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Review Paper

Current Research Trends in Electrical Discharge Machining: A Review

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Abstract

EDM is an unconventional electro thermal machining process used for manufacturing geometrically complex or hard material parts that are extremely difficult-to-machine by conventional machining process. The process involves a controlled erosion of electrically conductive materials by the initiation of rapid and repetitive spark discharges between the tool and work piece separated by a small gap of about 0.01 to 0.50. This gap is either flooded or immersed in a dielectric fluid. The controlled pulsing of direct current between the tool and the work piece produces the spark discharge. The EDM process that we know today is a result of various researches carried out over the years. EDM researchers have explored a number of ways to improve the sparking efficiency with various experimental concepts. Despite a range of different approaches, every new research shares the same objectives of achieving high metal removal rate with reduction in tool wear and improved surface quality. This paper reviews the vast array of research work carried out within past decades for the development of EDM. This study is mainly focused on aspects related to surface quality and metal removal rate which are the most important parameters from the point of view of selecting the optimum condition of processes as well as economical aspects. It reports the research trends in EDM.

Keywords: Electrical discharge machining, EDM parameters, machining characteristic.

Introduction

The history of EDM techniques goes as far back as the 1770's when it was discovered by English scientist, Joseph Priestly. He noticed in his experiments that electrical discharges had removed material from the electrodes. Although it was originally observed by Priestly, EDM was imprecise and riddled with failures.

During research to eliminate erosive effects on electrical contacts, the soviet scientists decided to exploit the destructive effect of an electrical discharge and develop a controlled method of metal machining.

In 1943, soviet scientists announced the construction of the first spark erosion machining. The spark generator used in 1943, known as the Lazarenko circuit, has been employed for several years in power supplies for EDM machines and an improves form is used in many application. Commercially developed EDM techniques were transferred to a machine tool. This migration made EDM more widely available and a more appealing choice over traditional machining processes.

Current Research Trends in EDM

As far as EDM is concerned, two kinds of research trends are carried out by the researchers viz modeling technique and novel technique. Modeling technique includes mathematical modeling, artificial intelligence and optimization techniques such as regression analysis, artificial neural network, genetic algorithm etc. The modeling techniques are used to validate the efforts of input parameters on output parameters since EDM is a complicated process of more controlled input parameters such as machining depth, tool radius, pulse on time, pulse off time, discharge current, offset depth, output parameters like material removal rate and surface quality. Novel techniques deal with hour other machining principles either conventional or unconventional such as ultrasonic can be incorporated into EDM to improve efficiency of machining processes to get better material removal rate and surface quality. Novel techniques have been introduced in EDM research since 1996.

Introduction of EDM

Electro 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.

The new concept of manufacturing uses non-conventional energy sources like sound, light, mechanical, chemical, electrical, electrons and ions. With the industrial and technological growth, development of harder and difficult to machine materials, which find wide application in aerospace, nuclear engineering and other industries owing to their high strength to weight ratio, hardness and heat resistance qualities has been witnessed. New developments in the field of material science have led to new engineering metallic materials, composite materials and high tech ceramics having good mechanical properties and thermal characteristics as well as sufficient electrical conductivity so that they can readily be machined by spark erosion. Non-traditional machining has grown out of the need to machine these exotic materials. The machining processes are non-traditional in the sense that they do not employ traditional tools for metal removal and instead they directly use other forms of energy. The problems of high complexity in shape, size and higher demand for product accuracy and surface finish can be solved through non-traditional methods. Currently, non-traditional processes possess virtually unlimited capabilities except for volumetric material removal rates, for which great advances have been made in the past few years to increase the material removal rates. As removal rate increases, the cost effectiveness of operations also increase, stimulating ever greater uses of nontraditional process. The Electrical Discharge Machining process is employed widely for making tools, dies and other precision parts[1].

EDM has been replacing drilling, milling, grinding and other traditional machining operations and is now a well established machining option in many manufacturing industries throughout the world. And is capable of machining geometrically complex or hard material components, that are precise and difficult-to-machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mold making industries, aerospace, aeronautics and nuclear industries. Electric Discharge Machining has also made its presence felt in the new fields such as sports, medical and surgical, instruments, optical, including automotive R&D areas.

Principle of EDM

In this process the metal is removing from the work piece due to erosion case by rapidly recurring spark discharge taking place between the tool and work piece. Show the mechanical set up and electrical set up and electrical circuit for electro discharge machining. A thin gap about 0.025mm is maintained between the tool and work piece by a servo system. Both tool and work piece are submerged in a dielectric fluid .Kerosene/EDM oil/deionized water is very common type of liquid dielectric although gaseous dielectrics are also used in certain cases[2].

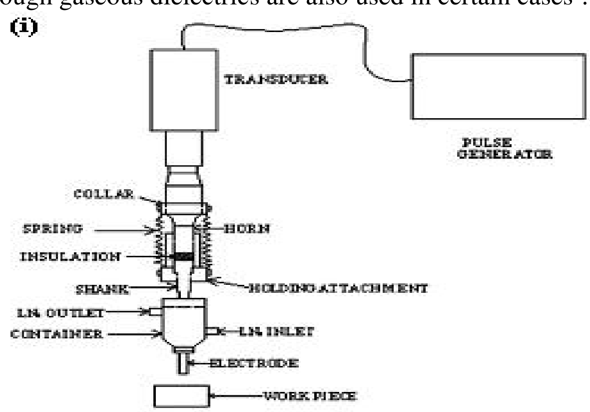

Figure-1
The schematic diagram of vibration assembly

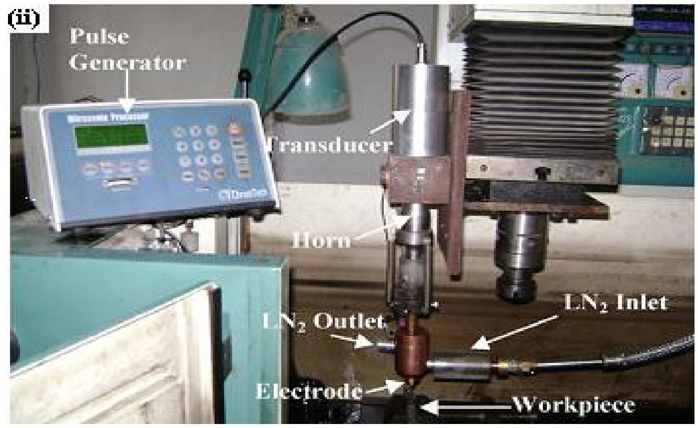

Figure-2
The electrode setup fixed on the EDM machine

Electric setup of the Electric Discharge Machining

The tool is made up of cathode and work piece is of anode. When the voltage across the gap becomes sufficiently high it discharges through the gap in the form of the spark in interval of from 10 of micro seconds. And positive ions and electrons are accelerated, producing a discharge channel that becomes conductive. It is just at this point when the spark jumps causing collisions between ions and electrons and creating a channel of plasma. A sudden drop of the electric resistance of the previous channel allows that current density reaches very high values producing an increase of ionization and the creation of a powerful magnetic field. The moment spark occurs sufficiently pressure developed between work and tool as a result of which a very high temperature is reached and at such high pressure and temperature that some metal is melted and eroded. Such localized extreme rise in temperature leads to material removal. Material removal occurs due to instant vaporization of the material as well as due to melting. The molten metal is not removed completely but only partially. As the potential difference is withdrawn, the plasma channel is no longer sustained. As the plasma channel collapse, it generates pressure or shock waves, which evacuates the molten material forming a crater of removed material around the site of the spark.

Mechanism of MRR

The mechanism of material removal of most widely established EDM process is the conversion of electrical energy it into thermal energy. During the process of machining the sparks are produced between work piece and tool. Thus each spark produces a tiny crater, and crater formation shown in this Fig. in the material along the cutting path by melting and vaporization, thus eroding the work piece to the shape of the tool.

It is well-known and elucidated by many EDM researchers that Material Removal Mechanism (MRM) is the process of transformation of material elements between the work-piece and electrode[3]. The transformation are transported in solid, liquid or gaseous state, and then alloyed with the contacting surface by undergoing a solid, liquid or gaseous phase reaction.

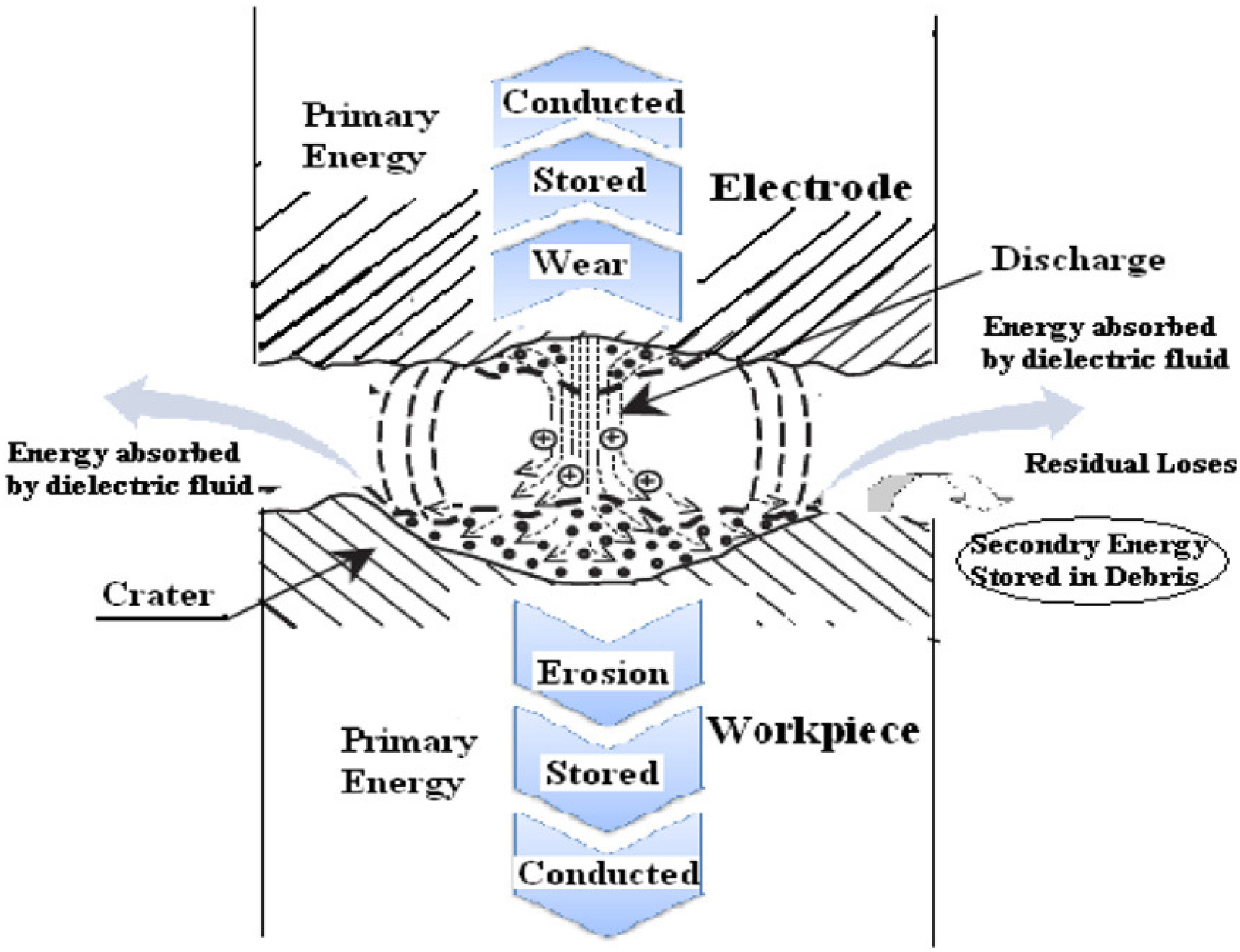

Figure-3
Mechanism of MRR

Methodology

Concept of single variable at a time approach at a time is used to find out the effect of inputparameters on the machining parameters viz; MRR, SR. A series of experiments were conducted to study the effects of various machining parameters of EDM. In each experiment, one input variable was varied while keeping all other input parameter at fixed value. Studies have been undertaken to observe the effect of selected parameters viz; discharge current, pulse on time, pulse off time, wire feed, servo voltage o MRR and SR. Experiments were carried out on D2 die steel material as a work-piece electrode and brass copper as a tool electrode. Distilled water has been used as a dielectric fluid throughout the tests.

Important parameter In EDM

On-time or pulse time: It is the duration of time (µs) for which the current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during this on-time.

Off-time Or Pause time: It is the duration of time between the sparks. This time allows the molten material to solidify and to be wash out of the arc gap.

Arc Gap: It is the distance between the electrode and the work piece during the process of EDM. It may be called as the spark gap.

Duty Cycle: It is the percentage of on-time relative to total cycle time. This parameter is calculated by dividing the on-time by the total cycle time (on-time plus off-time). The result is multiplied by 100 for the percentage of efficiency or the so called duty cycle.

Intensity: It points out the different levels of power that can be supplied by the generator of the EDM machine.

Voltage (V): It is a potential that can be measure by volt it is also effect to the material removal rate and allowed to per cycle. Voltage is given by in this experiment is 50 V.

Effect of Various Parameters on MRR and SR

Effect of peak current: To investigate the effect of peak current on MRR and SR, pulse-on time is varied while keeping other parameters like pulse-off time, servo voltage, wire feed rate constant.

At low pulse duration, the MRR is low and nearly constant as low discharge energy is produced b/w the working gap due to insufficient heating of work-piece and low pulse duration. At high pulse duration, MRR increases with increase in peak current because of the sufficient availability of discharge energy and heating of the work-piece material. The small increase in cutting speed at high value of peak current and pulse duration is related to inferior discharge due to insufficient cooling of the work material[4].

The surface roughness is function of two parameters, peak current and pulse-on time, both of which are function of power supply. A rough surface is produced at high peak current and/or pulse-on time. The reverse is also true. A finer surface texture is produced at low value of peak current and/or pulse duration and vice versa. This is due to because pulse energy per discharge is can be expressed as follows: $E= u(t).i(t)dt$

Where, $u(t)$ is the discharge duration, $i(t)$ is the discharge current and E is the pulse energy per discharge. Since the discharge voltage $u(t)$ stays constant during the discharge pulse duration and discharge current. Thus from above formula of discharge energy we can say at low value of discharge current and/or pulse duration discharge energy will be low and at high value discharge energy will be high. But higher discharge energy will worsen the surface roughness because of increase in diameter and depth of the discharge craters which is in agreement with work carried by Fuzhu Han Et.al. So in order to control the fine surface we must control the pulse energy per discharge.

Effect on time of pulse: To observe the effect of pulse-on time on MRR and SR value of peak current is varied while keeping the other parameter like pulse-off time, servo voltage, wire feed rate fixed.

The MRR increases with increase in pulse duration at all value of peak current. TheMRR is a function of pulse duration but at low value of peak current, the MRR is low due to the insufficient heating of the material and also after pulse duration, the MRR increases less because of insufficient clearing of debris from the gap due to insufficient pulse interval.

Surface roughness increases with increase in pulse duration at different value of peak current but it is observed that surface roughness at low value of pulse duration and high value of peak current is less than the at high value of pulse duration and low value of peak current. This is due to because at low pulse duration materials remove mainly by gasifying and forms craters with ejecting morphology due to high value of peak current and heat flux in the ionized channel, which causes the temperature of the work-piece to be raised or to be easily exceed the boiling point. On the other hand long pulse duration removes material mainly by melting and forms craters with melting morphology due to low value of peak current and heat flux in the ionized channel, which prevents the temperature of the work-piece from reaching a high value[5] Which is in agreement with the work carried by others.

Effect of pulse-off time: The MRR decreases when pulse-off time is increased as with long pulse-off time the dielectric fluid produces the cooling effect on wire electrode and work material and hence decreases the cutting speed.The surface roughness changed little even though the pulse-off time changed corresponding to a small value of pulse-on time. Mainly surface roughness improves with increase in pulse-off time. The surface roughness is high at low value of pulse-off time, this is due to because with a too short pulse-off time there is not enough time to clear the melted small particles from the gap b/w the tool electrode and work-piece and also not enough time for de-ionization of the dielectric: arcing occur and the surface becomes rougher. It is observed that surface roughness first decreaseswith increase in pulse-off time and then increases with increase in pulse-off time. This is because more energy is required to establish the plasma channel and there-for there is higher electrode wear and higher surface toughness[6].

Effect of servo voltage: The effect of servo voltage on MRR and Surface roughness is observed by varying pulse duration while keeping other variablelike pulse-off time, servo voltage, wire feed rate fixed.

The MRR increases with increase in servo voltage and then it starts to decrease. This is due to increase in servo voltage result in higher discharge energy per spark because of large ionization of dielectric between working gap. Consequently, the MRR increases. However, a too high voltage result in high discharge energy per spark which causes unfavorable break down of dielectric and large amount of debris between the working gap which unable the material removal rate increases.

The surface roughness at low value of pulse duration with increase in servo voltage first increases up to 30V and then decrease with increase in servo voltage. At high value of pulse duration the surface roughness continuously decrease with increase in servo voltage. This is due to because at low pulse duration the discharge energy is low so melted particles cannot flow out of the machining zone and impinge on the work-piece material and surface roughness increase but with increase in more servo voltage more energy is produced which leads to uniform melting and melted particles flushed out between the working gap[7].

Effect of wire feed rate: The MRR increases less or remains nearly constant with increase in wire feed rate. The maximum material removal rate is obtained at wire feed rate of 7m/min.

The MRR increases with increase in wire feed rate because there is less dissipation to the surrounding and hence more heat generated at spark gap, leading to higher material removal rate. For further increase in feed rate the cutting speed decrease due to the un-flushed debris between the working gap or unwanted melted particles between the working gap which form an electrically conductive path between the tool electrode and work-piece, causing unwanted spark between the tool electrode and work-piece. Thus only a portion of energy is used in work material removal which reduces the cutting speed. This is in agreement with work carried out by others.

Surface roughness decreases with increase in wire feed at different value of pulse on time. With increase in wire feed rate area of work-piece electrode is small in comparison with the wire electrode and most heat is generated on the work-piece electrode. So that uniform melting of the work-piece and vaporized or melted material flush away by the dielectric fluid sufficiently. As a result finish surface is produced by the machining which is in agreement with the work carried out by the others[8].

The present study experimentally is calculated by the distribution of input discharge energy of electric discharge machining, using heat transfer equations. The results is obtained by the especially of fraction of energy transferred to the work piece.

In this work EDM with ultrasonic assisted cryogenically cooled tool electrode has been successfully performed on M2 HSS work piece material. The electrode is wear ratio and surface roughness was significantly lower in UACEDM process in comparison with conventional EDM process and material removal rate was at par with that of conventional EDM[9].

In this process, the material removal mechanism uses the electrical energy and turns it into thermal energy through a series of discrete electrical discharges occurring between the electrode and work piece immersed in an insulating dielectric fluid. The thermal energy generates a channel of plasma between the cathode and anode at a temperature in the range of 8000-12,000^{0}C, initializing substantial amount of heating and melting of material at the surface of each pole[10].

Conclusion

When current increases, the MRR also increases. The higher the current, intensity of spark is increased and results in high metal removal rate. When the current is increased, surface roughness is also increased. When pulse-on-time increases, the MRR is decreased. The higher the pulse-on-time, intensity of spark decreases due to expansion of plasma channel and results in less metal removal. When Pulse-on-time is increased, surface roughness is decreased. With increase in pulse-off time, the MRR increases as with long pulse off time the dielectric fluid produces the cooling effect on wire electrode and work material, decreasing the cutting speed. Surface Roughness improves with increase in pulse-off time. The MRR first increase with increase in sevovoltage and then starts to decrease. At low value of pulse duration, the SR increases with increase in servo voltage up to 30 v and then decreases with increase in servo voltage while at high value of pulse duration SR decreases continuously with increase in servo voltage. The MRR first increases with increase in wire feed rate and then decreases with further increase in wire feed rate. The SR decreases with increase in wire feed rate.

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