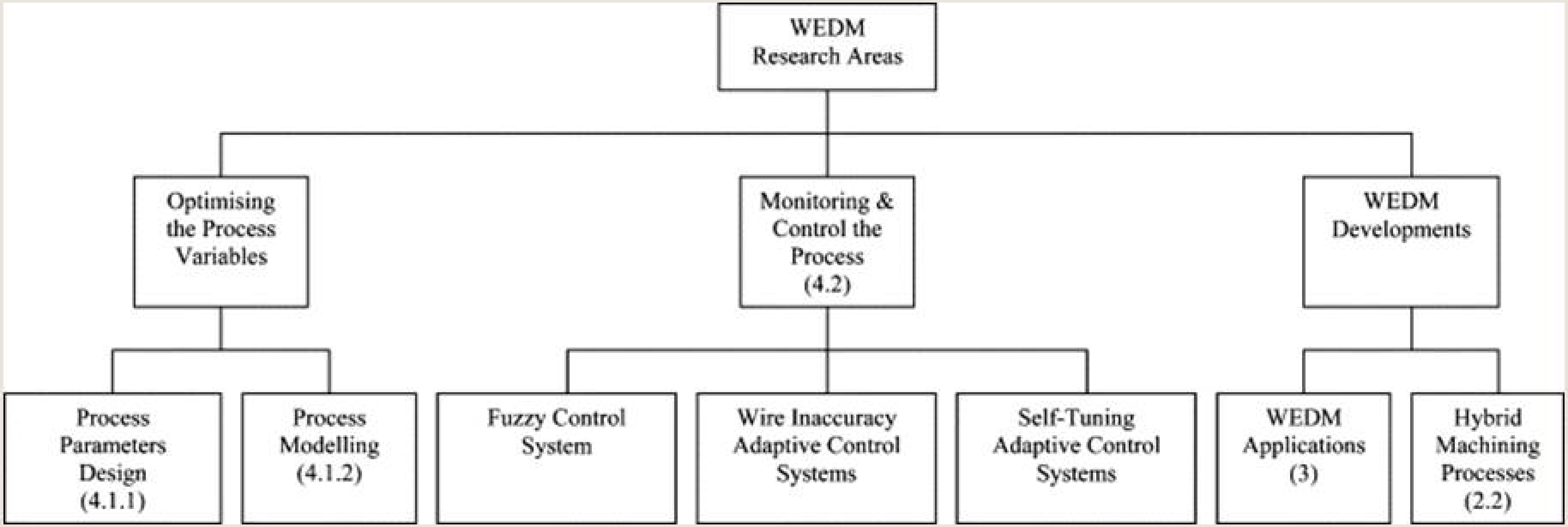
Turbine blades

To manufacture titanium earring shapes wire EDM proved the most cost effective when compared to stamping and laser cutting.

These simple, flat shapes, used in food processing, which usually would be stamped, were wire EDMed instead because they required a superior quality edge.



Classification of major WEDM research areas



MICROMACHINING

- Micro in micro machining implies that parts are made to the size of 1 to 999 μm.

- However Micro also means very small in the fields of machining, manufacture of small parts are not easy. Therefore micro components should also indicate too small components to be machined.

- Prof. Taniguchi defines Micro Engineering as the fields where components sizes are a few millimeters. When the part size is between 100μm to 100mm, a term MESO manufacturing is also used to address such parts.

Micromachining conditions

- The machining processes for micro/meso manufacturing can be derived from traditional machining processes such as turning milling, drilling, grinding, EDM, laser machining, etc., by judicious modification of these machines.

- Unit metal removal and improving equipment precision are the key factors for adapting the traditional machining processes to micro machining.

- Unit removal (UR) is defined as the part of work piece (length, area or volume) removed in one cycle of metal removal operation.

- UR gives the achievable tolerance on the part it should be much smaller than the size of the part it should be much smaller than the size of the component.

- The smallest UR is the size o0f the atom. UR of sub-micrometer order is also required when the object size is very small or when high precision of the product is required.

- It is difficult to achieve ideal UR and machine accuracy in the lower range of sizes, say 1 to 10 microns

- If the above two (small UR and high equipment precision) were satisfied micro- machining would be possible independent of the type of machining process.

Machinability of Electrode

- Most graphites are easily machined. Materials with high hardness values can cause machining problems. The fabricating time is influenced by the particle size and strength of the material along with the desired electrode detail.
- The maximum detail that may be obtained in graphite is limited by the material strength, particle and pore size. Machining time can be wasted by trying to machine in more detail than the material can handle. The resulting high scrap rates are due to chips and breaks.
- Minimum radii and close tolerances can be better machined from high-strength, small particle materials, and the resulting electrode will maintain that detail longer. Vanes 0.020" thick and over 1.0" high with flush holes 0.005" diameter are attainable with Angstrofine and Ultrafine class graphites. Roughing or large electrodes with little detail are easily machined from graphites in the Superfine and Fine

Angstrofine - Used where extremely fine detail and very smooth finishes are required.

Ultrafine - Used where strength, electrode detail, good wear, and fine surface finish are necessary.

Superfine - Used in large molds where detail is maintained and speed is important.

Fine - Used in very large cavities where detail and finish are not critical.

Typical EDM Machine

Typical Wire EDM Machine