OPTIMIZATION OF ELECTRICAL AND NON ELECTRICAL FACTORS IN EDM FOR MACHINING DIE STEEL USING COPPER ELECTRODE BY ADOPTING TAGUCHI TECHNIQUE

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ABSTRACT

Electrical Discharge Machining (EDM) is one of the most popular non-traditional machining processes used for machining conducting materials which are difficult to machine by convectional machining process. EDM is thermo-electric process in which metal melts and vaporizes and rapidly cool by dielectric forming debris and thus metal is removed by flushing process. In EDM, the objective is always to get improved Material Removal Rate (MRR) along with with minimal tool wear (EWR). Thus it is essential to estimate the material removal rate or productivity along with the minimal tool wear. It is required to estimate material removal rate and all over variables like tool wear for combination of tools and work pieces material during EDM process. Since machining rate and the resultant tool wear vary as per the choice of input machining parameters. So it is required to establish the process condition which result in increase material removal rate along with low tool wear. Since high carbon high chromium steel is being widely used for manufacturing of dies and moulds, thus it is selected as working material for electric discharge machining in the present investigation. The present work explores the machining conditions which include the effect of parameters like current, pulse on time, pulse off time, concentration of metal powder in dielectric on the MRR and EWR. It is attempted to find the optimal machining conditions for machining HCHCr steel using copper as tool. The experimental study was conducted on die sink type EDM located in institution central mechanical work shop. The design of experiment was conducted using Taguchi method of parametric design where in current, pulse on time pulse off time, mixed dielectric powder were selected and their effect on performance characteristic were MRR and EWR were studied. Experimental trials were conducted and result showed that current is the most significant parameter that influenced the machining response parameters like MRR and EWR.

KEYWORDS

The present work is under taken with the following objectives

1) To investigate electrical and non electrical process parameter on the response variable material removal rate and electrode wear rate.
2) Determination of optimal conditions using Taguchi method for design of experiment and response graph.
3) Identifying most significant and sub significant control factors using Anova (Ftest).

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1 INTRODUCTION

1.1 Background

The era of conventional machining, it has been used the machine like lathe, shaper and milling machines for material processing. Here initially the carbon steel tool where used for cutting and productivity was furthered increased with the advancement in cutting tool. The invention of tungsten carbide tools facilitated the machining and material removal rate (MRR) manifolds. With the development of 3D milling machines and machining centres, an innovative and versatile tool for productivity improvement has been developed. Emphasis was on higher material removal rates to reduce machining time. The same can be achieved through tungsten carbide cutters. Research and developments are on for developing strategies and parameters to develop the best carbide, geometry, coating combinations to realize good tool lifetime and good price performance ratio. During this period non-traditional machining was also developed and many areas for machining were considered, such as electric sparks, high velocity material jets, pulse magnetic fields, light beams, electro thermal, chemical reactions etc. were considered. These non-traditional methods were discovered to overcome difficulties such as complexity of shape, distortion sensitivity, brittle and hard materials. The solutions due to micro machine, difficult to handle jobs and difficult to machine materials such as cermets, ceramics, metal matrix composites etc. were the area of interest for researchers. For superior performance, machining of components made from such materials to close tolerances and higher surface finish is must. For the sake of economy the components must be machined at a fast rate in minimum number of set ups. These requirements are partly been met by the use of number of advance machining processes. These processes, often called as non-conventional machining methods, advance machining processes or modern machining processes are characterized by the absence of plastic deformation and chip formation, as is normally the case in conventional machining. For metal removal, non conventional methods directly utilize some form of the energy viz., thermal, mechanical and chemical. Thermal process mainly included Electrical discharge grinding (EDG), Electron beam welding (EBW), Electron beam machining (EBM), Laser Machining (LM), Plasma arc cutting (PAC), Thermal energy (TED) etc. Some of mechanical processes included Abrasive jet machining (AJM), Abrasive wear jet machining (AWJM), Abrasive flow machining (AFM), Ultrasonic machining (USM)

Similarly some of other notable electro-chemical methods included Electro-chemical machining(ECM), Electro-chemical grinding (ECG), Electro-stream drilling (ESD), Electro- chemical honing, turning etc. In some of the typical cases chemical milling and chemical blanking registered its importance due to various advantages. Classification of advance machining processes and their comparison is shown in Table 1. Some of the advance machining processes, amongst which the notable ones are EDM and ECM, have found fairly widespread applications in industry. Industry saw improved finishes at very high spindle speeds and because of this new heights of MRR were observed till twentieth century. Basic machining parameters to improve the amount of energy utilized for machining were developed. Limitations of the various processes were studied for improving the efficiency of the processes. Other area of development was the tool used to remove the material; the iron based tools were changed to air, abrasives, laser, electricity etc. The Electro discharge machining (EDM) used electricity as a source of energy and conductive materials as tool. Work piece and the tool were used as analysis and is used in industries as well as for the research purposes Although the process capability of ECM in terms of metal removal rate is much higher as compared to EDM but application wise EDM is more popular. An idea of the popularity of EDM may be obtained from survey conducted in USSR where EDM accounts for more than 75% of total utilization of newer machining processes. In USA a four-fold increase in the number of EDM machines installed in the industry was observed between the year 1990 and2000. Technological characteristics like material removal rate, energy distribution of EDM process has been investigated by various researchers. Considering all these findings it is believed that EDM has superseded other advanced manufacturing processes because of its easiness and compatibility.

The EDM Process

Electrical discharge machining (EDM), also referred as spark erosion machining, is a process consisting of the removal of metal particles from a work piece surface by a rapid succession of short time electric discharges. The tool used for spark erosion is an electrode whose shape is a negative replica of the contour to be produced on the work. The tool electrode and the work are held at an accurately controlled distance from one another, which are dependent on the operating conditions and referred to as spark gap. By means of suitable electrical equipment, accommodated in a generator, provisions are made for consecutive spark discharge between the electrode and the work piece, which serve the purpose of stock removal. Both the tool and the work are submerged in a dielectric medium.

Researcher investigated into the theoretical models of the EDM process and reported that spark discharge causes the release of electrical energy, which is converted into thermal and mechanical energy. As a result, certain volume of work piece material and also electrode material are heated to melting and vaporizing temperatures and thrown out in an explosion manner by mechanical and electrical forces. This process leave tiny pits and craters on the work and electrode surfaces, the size of such craters being dependent on the energy content of the spark. If high pulse energy is used, the craters will be relatively large,producing a rough surface. This type of eroding is called “roughing’. On the other hand, the use of low pulse energy will lead to smaller craters and thus smoother surface, the process being called “finishing”. The large number of mutually overlapping discharge craters results in a pitted structure of the surfaces, causing certain roughness and giving spark eroded surfaces, a characteristic matte appearance without any directionally oriented tool marks.The particles removed are carried off from the gap by the dielectric with the aid of a pressure or vacuum flushing arrangement and are later separated from the liquid in a filtration unit.The rate of stock removal is dependent on the polarity of the work electrode and tool electrode. The dielectric liquid has the function of reducing the cross-sectional area of the discharge channel to increase the energy density, i.e., to concentrate the energy of the spark on a small area and thus increase the efficiency of stock removal. In addition, the dielectric has a shielding function by preventing the access of air; detrimental oxidation will be eliminated during spark discharges. Finally, apart from cooling the work piece and the electrode, the dielectric serve the purpose of flushing the spark gap for the removal of debris.The process can be applied, in general, to any electrically conductive material. Other properties like strength, brittleness etc. do not impose any restrictions to the application of the EDM process. There are no physical cutting forces between the tool and work piece.Due to the process capability EDM has proved especially valuable in the machining of supertough materials such as the new space age alloys.work are submerged in a dielectric medium.

2 Literature Review

Extensive research in the field of EDM has led to better understanding of the phenomenon of metal removal rate by employing high energy electrical impulses. The key interest of scientists and technologists has been the development of efficient generators leading to higher rates of metal removal with excellent surface finish and low tool wear. This has lead to development of EDM machines with numerical and adaptive controls. In the section attempt has been made to club the work of different authors working on the same or similar array. Various study area of research is been discussed here in the section various researchers have studied the different factors combination for the performance improvement of EDM process. Current research area in EDM is shown in above figure. With the advancement in the technology and in the area of non convectional machining EDM has a wider scope. Presently the researchers are focused on improving the performance of EDM with new hybrid process. It includes the powder mixed electro discharge machine (PMEDM), ultrasonic electro discharge machine.

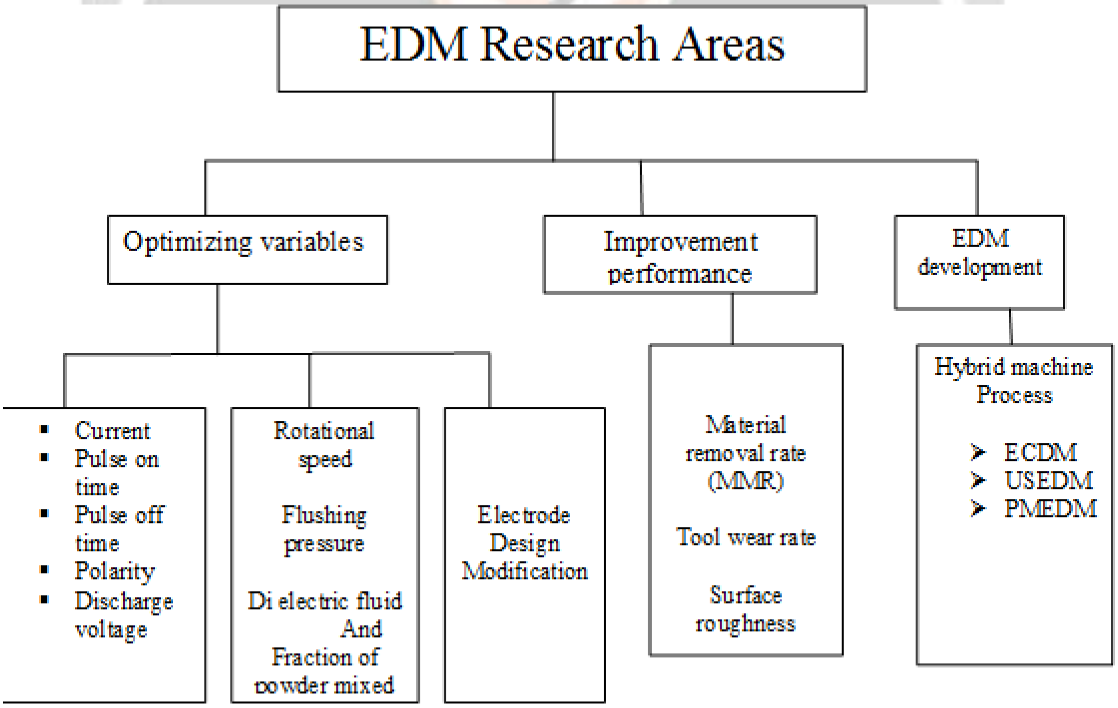

Figure 1 Showing The research area for the performance improvement [25]

T.C Bhagat et al. [11] investigated the controlling variable effect on the responding variable surface roughness for machining die steel with copper tungsten electrode and their optimization. In controlling parameters he varied voltage, current, pulse on time and pulse off time. He opted Taguchi method for optimizing the controlling variables for lower surface roughness. He concluded that current is dominating factor responsible for surface roughness.

R. Choudhary [14] studied the effect of various tool material (copper, brass, graphite) on the heat affected zone of work piece material EN-31while machining on EDM. Experimental study showed that graphite showed best response for MRR while copper tool show good response toward MRR. Brass tool gives superior surface finish but moderate MRR. In microstructure analysis, he observed deeper heat affected zone in work piece for graphite tool compared to copper and brass tool.

G.Chakraverti [17] compared the tool rotation effect and stationary tool on the performance parameters. Centrifugal force generated causes more debris to remove faster from machining zone, preventing arching and improves MRR. He concluded that the rotation of tool enhances fresh dielectric induce in machining area there by taking debris particle away from the machining zone. MRR has been increased at the cost of tool wear.

H.S payal [20] performed experiments in analysing surface integrity for different tool material for EDM machining of EN-31 steel. Graphite tool cutting has been resulted in deeper penetration for molten pool beneath the recast layer hence a poor surface finish is been obtain. On analysing the surface through scan electron microscope size of hole in the ligaments varies between 15-60 micron.

M.L Jeswani et al. [15] carried out the research by the addition of fine graphite powder into kerosene oil on the machining of tool steels. It was resulted out that the addition of 4 g/l of graphite powder increases the interspace for electric discharge initiation and lowered the breakdown voltage.MRR increases up to 4g/L and after that arching is taking place which has resulted in further lowering MRR.

H.Narumiya et al. [16] studied the addition aluminium and graphite powders in dielectric fluid which results in better surface finish than the silicon powder. The best results are obtained for aluminium and graphite powder particles having diameters less than 15 μ m and concentration ranges from 2 to 15 g/l.

P. Janmanee [11] studied the electrical factor respond for MRR, EWR, Surface roughness for machining tungsten carbide as work piece and copper graphite as tool. He concluded that current in majorly responsible for MRR and surface roughness. Crack density increase with increase in discharge current across the gap.

2 Methods

3.1 Selection of tool and work piece

In the manufacturing of dies and moulds generally a hard material which can withstand under stress is preferred. For making of dies punches a harder and a material which can withstand wear is used. Generally high carbon high chromium is used. Here in the study work piece adopted is HCHCr steel which is been purchased from local market (Thermal tooling). Initially a plate of 200 ×60 mm with 12 mm thickness was purchased. And then cut in to pieces 4×2 cm with 1.2 cm thickness.

A circular EDM copper rod, 99.9 percent pure of length 30 cm and diameter of 1.2 cm is being initially purchased and cut into 7cm length. Copper being cheap and higher thermal conductivity and good wear resistant make it suitable for tool cutting.

3.2 Determination of mechanical and chemical properties of tool and work piece

As the cutting tool and work piece is borough form local market it is needed to be tested. Testing of material for the chemical and mechanical is conducted at laboratory " kailtech test and research centre private limited" located at pardesipura electronic compex.

3.3 Preliminary study and identification of controlling parameters which affects output varable like MRR, EWR

P.C Pandey [21] stated the factors responsible for material removal rate and tool wear rate are Electrical parameters like current intensity majorly affects MRR.MRR increases with increase in current intensity across spark gap. Tool wears decreases with increase of spark current. Metal powder concentration in dielectric enhances machining performance. M.L Jeswani [15] investigated that increase of powdered graphite concentration up to 4 g/L in dielectric enhances MRR. It stabises the arching effect and gap voltage. V.S Murti [18] showed that vibration of tool enhances MRR at the cost of tool wear.

3.4 Design of experiment using Taguchi orthogonal array

Taguchi [25] is an optimization technique in design of experiment which is combination of mathematical model (curve fit) and statistical analysis. Taguchi is best method to solve optimization problem if the input or controlling parameters are much large in number (<50). It is decision making tool. It is best method to analyze interaction among the control variables during experiment. This method helps us to save time and money by reducing the number of experiments Taguchi is decision making statistical tool used to formulate the experimental layout, to analyze the effect of each parameter on machining characteristics and to predict the optimal choice for each parameter such as current, pulse on time, pulse off time and powder mixed dielectric.The taguchi array helps to formulate these influencing parameters in the form of matrix or array and helps to analyze the parameters which majorly influence the machining parameters and its order of influence and thus helps in optimizing them.

In the experiment four controlling parameters are taken current, pulse on time, pulse off time, copper concentration in dielectric fluid with each factor has three levels. These form actually 81 experimental combinations of these factors and levels. Taguchi helps in reducing theses experimental work to 9 experiments forming L9 array. Theses result data of L9 is then analyses to predict the main controlling factor responsible for MRR and EWR using taguchi and anova test.

3.5 Experiment trials to yield the output characteristics for each row of control matrix

The research aims at optimizing process parameters for higher material removal rate and lower wear rate.

In the experiment work piece material HCHCr steel is machined on EDM using cutting tool as copper electrode. The cutting action is thermo electric process. Both electrode and work piece get eroded during the cutting action execution. The machining time taken for each setting of current ,pulse on time ,pulse off time ,copper concentration in dielectric is 15 sec. MRR is calculated as mass of material lost before and after machining per unit time.

$$MRR = \frac{mass\ before\ machining - mass\ after\ machining\ (gram)}{time\ of\ machining\ (sec)}$$

$$EWR = \frac{mass\ before\ machining - mass\ after\ machining\ (gram)}{time\ of\ machining\ (sec)}$$

Figure 1showing work piece before machining

Figure 2showing work piece after machining

3.6 Application of Taguchi to find signal to noise ratio to yield optimal solution

There are factors which can be controlled while the process called controlling factor which are responsible for response signal. Here in our case controlling variable are current, pulse on time, pulse of time, copper concentration in dielectric. There are uncontrollable factors which cannot be controlled while the process proceeding called noise. Noise deviates our objective function from mean value. Here in the noise is in the form of hardness of work piece material, variation in dielectric strength. S/N ratio gives how the output signal is varying with the noise variation

There are two cases arrives in the examination

- Lower is the best : like in the case of tool wear rate

$$S/N = -10 \log \left(\frac{1}{n} \sum y_i^2 \right)$$

- Higher is the best : like in the case of Material removal rate

$$S/N = -10 \log \left(\frac{1}{n} \sum \frac{1}{y_i^2} \right)$$

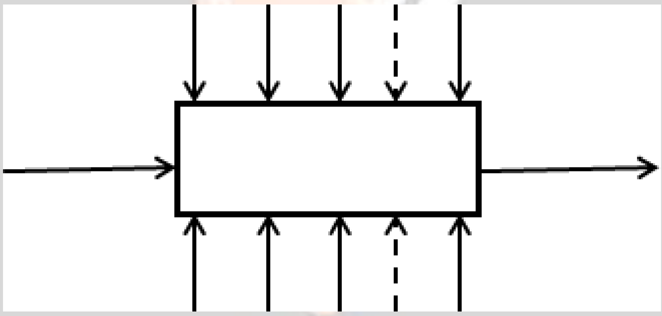

Figure 3 Layout of EDM process work

3.7 Conducting anova test for checking significance of control parameters variability

ANOVA is a particular form of statistical hypothesis testing heavily used in the analysis of experimental data ANOVA is useful in comparing (testing) three or more means (groups or variables) for statistical significance. Anova helps in comparing the variations between group and within group. Anova is a statistical tool used to analyse how the controlling parameters affect the response variable (MRR, EWR) within each level group and between levels group. F ratio is ratio of variance between group and variance within group.

3 Results and Discussions

Material removal rate

- Material removal rate is mainly affected by current followed by pulse on time and concentration of copper powder in dielectric fluid. MRR is least affected by pulse off time.
- Peak current is majorly contributes for MRR. MRR increases with increasing current across the spark gap.
- MRR increases with increasing copper concentration in dielectric concentration.

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4 Future Work

The scope of present work is limited to study the effect of electrical and non electrical parameters on machining of high carbon high chromium steel using copper as cutting tool electrode. The controlling factor chosen for the study were current pulse on time pulse off time and concentration of copper powder in kerosene which is used as dielectric medium. There are factors like pressure of flushing, tool vibration and rotation untouched in the study. Further these parameter can be optimized for MRR and EWR.

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