Study on Electric Discharge Machining and Scope for New Era

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Abstract - *Electrical discharge machining (EDM) is one of the non-customary machining processes. EDM process depends on thermoelectric energy between the work piece and an electrode. A pulse discharge occurs in a small gap between the work piece and the electrode and expels the undesirable material from the guardian metal through melting and vaporizing. The electrode and the work piece must have electrical conductivity keeping in mind the end goal to generate the spark. There are different sorts of items which can be created utilizing EDM, such as dies and moulds. Parts of aviation, car industry, and surgical segments can be done by EDM. Execution measures are distinctive for various materials, process parameters and for dielectric fluids. This paper reviews the research over, trends in EDM on ultrasonic vibration, dry EDM machining, EDM with powder additives, EDM in water, surface quality with wire EDM and function of dielectric fluid to for the EDM. This gives to comprehend the best possible working of EDM. Specialists are ravenous to discover the precise conduct of processes parameter over the surface nature of the processed workpiece.*

Key Words: Electric discharge, electrode, process parameter and surface quality.

1. INTRODUCTION

The EDM method was first introduced in 1770, when English chemist Joseph Priestly discovered the erosive effect of electrical discharges or sparks [1]. The EDM process is based on the thermoelectric energy created between a workpiece and an electrode submerged in an insulated dielectric fluid. The chain of events constituting the process of material erosion from the work surfaces by an electrical discharge machining can be explained in the following way. If a suitable voltage is applied across the tool electrode (in general cathode) and the workpiece (in general anode) which is submerged in an insulating dielectric medium, the dielectric medium break between them due to the growth of strong electrostatic field [2]. Because of the electric field, electrons are emitted from the cathode toward the anode on the electrode surfaces having the shortest distance between them. These electrons intrude on the dielectric molecules of the insulating medium, breaking these dielectric fluid molecules into positive ions and electrons. These secondary electrons move along on the same ionization path. This incident causes an increase in the electric field potency across the work surfaces and liberates a massive number of electrons. It creates an ionized column in the shortest spark gap between the tool electrode and the workpiece, thereby diminishing the resistance of the fluid column and causing an electrical discharge in the shortest distance point between the tool and the workpiece. The huge thermal energy creates very high temperature ranges between 8000^{0}C – 12000^{0}C which melts, vaporizes and ablates the material from the workpiece, and creates a small crater over the work surface as well as tool electrode [3]. The depth of crater on both tool electrode and workpiece are different in shape and size and it depends on polarity of power supply. The four basic functions of dielectric oil (specific to sinker EDMs and specially designed wire EDMs) are: insulation, ionization, cooling, and removal of waste particles [4]. Electrical discharge machining (EDM) is one of the most versatile non-contact type material removal processes. Thermal energy is using to machine electrically conductive materials regardless of hardness of the workpiece. Due to this it has typical advantage in the manufacture of mould, die, aerospace, automotive and surgical components. Because of EDM does not have direct contact between the electrode and the work piece eliminating problems related to mechanical stresses, chatter and vibration during machining. Today, an electrode as small as 0.1 mm can be used to 'drill' holes into curved surfaces at steep angles without drill 'wander' [5]. In general three stages can be notable in EDM:

- Ionisation and arc formation, at a localised area between the electrodes, following the application of a voltage exceeding the breakdown voltage;
- The occurrence of the main discharge as an electron avalanche striking the anode, with low electrical resistance in the discharge channel. The cathode is struck by ions and is heated less rapidly than the anode;
- Local melting and evaporation follow, and some material is removed from the site of the discharge by explosion occurring after the cessation of electrical discharge. The current density decreases with increasing discharge duration, the discharge tending to become an arc.

In modern days, several developments in EDM have paying attention on the production of micro-features. This has become possible due to the availability of new CNC systems and advanced spark generators that have helped to improve machined surface quality. Also, the very small process forces and good repeatability of the process results have made micro EDM the best means for achieving high-aspect-ratio micro-features [6]. Electric discharge machining is producing crater type surfaces which are suitable for the lubrication. In recent years, the need for products containing micro-features (e.g., micro-holes) has shown a pronounced and steady growth. As a matter of fact, micro-holes are used for several purposes in a lot of products, such as inkjet printer nozzles, spinner holes, turbine blades cooling channels, diesel fuel injection nozzles and drug delivery orifices [7]. For the development of micro-holed devices, the most important technologies currently available are micro-EDM, femtosecond and excimer laser machining, mechanical drilling and LIGA technologies. Micro-EDM technology has become a widely accepted non-traditional material removal process for micro-manufacturing allowing the machining of hard and high strength materials, the so called “difficult to cut”. Moreover, promising applications of micro-EDM are not only limited to the machining of high hardness alloys for micro-moulds or cutting tools: several applications deal with the fabrication of “difficult to make structures” (i.e. having complex three dimensional shape) or with the machining of micro-holes with high aspect ratios. This micro-technology can be considered as an ideal process to obtain burr-free micron-size features with high aspect ratios and, since it is a non-contact material removal process, micro-parts without distortion due to possible physical forces can be obtained [8].

2. LITERATURE REVIEW

2.1 History

During World War II the two Russian physicists B.R. Butinzky and N.I. Lazarenko were engaged with research, to play down wear on electric power contacts and to discover substitutes to expensive materials. They discovered a Resistance Capacitance type relaxation circuit which was widely used at the EDM machine in the 1950s and later served as the model for successive development in EDM. At the same time, the work of three American employees became the basis for vacuum tube EDM machine and the electronic servo system has automatically provided the proper electrode-to-work piece spacing for sparking, without the electrode contact [9]. The main aim of electric discharge machining has to machine conductive material with good surface finish, high material removal rate and less tool electrode wear.

So for improving the material removal rate and to easily flush away debris particles from the machining area perform the ultrasonic vibration assisted EDM while surface finish was unaffected [10]. The experimental study on Al–SiC composite material shows that the rotary electrode improves the MRR and reduces the surface roughness [11]. By adding some appropriate additives to the dielectric fluid such that they reduce the electrode wear rate in compare pure one.

The authors Karasawa and Kunieda doing experiment and they conclude that the material removal rate obtained with the side jet was 20% more than that of the submerged method, due to better flushing conditions. The improvement of performance using side jets may also be achieved in oil-based EDM, but fire risk is considerably higher when compared to the submerged method [12]. Surface roughness increased with Increase with pulsed current and pulse time increases surface roughness or low surface finish quality and increase in material removal rate with low machining cost and it’s vice versa [13].

Ultrasonic assisted cryogenically electrode using EDM have more material removal rate in comparison simple EDM, because ultrasonic vibrating electrode act as a high frequency pump which flushes the debris away and sucks clean dielectric fluid in narrow machining zone with high turbulences [14]. Material removal rate also depends on the types of electrode material are used. For machining stainless steel and carbides by using copper electrode it gives higher material removal rate than the Aluminum electrode because aluminum has low melting point and less specific thermal energy results in higher tool wear. The powder metallurgy technique for fabricating composite electrode has been tried so as to reduce the crakes and wear resistance [15]. The graphite electrode has very high melting point is used during machining of Tungsten Carbide ceramics [16]. Workpiece surfaces machined with water-based dielectrics and hydrocarbon oil are different both in appearance and in terms of their surface roughness values. Hydrocarbon oil usually results in a dirty appearance with carbon particles inside and around the craters. Deionised water usually results in oxides on the machined surfaces (particularly when the workpiece material is steel) and lower values of surface roughness.

2.2 Mechanism

Sample The material erosion mechanism primarily makes use of electrical energy and turns it into thermal energy through a series of discrete electrical discharges occurring between the electrode and workpiece immersed in a dielectric fluid [17]. The spark is visible evidence of the flow of electricity. This electric spark produces intense heat with temperatures reaching 8000 to 12000 degrees Celsius, melting almost anything [18]. When the pulsating direct current supply occurring at the rate of approximately 20,000–30,000 Hz is turned off, the plasma channel breaks down [19]. This causes a sudden reduction in the temperature allowing the circulating dielectric fluid to implore the plasma channel and flush the molten material from the pole surfaces in the form of microscopic debris. This process of melting and evaporation is very carefully controlled and localized so that it only affects the surface of the material. The EDM process usually does not affect the heat treat below the surface. With wire EDM the spark always takes place in the dielectric of deionized water. The conductivity of the water is carefully controlled making an excellent environment for the EDM process. The water acts as a coolant and flushes away the eroded metal particles chips are not mechanically produced. The volume of material removed per discharge is typically in the range of 10^{-6} –10^{-4} mm^3 and the material removal rate (MRR) is usually between 2 and 400 mm^3/min depending on specific application [20].

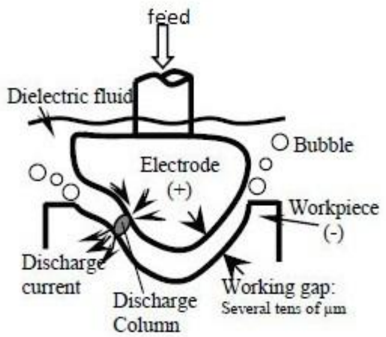

Fig -1: The concept of EDM Phenomenon

3. TYPES OF EDM

EDM process can be classified according to the type of dielectric fluid used. Dielectric fluid is an extremely important function regarding the quality of the machined parts. Since different dielectrics have different cooling rates and compositions, the choice of dielectric plays an important role in the EDM process. Dielectric media, circulated between the electrode and work piece, must be carefully selected and applied to maintain peak performance and control of the electrical spark. Another key factor is the dielectric media filtration system, which helps maintain consistent gap performance and dielectric cleanliness. The four basic functions of dielectric oil (specific to sinker EDMs and specially designed wire EDMs) are: insulation, ionization, cooling, and removal of waste particles. Different kinds of dielectric fluids are available for machining the parts in EDM. Die sink EDM generally operates with hydrocarbon oil, while wire, micro-EDM and fast drilling usually work with deionised water.

3.1 Die Sinking EDM

Two Russian scientists, B. R. Butinzky and N. I. Lazarenko, were involved in 1943 to examine ways of preventing the material erosion of tungsten electrical contacts due to sparking. They failed in this study but found that the material erosion was more precisely and in controlled manner if the electrodes were engrossed in a dielectric fluid. In die-sinking EDM systems, the electrode (cutting tool) and work-piece are attached to the machine tool. Sometimes EDM users apply the dielectric directly into the working gap by means of a jet, without submerging the electrode and the workpiece in the dielectric tank [21]. A power supply controls (generally DC motor with servo control mechanism) the electrical discharges and movement of the electrode in relative to the work-piece. The fact that the process takes place in a fluid medium improves the removal of metal chips from the cutting area and enhances cooling characteristics of the tool and workpiece. Improved cooling and fast discharge resulting from switching off of the electrical impulse (frequency between 50 and 500 KHz) improves the wear resistance of the electrode (tool) and improves surface integrity (Ra) of the machined surface. In this method workpiece have mirror type image of electrode tool. During operation the work-piece is submerged in a bath of dielectric fluid (non-conducting). Die-Sinking EDM is also called Sinker, Conventional, Plunge or Vertical EDM. During operation, hazardous gasses emitted from the dielectric tank which was easily inhaled by the operator and may cause adverse effect to health. EDM sink is a high amount energy consumption process in compared to conventional process for the same level of material removal rate [22].

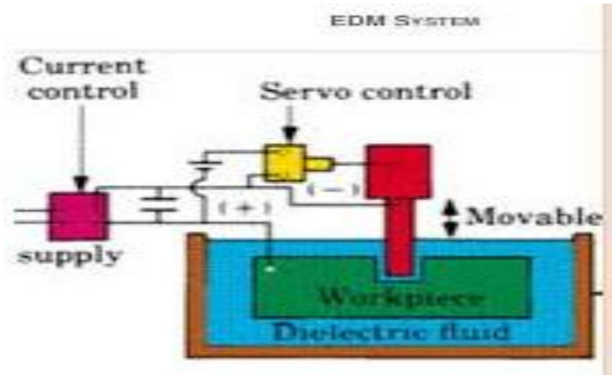

Fig -2: Schematic diagram of die sinking EDM

3.2 Wire-cut EDM

The wire-cut type of machine was developed in the 1960s for the purpose of making tools (dies) from hardened steel. The tool electrode in wire EDM is simply a wire. To avoid the erosion of material from the wire causing it to break, the wire is wound between two spools so that the active part of the wire is constantly changing. Since new wire electrode is always supplied by the rewinding mechanism in WEDM, the influence of wire electrode wear on machining accuracy can be neglected [23]. The fact that the wire itself is behaving like a metal string, straightened by two axial forces and deformed, by hydraulic forces in the gap, electro static forces acting on wire and electro dynamic forces inbuilt to the spark generation, make the wire to lose its perfect straight position. Hence, when cutting out a curvature, the lag effect of wire creates a geometrical error on the workpiece to be machined. This error can be of the order of a hundred microns, which for some applications becomes unacceptable [24]. The main problem in WEDM is arose when much debris stagnation in the gap and large wire vibration result in wire breakage, low removal rate and less geometrical accuracy [25]. Wang and Kunieda agreed that WEDM is applicable for finish cut especially for improving the straightness of the machined surface.

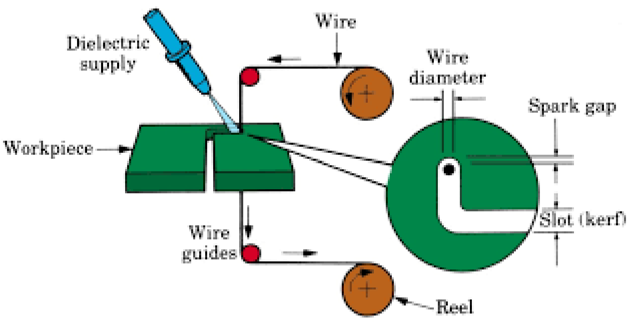

Fig -3: Schematic diagram of Wire EDM

3.3 Micro EDM

Micro-EDM can be considered as one of the most capable non-conventional micro-machining techniques due to its ability to machine high aspect ratio micro holes as well as complex 3D shapes in any conductive material [26]. Micro Electro Discharge Machining is a market growing processing technology due to the industrial interest and the increasing number of applications. The most important difference between micro EDM and EDM (for both wire and die sinking EDM) is the dimension of the plasma channel radius that arises during the spark: in conventional EDM is much smaller than the electrode but the size is comparable for micro EDM. Accurate observation and theoretical analysis of micro EDM processes are extremely difficult, however, due to the extremely complex material removal process that takes place during a short time and in a small space.

3.4 Dry EDM

In dry EDM, tool electrode is formed to be thin walled pipe. High-pressure gas or air is supplied through the pipe. The role of the gas is to remove the debris from the gap and to cool the inter electrode gap. The technique was developed to decrease the pollution caused by the use of liquid dielectric which leads to production of vapour during machining and the cost to manage the waste. Yu et al investigated the capability of the technique in machining cemented carbide material and compared the machining characteristics oil die sinking EDM. They found that for machining for the same geometrical shape oil die sinking EDM shows shorter machining time. But because oil die sinking requires time for producing electrodes, dry EDM should be more useful in actual production [27].

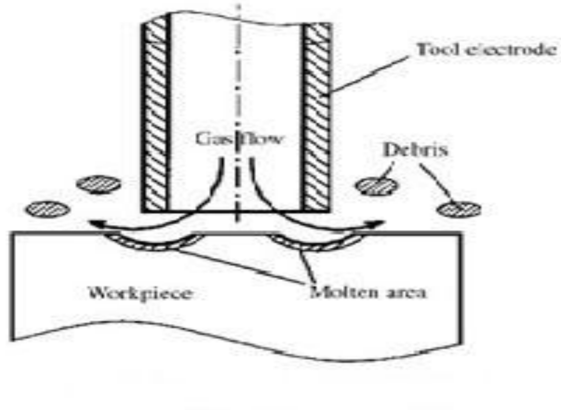

Fig -4: Principle of Dry EDM

3.5 Powder mixed EDM (PMEDM)

The mechanism of PMEDM is completely different from the conventional EDM. A suitable material in the form of fine abrasive powder is mixed into the dielectric fluid of EDM. When a suitable voltage is applied, the spark gap filled up with additive particles and the gap distance setup between tool and the work piece increased from 25–50 to 50–150 mm. The powder particles get energized and behave in a zigzag fashion which is shown in fig 5. These charged particles are accelerated by the electric field and act as conductors. The powder particles arrange themselves under the sparking area and gather in clusters. The chain formation helps in bridging the gap between both the electrodes, which causes the early explosion. Faster sparking within discharge takes place causes faster erosion from the work piece surface [28].

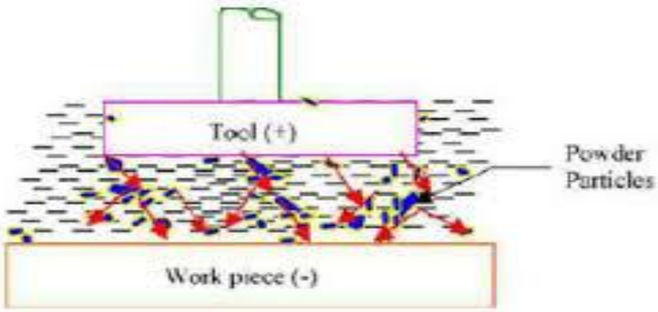

Fig -5: Schematic diagram of Powder mixed EDM

4. ADVANTAGES OF EDM

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. Complex dies sections and molds can be produced accurately, faster, and at lower costs. The EDM process is burr-free. Thin fragile sections such as webs or fins can be easily machined without deforming the part. The tool material should not need to be harder than the workpiece material because there is no direct physical contact between tool electrode and workpiece.

5. LIMITATION OF EDM

Material removal rate is slow; therefore, this process should only be used where other conventional machining processes are not suitable as machining cost is very high. Potential fire hazard associated with use of combustible oil based dielectrics. Power requirement is very heavy. Reproducing sharp corners on the workpiece is difficult due to electrode wear. Surface cracking may take place in some materials owing to their affinity to become brittle at room temperature especially when higher energy per pulse is used. Also the distortion of surface microstructure by this process is detrimental to some cases and necessitates subsequent etching. Workpiece metal must be an electrical conductor.

6. CONCLUSION

The EDM is an untraditional material removal process and flexible enough to meet the miscellaneous machining needs raised by the demand in the global and local metal cutting industries. With addition of computers, the EDM process has been extensively brought under various methods. Among them, the wire EDM has become more popular. In future trends there is also scope for rotating type EDM disc cutter which gives more material removal rate in compare wire EDM. It gives machining option of producing highly complex parts, independent of the mechanical properties of workpiece material. It has economical advantages in compare if same shape of material was machined through any conventional process. In this process the stochastic sparking phenomenon depends on both electrical and non electrical parameters and the quality of machined surface and metal removal rate also depends on types of die electric fluid were used. Material removal rate also depends on the melting point of the workpiece. Generally researcher focused on MRR, SR, TWR and specific energy required for the machining of workpiece. This method is very popular in the field of micromachining of parts with complex shapes and varying hardness requiring high profile accuracy and closed dimensional tolerances. However, the main advantage of the process is the relatively low machining speed as compared to other conventional machining process due to its thermal machining technique. The decisive goal of Wire EDM process is to accomplish an accurate and efficient machining operation combined with quality with at most best machining performance by targeting optimize machining condition.

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