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Electric Discharge Machining: A Review

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Abstract

Electric discharge machining is a nontraditional machining process which is an inevitable process now a day used in producing high dimensional accuracy product of such material which are hard and difficult to cut.There may be seen application of EDM process in the biotechnology, novel applications, miniature machines, information technology and many more. In EDM process thermoelectric energy is used as the cause of material removal of workpiece and tool electrode. This thermoelectric energy which is in form of discrete pulsed charge in between electrodes produces high temperature, hence melting and evaporation of both electrodes occur. Material removal from tool electrode is undesirable. Higher MRR and better surface properties are the desirable outcome of the EDM process. This present study provides the information of various process parameters, methods of optimizations and surface modification technics used in various published research paper by many researcher.

Keywords: EDM, MRR, TWR, ANOVA, RSM.

Nontraditional Machining Processes

Due to hugely improvement in the thermal, chemical and mechanical properties of contemporary engineering materials, the machining of these kinds of materials using traditional machining processes are practically unachievable. This is because of the fact that in traditional machining processes tool must be harder than workpiece.

High cost of tool materials and the damage produced while machining of the material are the dominant barrier for the use of materials. In addition to new developed engineering materials, more difficult to machining shapes, structures of low rigidity and micro machined parts with strong tolerances and great surface property are usually demanded. Traditional machining processes are often unable to produces these parts effectively. New processes are developed to meet these demands. These methods take part a distinguished character in the tool making, die making, aircraft and automobile industries. Nontraditional machining methods are classified according to action causing to material removal from the workpiece shown in figure 1.

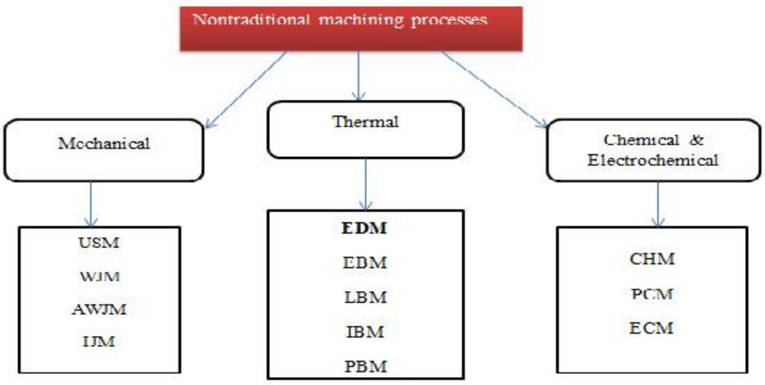

Figure 1 Nontraditional Machining Processes.

Electrical Discharge Machining

In manufacturing process EDM stands for electrical discharge machining. In this electro- thermal nontraditional machining process electric energy is utilized to generate electrical spark which produces thermal heat. This thermal heat is the main factor which causing the material removal from workpiece by fusion, evaporation and ablation. The application is best suited for those materials which are characterized by close tolerances of machining that would be extremely difficult or impossible to handle with any other method of machining. EDM has been mainly used for machining difficult to machine and high strength temperature resistance alloys.

History of EDM

The history of electro discharge machining (EDM) techniques has been discovered in the year 1770s by an English scientist after the invention of the relaxation circuit (RC) by B.R and N.I. Lazarenko [1]. They maintained the gap width between the tool and the workpiece by using a simple servo controller. By using this technique they found reduction in arching and made EDM more profitable. Since 1940, EDM has been refined using planetary and orbital motion techniques, pulse generator, computer numerical control (CNC), and the adaptive control system.However the EDM was not fully taken advantage of until when Russian scientists investigated how the erosive effect of the technique could be controlled and used for machining purposes [2]. In 1950s this combination was widely used as EDM technique. Extensive research let the progress of EDM during the 1960s when numeric problem related to mathematical modeling were tackled. In the year 1970s wire EDM was evaluated due to powerful generators, improved machining intelligence, new wire tool electrode and better flushing. In mid 1980s EDM technique were transformed into EDM machine tool and serves as a model for variant of EDM process. This made EDM more commonly available and appealing over traditional machining process [3]. The growth of EDM has become essential in manufacturing applications in 1980s. EDM was required for machining of complex shapes, making of die and molds, micromachining and prototyping. By proper use of computer with EDM which can make quality product with high accuracy and better surface finish manufacturing process has taken a ground breaking changes in 1980s. CNC in EDM process made it easy and automatically operation form beginning to final finished part [4]. Electric sparks produced in EDM in a very small gap between electrode and workpiece for a micro second and entire gap is filled with EDM oil. This sparking produces heat near the workpiece and tool and eroded material by melting evaporation and ablation process and EDM oil flushes out these debris particles from the machining area [5].

Working principle of EDM process

In EDM, a series of discrete electrical discharges are the causing factor for removal of material from workpiece. These sparks are generated by the electric field generated between the tool and workpiece electrode which are generated by RC circuit when both the electrode are immerged in the dielectric fluid. A small gap which is also known as spark gap or electrode gap is set between the electrodes by which spark is generated is it ionizes the dielectric fluid particle which are in the path of spark. The dielectric fluid provides the insulating medium for the EDM process which helps in pulsed arc discharge [6. A technique for material removal in EDM is described by Schumacher [7]. Figure 2 shows the working principle of EDM process.

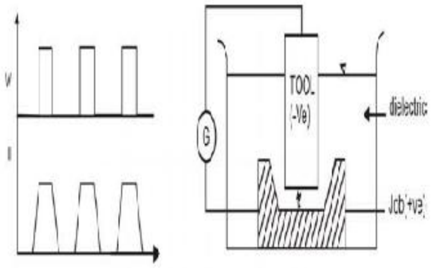

Figure 2 The basic working principle of EDM process

The pulsed electric discharge shows the erosive effect between the electrodes by which erosion takes place on both the electrodes [8]. The time of sparking initiation and discharge energy is influenced by the electrical resistance of dielectric fluid [9]. If the dielectric resistance is low then there occurs early discharge but capacitor gains higher charge value if the resistance is high. When operator preset the higher gap voltage than the servo reference voltage, it will increase the feed speed.

To monitor the spark gap width, in some cases average ignition delay time is preferred in place of average gap voltage [10]. Use of RC circuit in EDM cannot give the high MRR. Charging of capacitor takes the large portion of time of machining time which is shown in figure 3 [11]. As the time increases arc column diameter also increases and it became equal to diameter of generated discharge crater [12].

In the sparking region due to extremely high temperature generate by pulse sparks both material and dielectric liquids gets evaporated, which rapidly forms the bubble in dielectric fluid. The expansion of bubble is restricted by the inertia and viscosity of dielectric, but due to high temperature the pressure hence the size of bubble increaseswith time[13, 14]

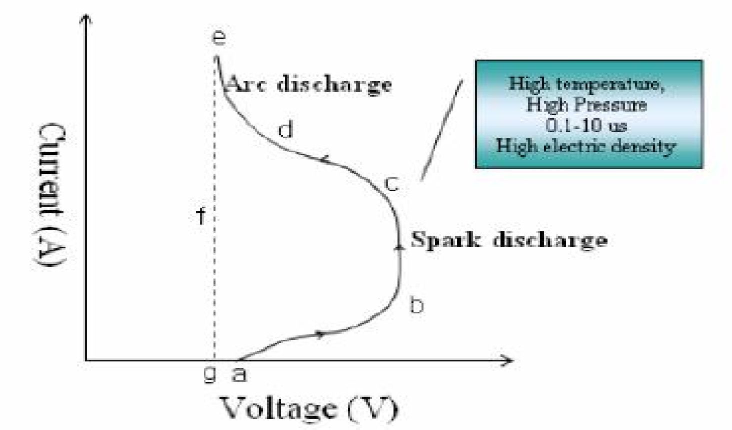

Figure 3 Graph for variation of currentwith voltage

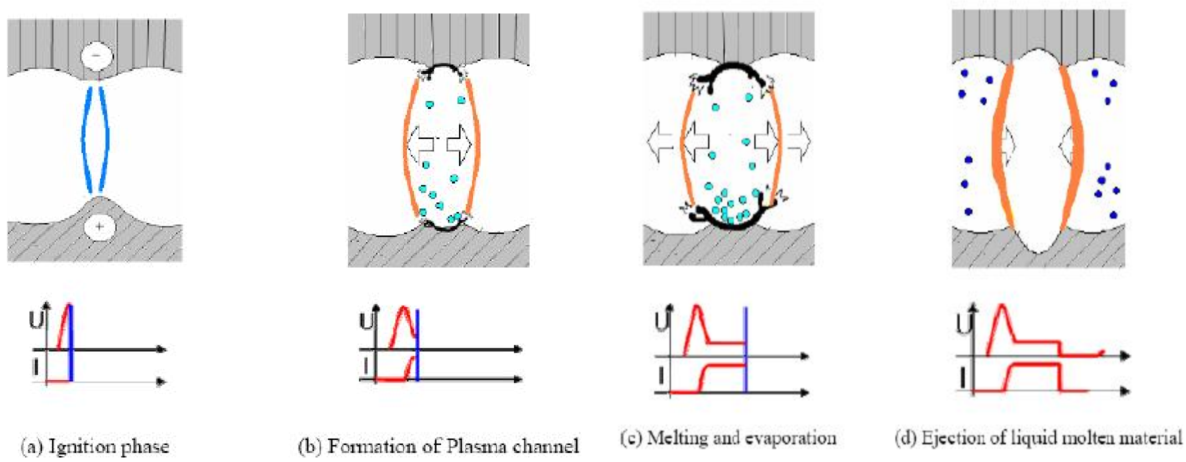

Figure 4 (a-d) Successive Stages of EDM Processes.

The dielectric liquid participated significantly in material removal process because of high pressure and velocity field developed by bubble serves as causing of material displacement in EDM[15, 16].

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1.2.4 Equipment's Used in EDM

Electrical discharge machining consists of several units which are discussed in detail as following –

(a) EDM Circuit

Generally, in EDM for generating spark or discharge two types of circuit are used, these are Resistance – Capacitance (RC) circuit and transistor circuit. The RC circuits cannot be used for higher Material removal rate but requirement of smaller cavity or cut configuration accomplished through RC circuits. Transistor circuits are suitable for higher material erosion while it has limitation to generate smaller features, because in transistor circuit switch on and off takes some time. These circuits are used in transport the electrical energy into heat energy and maintain the smallest gap (spark gap) between tool and job to create a series of sparks [17].

(b) Dielectric unit

The dielectric unit consists several parts such as a tank which is filled with EDM oil (dielectric fluid), a filtering unit to handle different types of dielectric, a pumping unit with proper control, delivery devices and reservoir for storing EDM oil. An ideal dielectric should have certain characteristics like adequate viscosity, high dielectric strength (i.e. initially remain non-conductive but after achieving threshold voltage it should converted into conductive nature), better electrical discharge efficiency (i.e. sparks should happen and it should discharge simultaneously collapse quickly and make it clean without any residue), low cost, good oxidation flexibility, effective cooling media and very high flash point. Dielectric fluid such as Mineral seal oil, lubricating oil, transformer oil, liquid petroleum, deionized water and paraffin oil are commonly used in EDM. High MRR and an effective cooling accomplished with deionized water but the cost of high electrode wear rate and low surface finish. The dielectric oil commonly used with a Sinker EDM process and deionized water is with wire-EDM process.

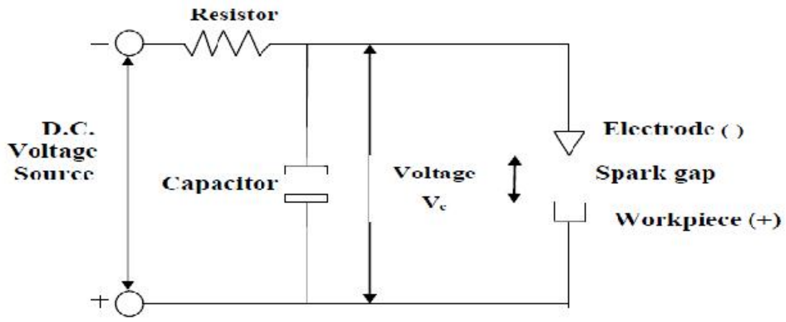

Figure 5 schematic diagram for Lazarenko RC Circuit

(c) Servo Feed Control

Servo feed control plays a vital role in ED machining, it maintained an inter-electrode gap (spark gap) between tool and workpiece for every sparks or discharges. In this system, a sensor is attached when dielectric bridge form and collapse then it senses and fed the signal to servo system to rise the inter-electrode gap. The whole control unit lift and dielectric fluid flushes and clean the machining zone. Again, whole control system with tool take the lower position for conducting next discharge. The lifting and lowering of servo control happens periodically and every time sparks generates and simultaneously dielectric flushing the debris particles from the machining area.

Literature review

Soni et al. [18] used scanning electron microscopy (SEM) to investigate the chemical composition and its variation during re-solidified layers of tool and workpiece. They conducted experiment with rotated electrode and varying discharge current and compared the result with stationary electrode They concluded that variations in chemical composition occurs because of migration of material either from electrode or workpieces in EDM. It was found that the significant amount of material eroded from both workpiece as well as tool material. The debris particles of die steel were alloyed with the electrode material and hardness of surface increased significantly. For blind hole machining the migration of tungsten was more from electrode to workpiece than the through hole machining.

Karthikeyan et al. [19] has suggested a mathematical equation *Y*= f(V, I, T) for EDM with process parameters percentage volume of SiC (25µ size), discharge current (I) and the pulse duration (T) for aluminium-SiC particulate composites. Full factorial with three level design was used for analysis. Mathematical equation has significant effect on SR, MRR and TWR. It was found that MRR decreases with increases in percentage volume of SiC, while surface roughness and TWR increased with increases in % volume of SiC.

Rebelo et al. [20] have analyzed the influence of pulse energy on surface integrity in EDM process, they revealed the surface integrity by using optical and scanning electron microscopy and found that the dimension of crater size increases with increase in pulse energy. X-ray diffraction was used for determining a white layer which consist a new phase of cementite and microprobe analysis was used for confirmation. It was observed that heat affected area changes with change in discharge energy by using X-ray diffraction.

Velusamy et al. [21] have interrogate the effect of input variable like flushing pressure(P), spark current (C) and Pulse On-Time (T) on output variable MRR and TWR during EDM process of as-sintered Al-MMC with 5% and 2.5% TiC reinforcement. In this investigation they have used Kerosene as a dielectric fluid. They have used a copper tool (99.99% pure copper) as a tool electrode to drill the specimens. Diameter of copper electrode was 7mm.

Amorim FL et al. [22] Suggested that thermo physical properties (thermal and electrical conductivity, heat to vaporize from room temperate, boiling temperature, thermal expansion and melting temperature) of the workpiece and toolelectrode considerably affects the process performance like MRR, TWR and surface integrity of workpiece material.

Jeswani ML [23] has analyzed the electrode erosion by dimensional analysis. He has developed an empirical relation relating material erosion from tool electrode to electro thermal properties of tool electrode. He has used density, specific heat, thermal conductivity, latent heat of vaporization of electrode material and energy pulse as input variables.

Mohari et al.[24] discussed the synthetic attention of electrode wear in EDM. They found that electrode wear depends on the machining on time and less wear (say, zero wear) observed with longer pulse on time. The electrode shape starts wear form edge portion, at the starting of machining and it was investigated through the randomly aligned (turbostratic) carbon.

Snoeys R et al. [25] proposed a model in which the electrode orbits relative to the workpiece for balancing the tool wear. In this process the electrode tool rotates making a planetary motion and it also produces an effective flushing action. Hence, by this method process efficiency and part accuracy increases.

Mohan et al. [26] have investigated the effect of tube electrode on the performance measures. In this investigation they have used tube electrode of varying hole diameter. They found that electrode tube hole diameter affects undoubtedly the MRR, TWR and surface integrity of workpiece. It was found from investigation that the decrease in hole diameter has produced a better MRR, surface integrity and higher TWR.

Kunieda M et al. [27] proposed a newly developed multi-spark EDM method to obtain higher material removal rates and lower energy consumption. They have used twin electrode discharge system. Energy consumption rate in this method was much lower than conventional EDM process.

T.R Paul et al.[28] have performed experiments for optimization of process parameters for MRR for EDM machining of Inconel 800. They have selected three controllable input parameters i.e. pulsed current, pulse on time and pulse off time. Oxygen free high conductive copper is used as electrode. For conducting experiments they have used central composite design for RSM method. They have found a very satisfactory MRR model in their experiments.

P. Srinivasa et al. [29]have studied that influence by design four factors such as current, servo control, duty cycle and open circuit voltage over the outputs on the MRR, TWR, SR and hardness on the die-sinker EDM process of machining AISI 304 SS. They had been employed the DOE technique with mixed level design and to analyze for performing a minimum number of runs. They achieved that for higher the MRR, the current, servo and duty cycle should be fixed as high levels and 95% confidence level with descending order in case of the TWR with same factors.

Singh et al [30]have inspected, effect of machining settings for instance overcut, peak current on MRR, TWR and Ra in the EDM of E31 tool steel heat treated with different tools such as copper, brass, copper tungsten and aluminum. From results copper and aluminum electrode gives the higher MRR, Overcut in diameter is minimum with the tools.

S. Abdurrehman et al [31]applied different process parameters on a work piece made of powder material. They were found that lower surface roughness value measured on the powder material with different use of electrode, not much influence the surface roughness.

M. S. Reza et al [32**]** have optimize the controlled parameters of the EDM using injection flushing type machining on multi performance characteristics using by GRA method. The process Parameters are optimized on different Response such as MRR, TWR and SR. For these experiments copper tool and AISI 304 stainless steel work piece is utilized. L18 Taguchi's orthogonal array design planned for experiments. The Selected machine settings are Ip, Ton, polarity, voltage and have been taken dielectric liquid pressure and machining depth.

Conclusion

This literature entails the outcome of machining of many materials by EDM process. Different researchers have used different process parameters i.e. pulse on time, pulse current, duty cycle, voltage gap and pulse of time for the machining of materials by EDM process. It has been Suggested that thermo physical properties (thermal and electrical conductivity, heat to vaporize from room temperate, boiling temperature, thermal expansion and melting temperature) of the workpiece and tool electrode considerably affects the process performance like MRR, TWR and surface integrity of workpiece material. Machining with rotational tool in disc shape improves MRR and surface roughness because a tangential force acted on outer surface of disc which was responsible for cutting the material and generation of centrifugal force due to rotation, removes the debris particle from the machining area and thus every time a fresh contact has to be done between workpiece and cutter.There is need to independently study the variation of pulse interval in conjunction with pulse duration on the surface modification phenomenon. There is a scope of studying the comparison of two surface modification methods i.e. material transfer from powders suspended the dielectric medium and material transfer from the electrode bodies. The overall EDM machining efficiency depends on the different process parameters and their optimization depends on imperial methods. Researchers have used Taguchi method, GRA and RSM methods for optimization of process parameters.

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