Material Removal Rate, Tool Wear Rate and Surface Roughness Analysis of EDM Process

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Abstract— Electrical discharge machining (EDM) is one of the non-traditional machining processes, based on thermo electric energy between the work piece and an electrode. In this process, the material removal is occurred electro thermally by a series of successive discrete discharges between electrode and the work piece. The parametric analysis of the EDM process by using different electrode materials has been carried out. The Material Removal Rate (MRR), Tool Wear Rate (TWR) and Surface Roughness (SR) is measured and recorded for detailed analysis. Different electrode

I. INTRODUCTION TO DIE-SINKING EDM

In the Die-Sinker EDM Machining process [1], two metal parts submerged in an insulating liquid are connected to a source of current which is switched on and off automatically depending on the parameters set on the controller. When the current is switched on, an electric tension is created between the two metal parts. If the two parts are brought together to within a minimum gap, the electrical tension is discharged and a spark jumps across. Where it strikes, the metal is heated up so much that it melts. Sinker EDM, also called cavity type EDM or volume EDM consists of an electrode and work piece submerged in an materials viz. Aluminium, Copper, Bronze and workpiece material as Stainless Steel 304 have been employed for the set of experiments. The dielectric used is Kerosene diluted with water. The objective of the analysis is to identify the best material in terms of higher MRR, lower TWR, and excellent surface finish. The different parameters considered while carrying out the experiments on the Die-Sinking EDM would be the voltage and current applied, depth of cut, time required etc.

EDM, NCM, MRR, TWR, Surface Roughness, Parametric Analysis insulating liquid such as, oil or, less frequently, other dielectric fluids. The electrode and workpiece are connected to a suitable power supply. The power supply generates an electrical potential between the two parts. As the electrode approaches the work piece, dielectric breakdown occurs in the fluid, forming a plasma channel, and a small spark jumps. These sparks usually strike one at a time because it is very unlikely that different locations in the inter-electrode space have the identical local electrical characteristics which would enable a spark to occur simultaneously in all such locations. These sparks happen in huge numbers at seemingly random locations between the electrode and the work piece. As the base metal is eroded, and the spark gap subsequently increased, the electrode is lowered automatically by the machine so that the process can continue uninterrupted.

Several hundred thousand sparks occur per second, with the actual duty cycle carefully controlled by the setup parameters.

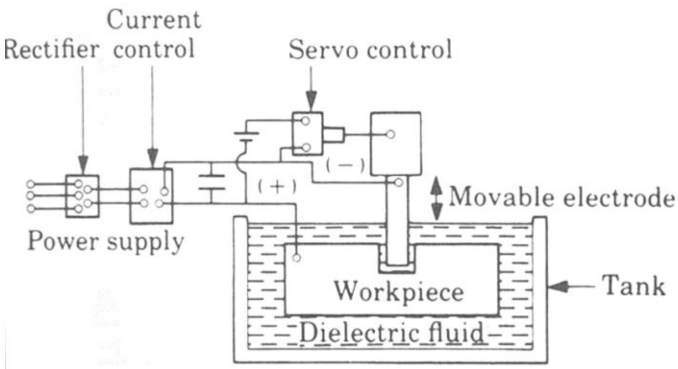

Fig: 1 Die-Sinker EDM Setup [1]

II. LITERATURE REVIEW

In this paper few selected research paper related to Die-sinker EDM with effect of MRR, TWR, surface roughness (SR) and work piece material have been discussed.

Nikhil Kumar et al. conducted experiments [1] with positive polarity of electrode. The pulsed discharge current was applied in various steps in positive mode. It is capable of ma chining of hard material component such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. The higher carbon grades are typically used for such applications as stamping dies, metal cutting tools, etc. AISI grades of tool steel is the most common scale used to identify various grades of tool steel. In this experiment using AISI P20 tool steel material, that is a pre hardened high tensile tool steel which offers ready machine ability in the hardened and tempered condition, therefore does not require further heat treatment. Subsequent component modifications can easily be carried out. Graphite electrode is more favourable than the copper electrode for the machining of steel work piece for MRR and TWR. It is also found that overall cost for machining of hard material with the use of graphite electrode is comparatively less than copper electrode.

Rajesh Choudhary et al. conducted [2] investigations on the machining of EN-3 1 die steel with different electrode materials (copper, brass and graphite) with electrical discharge machining (EDM) process. This study presents the analysis and evaluation of heat affected

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zones (HAZ) of the workpiece surfaces machined using different tool electrodes by EDM. The kerosene oil of commercial grade has been used as dielectric fluid. From the micro-structural analysis study it has been observed that heat affected zone is much deeper in the specimen machined by graphite electrode as compared to other tool electrodes. The following conclusions were arrived at: i) For the EN-3 I work material. Copper electrodes have high MRR as compared to the machining performed by graphite and brass electrodes. ii) Among the three tested electrode materials, brass electrodes produce comparatively high surface finish for the tested work material at high values of discharge current, while graphite shows the poor surface finish.

H S Payal et al. performed experiments [3] to determine parameters effecting surface roughness along with structural analysis of surfaces with respect to material removal parameters. Experimental work was conducted on EN-31 tool steel with copper, brass and graphite as tool electrodes with kerosene oil as dielectric fluid. Detailed analysis of structural features of machined surface was done by using Scanning Electron Microscope (SEM) and optical microscope to understand the mode of heat affected zone (HAZ) which alternatively affects structure of machined workpiece and hence tool life while investigating EDM surface by micrographs. It was observed that molten mass has been removed from surface as ligaments and sheets. In some cases, it is removed as chunks, which being in molten slate stuck to surface. MRR increases with increase in discharge current for all three electrodes. However, in case of brass and graphite, it decreases after some limit, due to pulse energy increases as the current increases. MRR does not observe linearity with pulse energy, may be due to the possible losses of thermal energy by conduction to surrounding material and dielectric fluid. An increase in current beyond certain limit for a given electrode area and material has adverse effect on MRR.

S.H.Tomadi et al. has evaluated the [4] effectiveness of EDM process with tungsten carbide, WC-Co in terms of the material removal rate, the relative wear ratio and the surface finish quality of the workpiece produced. It is observed that copper tungsten is most suitable for use as the tool electrode in EDM of WC-Co. Better machining performance is obtained generally with the electrode as the cathode and the workpiece as an anode. The Full Factorial Design of Experiment (DOE) is very useful in analyzing the optimum condition of parameters, main effect, and the significance of individual parameter to surface roughness, material removal rate and electrode wear of material. In the case of the Ra parameter, the most influential factors were voltage followed by the pulse off time, while the peak current and pulse on time was not significant at the considered confidence level. In order to obtain a good surface finish in the case of tungsten carbide, low values should be used for peak current, pulse off time and voltage. In the case of material removal rate, it was seen that pulse on time factor was the most influential, followed by voltage, peak current, and pulse off time.

J. A. Sa´nchez et al. describes [5] about the development of sinking and wire electro-discharge machining technology for two ceramics with a promising future (boron carbide and silicon infiltrated silicon carbide). The high removal rates, as well as the possibility of obtaining an excellent surface finish, prove the feasibility of the industrial application of this production method. In the case of WEDM, cutting rates of 21.3 mm^3 min^{-1} for B4C and 114 mm2 min□1 for SiSiC were obtained. In the case of finishing cuts, the best roughness values were $Ra = 0.56$ µm for B4C and $Ra = 3.5$ µm for SiSiC. In the case of SEDM, the maximum removal rate is obtained when a set of capacitors is connected in parallel between the electrode and the workpiece. Thus, removal rates of 8.3 mm^3 min^{-1} for B4C and 10.1 mm^3 min^{-1} for SiSiC were obtained, always using copper electrodes.

Kuldeep Ojha et al. proposed a [6] hybrid machining process (HMP) involving high-speed machining (HSM). An increase in material removal rate was reported but success of such machining was found to be dependent to a large extent on the availability and performance of a single cutting / dielectric fluid. Experimental results showed that material removal rate could be increased greatly by introducing ultrasonic vibration. The comparison of MRR in traditional EDM in gas and ultrasonic vibration assisted gas medium EDM for machining cemented carbides workpiece was reported. MRR was found considerably higher for a particular discharge pulse-on time for ultrasonic vibration assisted machining.

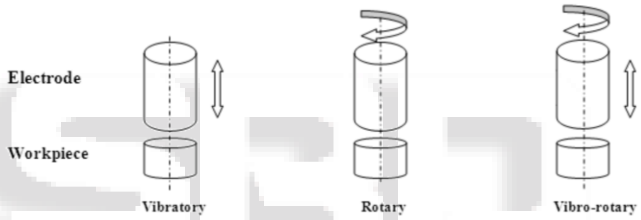

Fig. 2 : Vibratory, rotary and vibro-rotary electrode [6]

Hitesh B. Prajapati et al. has [7] concluded the following:

– Peak current, pulse off time and pulse on time significantly affects the MRR and SR in EDM.
– Analysis of variance shows that peak current and Pulse on time are having more influence to material removal rate.
– Surface roughness was mainly affected by the current and pulse on time. At higher value of current causes the more surface roughness. Higher surface finish can be achieved value can be achieved at lower current.
– Peak current and pulse on time are the most influential parameters for reducing surface quality.
– The Brass electrode gives the poor material removal rate and gives the better than surface finish than other two electrodes.
– The graphite electrode gives the most material removal rate and gives the better than surface roughness but it gives high electrode wear ratio.
– The material powder electrode gives the better MRR than solid electrode.
– Similarly Brass electrodes gives lowest MRR among three electrodes when Peak current = 17 A, 45 µs pulse on time, 60 µs pulse on time.

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– Brass electrodes gives better surface finishing among three electrodes when Peak current = 17 A, 65 µs pulse on time, 45 µs pulse on time.

– Similarly copper electrodes gives poor surface finishing among three electrodes when Peak current = 28 A, 65 µs pulse on time, 60 µs pulse on time.

Sharanjit Singh et al. has described [8] that the main factors determining the suitability of material are, we can achieve maximum MRR, wear ratio, cost and ease with which it can be shaped or fabricated to the desired shape. Generally, by using a sufficient number of electrodes of material having a low wear ratio, it is possible to produce the same accuracy of machining as with a single electrode of material with a high ratio. Keeping in mind technical and economic considerations various materials that can be used as electrode is shown in table 1

S No.	Material	Wear Ratio	Metal Removal Rate	Fabrication	Cost	Application
1.	Copper	Low	High on rough range	Easy	High	On all metals
2.	Brass	High	High only on finishing range	Easy	Low	On all metals
3.	Tungsten	Lowest	Low	Difficult	High	Small holes are drilled
4.	Tungsten copper alloy	Low	Low	Difficult	High	Used higher accuracy work
5.	Cast iron	Low	Low	Easy	Low	Used on few materials
6.	Steel	High	Low	Easy	Low	Used for finishing work
7.	Zinc based alloy	High	High on rough range	Easy die casted	High	On all metals
8.	Copper graphite	Low	High	Difficult	High	On all metals

Table.1 : Selection of electrode material [8]

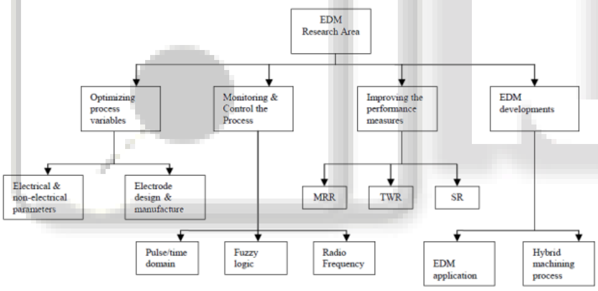

Fig.3 : Classification of major EDM research areas [8]

III. CONCLUSION

For high discharge current, copper electrodes show highest MRR, whereas Brass gives good surface finish and normal MRR. Since EDM is a thermal method, special attention must be paid to surface integrity. Surface and subsurface damage may be induced owing to thermal fatigue or to the material recast on the surface after removal. The MRR could be improved by carrying out research on electrode design, process parameters, EDM variations, powder mixed dielectric and electrically insulated electrodes. It is found that the basis of controlling and improving MRR mostly relies on empirical methods. This is largely due to stochastic nature of the sparking phenomenon involving both electrical and non-electrical process parameters along with their complicated interrelationship.

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