Study of Process Parameters and Electrode Materials used in Electro Discharge Machining

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***Abstract*—Today's global market requires a good quality of the product in minimum time. Electrical discharge machining is an unconventional machining process, which is used when traditional machining process does not meet the necessary requirement effectively and economically. This process is used for machining of hard material and complex shapes. In this process material removal takes place thermo-electrically by a formation of a plasma channel between the workpiece and tool electrode surrounded by a dielectric fluid in the same tank. Determination of process parameters is essential for effective utilization of these parameters and it is also involved with many response parameters. This paper deals with the study of a various process parameters and electrode materials from various literatures in the field of electrical discharge machining. Optimization of machining parameters plays an important role to achieve a best quality product at a reasonable price.**

***Index Terms*— EDM, optimization, process parameters, electrode materials**

I. INTRODUCTION

It is advanced thermal based machining process primarily used for machining materials which are difficult to machine with traditional techniques. In 1770, Joseph Priestly, a British first discovered the erosive effects of electrical discharges. In 1943, Soviet researchers B. Lazarenko and N. Lazarenko had described the destructive effect of an electrical discharge, further developed a controlled process for machining materials that are good conductors of electricity. However only electrically conducting, semiconducting materials can be machined by this process. High hardness and high toughness materials are machined by the electrical discharge machining process as it is difficult to be machined by turning, milling, drilling and by so other traditional machining processes. In EDM, there is no physical contact between tool and workpiece. This process is mostly suited for making intricate cavities and contours; these would be difficult to produce with normal machines like grinding end mills or other cutting tools. The shape of the obtained cavity is a replica of the shape of tools. All the conductive material can be worked by EDM. The EDM electrode is the tool that determines the shape of the cavity to be produced. The EDM setup consists of the tank in which the dielectric fluid is filled. Electrode & workpiece submerged into the dielectric fluid. The servo system is commanded by signals from gap voltage sensor system in the power supply, which controls the feed of electrode & workpiece to precisely match the rate of material removal. The power supply is an important part of any EDM system, which transforms the alternating current from the main utility supply into the pulse direct current required to produce the spark discharge at the machining gap. Materials of any hardness can be machined by this process. No burrs are left on a machined surface. One of the main advantages of this process is that thin and brittle components can be machined without distortion. Complex internal shapes can be machined. This process can only be employed in electrically conductive materials. The material removal rate is low. Compared to conventional machining processes this process is overall slow. Unwanted erosion and over cutting of material can occur. A rough surface finishes when at high rates of material removal.

II. WORKING PRINCIPLE OF EDM PROCESS

To understand how EDM removes metals let examine a single spark erosion process. As a D.C electricity reaches the electrode and parts and intense electric field develops in a gap. Microscopic contaminants suspended in dielectric fluid are attracted by field and concentrated at a field of the strongest point. These contaminants build a high conductive bridge the gap. as a field voltage increase, this material in conductive bridge heats up so pieces ionized form a spark channel between electrodes and workpiece. At this point, both temperature and pressure in a channel rapidly increases and generating a spark. A small amount of metal melts and vaporized from electrode workpiece, at the point of spark contact. Bubble composed gaseous by-products vaporization rapidly expand outward spark channel. Once the process ends sparking and heating action stops collapsing the spark channel. Further dielectric fluid then rushes into the gap, flushing molten metal from both the surface of electrode and workpiece. These EDM solid consists of small solidification material and gas bubbles. The resulting EDM parts can have several absorbed layers, such as a top layer, recast layer, and heat affected zone. Figure of electrical discharge machining process is shown below in fig. 1

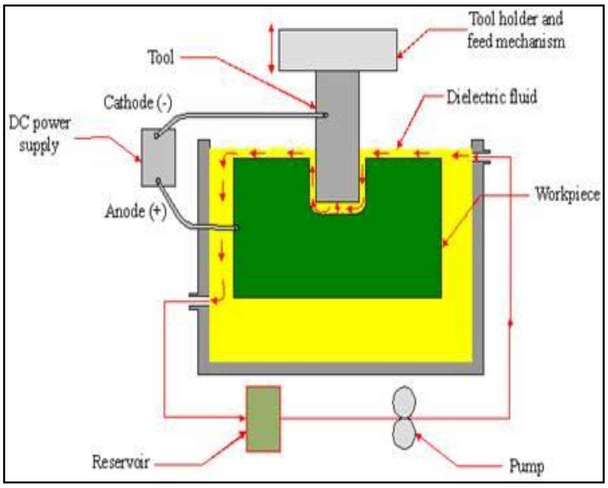

Fig. 1 Basic Working Diagram of EDM

The discharge current is the value of the applied current to the tool during the pulse on time in the EDM. It is one of the most primary input parameters of an electrical discharge machining process. Pulse on time is the time for which the electrode is applied a current during each EDM cycle. The material removal rate is directly proportional to a certain amount of energy applied during pulse on time. Pulse off time is the time waiting for the interval during two pulses on time period. Gap voltage is potential difference applied between the electrode and workpiece.

III. LITERATURE SURVEY

A. P. Tiwary et al. (2014) [1] investigated micro-electro-discharge machining process parameters during machining of Ti-6Al-4V using combined methods of RSM and fuzzy technique. Experimentations were carried out on the basis of DOE. To select the most desirable factor level combinations a fuzzy-TOPSIS method was used. The micro-EDM process, which influence MRR, TWR, OC, and taper. Order of micro-EDM process parameters considered in this study in terms of their importance has been observed as a pulse on time, peak current, gap voltage and flushing pressure. The outcome of this research can be utilized in micro manufacturing industries and other researchers to improve the geometrical accuracy and precision of the machined through micro-hole.

Rajesh Khanna et al. (2015) [2] studied the response variables material removal rate and tool wear rate correlate the machining parameters such as a pulse on-time, pulse off-time, and water pressure, in the Electro discharge machining of drilling process of Al-7075. Brass rod of 2 mm diameter was selected as a tool electrode. An experimental plan was planned based on Taguchi method. The optimization results showed that the combination of maximum pulse on-time and minimum pulse off-time gives maximum MRR. Tool wear rate was most significantly affected by pulse on-time, pulse off-time. Multi-quality characteristics for the same material considering material removal rate and tool wear rate were given as under by Taguchi grey relational analysis. The predicted value of grey relational grade is 0.685120. The experimental value at the optimal setting was observed to be 0.0359 mm3/min and 0.252 g/s for MRR and TWR.

Jong Hyuk Jung et al. (2010) [3] studied optimal machining conditions for drilling of a micro-hole of minimum diameter and maximum aspect ratio. The Taguchi method was employed to determine the relations between the machining parameters and the process characteristics. The electrode wear and the entrance and exit clearances had a significant effect on the diameter when the diameter of the electrode is identical of the micro-hole. Grey relational analysis was used to determine the machining parameters affecting the electrode wear and the entrance and exit clearances. Input voltage and the capacitance was found the most significant controlling parameters. A micro-hole of 40μm average diameter and an aspect ratio of 10 could be machined under these conditions.

Yan-Cherng Lin et al. (2009) [4] investigated a novel process of magnetic-force-assisted electrical discharge machining. MRR of the magnetic-assisted EDM were found nearly three times compared to conventional EDM, and the SR was less than that of conventional EDM. The machined surface was found smoother than conventional EDM and surface crack were reduced in magnetic-force-assisted EDM process. ANOVA results indicated that the peak current, pulse duration, and no load voltage were the significant machining parameters that obviously affected the multiple performance characteristics in the magnetic-force-assisted EDM process.

The Anirban Bhattacharya et al. (2012) [5] investigation were carried to identify the appropriate parameter settings for rough and finish machined surface. The MRR was found to be dependent upon pulse off and on time and current. But, SR was significantly affected by pulse on-time, current, and powder and the combined effect of the workpiece, powder, and the electrode. EN31 results in maximum MRR as compared to the other two materials for similar process settings. Copper electrode used with aluminum powder suspended in the dielectric maximized the MRR, were as graphite powder resulted in a lower MRR but improved surface finish. The MRR for H11 was lower than EN31 but significantly higher than HCHCr under similar process condition.

R. Ramakrishnan et al. (2006) [6] investigate the multi-objective optimization of the WEDM process using Taguchi design methodology. The process parameters such as pulse on time, wire tension, wire feed speed, and ignition current intensity were studied for machining of heat-treated tool steel. The validity of the developed optimization tool was tested and provided a consistent result. The researcher can attempt to consider the other performance criteria, such as surface waviness, and surface flatness as output parameters in their studies.

T. A. El-Taweel (2009) [7] investigated MRR and TWR in EDM process of CK45 steel using Al–Cu–Si–TiC P/M electrode which were modeled and analyzed through RSM. TiC percent, peak current, dielectric flushing pressure, and pulse on-time were been employed to carry out the experimental study. Al–Cu–Si–TiC P/M electrodes was found more sensitive to peak current and pulse on-time than any other conventional electrodes. Peak current was found to be an important factor affecting both MRR and TWR, were flushing pressure was found to have little effect.

S. Singh (2012) [8] applied the designs of experiments and grey relational analysis approach to optimize parameters for machining of 6061Al/Al2O3p/20P aluminum metal matrix composites. The L18 orthogonal array was planned to determine an optimal setting. Experimental results have shown clearly that the material removal rate, tool wear rate and surface roughness in the EDM process can be improved effectively through the grey relational analysis approach. An optimal combination of machining parameters was determined by grey relational analysis for multiple performance characteristics.

Yu Huang et al. (2013) [9] studied the effect of cutting parameters on surface roughness, material removal rate and average gap voltage in the WEDM of high hardness tool steel YG15, which are experimentally investigated for both rough cutting and finish cutting. On rough cutting the pulse-on time has the important effect on Ra, and the effects of a pulse on time, pulse off time, and cutting feed rate were more important than wire tension, wire speed, and water pressure on MRR. On finish cutting, power and cutting feed rate had the extremely important effect on Ra; and pulse-on time, cutting feed rate, and water pressure were more important than other factors on MRR. The ANOVA for regression analysis indicated that the estimated model for MRR on rough cutting and for Ra on finish cutting were significant.

Thella Babu Rao et al. (2013) [10] investigated compliance of an integrated approach, principal component analysis coupled. Taguchi's robust theory for simultaneous optimization of correlated multiple responses of wire electrical discharge machining process for machining SiCP reinforced ZC63 metal matrix composites. PCA was used as multi-response optimization technique to derive the composite principal component which acts as the overall quality index in the process. Taguchi's S/N ratio analysis was applied to optimize the CPC. The derived optimal process responses were confirmed by the experimental validation tests results. The analysis of variance was conducted to find the effects of choosing process variables on the overall quality of the machined component. This methodology could be also applied for different machining process on different materials in different machining conditions so as to automate the machining process based on the chosen optimal values.

IV. EFFECT OF VARIOUS PROCESS PARAMETERS ON RESPONSES

Surface roughness decreases when there is a decrease in peak current as well as a pulse on time. For surface roughness peak current and duty cycle are primarily important to maintain it in desired levels. As compared to pulse off time current has the largest effect on the surface roughness. A Less rough surface can be obtained by setting small pulse duration period along with relatively high enough discharge current. Highest current improves material removal rate, but surface roughness and electrode wear rate also increases. With the increase in the pulse off time, the spark contact time within the workpiece decreases and it will decrease the material removal rate. Material removal rate steadily increases with increase in discharge current and duty cycle. At lowest pulse off time tool wear is constant or null, but it decreases with increase in pulse off time. The pulse current only has more influence on electrode wear rate, where a pulse on time has less effect on it. Tool wear rate is lowered by applying low current level with long pulses. Electrode wear is less when the pulse is on and respectively it is null when a pulse is off.

V. COMPARISION OF DIFFERENT ELECTRODE MATERIALS

In early days, metallic electrodes were used mostly then today recently used. The advantage of a metallic electrode is electrical conductivity and mechanical integrity. Disadvantages of these metallic electrodes were they were difficult to fabricate and low cutting speed. Brass has a high degree of stiffness than copper, so it is easier to machine. Brass is mostly used for high-speed small hole machines. Due to poor electrical conductivity for tungsten, it cuts material very slowly then brass and copper. Graphite electrodes are preferred for all sinker EDM applications. Graphite has the low mechanical strength than any other metallic electrodes. Copper has a good structural integrity. Copper generally wear more than the graphite. Graphite has faster speed than copper for roughing and finishing. Likewise, a metallic electrode the graphite does not have to be de-burred, which results in reducing its manufacturing cost. Both copper and graphite tools, average machining voltage has less effect on material removal rate and surface roughness. Increasing discharge current with copper electrode there is a high material rate of removal were as brass gives fine surface finish and normal material removal rate. Copper has the major advantages over graphite due to it performs better in discharge dressing.

VI. DIFFERENT OPTIMIZATION METHODS

Taguchi robust design technique is suited for modeling the functions which depend on various variables. Taguchi provides a procedure that applies orthogonal array from the statistical design of experiments to obtain the best model with less number of experiments and efficiently. Taguchi method is a simple, efficient and systematic and it uses a signal-to-noise ratio to quantify the variation in data. It has three categories higher is best, lower is best and nominal is best. RSM is useful in analyzing the influence of the independent variables on specific dependent responses by quantifying the relationship amongst one or more measured response and vital input factors. Grey theory is used were the solution to be the model is incomplete and ensure of information. Grey relational analysis method is used to solve the complicated inter-relationship among the multiple performance characteristics.

Artificial bee colony algorithm is also a good and successfully applied the method to find out the best optimal process parameters of muli-response. The genetic algorithm is a probabilistic search method that transforms a set of mathematical objects within the associated fitness value, into the new population of offspring objects.

VII. CONCLUSION

The present paper gives a study on optimization of various machining parameters on EDM. From literature review, it is observed that, there is lot of work done on various work pieces which are difficult to be machined by conventional machining. Various electrodes used are graphite, brass, copper and aluminum. For optimization purpose, mostly Taguchi technique is used. But also there are some other techniques used such as Grey relational analysis, Response surface methodology, Genetic algorithm and artificial neutral network. So, from above literature review, it is concluded that materials that are difficult to be machined by traditional machining, can be machined by non-traditional machining i.e.by using Electro Discharge Machining process. Review shows that Optimization is one of the most useful tools used in production sectors to get at the best manufacturing conditions, which is a need for industries towards manufacturing of quality products at lowest cost. Limited work has been done on OHNS materials. OHNS-O2 grade has been machined in electrical discharge machine and has wide applications in the industrial field.

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