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Study of Machining Parameters in EDM

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Abstract— Since the thermal energy produced in electrical discharge machining process is due to the applied electrical energy, it is very important to enhance the electrical process parameters to improve the process efficiency. The present study discusses about having an overview of the EDM process and influence of process parameters such as input electrical variables and discharge energy on performance measures such as material removal rate, radial overcut and electrode wear rate. This study also discusses about controlling the electrical process parameters, and empirical relationships between process parameters and optimization of process parameters in EDM process. From the review results, it has been observed that the efficacy of the machining process can be improved by electrical process parameters, and only less attention has been given for enhancing such parameters.
Keywords— Electro Discharge Machining, MRR, EWR, Radial Overcut, Flushing.

I. INTRODUCTION

Electro Discharge Machining is a non-conventional or non-traditional machining process which is used for machining hard materials which are difficult to machine by conventional machining process. EDM can be used in machining difficult cavities and contours. There are various types of products which can be produced using EDM with high precision and good surface quality, such as dies and moulds, parts for aerospace and automotive industry and surgical components. EDM has been replacing drilling, milling, grinding and other traditional machining operations and is now a well established machining option in many manufacturing industries throughout the world. And is capable of machining geometrically complex or hard material components, that are precise and difficult-tomachine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mold making industries, aerospace, aeronautics and nuclear industries. Electric Discharge Machining has also made its presence felt in the new fields such as sports, medical and surgical, instruments, optical, including automotive R&D areas.

II. WORKING PRINCIPLE OF EDM

Electrical discharge machining (EDM), is one of the non-conventional machining processes, where tool and workpiece do not come into contact with each other during the machining process. If an appropriate voltage is developed across the tool electrode (normally cathode) and the workpiece (normally anode), the breakdown of dielectric medium between them happens due to the growth of a strong electrostatic field. Owing to the electric field, electrons are emitted from the cathode toward the anode on the electrode surfaces having the shortest distance between them. These electrons impinge on the dielectric molecules of the insulating medium, breaking these dielectric fluid molecules into positive ions and electrons. These secondary electrons travel along on the same ionization path. This event causes an increase in the electric field strength across the work surfaces and liberates a large number of electrons. It creates an ionized column in the shortest spark gap between the tool electrode and the workpiece, thereby decreasing the resistance of the fluid column and causing an electrical discharge in the shortest distance point between the tool and the workpiece. The normous thermal energy melts and vaporizes the material from the workpiece, which creates a small crater over the work surface. There happened a collapse of the ionized column with the termination of the electrical energy by means of the switching circuit and then surrounding dielectric fluid occupies its place. The melted debris is removed by the flushing process. The conduction of dielectric medium can be determined by the current, duration and pulse energy.[1].

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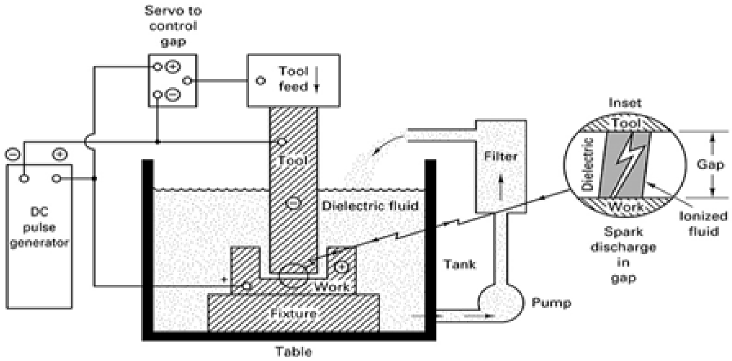

Fig. 1 Electro Discharge Machining

III. LITERATURE SURVEY

T. Muthuramalingam , B. Mohan.[1] discussed about having an overview of the EDM process, modeling of process parameters, and influence of process parameters such as input electrical variables, pulse shape, and discharge energy on performance measures such as material removal rate, surface roughness and electrode wear rate. From the review results, it has been observed that the efficacy of the machining process can be improved by electrical process parameters, and only less attention has been given for enhancing such parameters.

Rajesh Choudhary, Parlad Kumar and Jagdeep Singh [2] performed the experiments by using copper silicon carbide (CuSiCp) composite tool electrode on an EDM with selected input parameters on AISID3 die Steel workpiece. Micro structure analysis reveals the presence of micro-holes and cavities on machined surface .Depth of re-solidified layer increases with increase of gap current..

Singh Jaspreet, Singh Mukhtiar, Singh Harpreet [3] investigated comparision of machining characteristics of D3 Steel,EN8 Steel and EN31 Steel materials, before and after deep cryogenic treatment using taguchi L18 array in EDM. Results of study suggested that best improvement in tool wear and surface roughness was reported by D3 Steel followed by EN8 and then by EN 31.

B.Venkatesh, Naveen.P , Maurya.B , Shanthi Priya.D [4] discussed the effect of increase in pulsed current on MRR,TWR,SR in alloy steels viz.,EN31,EN8,HCHCr.

The electrode materials viz. copper ,brass,chromium copper .Results of study suggested that SR increases with increases in pulse current .Chromium Copper electrode has been preferred for highest MRR ,Dimensional accuracy and surface finish.

Vikas, Shashikant, A.K.Roy and Kaushik Kumar [5] investigated comparision of

MRR for EN19 and EN41 in die sinking EDM machine using discharge current and voltage as input processing parameters. Taguchi method with S/N ratio and ANOVA suggested that discharge current in case of the EN41 material and EN19 material had a larger impact as compare to other processing parameters on the MRR.

Sunil. B. Mishra , Prof. J. K. Sawale [6] conducted experiments on AISID3 Steel using EDM by taguchi method for design of experiment and Optimum values of process parameters are obtained using grey relational analysis method. Experiment showed that process control parameters like discharge current ,pulse on time, pulse off time and spark gap affects MRR and SR in such a way that MRR increases with the increase in discharge current and Spark on time.

Harpreet Singh, Amandeep Singh [7]compared MRR using AISID3 Steel as workpiece and tool materials as copper and brass with pulse on /pulse off as parameters.experiment showed that MRR is increased with increase in pulse off time and MRR decreased with increase in pulse on time in case of brass electrode and decrease in copper electrode.

Anand Prakash Dwivedi,IAENG,Sounak Kumar Choudhury [8] conducted comparative study on of Rotational and Stationary Tool EDM, which deals with providing rotational motion to the copper tool for the machining of AISI D3 Tool Steel and the results have been compared with stationary tool EDM. It has been found that the tool rotation substantially increases the MRR up to 28%. The average surface finish increases around 9-10% by using the rotational tool EDM.

Harpreet Singh, Amandeep Singh [9] studied wear behavior of AISID3 Steel in EDM and compare tool wear rate of cryogenic treated copper and brass electrode eith simple copper and brass electrode using current setting as 4A and 8A.Results obtained as tool wear of cryogenic treated copper electrode is 50% less than copper electrode at 4 ampere current and 30% less at 8 ampere. And that of brass electrode is 8% less than brass electrode at 4 ampere and 5% less at 8 ampere.

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Pravin R. Kubade, V. S. Jadhav [10] conducted and analysed experiments using taguchi method with L9 orthogonal array.It is found that MRR is mainly influenced by peak current .TWR is influenced by peak current and pulse on time ,duty cycle and gap voltage has very less effect on TWR.Peak current has most influence on radial overcut then followed by duty cycle and pulse on time with almost very less influence by gap voltage.

Ajeet Bergaley, Narendra Sharma [11] performed parameter optimization for MRR and TWR considering electrical and non electrical factors such as pulse on time, pulse off time, dielectric fluid material, flushing pressure ,tool rotation. Design of experiment is done by using taguchi method which showed that peak current had significant effect on MRR.

P. Balasubramanian, T. Senthilvelan [12] carried out work using EN8 and D3 steel materials using EDM process. process parameters that have been selected are peak current, pulse on time, die electric pressure and tool diameter. The outputs responses are MRR, TWR and SR. The Cast Copper and Sintered Powder Metallurgy Copper (P/M Copper) have been considered as tool electrodes.. Response surface methodology(RSM) has been used to analyze the parameters and analysis of variance (ANOVA) has been applied to identify the significant process parameter.

G. Bharath Reddy, V.S.P. Vamsi [13] studied the effect of micro-sized metal powders ,when they are mixed with dielectric fluid during EDM of different steels.MRR and SR are taken as output parameters. taguchi method is used for D.O.E .The achieved results of work indicted that fine metal powders in dielectric increases MRR and reduces SR.

K.D.Chattopadhyay, S.Verma, P.S.Satsangi ,P.C.Sharma [14]analysed results by using taguchi method to identified significant parameters and their degree of contribution in process output using EN8 material. Experimental results further revealed that maximizing the MRR while minimizing EWR and improving thesurface roughness, cannot be achieved simultaneously at a particular combination of control parameters setting.

V. Muthukuma, N. Rajesh, R. Venkatasamy, A. Sureshbabu, N. Senthilkumar[15] studied Response surface methodology is for prediction of radial overcut in EDM process for Incoloy 800 superalloy with copper electrode. The current, pulse-ontime, pulse-off time andvoltage are considered as input process parameters to study the ROC. The experiments were planned as per central composite design (CCD) method. After conducting 30 experiments, a mathematical model was developed to correlate the influences of these machining parameters and ROC. The significant coefficients were obtained by performing ANOVA at 5% level of significance. From the obtained results ,It was found that current and voltage have significant effect on the radial overcut.

Kumar Sandeep[16] This paper reviews the vast array of research work carried out within past decades for the development of EDM. This study is mainly focused on aspects related to surface quality and metal removal rate which are the most important parameters from the point of view of selecting the optimum condition of processes as well as economical aspects. It reports the research trends in EDM.

Jeevamalar , S Ramabalan[17] studied that Most of the research work that has been carried out for improving the performances Most of the research work that has been carried out for improving the performances. Many research works have been taken by the optimization techniques like, Response Surface Methodology, ANNOVA, Taguchi, Scanning Electron Microscope.

Bud Guitrau[18] reviewed the fundamentals of EDM and how EDM works mainly because simply need to know this. More importantly, is never have to be satisfied with a canned setting. The elements of on-time, off-time, spark gap, polarity, servo voltage, etc. are all distinctly different, but all must be used together in concert to obtain the desired results. also just covered how easy the control makes this for us, but still must know how EDM works so you can push, troubleshoot or modify any canned setting that comes up.

III. PROCESS PARAMETERS AND PERFORMANCE MEASURES

A. Process Parameter

1) Electrical Parameters: Electrical parameters such as the Ton, Toff, Voltage and Peak Current are playing an important role in output performance measures. Here we discuss about the effects of electrical parameters on the various performance measures.

a) Peak Current: This is the amount of power used in discharge machining, measured in units of amperage, and is the most important machining parameter in EDM. During each on-time pulse, the current increases until it reaches a preset level, which is expressed as the peak current. In both die-sinking and wire-EDM applications, the maximum amount of amperage is governed by the surface area of the cut. Higher amperage is used in roughing operations and in cavities or details with large surface areas. Higher currents will improve MRR, but at the cost of surface finish and tool wear. This is all more important in EDM because the machined cavity is a replica of tool electrode and excessive wear will hamper the accuracy of machining. New improved electrode materials, especially graphite, can work on high currents without much damage.

b) Pulse duration and pulse interval: Each cycle has an on-time and off-time that is expressed in units of microseconds. Since all the work is done during on-time, the duration of these pulses and the number of cycles per second (frequency) are important. Metal removal is directly proportional to the amount of energy applied during the on-time. This energy is controlled by the peak amperage and the length of the on-time. Pulse on-time is commonly referred to as pulse duration and pulse off-time is called pulse interval. With longer pulse duration, more workpiece material will be melted away. The resulting crater will be broader and deeper than a crater produced by a shorter pulse duration. These large craters will create a rougher surface finish. Extended pulse duration also allow more heat to sink into the workpiece and spread, which means the recast layer will be larger and the heat affected zone will be deeper.

c) Gap Voltage: The tool servo-mechanism is of considerable importance in the Efficient working of EDM, and its function is to control responsively the working gap to the set value. Mostly electro-mechanical (DC or stepper motors) and electro-hydraulic systems are used, and are normally designed to respond to average gap voltage. The most important requirements for good performance are gap stability and the reaction speed of the system; the presence of backlash is particularly undesirable. The reaction speed must be high in order to respond to short circuits or open gap conditions. Gap width is not measurable directly, but can be inferred from the average gap voltage.

d) Duty Factor: Duty factor is a percentage of the pulse duration relative to the total cycle time. Generally, a higher duty factor means increased cutting efficiency. It is calculated in percentage by dividing pulse duration by the total cycle time (on-time + off-time).

e) Intensity: It points out the different levels of power that can be supplied by the generator of the EDM machine.

f) Pulse Frequency: Pulse Frequency is defined as number of cycles produced at the gap in one second.

Pulse Frequency (KHz) = 1000/Total Cycle Time (□s)
= 1000/Pulse on + Pulse off (□s)

2) Non Electrical Parameters: Non-electrical parameters such as the Rotations of electrode, flushing of dielectric fluid and tool shape are also influencing the output performance measures. Here we discuss about the effects of non-electrical parameters on the various performance measures.

a) Work piece Material: Workpiece material is one of the non-electrical parameters which influence the performance characteristics of EDM. There are many materials such as die materials, alloys, super alloys and titanium alloys which are very hard to cut.

b) Electrode Material: Generally tool materials are classified into metallic, non-metallic and combination of metallic and non-metallic materials. Usually Copper, Brass, graphite, Copper-Tungsten, Silver Tungsten, Copper Graphite and Tungsten Carbide are used as a tool material in EDM which have better conductivity, good resistance and wearing capacity.

c) Electrode Shape: The performance characteristics mainly depend upon the tool shape. Many shapes in electrode such as Rectangular, Square, Cylindrical, Hexagonal and Circular are used.

d) Rotation of Tool Electrode: The rotational movement of electrode is used to increase the Metal Removal Rate in EDM due to the centrifugal force on workpiece.

e) Type of Dielectric: Dielectric medium acts as an insulator medium which doesn't conduct electricity and used to flush the eroded particles. And it cools region, tool and work material. Paraffin, White Spirit, Kerosene, deionised water, hydrocarbon Fluids and transformer oil are the different EDM dielectric fluids.

f) Flushing System and Pressure: The dielectric fluid must be circulated freely between Tool and Work Material. Eroded particles should be flushed out at the earliest. There are many methods of flushing. They are, Pressure Flushing, Suction Flushing and Side Flushing

3) Performance Measures: A significant number of papers have been focused on ways of yielding optimal EDM performance measures of high Material Removal Rate, low Tool Wear Rate (TWR), satisfactory SQ, and satisfactory RO. This section provides a study into each of the performance measures and the methods for their improvement

a) Material Removal Rate: MRR is influenced by the physical properties of the workpiece material. The melting point and the thermal conductivity of the workpiece are important. Copper, as an example, has a low melting point, but the metal removal is still generally low. This is due to copper being a good thermal conductor. This means heat is dissipated too quickly and therefore interferes with efficient metal removal. Tool steel, on the other hand, has a higher melting point, but is not as good a thermal conductor and therefore has better metal removal rates than copper. It is important to consider both properties of the workmetal when evaluating EDM performance.

b) Tool Wear Rate: There are four different types of wear: volumetric, corner, end, and side . Corner wear is usually the most important since it will determine the degree of accuracy of the final cut. If an electrode can successfully resist erosion at its most vulnerable points, then overall wear will be minimized and maximum electrode life achieved. The ability of an electrode material to produce and maintain detail is directly related to its resistance to wear and its machinability.Corner wear is also important if the electrode is to be dressed. The electrode will have to be dressed back beyond this worn area.

c) Radial Overcut: In case of die sinking EDM (or sinker EDM), a relatively soft graphite or metallic electrode can be used to cut hardened steel, or even carbide. The EDM process produces a cavity slightly larger than the electrode. This excess dimension on the workpiece cut out by the tool during machining is called Tool Overcut (TOC). It is calculated as half the difference of the diameter of the hole produced on the workpiece to the tool diameter It is always desirable to achieve minimum TOC for better performance of the EDM process. [10]

d) Wear Ratio (WR): WR is the ratio of Tool Wear Rate and Material Removal Rate. Choosing same material of tool and workpiece improve the Material Removal Rate.

e) Average Surface Roughness (Ra): Surface roughness is an important output performance in EDM which is influences the product quality and cost. Surface roughness is measured by surface roughness tester.

f) Surface Quality (SQ): Surface Quality is determined by two thermally affected layers. The White Layer or Recast Layer (WL/RCL) is the layer which is formed by the unexpelled molten metal being rapidly cooled by the dielectric fluid during the flushing process. The Heat-Affected Zone (HAZ) is the layer which lies below the recast layer. This is formed due to altering the metallurgical properties of the metal. Below the heat affected zone is the parent material and this area is unaffected by the EDM process.

IV. THE ROLE OF THE DIELECTRIC

Regardless of electrode and work piece polarity, the electrode is advanced into the workpiece through an insulating liquid medium, or dielectric. These are typically a hydrocarbon or silicon-based dielectric oil for sinker machines and deionized water for wire EDM machines, although presently there are several makes of WEDM that use oil as a dielectric. The dielectric fluid is integral to the EDM process as it provides insulation against premature discharging, cools the machined area, and is used to flush away heat, damaged dielectric and the EDM chips and debris. The slides demonstrated as the electrode or wire nears the work piece, an intense electromagnetic flux or “energy column” is formed around this gap. This field attracts the resistive ions in the oil and aligns them in the direction of electrode polarity like millions of tiny compass points or bar magnets. This field continues to increase in intensity until all the ions are polarized and aligned between the electrode and the work piece in a manner similar to the grain of organic wood. [18]

V. EFFECT OF VARIOUS PARAMETERS ON MRR, SR,TWR,RO

A. Effect of Peak Current

At low pulse duration, the MRR is low and nearly constant as low discharge energy is produced b/w the working gap due to insufficient heating of work-piece and low pulse duration. At high pulse duration, MRR increases with increase in peak current because of the sufficient availability of discharge energy and heating of the work-piece material[16] The surface roughness is function of two parameters, peak current and pulse-on time, both of which are function of power supply. A rough surface is produced at high peak current and/or pulse-on time. The reverse is also true. A finer surface texture is produced at low value of peak current and/or pulse duration and vice versa. EWR increases with increase in peak current during PP. If pulse current is increased, the amount of debris in the gap becomes too high. The particle could then form an electrically conducting path between the electrode and work material, causing unwanted discharges, which become arcs and reduce the sparking efficiency. Since EWR is the ratio of electrode erosion and work material removal it increases with peak current. However, EWR decreases with increase in the peak current during NP. Radial overcut is the inherent parameter to the EDM process which is unavoidable though suitable compensations are provided at the tool design. In order to achieve the greater accuracy in EDM process overcut should be minimum Minimum ROC occurs for a middle level of current .[10]

B. Effect on Time Of Pulse

The MRR increases with increase in pulse duration at all value of peak current. TheMRR is a function of pulse duration but at low value of peak current, the MRR is low due to the insufficient heating of the material and also after pulse duration, the MRR increases less because of insufficient clearing of debris from the gap due to insufficient pulse interval[16] Surface roughness increases with increase in pulse duration at different value of peak current but it is observed that surface roughness at low value of pulse duration and high value of peak current is less than the at high value of pulse duration and low value of peak current. This is due to because at low pulse duration materials remove mainly by gasifying and forms craters with ejecting morphology

The EWR decreases with the decrease in pulse on-time during PP. The phenomenon may be attributable to long pulse on-time, which provides better heat removal around the surface of the copper electrode, which is normally a good thermal conductor. The decrease in temperature on the surface of the electrode causes less wear on the electrode. Radial overcut is the inherent parameter to the EDM process which is unavoidable though suitable compensations are provided at the tool design. In order to achieve the greater accuracy in EDM process overcut should be minimum. Therefore, parameters affecting the overcut are essential to recognize. Minimum ROC occurs at minimum level of pulse-on time

C. Effect Of Pulse-Off Time

The MRR decreases when pulse-off time is increased as with long pulse-off time the dielectric fluid produces the cooling effect on wire electrode and work material and hence decreases the cutting speed[16]. The surface roughness changed little even though the pulse-off time changed corresponding to a small value of pulse-on timeThe surface roughness is high at low value of pulse-off time, this is due to because with a too short pulse-off time there is not enough time to clear the melted small particles from the gap b/w the tool electrode and work-piece and also not enough time for deionization of the dielectric: arcing occur and the surfacebecomes rougher. electrode wear is also influenced by off-time. Perhaps this erroneous perception is due to the reasoning: if 10% wear is incurred in 1 hour, if I doubled the off-time, the job would take about twice as long and the total wear should then be 20%. Minimum ROC occurs at minimum level of pulse-off time.

D. Effect Of Servo Voltage

The MRR increases with increase in servo voltage and then it starts to decrease. This is due to increase in servo voltage resulting higher discharge energy per spark because of large ionization of dielectric between working gap. Consequently, the MRR increases. However, a too high voltage result in high discharge energy per spark which causes unfavorable break down of dielectric and large amount of debris between the working gap which unable the material removal rate increases. The surface roughness at low value of pulse duration with increase in servo voltage first increases up to 30V and then decrease with increase in servo voltage. At high value of pulse duration the surface roughness continuously decrease with increase in servo voltage. This is due to because at low pulse duration the discharge energy is low so melted particles cannot flow out of the machining zone. TWR has less effect of voltage,so that it should be negligible. Minimum ROC occurs for a minimum level of voltage.

VI. CONCLUSION

The present review paper gives a study on 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. The electrodes used are copper, aluminium etc. And for optimization purpose.

Following results are observed during study,

The material removal rate (MRR) is mainly affected by peak current (Ip). Pulse on time (Ton) and gap voltage (Vg) have considerable effect on MRR. The effect of duty cycle (t) on MRR is negligible.

Electrode wear rate is mainly influenced by peak current (Ip) and pulse on time (Ton).Duty cycle (t) and gap voltage has very less effect on electrode wear rate

Peak current (Ip) has maximum effect on radial overcut (ROC). Duty cycle (t) and pulse on time (Ton) also have considerable effect on radial overcut. Gap voltage (Vg) has negligible effect on ROC

SR increases when the discharge current and pulse off time increases, whereas the pulse on time at higher values reduces the SR.

REFERENCES

[1] T. Muthuramalingam , B. Mohan, A review on influence of .electrical process parameters in EDM process,archives of civil and mechanical engineering 15(2015) 87-94.

[2] Rajesh Choudhary, Parlad Kumar and Jagdeep Singh, Analysis of Electro Discharged Machined Surfaces of AISI D3 Steel by Composite Tool Electrode, International Journal of Surface Engineering & Materials Technology, Vol. 2 No. 2 July-December 2012, ISSN: 2249-7250.

[3] Singh Jaspreet, Singh Mukhtiar, Singh Harpreet, Analysis of Machining Characteristics of Cryogenically Treated Die Steels Using EDM , International Journal of Modern Engineering Research (IJMER) Vol. 3, Issue. 4, July - Aug. 2013 pp-2170-2176.

[4] B.Venkatesh, Naveen.P , Maurya.B , Shanthi Priya.D, Experimental investigation of EDM using Electrode Materials Copper, Brass and Chromium Copper for alloy steels, International Journal of Advance Engineering and Research Development vol 2,Issue 4, -2015

[5] Vikas, Shashikant, A.K.Roy and Kaushik Kumar, Effect and Optimization of Machine Process Parameters on MRR for EN19 & EN41 materials using Taguchi, 2nd International Conference on Innovations in Automation and Mechatronics Engineering, ICIAME 2014.

[6] Sunil. B. Mishra , Prof. J. K. Sawale , Process parameter optimisation in EDM for AISI D3 steel by grey relational analysis method, International journal of innovations in engineering and technology [IJIERT] ISSN: 2394-3696 VOLUME 2, ISSUE 5, MAY-2015.

[7] Harpreet Singh, Amandeep Singh, Effect of Pulse On/Pulse Off Time On Machining Of AISI D3 Die Steel Using Copper And Brass Electrode In EDM , International Journal of Engineering and Science ISSN: 2278-4721, Vol. 1, Issue 9 (November 2012), PP 19-22.

[8] Anand Prakash Dwivedi, IAENG, Sounak Kumar Choudhury ,comparative assessment of MRR,TWR and surface integrity in rotary and stationary tool EDM for machining AISID3 tool steel, Proceedings of the World Congress on Engineering 2015 Vol II WCE 2015, July 1 - 3, 2015, London, U.K.

[9] Harpreet Singh, Amandeep Singh, Wear Behavior of AISI D3 Die Steel Using Cryogenic Treated Copper and Brass Electrode in Electric Discharge Machining , International Journal of Modern Engineering Research (IJMER) Vol.2, Issue.6, Nov-Dec. 2012 pp-4462-4464.

[10] Pravin R. Kubade, V. S. Jadhav, An Experimental Investigation of Electrode Wear Rate (EWR), Material Removal Rate (MRR) and Radial Overcut (ROC) in EDM of High Carbon-High Chromium Steel (AISI D3) , International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-1, Issue-5, June 2012.

[11] Ajeet Bergaley, Narendra Sharma, Optimization of Electrical and Non Electrical Factors in EDM for Machining Die Steel Using Copper Electrode by Adopting Taguchi Technique , International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-3, Issue-3, August 2013.

[12] P. Balasubramanian, T. Senthilvelan, Optimization of Machining Parameters in EDM process using Cast and Sintered Copper Electrodes, 3rd International Conference on Materials Processing and Characterisation (ICMPC 2014).

[13] G. Bharath Reddy, V.S.P. Vamsi, ParametricAnalysis on Powder mixed Electric discharge machining of various Steels using Taguchi method, International Journal of Advance Research In Science And Engineering http://www.ijarse.com IJARSE, Vol. No.4, Special Issue (02), February 2015.

[14] K.D.Chattopadhyay, S.Verma, P.S.Satsangi ,P.C.Sharma , Development of empirical model for different process parameters during rotary electrical discharge machining of copper–steel (EN-8) system, journal of materials processing technology 2 0 9 (2 0 0 9) 1454–1465.

[15] V. Muthukuma, N. Rajesh, R. Venkatasamy, A. Sureshbabu, N.Senthilkumar, Mathematical Modeling for Radial Overcut on Electrical Discharge Machining of Incoloy 800 by Response Surface Methodology, 3rd International Conference on Materials Processing and Characterisation (ICMPC 2014), V. Muthukumar et al. / Procedia Materials Science 6 (2014) 1674 – 1682.

[16] Kumar Sandeep, Current Research Trends in Electrical Discharge Machining: A Review, Research Journal of Engineering Sciences Vol. 2(2), 56-60, February (2013), ISSN 2278 – 9472.

[17] Jeevamalar , S Ramabalan, die sinking edm process parameters, Int. J. Mech. Eng. & Rob. Res. 2015, ISSN 2278 – 0149.

[18] Bud Guitrau, the fundamentals of edm,