International Journal of Research in Advent Technology, Vol.2, No.4, April 2014

E-ISSN: 2321-9637

Variation in surface roughness of AISI D2 Tool steel after machining on EDM (Electrical Discharge Machine): A Review

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Abstract-In this study, various EDM parameters (Discharge Current, Pulse On-Time, Pulse Off-Time, Gap Voltage) and techniques are affects the surface roughness. The effectiveness of the EDM process with AISI D2 tool steel is evaluated in term of surface roughness of the Workpiece using EDM machine and makes sure the good surfaces-quality. Therefore to increase the efficiency, quality and flexibility identical process parameters, proficient to machine different features, must be analyzed. At the present time, a lot of various parts require a high level surface finish. Traditional hand polishing procedure, which is the mostly used for this reason, represents lengthy and costly solution. Low Surface Roughness process that utilizes some nanoparticles, Micro-particle powder mixed into the dielectric fluid. This process produces better surface finishes in comparatively shorter time. Additional profit include a decrease in machining time as well as reduced finishing time compared to standard EDM machine. It achieves a unvarying surface finish over larger Workpiece area, reducing polishing times and related shortest labor. The significance of surface finishing of electric discharge machined parts has been predictable by the manufacturing industry and it is still continues to be the major concern along with the researchers. This paper reports state of art technology relating to surface integrity of "Electro Discharge Machined" surfaces.

Index Terms- Electrical Discharge Machine (EDM)1, Surface Roughness2, Powder-Mixed Dielectric3, Tool Geometry4 ,Cryogenic Treatment5.

1. INTRODUCTION

The electrical discharge machining is extensively used for metal removal process. The process is characterized by particularly exact tolerances and situations which are tremendously complex or impossible to handle with any other process of machining. Electrical discharge machining is a thermo-electrical material removal process, in which tool electrode shape is produced into a work material with the shape of the electrode essential the area in which the spark erosion will arise [DF Douw,(1990)]. In EDM a number of repetitive electrical discharges of small duration and high current density between the work piece and the tool occur. Machining by EDM is an important and cost-effective method for extremely tough and brittle electrically conductive materials. In EDM, there is no direct contact between work piece and the electrode, hence there are no mechanical forces existing between tool and workpiece. The conductive material can also be machined via EDM irrespective of the hardness or toughness of the material [S Kumar, (2013)].

2. WORKING PRINCIPLE OF EDM

Electrical Discharge Machining (EDM) also called material removal process through sparks erosion machining. When two conducting wires are permissible to touch each other an arc is produced. When there is a point contact between two wires, an arc is produced, results in a removal of small amount of metal.

The material is removed from the work piece due to erosion caused by frequent electrical spark discharge between the work piece and the tool. There is a small gap between tool and work piece known as spark gap or gap width as shown in **Fig. 1.** The work piece and tool electrode both are submerged in the dielectric fluid namely as EDM oil, deionized water and kerosene [A. Pandey, (2010)].

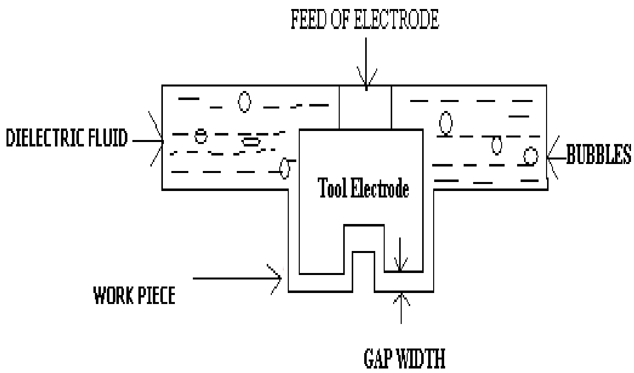

Fig.1 Schematic of spark gap [A. Pandey, (2010)]

3. MAIN PROCESS PARAMETERS OF EDM

***3.1 Pulse- On Time*.** The period of time (µs) for which the current is allowed to flow per cycle. Material removal and Surface finish are directly proportional to the amount of energy applied during this pulse on-time.

***3.2 Pulse- Off Time*.** The period of time between the two corresponding sparks. This time allows the molten material to solidify and to be wash out of the arc gap.

***3.3 Spark Gap*.** It is the distance between the tool and the workpiece during the process of EDM. It may be called as the arc gap.

***3.4 Duty Factor*.** It is the percentage of pulse on time relative to total cycle time. This factor is calculated by dividing the pulse on time by the total cycle time (pulse on time + pulse off time). The outcome is multiplied by 100 for the percentage of efficiency.

***3.5 Current Intensity (I)*.** It points out the different levels of power that can be provided by the generator of the EDM machine.

***3.6 Voltage (V)*.** It is a potential that can be measure in volt it is also effect to the material removal rate (MRR) and allowed to per cycle.

4. RECENT DEVELOPMENTS IN EDAM

In open Literature, a lot of work has been reported by many researchers. There are two types of research trends commonly reported by researchers namely Modeling Technique and Novel Technique.

Modeling technique includes mathematical model, simulated intelligence and optimization techniques such as Regression Analysis, Artificial Neural Network and Genetic Algorithm. The modeling techniques are used to validate the efforts of input parameters on output parameters as discussed above EDM is a complicated process of more controlled input parameters such as machining depth, tool dimensions, pulse on time, pulse off time, discharge current intensity, offset depth (distance downward), output parameters like material removal rate, tool wear rate and surface quality [S kumar,(2013)].

Novel techniques deal with other machining principles either traditional or non-traditional such as ultrasonic can be included into EDM to improve effectiveness of machining processes to get better material removal rate, tool wear rate and surface finishing. Novel techniques have been introduced in EDM research since 1996 [S kumar, (2013)].

5. SURFACE ROUGHNESS

Surface integrity or surface roughness, also known as surface texture are terms used to express the general quality of a machined surface, which is concerned with the geometric irregularities and the quality of a surface [M. Mahardika,(2008)].

6. WORKPIECE MATERIAL

In the present study AISI D2 material (American Iron Steel Institute D2 tool steel) is high carbon high chromium dies steel material [PB Wagh,(2013)]. AISI D2 tool steel has characteristics like inability dimensional stability during hardening, good combination of hardness, toughness and also tempering. It has high wear resistance and high compressive strength. It is used in the field of manufacturing tools in mould industries. The composition of AISI D2 material presented in table 1 [M K Pradhan,(2009)].

Table 1.Composition of AISI D2 material [P B Wagh ,(2013)].

Element	C	Mn	Si	Cr	Ni	Co	V	Fe
Composition Weight (%)	1.5	0.3	0.3	12	0.3	1.0	0.8	Remaining

7. TOOL MATERIALS

The followings are the different electrode materials which are used commonly in the industry:

7.1. Graphite. Graphite is the preferred electrode material for 90% of all EDM applications. Thus, it is important that we expend considerable effort to understand its properties and application to EDM.

7.2. Copper. With development of the transistorized, pulse-type power supplies, Electrolytic (or pure) Copper became the metallic electrode material of choice. This is because the combination of Copper and certain power supply settings enables low wear burning. Also, Copper is compatible with the polishing circuits of certain advanced power supplies.

7.3. Brass. Brass ensures stable sparking conditions and is normally used for specialized applications such as drilling of small holes where the high electrode wear is acceptable. In addition to the servo-controlled feed, the tool electrode may have an additional rotary or orbiting motion.

8. METHODS AND TECHNIQUES OF MACHINING

In this review paper, the effect on surface roughness obtained during machining process conducted on EDM. The various electrodes made by different methods and their effect on surface roughness of the workpiece during EDM is compared and discussed below-

8.1 Effect on Surface Roughness in EDM with Copper Electrodes

The important concern was the optimization of the process parameters such as pulse current intensity (I_p), pulse duration (T_{on}), pulse off time (T_{off}) and open circuit voltage (V) for minimize Surface roughness. The current intensity, Pulse on time, and interaction term of pulse current with other input parameters considerably affect the surface finishing. The Surface finishing was directly depends on pulse current intensity (I_p) and pulse duration (T_{on}). The study based on RSM (Response Surface Methodology) models can be used effectively in machining of AISI D2 tool steel in order to obtain best possible EDM efficiency [M K Pradhan ,(2009)].

It was reported that the pulse duration was the most dominant factor for surface integrity followed by duty factor, pulse current and discharge voltage. The optimal operational conditions established by grey analysis approach were as follows: a pulse current 1 A, pulse duration 50 µs, duty cycle = 80 % and discharge voltage 40 V. By using these processes a parameter value which gives the minimum output results such as surface roughness the surface crack density have also been predicted. This may provide an efficient guideline to pick the optimum parameter settings for attaining desired SR during EDM die sinking of AISI D2 tool steel [M K Pradhan,(2013)]. EDM is a thermal removal process. The atomic force microscopy (AFM) technique is the study of surface morphology of the EDM specimen which revealed that the higher discharge energy results in a poorer surface structure. A low discharge energy should be used to avoid excessive machined damage [Y.H. Guu,(2005)].

8.2 Effect on Surface Roughness with Different Tool geometry

There are four different electrode geometry is taken into consideration. They are Round(C) – diameter15 mm, Square(S) – 15mm x 15mm, Rectangle(R) – 15mm x 19mm, Triangle (T) – 15mm x 15mm x 15mm. Surface Quality also good tor triangle and Rectangle Geometry. Finally shows that as the pulse on time and pulse off time difference increases the MRR and SR both give negative results that MRR decreases and SR increases. But as they come nearer to each other both the output parameter showing good results as given away in fig.2 [V. Kamlesh Dave,(2012)].

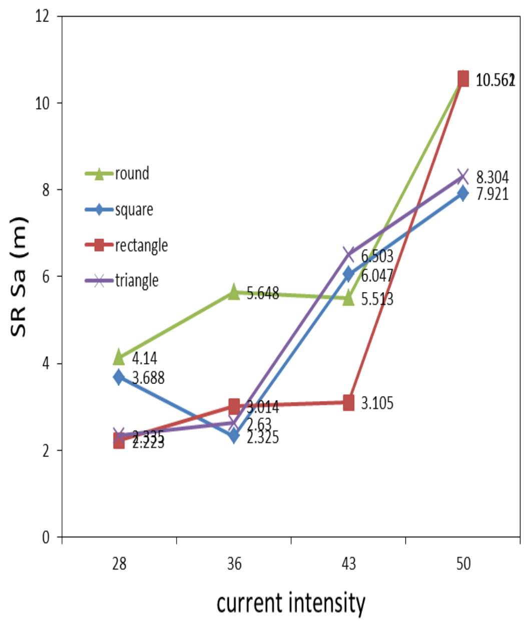

Fig.2 effect on surface roughness of different tool material [V. Kamlesh Dave,(2012)]

The electrode geometry and electrode materials are playing a greater role to affect the MRR and Surface Roughness with varying nature of process parameters [A. B. Patel,(2013)].

8.3 effect on surface roughness in EDM with using different tool materials

The difference in the surface finishing of the machined hole due to the control of the machining parameters. It is originate that the deviation in the surface roughness of the machined hole varies randomly for all electrodes but when copper is used as tool electrode the variation is less. With a supply current of 8 amperes, a flushing pressure of 20 lb/sq. inch, and pulse-on time of 58µsec, results in very less surface roughness of the machined area [N.A. Kumar ,(2012)].

8.4 Effect on Surface Roughness in EDM with using with tool made by Powder Metallurgy

A researcher correlated the usefulness of electrodes made through powder metallurgy (PM) in comparison with conventional copper electrode during electrical discharge machining. Experimental outcome are accessible on electric discharge machining of AISI D2 steel in kerosene with copper- tungsten (30% Cu and 70% W) tool electrode made through powder metallurgy (PM) technique and Cu electrode. During Machining of AISI D2 steel it is found that electrode material, current and duty cycle has significant effect on both the performance parameters. Best parameter selection within the experiment range for maximum MRR is with copper electrode at 10.5 A current, 0.66 duty cycle and 0.7 Kg/cm^2 flushing pressure and for minimum surface roughness is with copper tungsten electrode at 4.5 A current, 0.50 duty cycle and 0.3 Kg/cm^2 flushing pressure. From above it is obtained that Cu electrode is better for higher MRR and CuW electrode gives minimum surface integrity. Therefore if the condition is to have elevated material removal rate then it is recommended to use Cu electrode and if the requirement is to have better surface finish only on the machined surface of AISI D2 steel then it is recommended to use CuW electrode made through Powder Metallurgy [N. Bari,(2008)].

Method of suspending Nano graphite powder in EDM oil, by ultrasonic vibration of dielectric fluid, and by means of the number of discharge pulses in order to improve the accuracy of the Powder mixed dielectric micro-EDM process. As a result, machining time has been significantly reduced up to 35%, accuracy increased, and the appearance of micro cracks on the workpiece surface has been reduced [G. S. Prihandana,(2011)]. As nano graphite powder added in dielectric fluid, micro-cracks appeared a smaller amount on the workpiece surface [C. Sommer,(2005)]. In order to improve the quality of surface finishing in micro-EDM processes, investigations on using powder mixed dielectric have been obtainable. For example, at short discharge energies[S.H. YEO,(2007)]. The effects of silicon powder mixed into the dielectric fluid in the EDM of AISI D2 die steel and reported that the suspension of silicon powder in the dielectric fluid enhances material removal rate [Y.F. Tzeng,(2005)].

The surface roughnesses are relatively insensitive to the type of tool steels used. This is because at a given discharge condition, these two parameters are determined, to a greater degree, by the thermal properties of the rapidly solidifying metal, that of the dielectric and the flushing Condition used [L. C. Lee,(1988)]. When the urea was added to the dielectric, the surface roughness deteriorated with an increase in peak current. Since an increase in the peak current increased the discharge energy and the impulsive force, removing more molten material and generating deeper and larger discharge craters. Hence, the surface roughness became increases [B.H. Yan,(2005)].

8.5 Effect on Surface Roughness in EDM with Cryogenic Treatment

In electronics industries, Aluminum, Brass, Copper, Tin, Leads have better wear resistance after cryogenic treatment [M. Singh,(2012)]. Researcher was checked the surface roughness by using four different types of electrodes i.e. Cu, cryogenic treated Cu, Br and cryogenic treated Br. All tools have the same size in cylindrical form with a diameter of 22mm used as an electrode [H. Singh,(2012)]. It is observed that the brass electrode gives the better surface finish as compare to the copper electrode. Among the brass electrode and cryogenic treated brass electrode, the cryogenic treated brass electrode has given better surface finish. This may be due to fact that cryogenic treatment of the brass resulted in improving the thermal conductivity [W. Ping,(2003)]. Cryogenic tempering increases the hardness of AISI D2 steel and electrical/thermal conductivity of copper electrode which ultimately helps in increasing the material removal rate [S. Nandan, (2013)]

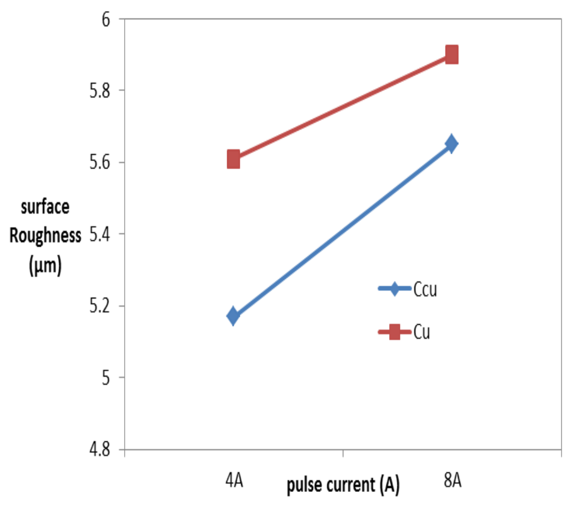

Fig.3 Effect of cryogenic treatment (taken at X-axis pulse current and at Y-axis surface finishing)

9. CONCLUSION.

From the literature review, it may therefore be concluded that Surface roughness is directly proportional to linear effect of pulse current and pulse on time when we use the copper tool. Higher discharge energy results in a poorer surface structure. To avoid excessive machined damage, low discharge energy should be used. It is observed that the brass electrode gives the better surface finish as compare to the copper electrode so that brass tool used in EDM, that can serve the purpose of low speed machining with good quality products in reduced costs and cryogenic treated brass electrode has given better surface finish. Recent advancements in various aspects of electrical discharge machining that reflect the state of art in these methods are presented in this review paper.

The EDM plays a most important role in medical, electric , automotive and aeronautic industry & making a various mechanical component of complex shape in manufacturing industries.

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