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Comparative Study of Rotational Tool EDM and Stationary Tool EDM - A Review

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ABSTRACT

Electrical Discharge Machining (EDM) is a non-conventional machining process in which the machining takes place through spark erosion between tool electrode and workpiece. EDM is used for hard materials which are generally difficult to machine using conventional machining method. Research has been done on EDM to improve its performance measures like Material removal rate (MRR), tool wear rate (TWR), surface roughness (SR) and dimensional accuracy. Various researchers have performed the work on various types of EDMs like Die Sinking EDM, Dry EDM, Powder Mixed EDM (PMEDM) and Wire EDM (WEDM) etc. In this paper objective is to review the research done on EDM assisted with rotary tool. In this paper there is also a depiction about the machining and non-machining parameters used during the particular research work. Present paper reviews the research work done on rotary and orbital EDM to improve its performance measures like MRR, TWR and SR.

Keywords : Electrical Discharge Machine, Rotary tool EDM, Material Removal Rate, Tool Wear Rate

I. INTRODUCTION

Electric Discharge Machining (EDM) process started around 1770 when an English Scientist Joseph Priestly found the erosive impact of the electric discharges. In 1930, first effort were made to machine metals and diamonds using electric discharges, and the process was known by the name as "arc machining or spark machining" process. Then after, in 1943, two Russian Scientists, B.R. Lazarenko and N.I. Lazarenko at the Moscow University did innovative work on EDM. The destructive effect of an electric discharge was channelized and a controlled process for the machining of materials was developed. The relaxation-capacitance (RC) circuit was introduced in 1950s, which provided the first consistent dependable control of pulse time and a simple servo system control circuit to automatically sense the required inter-electrode gap between the tool and the work-piece. In 1980s, the introduction of Computer Numerical Control (CNC) in EDM, brought tremendous advancement in improvising the efficiency of the machining process. Modern EDM machines are so stable these days that these can be operated round the clock under adaptive control system monitoring (Kumara et al., 2009).

Electrical discharge machining is versatile among all electrical machining methods.EDM is most precise production procedure for creating complicated or elementary shapes, geometrics components and assemblies. It is basically a non-conventional material removal process. Its exclusive characteristic of using thermal energy to machine electrically conductive parts despite of hardness has been its unique advantage in the manufacture of mould, die, automotive, aerospace and surgical components. In this process electrode does not make direct contact with work piece where it can be remove mechanical stresses, chatter and vibration problem during the process (Ho & Newman, 2003).

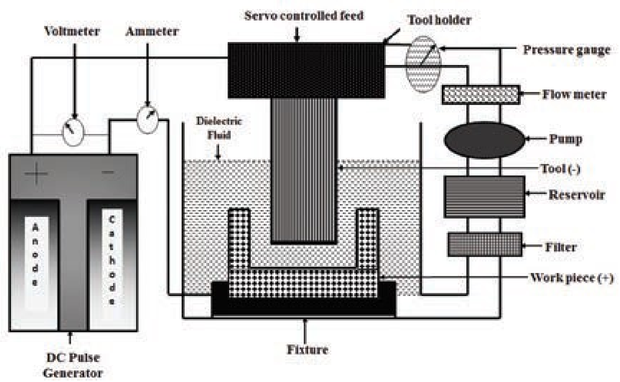

Figure 1: Schematic diagram of Electric Discharge Machining Process [Anand Prakash Dwivedi*, Sounak Kumar Choudhury,2016]

The major drawbacks of this process are its low MRR and poor surface finish. Currently the researcher had adopted various methodologies to overcome these problems by using powder mixed dielectric, vibration machining etc. Tool rotation method has been a good alternative to overcome these drawbacks, but in the past years there has been very less use of it. (Dwivedi & Choudhury, 2016).

II. WORKING PRINCIPLE

EDM machining is carried out by means of electric sparks that jump between two electrodes subjected to a voltage and submerged in a dielectric fluid. Thus, the voltage applied to them must be enough to create an electric field higher than the dielectric rigidity of the fluid used in the process. As a consequence of this electric field, 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. These effects make a little part of metal volume melt or even vaporise. In these conditions, that is, ions and electrons crashing among them and therefore creating high temperatures in both poles, a gas all or bubble is formed around the plasma channel and then begins to grow providing just at the end of the discharge a large ball of gas. In this situation, electric current is shut off and the plasma channel collapses producing the spark to disappear .Due to the sudden decrease of internal pressure of the gas ball, the dielectric fluid breaks it making the ball implode, that is, explode inwards. As a consequence of this implosion, an ejection of molten metal is carried out and, afterwards, this ejected molten material solidifies in the form of little balls formed the so called EDM splinter or debris. Basically, there are two different types of EDM: 1)Die-sinking 2) wire-cut. Die-sinking EDM reproduces the shape of the tool used (electrode) in the part wire-cut EDM a metal wire (electrode) is used to cut a programmed outline into the piece. In spite of the advantages that present EDM processes, one of the most important drawbacks is the high manufacturing time. This is really important when obtaining low values of surface roughness is pretended .In such case, an inadequate selection of operation conditions may cause quite high process times without achieving an improvement on the surface roughness properties.

III. INTRODUCTION OF ROTARY TOOL EDM

In rotary EDM, rotational movement is imparted to the tool electrode immersed in a dielectric fluid during the machining process. The upper plate of the attachment was attached to ram of EDM machine. DC motor drive provides the rotary motion to the tool electrode. A tool chuck was provided at the bottom of the assembly to hold the tool electrode. In this process cylindrical solid or hollow tube electrode can be used to machine the materials.

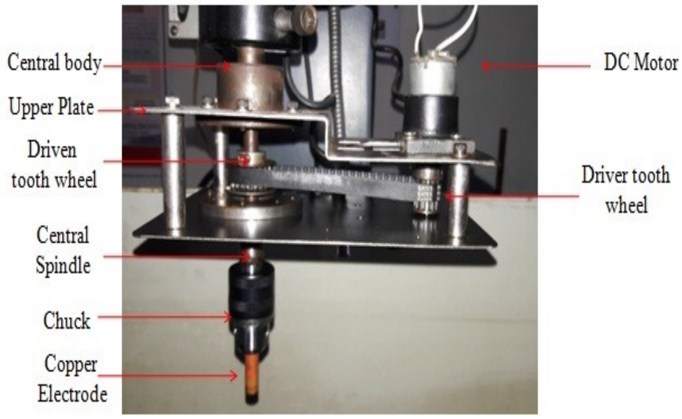

Figure 2 : Rotary Attachment

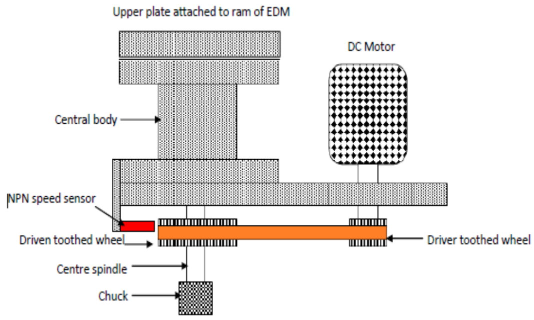

Figure 3 : Components of the electrode rotational attachment

The rotary motion is an additional motion imparted to the tool electrode as compared to die-sinking EDM. The various components of the rotary spindle attachment fabricated for the development of Electric Discharge Surface Grinding (EDSG) experimental set up on EDM machine. Setup is used to generate rotary motion for the electrode and is fixed with the quill of the machine. DC motor is attached with the clamp and further with its main spindle. The input voltage is supplied to the rotary arrangement by the DC power supply.

A schematic drawing shown in Fig. 2 and 3 illustrates the fixing of rotary arrangement with the main spindle of the machine. Rotary motion is transferred from horizontal plane to the vertical plane.

IV. SURVEY ON STATIONARY TOOL EDM & ROTARY TOOL EDM

Chattopadhyay et.al (2008) examined the machining characteristics of EN-8 steel with copper as a tool electrode during rotary electrical discharge machining process. In the case of MRR and EWR, it has been examined that the decrease in pulse on time, decrease in electrode rotation and increase in peak current, increases both the machining output.

Chattopadhyay et.al (2009) explored the machining qualities of EN-8 steel with copper as a tool electrode during rotary electrical discharge machining process. The experimental models for forecast of output parameters have been created utilizing linear regression analysis by applying logarithmic data transformation of non-linear equation. Three independent input parameters of the model peak current, pulse on time and rotational speed of tool electrode were selected as variables for evaluating the output parameters such as metal removal rate (MRR), electrode wear ratio (EWR) and surface roughness (SR). Analysis has been carried out using Taguchi's suggested signal–noise ratio formula and ANOVA has been conducted to recognize the significant parameters and their degree of contribution in the process output. Analyzed results shows that peak current and pulse on time are the most significant and significant parameters for MRR and EWR, respectively. But peak current and electrode rotation become the most significant and significant parameters for SR, respectively. Experimental results further exposed that maximizing the MRR while minimizing EWR and improving the surface roughness, cannot be achieved simultaneously at a particular combination of control parameters setting. In addition, the predictions based on the above developed models have been verified with another set of experiments and are found to be in good agreement with the experimental results.

Darji & Pillai (2012) have presented that by using solid tool in Micro EDM has been broadly utilized for micromachining of materials like EN-8 steel, composite material, Inconel etc. In this paper it focused on optimization of Material Removal Rate (MRR) utilizing Rotary electrode attachment. The analyses study was led for changing machining parameter like polarity, peak current, rotational speed of electrode and pulse on time utilizing Taguchi system to research the machining qualities of Hastelloy C276 with 0.5 mm Graphite pole as Electrode. Significant machining parameter for MRR were identified by using signal to noise ratio and ANOVA, The results of the Experiment state that Polarity is more in flushing Parameter than Peak current, Rotational speed of Electrode and Pulse on time for material removal rate.

Dave et.al (2013) have explored various effects of basic machining parameters on dimensional accuracy of the micro holes by measuring top and bottom radial overcuts and taper angle and electrode gets more utilized during micro-electro-discharge machining of aluminium (Al 1100) with tungsten electrode of diameter 300μm. The microelectrodes have been cut using a foil electrode and shaped using a Wire Electric Discharge Grinding (WEDG) system. Taguchi methodology has been utilized for design of experimentation with gap voltage, capacitance, and pulse ON time as electrical parameters and thickness and electrode rotation as non-electrical parameters. The result shows that the stationary electrode condition is found to be the optimum condition for top and bottom radial overcuts and taper angle, while for electrode depletion, the lowest level of rotational speed considered for experimentation is observed to be optimal.

Dwivedi & Choudhury (2016a) has performed experiments on AISI-D3 steel using rotary tool motion. The comparison between stationary EDM and rotary EDM is done. The result represents that the tool rotation phenomenon significantly improves the average MRR and surface finish by 41% and 12% respectively. The surface finish was more uniform in structure with less number of micro cracks and thinner recast layer as compared to the stationary tool EDM.

Dwivedi & Choudhury (2016b) focused on the surface integrity improvement of the AISI D3 tool steel using the tool rotation during the EDM process. Surface Roughness (Ra), Micro-Cracks and Recast Layers have been examined and studied as the output parameters. Their research was focused on the surface integrity improvement of the AISI D3 tool steel utilizing the rotary EDM attachment. Surface Roughness (Ra), Micro-Cracks, Recast Layer have been inspected and considered as output parameters. The outcomes demonstrate that the machined work piece has a better surface, fewer micro-cracks and thinner recast layers as compared to the stationary tool EDM process.

Gaur & Bharti (2015) explored the impact of gap current, pulse on time, duty factor, tool electrode rpm and especially the polarity of the machine on Material Removal Rate (MRR) and surface roughness (Ra) for machining of Nimonic alloy. It was examined with suitable control of input parameters of Electrical Discharge Drilling (EDD), MRR and Ra value both found to be improved together from 60 to 90 mg per minute and 4.8 to 2.9 μm respectively which confirm the viability of using tool electrode rotation in EDM machining.

Kumar (2013) has investigated the advancement of Electrical Discharge Machining processes with main focus of the surface quality and MRR. He has concluded that increasing the current, MRR and surface roughness increases and with increase in pulse on time MRR and surface roughness decreases.

Teimouri & Baseri (2012) surveyed on the impact of tool rotation and different intensities of external magnetic field on electrical discharge machining (EDM) performance. The Experiments was done in three parts of low energy, middle energy and high energy. The impact of process parameters were examined on main outputs of material removal rate (MRR) and surface roughness (SR). In order to compare the input parameters and output values two mathematical models were developed to predict the MRR and SR according to variations of discharge energy, magnetic field intensity and tool rotational speed. Results indicated that by applying a rotational magnetic field around the machining gap, improves the MRR and SR. Combination of rotational magnetic field and rotary electrode increases the machining performance, in comparison of previous conditions. This is due to better flushing debris from machining gap. This work introduced a new method for improving the machining performance, in cost and time points of view.

Vincent & Kumar (2016) presented the execution parameters of EDM process to accomplish the feasibility in machining of nitride steel En41b. The machining was done using rotary tubular copper and brass electrodes, in which the tool electrodes may have an additional rotary or orbiting motion, in addition to the servo-controlled feed. Taguchi's signal-to-noise ratio and grey relational analysis were applied in this work to improve the multi-response characteristics such as MRR and EWR on En41b steel and the optimum combination of control parameters such as current, gap voltage, pulse ON time and pulse OFF time were obtained.

V. PROCESS & PERFORMANCE PARAMETER

Pulse On-time: It is the length of time (μs) for which the current is permitted to run per cycle. Material removal is specifically relative to the measure of energy connected within this on-time.

Pulse Off-time: It is the time period between sparks. This time permits the liquid material to solidify and to be wash out of the arc gap.

Voltage (V): It is a potential that can be determine by volt. It is similarly effect to the material removal rate and allowed to per cycle.

Duty Cycle: It is the ratio of pulse on-time to total cycle time is called duty cycle. It is generally expresses in percentage.

Arc Gap: It is the gap which is maintained between the electrode and work piece during the process of EDM.

Peak Current: It is the most significant machining parameter in EDM; it is the measure of power utilized as a part of discharge machining. In every pulse on-time the current increases until it achieves a preset level, which is known as the peak current.

Polarity: The polarity normally of two type, positive polarity and negative polarity. Material evaporation at both electrode spots is found due to the high temperature when current passes through the gap between electrode and work piece.

Electrode Speed: The Electrode is rotated with the help of electric motor. The speed of the rotating electrode is controlled by power supply. For the estimation of the speed tachometer is utilized.

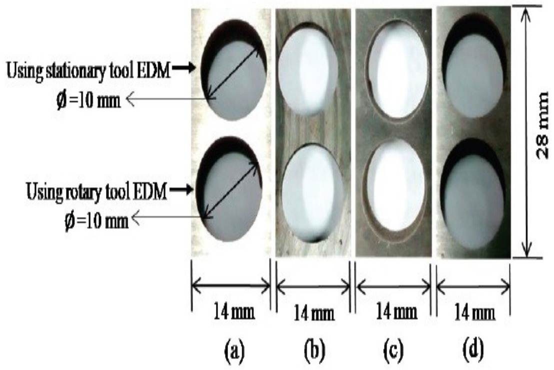

Fig. 4.Comparison for Material Removal Rate for rotary tool EDM & stationary tool EDM [Dwivedi & Choudhury, 2016]

VI. PROCESS & PERFORMANCE PARAMETER

Material Removal Rate (MRR): It is the ratio of the difference between the work piece before machining (the initial weight) and work piece after machining (the final weight). From literature survey it was found that material removal rate is more in the rotary tool

EDM as compared to the stationary tool EDM and it has been shown in Fig.4.

Surface Quality: Surface quality is a wide execution measure used to examine the state of the machined surface. It involves parts such as surface roughness, heat affected zone, recast layer and micro cracks. The surface roughness was measured utilizing Optical Profilometer for getting the Ra value. From the literature survey it was found that the surface finish during rotary tool EDM improves as compared to the stationary tool EDM process.

Tool Wear Rate: TWR is an execution measure for the wearing down rate of the tool electrode and is a cause generally taken into account when considering the geometrical accuracy of the machined characteristic.

VII. SUMMARY

From literature reivew it concludes that rotary tool EDM gives a better MRR and surface finish as compare to stationary tool EDM. The tool rotation helps in developing the flushing difficulty which generates during the machining of small holes and cavities. The quality of the holes produced with the rotary EDM is better than the holes produced by the stationary tool EDM. Further rotary EDM increases the MRR, flushing efficiency and quality of the holes as compared to the stationary tool EDM. With the increase in the current, the MRR is significantly increased with a slight change in TWR. Also, arc can be controlled to get the desired sharpness at the edges by setting suitable way of rotation.

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