A Review Paper on Rotary Electro-Discharge Machining

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***Abstract*—This paper presents review on rotary EDM. EDM process is based on thermoelectric energy between the work piece and an electrode. EDM is widely used in parts of aerospace, automotive industry and surgical components. This paper also includes study of EDM with stationary electrode, rotary electrode and rotary electrode with orbital motion. The different performance measurement characteristics such as MRR, EWR, SR, DAROC, STDEV, HQC is studied.**

***IndexTerms*—Rotary EDM, stationary electrode, performance measurement**

I. INTRODUCTION

Electrical discharge machining (EDM) is a non-traditional concept of machining which has been widely used toproduce dies and molds. It is also used for finishing parts for aerospace and automotive industry and surgical components. EDM process is carried out in presence of dielectric fluid which creates path for discharge. When potential difference is applied across the two surfaces of workpiece and tool, the dielectric gets ionized and an electric spark/discharge is generated across the two terminals. The potential difference is applied by an external direct current power supply connected across the two terminals. The polarity of the tool and workpiece can be interchangeable but that will affect the various performance parameters of EDM process. Application of focused heat raises the temperature of workpiece in the region of tool position, which subsequently melts and evaporates the metal. In this way the machining process removes small volumes of workpiece material by the mechanism of melting and vaporization during a discharge. Fig.1 shows the layout of EDM process which indicates the working of EDM.

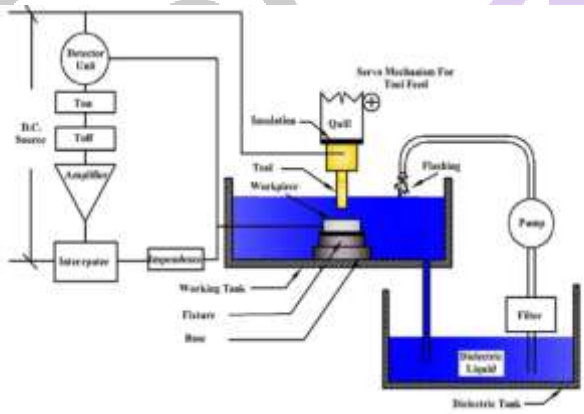

Fig.1 Layout of Electrical Discharge Machining [1]

II. LITERATURE REVIEW

Chow et al. [2] performed rotary EDM on Ti-6Al-4V alloy with copper as a electrode and found that RDE-EDM improved MRR by locating the workpiece above the RDE, thus efficiently increasing the debris removal rate. EWR also decreases uniformly around the periphery of the disk electrode. In this, optimized discharge current is essential because the temperature during discharge is extremely sensitive to the discharge current due to the small area of the micro slit. A greater MRR and lower EWR can be obtained by properly optimizing the discharge current. As shown in Fig.2 gravitational force causes the conventional RDE to discharge the debris from the gap, thus reducing the material removal rate. The gravitational force in the new design facilitates, contrarily, a greater contribution to the improvement of the debris removal rate.

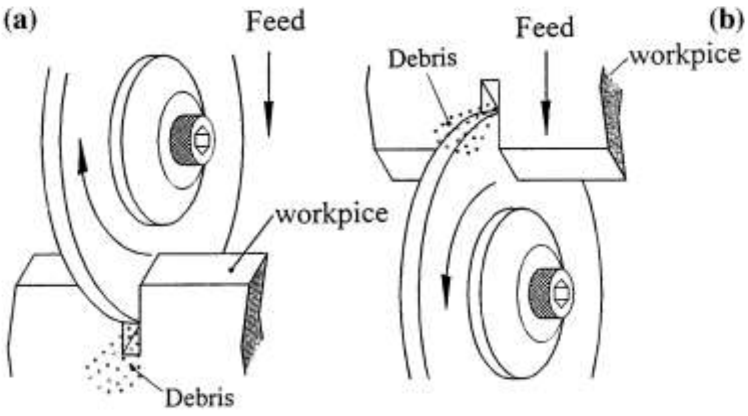

Fig.2 Schematic diagrams of EDM with: (a) a conventional rotating disk electrode RDE and; (b) a modified RDE [2]

Soni and Chakraverti [3] studied that the orbital motion of the electrode permits one to improve, to some extent, form and dimensional accuracy in the machining process, performs roughing and finishing operations with the same tool and helps to stabilize the erosion process. The MRR improved with the rotating electrode due to improved flushing action and sparking efficiency. The MRR is better in through-hole machining than in blind-hole machining at all rotating speeds. Fig.3 indicates EDM with stationary electrode, rotating electrode and rotating electrode with orbital motion.

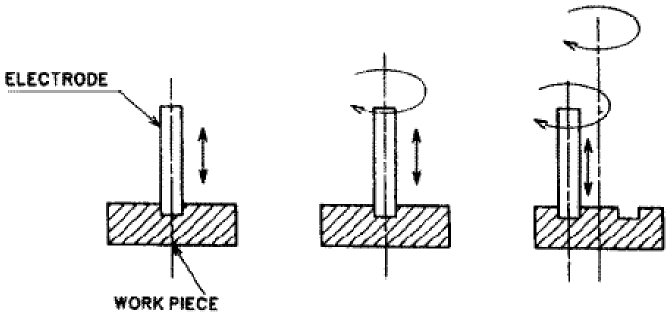

Fig.3 EDM with (a) stationary electrode, (b) rotating electrode, (c) rotating electrode with orbital motion [3]

Ghoreishi and Atkinson [4] reported that the vibro-rotary electrode compared with the separate rotary or vibratory electrodes gave satisfactorily results when most common combinations of requirements, maximum MRR, minimum TWR and surface quality. The best result of employing a vibro-rotary electrode was achieved in finishing regime when the gap was narrow and current was low.Theystudied the effects of axial vibration alongwith the rotation of electrode on the material removal and electrode wear during electrical discharge machining. Theyhave reported that the introduction of high frequency axial vibration on a rotating electrode improves MRR significantly for a specified surface finish. Fig.4 shows vibratory, rotary and vibro-rotary electrode.

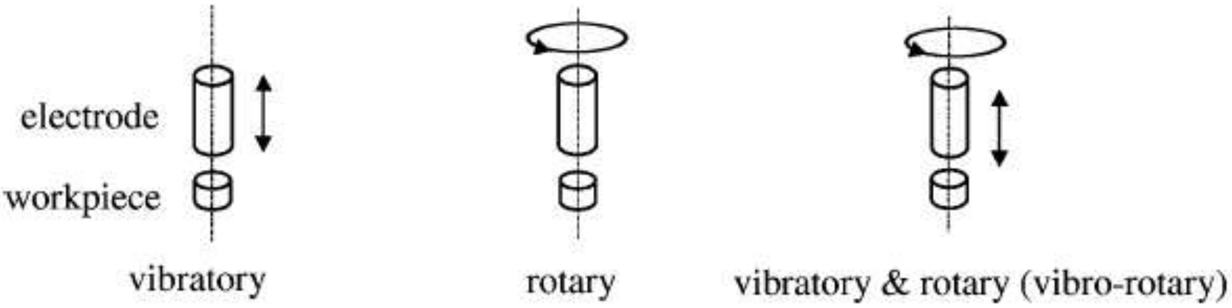

Fig.4 Vibratory, rotary, vibratory & rotary electrode [4]

Koshy et al. [5] presented a rotating disk type electrode in Fig.5. The electrode is rotated and sunk simultaneously to machine a rectangular slot in a plate workpiece. The rotation would impart a velocity to the dielectric in the gap and effectively flush the gap resulting in increased MRR and the machined surface is better than that obtained with a stationary electrode. Because the tool wear is not localised and is evenly spread over the entire circumference of the disk, shape degeneration of the electrode is not acute and better reproduction of corners is viable.

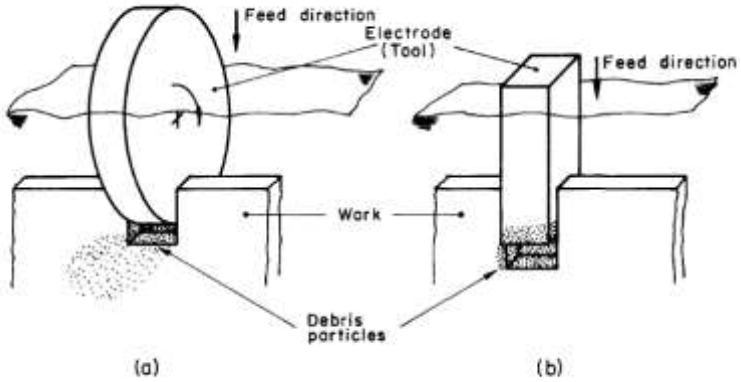

Fig.5 (a) Rotary electrode and (b) conventional electrode [5]

Chattopadhyay et al. [6] investigated the machining characteristics of EN-8 steel with copper as a tool electrode during rotary EDM process. The empirical models for prediction of output parameters have been developed using linear regression analysis by applying logarithmic data transformation of non-linear equation. A rotary electrode holder arrangement was developed to study the effect of rotation of electrode at different cutting conditions. Electrode was rotated by worm and worm wheel mechanism whose speed was controlled by variable regulated power supply as shown in Fig.6. The electrode was rotated and sunk simultaneously to generate cylindrical profile on workpiece. A mechanical tachometer is used to measure the speed of rotating electrode.

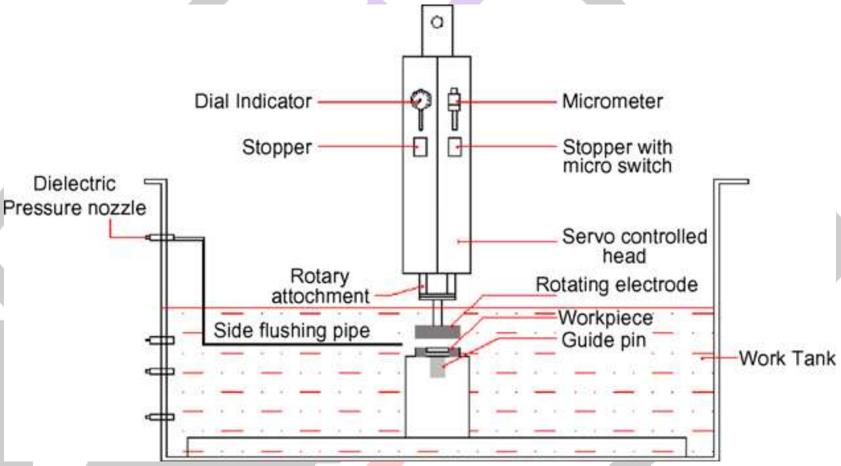

Fig.6 Schematic diagram of rotary EDM [6]

III PERFORMANCE MEASUREMENT

a) Material Removal Rate (MRR)

MRR is the material removed in a given amount of time. It is formulated as below and is expressed in grams per minute. The MRR will decide the speed of machining. Generally, the MRR is increased with the intensity of current and will cause more surface damages in the machined surfaces. It was observed that the volume of material removed increased with the increase in supply voltage, and this could be due to the generation of a large number of positively charged hydrogen bubbles at the higher value of supply voltage. These hydrogen bubbles act as insulating medium, which become enlarged with time and envelope the tool. The MRR improves with the rotating electrode due to improved flushing action and sparking efficiency. However, surface roughness is higher. Rotary disk electrode improves the productivity of EDM.MRR is superior to stationary electrode [5]. The effect of EDM drilling with the rotating tube electrodehas produced higher material removal rate thanthe rotating solid electrode.The increase in rotational speed of the tube electrodehas produced higher MRR, EWR and better SR [7]. The MRR can be calculated by the equation as

$$MRR = \frac{w_b - w_a}{t_m} \quad (1)$$

wherew_b and w_a are the weights of the work piece before and after machining and t_m is the machining time.

b) Electrode wear rate(EWR)

EWR affect the dimensional accuracy of machined component. It can be calculated by the ratio of weight difference of the sample and electrode and after EDM process to the machining time. EWR increases with increasing speed, but the wear ratio is not significantly affected. Electrode corner wear and hole corner radius in blind-hole machining are lower with the rotating electrode..The tool wear rate increases with increasing speed,but the wear ratio is not significantly affected.Electrode corner wear and hole corner radius inblind-hole machining are lower with the rotating electrode[3]. The EWR is either increased by peak current or decreased by pulse duration. The discharging energy is consumed in the erosion of material, in the discharge channel and in the electrode and is given in the equation 2. The discharging energy for EDM is defined as

$$W_e = \int_o^{on} E(t)I(t)dt \ (2)$$

Where W_e denotes the discharge energy, E represents thedischarge voltage, I is the peak current and t the pulse duration [].EWR is expressed by the following equation 3 where $w_{tb}$and$w_{ta}$are the weights of the electrode before and after machining respectively and tm is machining timeEWR is expressed by the following equation

$$EWR = \frac{w_{tb} - wt_a}{t_m} \ (3)$$

where$w_{tb}$and $w_{ta}$are the weights of the electrode before and after machining respectively and t_m is machining time.

c) Surface roughness

As surface roughness and the material removal rate are inversely proportional to each other, it is necessary to correlate the machining parameters, which produce machined component with good surface finish at high MRR. Many researchers have conducted experiments to achieve better surface finish with appropriate MRR. The SR initiallyincreases with increasing rotational speed of the tool and then decreases with anincrease in rotational speed of the tool. This is because the material removed byelectric discharge becomes strong with an increase in rotational speed of the toolelectrode, the crater size generated by electric discharge becomes large and deep;therefore the SR rises [8].Before measurement of surface finish, the specimen were cleaned and dried. Surface roughness of each specimen was assessed using the stylus method. All the measurements were carried out with portable roughness measuring instrument make (MITUTOYO). Sampling length is defined as cut-off length of the filter used to separate waviness and roughness. The cut off length for each specimen was 0.8 mm.

d) Depth averaged radial overcut (DAROC)

It is the term used to specify the quality of the drilled hole in terms of overcut. It is specified in mm.

DAROC = 1/n (Hole diameter –Tool diameter) (4)

where n = number of locations along the depth of the hole where hole diameter has been measured.

e) Standard deviation (STDEV)

It is also a parameter used to represent the quality of hole in terms of hole dimensions. It is calculated using equation 5 as Standard deviation where $\overline{x}$ is the average of readings

$\overline{x}$ = Average of six different depth diameters. n = no of different diameter

$$\text{Standard deviation} = \sqrt{\frac{\sum (x-\overline{x})^2}{(n-1)}} \quad (5)$$

f) Hole quality factor (HQF)

For any hole to be of good quality, it should have minimum possible DAROC and minimum possible STDEV. Minimum DAROC will make the hole a replica of the tool shape, and minimum STDEV will minimize variation in the hole diameter along the hole depth [9]. Hence, a hole quality factor (HQF) can be calculated as follows. It is expressed in terms of equation

$$HQF = \frac{1}{DAROC * STDEV} \quad (6)$$

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