Optimization of EDM Parameters by Using Taguchi Method for Machining OHNS01

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Abstract

Optimization is one of the techniques used in manufacturing sectors to arrive for the best manufacturing conditions, which is an essential need for industries towards manufacturing of quality products at lower cost. The present work is aimed at characterizing the electrical discharge machining of OHNS01 by using copper electrode.Taguchi design of experiments is used to conduct experiments by varying the parameters - current, feed rate and pulse on time. The process performance of is measured in terms of Material removal rate (MRR),Tool wear rate (TWR), Surface Roughness (SR), Signal to noise (S/N) ratio and the analysis of variance (ANOVA) are employed to find the optimal level for the EDM machining.

Keywords

Electrical Discharge Machine (EDM), Metal Removal Rate (MRR), Tool WearRate (TWR), Surface Roughness(SR), Analysis of Variance (ANOVA), Taguchi Method.

I. Introduction

Electrical Discharge Machining:

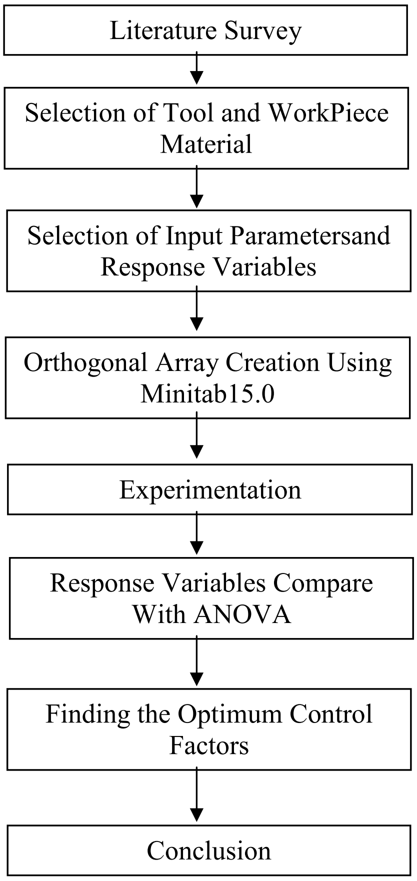
Electric discharge machining (EDM), sometimes colloquially also referred to as spark machining, spark eroding, burning, die sinking or wireerosion, is a manufacturing process whereby a desired shape is obtained using electrical discharges (sparks). Material is removed from the work piece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the tool or electrode, while the other is called the work piece-electrode, or work piece. When the distance between the two electrodes is reduced, the intensity of the electric field in the volume between the electrodes becomes greater than the strength of the dielectric (at least in some point(s)), which breaks, allowing current to flow between the two electrodes. This phenomenon is the same as the breakdown of a capacitor (condenser) (see also breakdown voltage). As a result, material is removed from both the electrodes. Once the current flow stops (or it is stopped – depending on the type of generator), new liquid dielectric is usually conveyed into the inter-electrode volume enabling the solid particles to be carried away and the insulating properties of the dielectric to be restored. Adding new liquid dielectric in the inter-electrode volume is commonly referred to as flushing. Also, after a current flow, a difference of potential between the two electrodes is restored to what it was before the breakdown, so that a new liquid dielectric breakdown can occur.

Fig 1.1 : Electrical discharge machine (EDM)

II. Problem Description

In EDM research the response variables like that MRR, TWR can be analysis by the various electrolyte tools and machine can be used. In ourproject the EDM machine (MMT- VIDYUNT EM150) and response variables are MRR, TWR can be analyzed. In our project work piece material for OHNS01 and electrolyte copper tool can be selected and EDM control parameters are current, feed rate,pulse on time can be selected for machining the OHNS01 after the response variables are Material removal rate, Tool wear rate and Surface roughness found out.

III. Methodology



IV. Selection of Tool And Work Piece Material

Brass

Brass was one of the first EDM electrode materials. It is inexpensiveand easy to machine. Today, however, brass is seldom used as an electrode material in modern sinker EDMs, due to its high wear rate. In certain applications or in older machines with RC power supplies for which wear is not a primary concern, brass still has limited use, since it exhibits a higher degree of stiffness and is easier to machine than copper. Brass, however, is one of the most commonly used materials for High Speed Small Hole Machines.

Copper

With development of the transistorized, pulse-type power supplies, Electrolytic (or pure) Copper became the metallic electrode material of choice. This is because the combination of Copper and certain power supply settings enables low wear burning. Also, Copper is compatible with the polishingcircuits of certain advanced power supplies. Many shops in both Europe and Japan still prefer to use Copper as the primary electrode material, due to their tool making culture that is averse to the untidiness of working with graphite. Due to its structural integrity, Copper can produce very fine surface finishes, even without special polishing circuits. This same structural integrity also makes Copper electrodes highly resistant to DC arcing in poor flushing situations. Copper is frequently used to make female electrodes on a Wire EDM for subsequent use in reverse burning punches and cores in the Sinker EDM. There are a number of significant disadvantages associated with Copper electrodes. Copper electrodes will generally burn only half as fast as graphite electrodes. Copper is a soft and gummy material to machine or grind.Copper is an extraordinarily difficult material to de-burr. It can take longer to de-burr a Copper electrode than to manufacture it. The addition of 1-3%Tellurium to Copper improves its machinability to a level similar to brass, eliminating the Gummy properties normally exhibited by Copper when it is machined or ground.

Tungsten

Due to the combination of its high density, tensile strength, and melting point, Tungsten had been the electrode material of choice for certain limited EDM applications. It is important to note that Tungsten, due to its relatively poor electrical conductivity, cuts much slower than Brass or Copper. Also, due to its high cost and very low machinability, Tungsten is seldom used.

Copper Tungsten

Copper Tungsten (CuW) is a powder metal product designed tocombine the best EDM properties of Copper and Tungsten. Copper Tungsten combines the high electrical conductivity of copper with the high melting point of tungsten. The combination of these two metals creates an electrode material with very good wear properties. Copper Tungsten is unmatched for its wear resistance, holds up very well in sharp corners, and is readily machined and ground without the burr issues associated with Copper. Copper Tungsten is also the preferred material for EDM Carbide. Copper Tungsten cannot be manufactured by conventional alloying techniques, since the Copper would vaporize before the Tungsten began to melt. That is why Copper Tungsten is made by the powder metal process. Copper and Tungsten powder are pressed into a pre-form and then sintered.

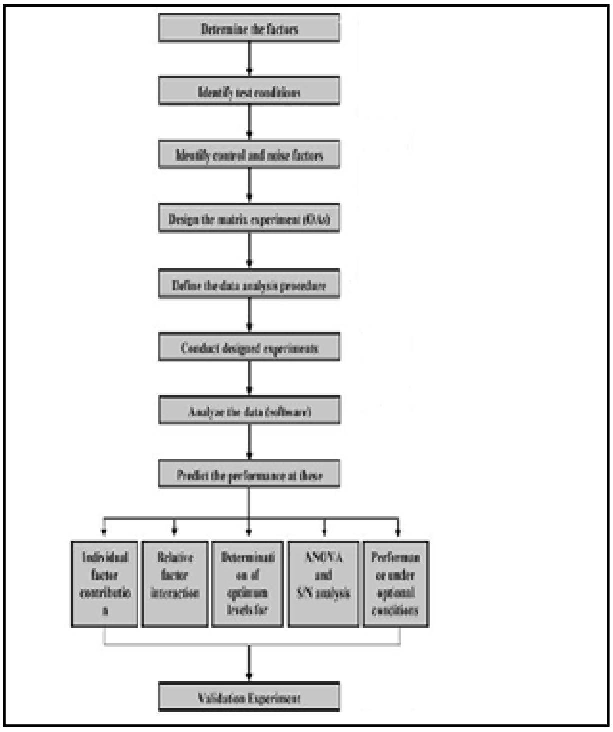
Graphite

Graphite is the preferred electrode material for 90% of all sinker EDMapplications. Thus, it is important that we expend considerable effort to understand its properties and application to EDM. Graphite was introduced to the EDM industry approximately 50 years ago. One of the early well-known brands of graphite was manufactured by General Electric, and known by the trade name of Gentrode. Graphite is made from Carbon derived from petroleum. The powdered Carbon is mixed with a petroleum based binder material and then compacted. How the graphite is compacted in this stage of production is vitally important to its ultimate properties. All early graphite were made by compressing the powder/binder mixture in only one direction, resulting in properties or "grain" similar to wood, that varied relative to the direction of pressing. As an outgrowth of the space program, methods were developed to isstatically press graphite such that its properties became "isotropic", that is the same in all directions. All high quality, high performance graphite's are now manufactured this way. After compacting, the "green" compacted material undergoes a series of thermal treatments that convert the Carbon to graphite.

Copper Graphite

Copper graphite is graphite manufactured with a controlled amount ofinterconnected porosity which is then infiltrated with Copper by capillary action in a furnace. The resulting material has increased electrical conductivity and mechanical strength. Copper graphite offers the combined benefits of the ease of fabrication of graphite, and the burn stability and "safety" of Copper. Copper graphite has shown particular advantage when applied to aerospace applications such as Titanium, Inconel, and other high temperature aerospace alloys. Copper graphite is also applied to the EDM of carbide. Copper graphite electrodes are not nearly as fragile as graphite electrodes. In fact, Copper graphite sheets areavailable in thickness down to .003". It should be noted; however, that Copper graphite suffers from increased corner wear when compared to the same non-impregnated grade.

V. Design of Experiments



A. Selection of the Independent Variables

Before conducting the experiment, the knowledge of the productprocess under investigation is of prime importance for identifying the factorslikely to influence the outcome. In order to compile a comprehensive list offactors, the input to the experiment is generally obtained from all the peopleinvolved in the project.

B. Deciding the Number of Levels

Once the independent variables are decided, the number of levels foreach variable is decided. The selection of number of levels depends on how theperformance parameter is affected due to different level settings. If theperformance parameter is a linear function of the independent variable, then thenumber of level setting shall be However, if the independent variable is notlinearly related, then one could go for or higher levels depending on whetherthe relationship is quadratic, cubic or higher order.In the absence of exact nature of relationship between the independent variableand the performance parameter, one could choose level settings. After analyzingthe experimental data, one can decide whether the assumption of level setting isright or not based on the percent contribution and the error calculations.

C. Selection of an Orthogonal Array

Before selecting the orthogonal array, the minimum number ofexperiments to be conducted shall be fixed based on the total number of degreesof freedom present in the study. The minimum number of experiments that mustbe run to study the factors shall be more than the total degrees of freedomavailable. In counting the total degrees of freedom the investigator commits 1degree of freedom to the overall mean of the response under study. The numberof degrees of freedom associated with each factor under study equals one less24than the number of levels available for that factor. Hence the total degrees offreedom without interaction effect is 1 + as already given by equation 2.1. Forexample, in case of 11 independent variables, each having 2 levels, the totaldegrees of freedom is 12. Hence the selected orthogonal array shall have at least12 experiments. An L12 orthogonal satisfies this requirement.

In our project will be select three control variables and three levelsdepend upon the L9 orthogonal array.

D. Assigning the Independent Variables to Columns

The order in which the independent variables are assigned to thevertical column is very essential. In case of mixed level variables andinteraction between variables, the variables are to be assigned at right columnsas stipulated by the orthogonal array. Finally, before conducting the experiment, the actual level values ofeach design variable shall be decided. It shall be noted that the significance andthe percent contribution of the independent variables changes depending on thelevel values assigned. It is the designer's responsibility to set proper levelvalues.

E. Conducting the Experiment

Once the orthogonal array is selected, the experiments are conductedas per the level combinations. It is necessary that all the experiments beconducted. The interaction columns and dummy variable columns shall not beconsidered for conducting the experiment, but are needed while analyzing thedata to understand the interaction effect. The performance parameter understudy is noted down for each experiment to conduct the sensitivity analysis.

F. Analysis of the Data

Since each experiment is the combination of different factor levels, itis essential to segregate the individual effect of independent variables. This canbe done by summing up the performance parameter values for the25corresponding level settings. For example, in order to find out the main effect oflevel 1 setting of the independent variable 2, sum the performance parametervalues of the experiments 1, 4 and 7. Similarly for level 2, sum the experimentalresults of 2, 5 and 7 and so on.Once the mean value of each level of a particular independentvariable is calculated, the sum of square of deviation of each of the mean valuefrom the grand mean value is calculated. This sum of square deviation of aparticular variable indicates whether the performance parameter is sensitive tothe change in level setting. If the sum of square deviation is close to zero orinsignificant, one may conclude that the design variable is not influencing theperformance of the process. In other words, by conducting the sensitivityanalysis, and performing analysis of variance (ANOVA), one can decide whichindependent factor dominates over other and the percentage contribution of thatparticular independent variable.

G. Inference

From the above experimental analysis, it is clear that the higher thevalue of sum of square of an independent variable, the more it has influence onthe performance parameter. One can also calculate the ratio of individual sum ofsquare of a particular independent variable to the total sum of squares of all thevariables. This ratio gives the percent contribution of the independent variableon the performance parameter. In addition to above, one could find the nearoptimal solution to the problem. This near optimum value may not be the globaloptimal solution.

VI. Experimental Work

A. EDM Characteristics

- Metal removal technique: By using powerful electric spark
- Work material: Electrical conductive materials and alloy
- Tool removal: Copper, yellow brass, alloy of zinc, copper, tungsten
- Metal removal rate: 15 to 80
- Spark gap: 0.005 to 0.05mm
- Spark frequency: 200-500 kHz
- Volts: 30-250V
- Current: 5-60A
- Temperature: 10000*C
- Dielectric fluid: petroleum based hydrocarbon fluids, paraffin, and white spirit

B. EDM Parameters

S.NO	CONTROL FACTORS	RESPONSE VARIABLES
1.	Current	MRR
2.	Pulse On Time	TWR
3.	Pulse Off Time	SR
4.	Gap Voltage	% Of Wear Rate
5	Feed Rate	
6.	Flushing Pressure	
7.	Die Electric Fluid	

C. Control Factor

Control Variable	Level 1	Level 2	Level 3
Current(Amps)	10	15	20
Feed rate(mm/rev)	10	11	12
Pulse on time(µ.sec)	4	5	6

CURRENT (Amps)

The peak current is a measure of the power supplied to the dischargegap. A higher current leads to a higher pulse energy and formation of deeperdischarge craters. This increases the material removal rate and the surfaceroughness value. It is expressed in amperes. In the current can be vary incontroller of electrical discharge machine

PULSE ON TIME (µ.sec)

The duration of time, the current is allowed to flow per cycle. Material removal is directly is proportional to the amount of energy appliedduring on time. Amount of energy is really controlled by the peak current andthe length of time. In the pulse on time can be vary in controller of electricaldischarge machine.

FEED RATE (mm/rev)

The electrode moved in downward movement in depth of cut to perrevolution of electrode in electrical discharge machine. In the feed rate can bevary in controller of electrical discharge machine.

S. NO	MRR			TWR		
	Before Machining weight (gm)	After Machining Weight (gm)	Time of Machining (min)	Before Machining weight (gm)	After Machining Weight (gm)	Time of Machining (min)
1	351.390	351.278	15	91.915	91.911	15
2	351.278	351.194	15	91.911	91.907	15
3	351.194	351.133	15	91.907	91.892	15
4	351.133	350.254	15	91.892	91.875	15
5	350.254	349.158	15	91.875	91.862	15
6	349.158	348.868	15	91.862	91.840	15
7	348.868	347.294	15	91.840	91.840	15
8	347.294	346.514	15	91.824	91.762	15
9	346.514	345.299	15	91.762	91.731	15

$$MRR = \frac{m_1 - m_2}{t * \rho} X1000$$

= (351.390-351.278)/(15 X 8.67) X1000
= 0.8612 mm^3 / min

$$TWR = \frac{W_1 - W_2}{t * \rho} X1000$$

=(91.915-91.911)/(15 X8.096) X 1000
=0.0296 mm^3 / min

Experimental Based on L9 orthogonal array

CURRENT	FEED RATE	PULSE ON TIME	MRR (mm^3/min)	TWR (mm^3/min)	SR (um)
1	1	1	0.8612	0.0297	3.021
1	2	2	0.6459	0.0296	3.204
1	3	3	0.4690	0.1116	4.086
2	1	2	6.7589	0.1264	4.773
2	2	3	8.4275	0.0967	4.863
2	3	1	2.2299	0.1636	3.273
3	1	3	12.1030	0.1190	6.379
3	2	1	5.9976	0.4613	4.273
3	3	2	9.3425	0.2306	5.413

Optimization Using Taguchi Analysis
Signal to Noise Ratio Result

S. NO	**RESPONSE VARIABLES**			**S/N RATIO**		
	MRR (mm^3/ min)	**TWR (mm^3/ min)**	**SR (um)**	**MRR (DB)**	**TWR (DB)**	**SR (DB)**
1	0.8612	0.0297	3.021	-1.2979	30.5449	-9.6030
2	0.6459	0.0296	3.204	-3.7969	30.5742	-10.1139
3	0.4690	0.1116	4.086	-6.5765	19.0467	-12.2260
4	6.7589	0.1264	4.773	-16.5979	17.9651	-13.5758
5	8.4275	0.0967	4.863	18.5140	20.2915	-13.7381
6	2.2299	0.1636	3.273	6.9657	15.7243	-10.2989
7	12.1030	0.1190	6.379	21.6579	18.4891	-16.0951
8	5.9976	0.4613	4.276	15.5595	6.7203	-12.6147
9	9.3425	0.2306	5.413	19.4093	12.7428	-14.6688

Taguchi Analysis: MRR versus CURRENT, FEED RATE, PULSE NO TIME

Response Table for Signal to Noise Ratios Larger is better
MRR VS Current, Feed rate, Pulse on time

LEVEL	CURREENT (Amps)	FEED RATE (mm/rev)	PULSE ON TIME (µ.sec)
1	-3.895	12.318	7.074
2	14.024	10.088	10.732
3	18.875	6.598	11.198
Delta	22.770	5.720	4.125
Rank	1	2	3

Taguchi Analysis: TWR versus CURRENT, FEED RATE, PULSE NO TIME

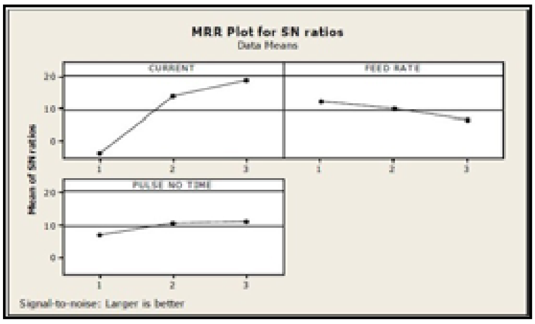
Response Table for Signal to Noise Ratios Smaller is better
TWR VS Current, Feed rate, Pulse on time

LEVEL	CURREENT **(Amps)**	FEED RATE **(mm/rev)**	PULSE ONTIME **(µ.sec)**
1	26.87	22.41	17.74
2	18.03	19.28	20.50
3	12.66	15.87	19.31
Delta	14.21	6.54	2.76
Rank	1	2	3

Taguchi Analysis: SR versus CURRENT, FEED RATE, PULSE NO TIME

LEVEL	CURREENT **(Amps)**	FEED RATE **(mm/rev)**	PULSE ON TIME
1	-10.65	-13.09	-10.84
2	-12.54	-12.16	-12.79
3	-14.46	-12.40	-14.02
Delta	3.81	0.94	3.18
Rank	1	3	2

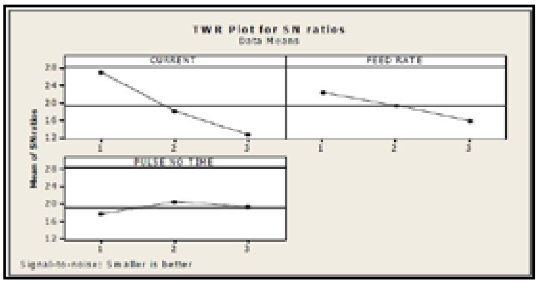
Taguchi Analysis: MRR versus CURRENT, FEED RATE, PULSE NO



For OHNS steel optimum machining condition for material removal rate (MRR) during machining on EDM were current (20A), feed rate (10mm/rev), pulse on time (6u.sec) with positive polarity.

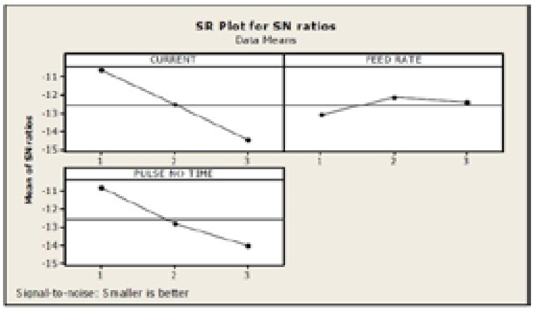
Taguchi Analysis: TWR versus CURRENT, FEED RATE, PULSE NO TIME

Response Table for Signal to Noise Ratios Smaller is better



For OHNS steel optimum machine condition for tool wear rate (TWR) during machining on EDM were current (20A), feed rate (12mm/rev), pulse on time (4u.sec).

Taguchi Analysis: SR versus CURRENT, FEED RATE, PULSE NO TIME



For OHNS steel optimum machining condition for surface roughness (SR) during machining on EDM were current (20A), feed rate (10mm/rev) and pulse on time (6u.sec).

Anova Result

SUMMARY						
Groups	Count	Sum	Average	Variance		
Column 1	9	46.8355	5.20394444	18.6329417		
Column 2	9	1.3685	0.15205556	0.01729408		
Column 3	9	39.285	4.365	1.25024925		
ANOVA						
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	131.92293	2	65.961465	9.94369708	0.00071525	3.40282611
Within Groups	159.20388	24	6.63349501			
Total	291.12681	26				

VII. Conclusion

Following conclusion were for optimum MRR, TWR, and SR during the machining of OHNS01 steel on EDM.For OHNS01 steel optimum machining condition for material removal rate (MRR) during machining on EDM were current (20A), feed rate (10mm/rev), pulse on time (6u.sec) with positive polarity. For OHNS01 steel optimum machine condition for tool wear rate (TWR) during machining on edm were current (20A), feed rate (12mm/rev), pulse on time (4u.sec). For OHNS01 steel optimum machining condition for surface roughness (SR) during machining on EDM were current (20A), feed rate (10mm/rev) and pulse on time (6u.sec).

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