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Parametric Investigation on AISI D3 Tool Steel in Electrical Discharge Machine –A Review

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Abstract

The Electrical Discharge Machining process is employed widely for making tools, dies and other precision parts. 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 mould 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. The following study was carried out to review the work of various researchers performed on EDM.

***Keywords:** EDM, Tool Steel, ANOVA, MRR, TWR, SR, S/N Ratio*

INTRODUCTION

EDM is a non-conventional manufacturing process. In this process, the material is removed by erosive action of electric discharges occurring between a tool electrode and workpiece, based on the fact that no tool force is generated during machining. Both workpiece and tool electrode are submerged in a solution called dielectric as shown in Fig. (1.1). The mechanical characteristics of workpiece and electrode are not a matter of concern as the electrical energy is converted into thermal energy causing melting of the material. EDM process allows the machining of hard materials and more complex shapes which cannot be processed by other conventional methods.

The EDM process is normally applied to mould and die making. As Compared to the conventional machining methods, the material removal rate of this machining remains rather low.

EDM is a process of removing material in a closely controlled manner from an electrically conductive material immersed in a liquid dielectric by a series of randomly distributed discrete electrical sparks or discharges. Non-conducting materials cannot act directly on electrode to achieve EDM. In order to machine these materials with EDM, the conditions that electrical discharges can be produced on their surface must be created. See Figure 1.1.

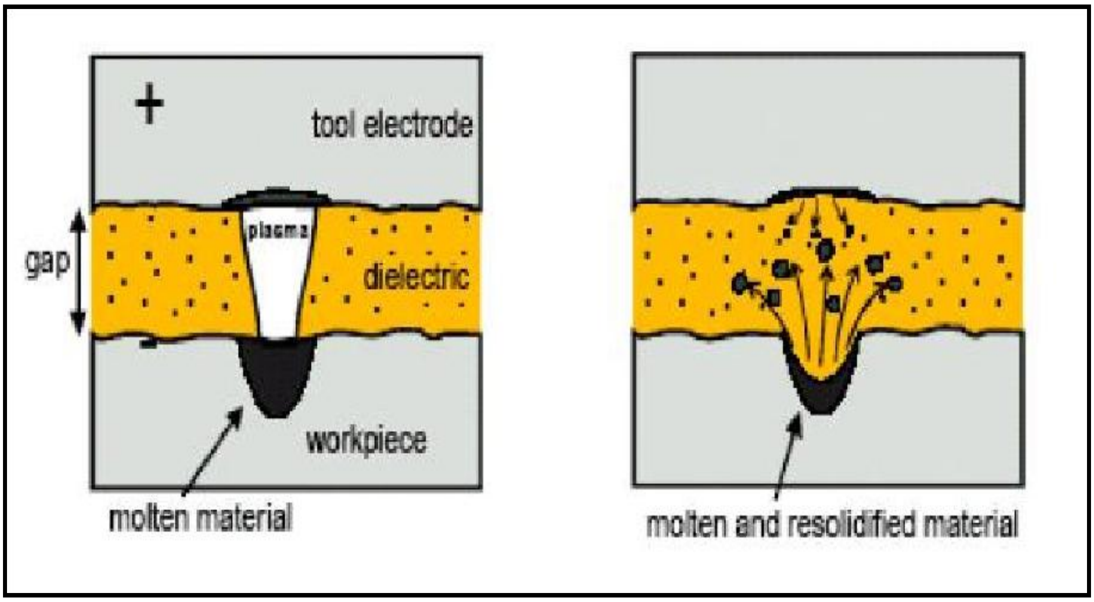

Fig. (1.1): Spark gap and material removal due to one pulse in EDM process

LITERATURE REVIEW

Ho and Newman (2003) carried out the research work from the inception to the development of die-sinking EDM. They made research EDM related to improving performance measures, optimizing the process variables, monitoring and control the sparking process, simplifying the electrode design and manufacture. They presented the classification of the various research areas and possible future research directions.

Margaret (2004) showed the analysis of the various inputs into EDM and the resulting outputs into the environment. A simplified model is used to analyze the process; the main categories of flow in the model are material and energy flow. It was concluded that the materials which were machined by EDM have no effect on the environment.

Abbas et al, Solomon et al and Bahari et al (2006) studied the recent trends in field of Electrical discharge machining (EDM) which is one of the earliest non- traditional machining processes. EDM process is based 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 removes the unwanted material from the parent metal through melting and vaporizing. The electrode and the work piece must have electrical conductivity in order to generate the spark. There are various types of products which can be produced using EDM such as dies and moulds. Parts of aerospace, automotive industry and surgical components can be finished by EDM. They review the research trends in EDM on ultrasonic vibration, dry EDM machining, EDM with powder additives, EDM in water and modeling technique in predicting EDM performances.

Dhar and Purohit (2007) evaluated the effect of current (c), pulse-on time (p) and air gap voltage (v) on MRR, TWR, of EDM with Al–4Cu–6Si alloy–10 wt. % SiCP composites. This experiment can be using the PS LEADER ZNC EDM machine and a cylindrical brass electrode of 30 mm diameter. And three factors, three levels full factorial design was using and analyzing the results. A second order, non-linear mathematical model has been developed for establishing the relationship among machining parameters. The significant of the models were checked using technique ANOVA and finding the MRR, TWR and ROC increase significant in a non-linear fashion with increase in current.

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Karthikeyan et. al (1999) presented the mathematical molding of EDM with aluminum-silicon carbide particulate composites. Mathematical equation is Y=f(V, I, T). And the effect of MRR, TWR, SR with Process parameters taken in to consideration were the current (I), the pulse duration (T) and the percent volume fraction of SiC (25 µ size). A three level full factorial design was choosing. Finally the significant of the models were checked using the ANOVA. The MRR was found to decrease with an increase in the percent volume of SiC, whereas the TWR and the surface roughness increase with an increase in the volume of Sic. it shown the graph between interactive effect of the percent volume of Sic and the current on MRR graph. **See Figure 2.1**

Kocher et. al (2012) evaluated the effect of current, using two electrodes such as the copper-tungsten and copper and graphite on the surface roughness on the AISI D3 tool steel and observed that Copper-Tungsten is giving good quality surface as compare to copper electrode and graphite electrode. Graphite is recommended for roughing and copper electrode is recommended for semi finishing process but Copper –Tungsten is best for finishing process. Copper –Tungsten is costly than copper. But it gives good surface finish. **See Figure 2.2**

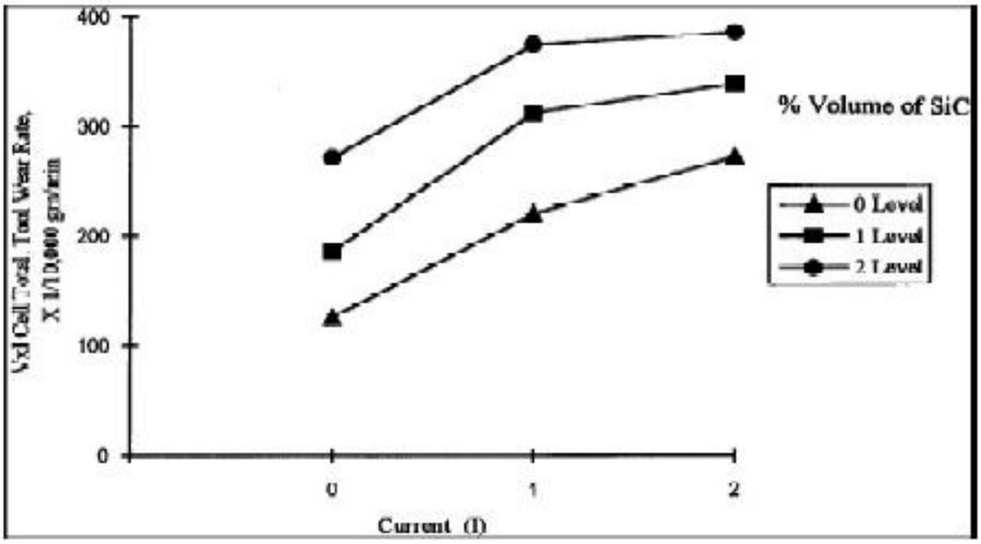

Fig. (2.1): Graph between interactive effect of Sic and Current on MRR

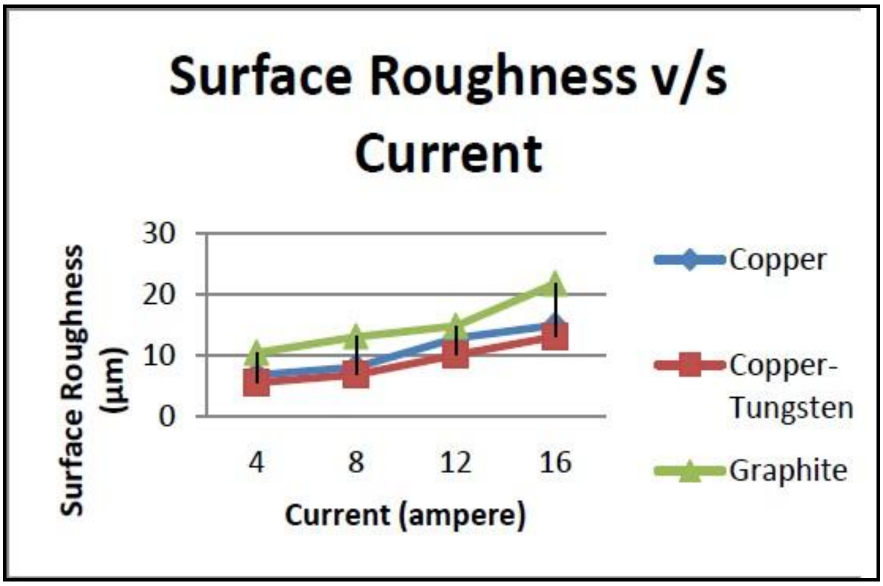

Fig. (2.2): The effect of discharge current on surface roughness of D3 tool steel

Puertos and Luis (2005) defined the optimization of machining parameter for EDM of Boron carbide of conductive ceramic materials. It is these conditions that determine such important characteristics as surface roughness, electrode wear, and MRR. In this article, a review of the state of art of the die-sinking EDM processes for conductive ceramic materials, as well as a description of the equipment used for carrying out the experiments, are presented.

Also, a series of mathematical models will be devised using design of experiments techniques combined with multiple linear regression, which will allow us, while only performing a small number of experiments, to select the optimal machining conditions for the finishing stage of the EDM process.

Tsai et al (2003) used working material of graphite, copper and copper alloys are widely using EDM because these materials have high melting temperature, and excellent electrical and thermal conductivity. The electrodes made by using powder metallurgy technology from special powders have been used to modify EDM surfaces in recent years, to improve wear and corrosion resistance. Electrodes are made at low pressure (20 MPa) and temperature (200 °C) in a hot mounting machine

According to the experimental results, a mixing ratio of Cu– 0wt%Cr and a sinter pressure of 20 MPa obtained an excellent MRR. Moreover, this work also reveals that the composite electrodes obtained a higher MRR than Cu metal electrodes. The recast layer was thinner and fewer cracks were present on the machined surface. Study of parameter in EDM by using the RSM, the parameter like MRR, TWR, gap size and SR and relevant experimental data were obtained through experimentation by Sameh S.

Mohan and Satyanarayana (2002) evaluated the effect of the EDM Current, electrode marital polarity, pulse duration and rotation of electrode on metal removal rate, TWR, and SR, and the EDM of Al-Sic with 20-25 vol. % SiC, Polarity of the electrode and volume present of SiC, the MRR increased with increased in discharge current and specific current it decreased with increasing in pulse duration. Increasing the speed of the rotation electrode resulted in a positive effect with MRR, TWR and better SR than stationary.

The electric motor can be used to rotate the electrode(tool) AV belt was used to transmit the power from the motor to the electrode Optimization parameters for EDM drilling were also developed to summarize the effect of machining characteristic such as MRR, TWR and SR.

J. Simao et. al developed the surface modification using by EDM, details are given of operations involving powder metallurgy (PM) tool electrodes and the use of powders suspended in the dielectric fluid, typically aluminum, nickel, titanium, etc. experimental results are presented on the surface alloying of AISI H13 hot work tool steel during a die sink operation using partially sintered WC / Co electrodes operating in a hydrocarbon oil dielectric.

An L8 fractional factorial Taguchi experiment was used to identify the effect of key operating factors on output measures (electrode wear, workpiece surface hardness, etc.). With respect to micro hardness, the percentage contribution ratios (PCR) for peak current, electrode polarity and pulse on time. Even so, the very low error PCR value (for micro hardness ~6%) implies that all the major effects were taken into account.

Thus after going through literature we have taken two electrodes i.e. copper and graphite for experimental setup and P20 steel as the workpiece and a comparative study has been made.

Khan et. al (2007) presented an analysis to evaluate the electrode wear along the cross-section of an electrode compared to the same along its length during EDM of aluminum and mild steel using copper and brass electrodes.

In an overall performance comparison of copper and brass electrodes, it is found that electrode wear increases with an increase in both current and voltage, but wear along the crosssection of the electrode is more compared to the same along its length. This is due to easier heat transfer along the length compared to the same along the cross-section of the electrode. It was also found that the wear ratio increases with an increase in current. That means though a higher current causes more removal of work material and the electrode, comparatively more material is removed from the electrode. The highest wear ratio was found during machining of steel using a brass electrode.

The low thermal conductivity of brass electrodes causes less heat loss, and its low melting point results in fast melting of the electrode material. At the same time, low thermal conductivity of steel results in poor heat absorption, and its high melting temperature causes poor removal of work material. These factors result in the highest wear ratio during machining of steel using a brass electrode. The highest material removal rate was observed during machining of aluminum using brass electrodes.

Comparatively low thermal conductivity of brass as an electrode material does not allow the absorption of much heat energy, and most of the heat is utilized in the removal of material from aluminum work-piece at a low melting point. But during machining of steel using copper electrodes, a comparatively smaller quantity of heat is absorbed by the work material due to its low thermal conductivity. As a result material removal rate becomes very low.

From the above discussions the following conclusions can be drawn:

1) Electrodes undergo more wear along their crosssection compared to that along its length.

2) EW increases with increase in current and voltage. Wear of copper electrodes is less than that of brass electrodes. This is due to the higher thermal conductivity and melting point of copper compared to those of brass.

3) During machining of mild steel, electrodes undergo more wear than during machining of aluminum. This is due to the fact that the thermal conductivity of aluminum is higher that of mild steel, which causes comparatively more heat energy to dissipate into the electrode during machining of mild steel

4) The WR increases with increase in current and gap voltage Vg. The highest wear ratio was found during machining of steel using a brass electrode

Kumar and Singh (2007) performed a comparative study of the performance of different electrode materials in two media. Electrical discharge machining (EDM) has been recognized as an efficient production method for precision machining of electrically conducting hardened materials.

Copper and brass are two commonly used electrode materials with kerosene as the dielectric medium. Then comparison of the performance of copper -chromium alloy with copper and brass as EDM electrode materials for machining OHNS die steel using kerosene and distilled water as dielectric media has been made.

Keeping all other machining parameters same, the hardened work material was machined with the three electrodes at different values of discharge current. It has been found that copper -chromium alloy shows better results than copper and brass in terms of material removal rate, dimensional accuracy (lateral over cut) and surface finish in both the dielectric media.

At the same time, tool wear rate of this alloy is lower which results in better accuracy and trueness of the machined profiles because the mirror image of the tool electrode is reproduced in the work piece. Regarding the use of distilled water as a dielectric medium, though material removal rate is low and tool wear rate is high, but hardness and finish of the machined surface show a marked improvement.

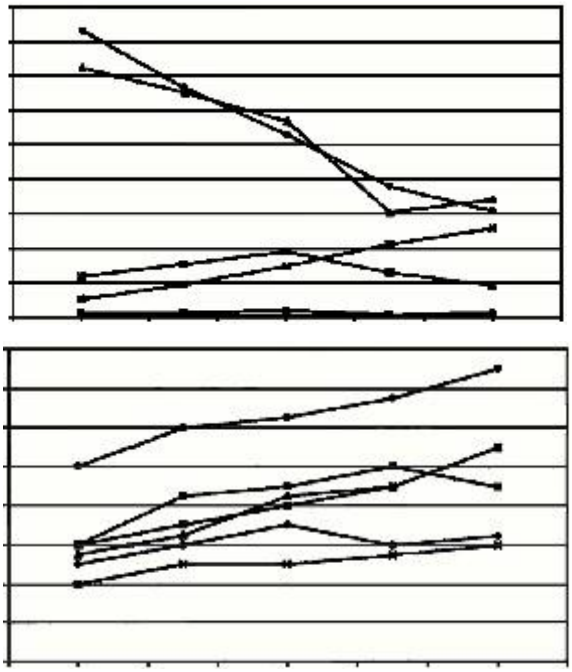

Fig. (2.3): Graphs of variations of tool wear rate and dimensional accuracy with discharge current

Following outcomes can be drawn

1) Copper-chromium alloy clearly distinguishes itself as a superior electrode material which gives higher material removal rate, superior surface finish and least over cut (better dimensional accuracy) in both the dielectric media. The tool wear rate of this alloy is very low. It is especially important in EDM process because the machined surface is a mirrorimage of the electrode shape and any unequal shape degeneration of the tool electrode may lead to the rejection of manufactured parts.

2) Though copper-chromium alloy is expensive than copper and brass, the numerous advantages offered by it far outweigh the cost factor. MRR is less and TWR is higher in distilled water as compared to kerosene for all the three electrode materials. The addition of 1% chromium to copper has improved its properties as an EDM electrode material substantially. It is envisaged that there will be an optimum percentage of chromium in copper which will give the best overall performance It provides an opportunity to combine EDM with electrochemical machining by adding chemicals like sodium chloride or sodium nitrate in distilled water (which is not possible when kerosene is used as the dielectric), thus combining the advantages of both the processes. Other polar liquids like ethylene glycol may also be added to distilled water.

CONCLUSION

From the research papers in this classification, it is observed that few works has been reported on EDM on the materials like AlSic, EN-19, SKH 57, AISI H13, AISI D2 tool steel, and various composite materials. Study on EDM of different material and different mathematical model can be used to validate the experimental results.

Considering above literature review, we have decided to select the work piece material as high carbon high chromium i.e. AISI D3 tool steel.

The conclusion of the study carried out is to study and analyze the effect of different electrode materials upon two very important parameters of the Electric Discharge Machining i.e. Material Removal Rate and Tool Wear Rate. Also the effect was studied on Surface roughness of the work-piece. The machine has the capability to vary the polarity, peak current, pulse on- time, pulse off-time, pulse duration etc. Considering the capability of the machine and the output required for the experimentation, peak current, pulse duration were decided to be taken as the variable and all the other factors have to be kept fixed. The machining parameter selected for peak current, pulse duration, and electrode material using Taguchi design approach analyzing the responses MRR, TWR, and SR.

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