EXPERIMENTAL VALIDATION TO PROCESS PARAMETER IN WIRE CUT EDM

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Abstract: This work briefly discusses about the standard practices on Wire cut Electric discharge machining the advance (modern), special type of electric discharge machining with uses a small diameter wire as a cutting tool on the work piece. Study focus on process parameters that can affect the quality of machining, cutting or drilling. Electrical Parameters. Non-Electrical Pa- rameters. Electrode based parameters. In short process defined known as wire cut EDM. Wire cut Electric discharge ma- chining is the thermal mass- reducing process that uses a continuously moving wire to remove material by means of rapid controlled repetitive spark discharges. A dielectric fluid is used to flush the removed particles, regulate the discharge, and keep the wire and work-piece cool. The wire and work-piece must be electrically conductive. In this Investigation the effects of wire cut Electrical Discharge Machining technique the process parameters on quality characteristics viz. cutting rate, surface roughness, gap current and dimensional deviation while machining Aluminium work material, Copper work material Brass work material work material is carried out on of multi objective optimization work using Taguchi technique and utili- ty concept. Today's wire cut electrical discharge machines have several features and improvements from machines manu- factured in the past.

Keywords: WCEDM, Material removal rate (MRR), Ishikawa cause-effect, Taguchi technique, Dielectric System.

1. INTRODUCTION:

Wire cut Electrical Discharge Machining is an indispen-sable unconvetional machining process, capable of pro-ducing complex 2D & 3D shapes with good accuracy and precision to fullfill the today's need of the lean manufac-turing industries 4.0, for lean production. It is used in the defence, aerospace, aeronautical, shiping, automotive, die and tool industries and virtually in all the areas of con- ductive material machining due to their hardness or toughness.Accompanying the development of mechanical industry, the demands for alloy materials having high hardness, toughness and impact resistance are increasing. Neverthless, such materials are difficult to be machined by conventional machining process. Hence, unconventional machining methods including electrochemical machining, ultrasonic machining, electrical discharging machine (EDM) etc, are used to machine such & difficult to ma- chine tough materials. Where Wire cut Electrical Dis- charge Machining also is the technique in which thin wires as an electrode convert the electrical energy to thermal energy for cutting materials. With this process, alloy steel, conductive ceramics and defence, aerospace, aeronautical materials can be machined irrespective to their hardness and toughness. Aditionaly, Wire cut Elec-trical Discharge machining is capable of producing a ac- curate dimention, fine, precise, corrosion and wear re-sistant surface.

In above work "Study to validation the Effect of Process Parameters on Performance Measures of Wire cut Electri- cal Discharge Machining" while machining work material Aluminium, Copper, Brass. Aim to the analytical models is to achieve greater machining accuracy, productivity with a desired surface finish. Cutting parameters most use full for obtaining higher cutting efficiency or accuracy is required. As per time frame Wire cut Electrical Discharge Machining isstillnotcompletelysolved,evenwith the most up-to-date. This is of course due charecterstic of the complex stochastic steps mechanisms. Finaly, the rela- tionships between the cutting parameters and the process performance are tough to model accurately.

2. Focused area of the parameters:

This work prefer to define a complex technique for In- vestigation of the working ranges and levels of the wire cut EDM process parameters using one factor at a time approach, while machining Aluminium, Copper & Brass work material. practically determination of the effects of the various process parameters via pulse on time, pulse off time, spark gap set voltage, peak current, wire feed and wire tension on the performance measures like cut- ting rate, surface roughness, gap current and dimensional deviation in wire cut EDM process.Optimization of the performance measures using Taguchi method. Modeling of the performance measures using response surface methodology (RSM) .Single response optimization of the process parameters of wire cut EDM process using RSM and desirability function. Multi-objective optimization of the process parameters of wire cut EDM process using

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desirability function in conjunction with RSM .Multi- objective optimization of the process parameters of wire cut EDM process using Taguchi‟s technique and utility concept. Validation of the results by conducting confirma-tion experiments.

3. Process Parameters in Wire Cut EDM

The parameters that play important major role for consid- ering in machining such as cutting & drilling. shikawa cause- effect diagram as shown in fig 1.

(a) Electrical parameters: Peak current, Dielectric pressure, pulse on time, pulse off time and supply Gap voltage, Voltage and polarity, Average gap current.

(b) Non-electrical parameters: Wire tension, Wire feed rate, Wire speed, feed rate, machining time, gain and rate of flushing.

(c) Electrode based parameters: Material, size of the wire.

(d) Dielectric System: characteristics other flow, Type, viscosity.

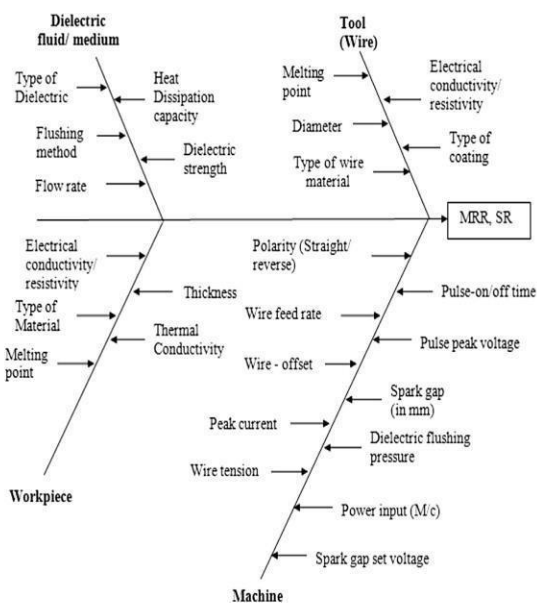

Fig. 1.Ishikawa Cause Effect Diagram

4. Cutting Parameters:

(i) Peak current: IP the maximum value of the current passing through the electrodes for the given pulse. The IP setting current range available on the present Wire cut Electrical Discharge Machining machine is 10–235 am-pere which is used in steps of 10 ampere. Increase in the IP value will increase the pulse discharge energy which in turn can improve the cutting rate further. For higher value of IP, gap conditions may become unstable with improper combination of T on, T off, SV & SF Setings.

(ii) Dielectric pressure: The pressure with which the coolant strikes the inter-electrode gap is determined in two levels- high and low. The flushing pressure is deter- mined according to the material. For machining Cu, Al, Brass, high flushing pressure is recommended.

(iii) Pulse on time: period for which the voltage is ap- plied across the gap & denoted by T ON. The range of pulse on time is 1 to 10, in steps of 1. Higher the TON setting larger is the pulse on period. The single pulse dis- charge energy increases with increasing T ON period, resulting in higher cutting rate and poor surface finish.

(iv) Pulse off time: The period for which voltage across the gap is absent & denoted by T off. The range of pulse off time is 1 to 10, in steps of 1. Higher the T off setting larger is the pulse off period. This results in better surface finish.

(v) Voltage and polarity, Gap voltage: Potential dif- ference across the work piece and wire electrode. It is read directly on the voltmeter. Gap voltage depends on the set values of gap potentiometer and sensitivity poten- tiometer. Ranges between 40-60V results in better MRR and fine finish. High gap voltage gives poor finish. **(vi)Average gap current:** the actual current consumed by the machining process. Its value is read on the amme- ter directly. The values of average machining current giv- en in the guidelines charts are indicative and differ with machines. Normally the wire can pass current of 8-10A in water. Since air bubbles are mixed in water only 75% of the above value may be achievable. High gap currents results in high MRR and vice versa for surface Rough- ness.

5. Non-electrical parameters:

(i) Wire tension: Wire tension is a gram-equivalent load with which the continuously fed wire is kept under tension so that it remains straight between the wire guides. Wire tension can be adjusted by the wheel pro- vided on machine column. While the wire is being fed continuously, appropriate wire tension prevents the un- desirable wire deflection from its straight path. The wire deflection is caused due to spark induced reaction forces and water pressure. A brass wire of 0.25mm diameter can be applied with a maximum tension of 1600gm. Opti- mum wire tension results in high MRR and low surface roughness.

(ii) Wire feed rate: Wire feed rate is the rate at which fresh wire is fed continuously for sparking. It has a range of 1 to 10 in steps of 1. Wire feed rate has great influence on

MRR. With a wire feed rate of 8m/min, brass wire spool of 5kg will last for about 24 hours.

(iii) Wire speed: There are 04 different speeds of wire feed: the speed of wire feed could be edited in parameter setting of auto cut software. Speed range: - 0 to 3 where 0 is fastest speed. While 3 is slowest speed

(iv) Work feed Rate: 4mm/ minute

(v) Machining Time: initially the low range 20-85 sec. **(vi) Gain and rate of Flushing/ Flushing Pressure:** Flushing Pressure is for selection of flushing input pres- sure of the dielectric. The flushing pressure range on this machine is either 1 (High) or 0 (low). High input pressure of water dielectric is necessary for cutting with higher values of pulse power and also while cutting the work piece of more thickness. Low input pressure is used for thin work piece and in trim cuts.

6. Performance measures: Wire Cut EDM perfor- mance, regardless of the type of the electrode material and dielectric fluid, is measured usually by the following criteria:

(i) Material removal rate (MRR): Maximum of MRR is an important indicator of the efficiency and cost effectiveness of the WEDM process, however increasing MRR is not always desirable for all applications since this may scarify the surface integrity of the work piece. A rough surface finish is the outcome of fast removal rates. The material removal rate (MRR) for WEDM can be ob-tained from the expression MRR = vfh / b Where, vf/feed rate of wire into the work piece in mm/min, h- work piece thickness or height in mm, density of the material in g/mm, b- Kerf given by: b = dw + 2s, Where, Dw-wire diameter in mm, s- gap between work piece & tool in mm.

(ii) Electrode wear (EW): The electrode wear also depends on the dielectric flow in the machining zone. If the flow is too turbulent, it results in an increase in elec- trode wear. Pulsed injection of the dielectric has enable reduction of wear due to dielectric flow.

(iii) Surface roughness (Ra): The surface produced by WCEDM process consists of a large number of craters that are formed from the discharge energy. The quality surface mainly depends upon the energy per spark.

7. Taguchi Method & Taguchi's Philosophy: Taguchi‟s comprehensive system of quality engineering is focus on the effective application of engineering strate-gies rather than advanced statistical techniques. Consist of upstream and shop-floor quality engineering. Upstream methods -: small-scale experiments to reduce variability and remain cost-effective, and robust designs for large- scale production and market place. Shop-floor techniques provide cost-based, real time methods for monitoring and maintaining quality in production. The farther upstream a quality method is applied, the greater leverages it produces on the improvement, and the more it reduces the cost and time. Taguchi‟s philosophy is founded on the following three very simple and fundamental concepts (Ross,

1988; Roy, 1990): Quality should be designed into the product and not inspected into it.

Quality is best achieved by minimizing the deviations from the target. The product or process should be so de- signed that it is immune to uncontrollable environmental variables. The cost of quality should be measured as a function.

8. Methodologies Genichi Taguchi:

An international consultant in the field of total quality control and assurance formulated both a philosophy and a methodology for the process of quality improvement that depends on statistical concepts, especially statistically designed experiments. Taguchi defined quality as the loss imparted to the society from the time a product is shipped to the market. The primary goals of the taguchi method- ology can be described. The reduction in the variation of a product design to improve quality and lower the loss imparted to society. The proper product or process im- plementation strategy which can further reduce the level of variation.

(i) Signal -to -noise ratio

The simplest form of signal-to-noise ratio (S/N) is the ratio of the mean (signal) to the standard deviation (noise) by Genichi Taguchi Methodologies.

$$\text{Type 1}: S/N_{LB} = -10 \log_{10}[\textstyle\sum Y_{ij}^2 / n]$$
$$\text{Type 2}: S/N_{HB} = -10 \log_{10}[(1/n)(\textstyle\sum 1/Y_{ij}^2)]$$

Where Yij is the value of the response 'j' in the ith exper- iment condition, with i = 1, 2, 3,…n; j = 1,2…k.

(ii) Orthogonal arrays

Orthogonal arrays are highly fractional orthogonal de- signs proposed by Dr. Genichi Taguchi, a Japanese indus- trialist. These designs can be used to not only applicable to two level factorial experiments, but also can investigate main effects when factors have more than two levels. De- signs are also available to investigate main effects for certain mixed level experiments where the factors included do not have the same number of levels.

9. Design of experiments:

Entire experiments based on varying the process parame-ters which affect the machining process to obtain the re-quired quality characteristics. Quality characteristics are the response values or output values expected out of the experiments. There are 4 such quality characteristics. The most commonly used are:

(i) Larger the better **(ii)** Smaller the better. **(iii)** Nominal the best **(iv)** Classifiedattribute

10. Signed Optimization steps using Taguchi method

Step is focus the original response values are transformed into S/N ratio values. Further analysis is carried out based on these S/N ratio values. The material removal rate is a higher-the-better performance characteristic, since the maximization of the quality characteristic of interest is sought and can be expressed as $S/NHB = -10 \log10 [(1/n) (\sum 1/ Yij 2)$ Where n = number of replications and yij = observed response value, Where i=1, 2... ....n; j = 1, 2...k. The surface roughness is the lower-the-better perfor- mance characteristic and the loss function for the same can be expressed as, $S/NLB = -10 \log10 (\sum Yij\ 2 / n]$ The S/N ratio values for the experimental results were calcu- lated and presented.

11. Work piece specimen properties:

(i) Copper: It was the original material first used in wire cut EDM. Although its conductivity rating is excellent, its low tensile strength, high melting point and low vapor pressure rating severely limited its potential.

(ii) Brass: first logical option of copper when early wire EDM users was looking for better performance. Brass EDM wire is a combination of Cu and Zn, typically al- loyed in the range of 63–65% Cu and 35–37% Zn. The addition of zinc gives significantly higher tensile strength, a lower melting point and higher vapor pressure rating; now it is commercially available in a wide range of ten-sile strengths and hardness.

(iii) Alloy steel: Steel that has small amount of one or more alloying elements other than carbon such as manganese, silicon, nickel, titanium, copper, chromium and aluminium added. This produces specific properties that are not found in regular carbon steel. Alloy steel are workhorses of industry because of more economical cast , huge range of availability , easy of processing , good mechanical properties , generally alloy steel are more expensive to heat and mechanical treatment than carbon steel.

Experimental Work: - Machine setup

Fig.2 Wire Cut EDM setup

12. Technical Specification of Machine (Table-I)

Longitudinal travel of work piece	325MM
Transverse travel of worktable	410MM
Movement of worktable per revolution of hand wheel	5MM
Maximum width of work piece (W)x Length of work piece(L)	415MMx635MM
Maximum weight of work piece (kg)	405kg
Maximum thickness of cutting (not include the precision and hard alloy)	310MM
Maximum taper by cutting	+/-3 Degree/100 MM
Variation of dimensions on longitudinal section	0.012MM
Variation of dimensions on transverse section	0.018MM
Maximum fineness of machining surface Ra	1.30-2.8μm

Cutting accuracy	0.015mm
Selecteddiameterofelectrode wire	Ø0.15- Ø0.28mm
Maximum length of wire stored	305MM
Total power of the machine	1.5 KVA
Motorforworkingfluidpump type	125W, flow 25L/min
Overall dimensions of ma- chine tool (length x Height)	1650x1300x1800mm
Weight of machine tool	1700kg

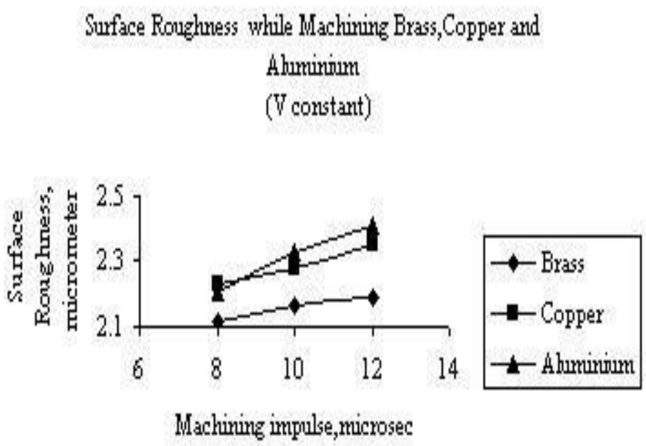

Fig.3 Surface Roughness while machining Brass, Copper & Aluminum (Voltage constant)

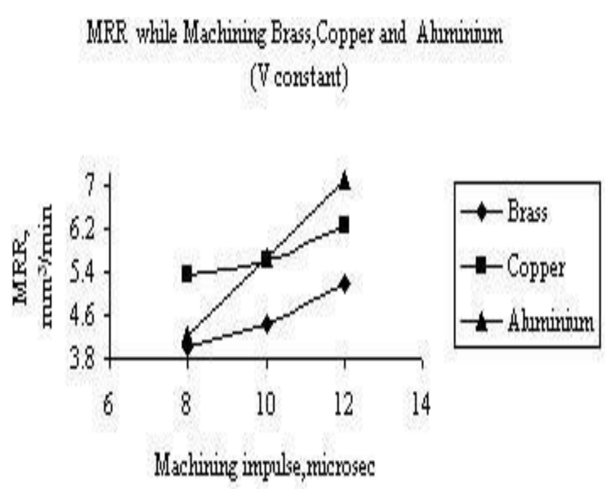

Fig.4 MRR while machining Brass, Copper & Aluminum (Voltage constant)

Machining cost data (Table-II)

Wire speed, m/min	Time taken in minutes	Wire con-sumption in grams	Machin-ing cost, Rs
2	30.22	5.60	580
3	28.60	6.86	555
4	26.35	8.70	540

13. Results and Discussion

Now practically it is clearly understand that each parame- ter play very important role for considering good machin- ing done on wire cut EDM process. Three specimens tak-en entire work to understand the results machining of Al- uminium, Copper, & Brass work material & now as shown in table for specimen Copper, Brass, Aluminium work material MRR and Ra is shown in fig.3 the design matrix and the results from the practical plan of MRR and Ra are shown in Table-II. In order to obsearve the results of the practical runs, analysis of variance (ANOVA) was utilized to examine the impact on cutting parameters of Wire cut EDM on the Table II. Results of practical runs by TaguchiL methods MRR and Ra. If some cutting pa- rameters do not significantly affect the MRR and Ra, they can be fixed at the recommended values and can be ex- cluded in predictive model generation and optimization process.

14. Conclusions:

This study aimed to study , characterize and evaluate the advanced machining process wire cut EDM which is con- trolled by number of machining parameters, really it is too tough for finding the different parametric Peak current, Dielectric pressure, pulse on time, pulse off time and sup- ply Gap voltage, Voltage and polarity, Average gap cur- rent. Non-electrical parameters, Wire tension, Wire feed rate, Wire speed, work feed rate, machining time, gain and rate of flushing. Electrode based parameters: Material and size of the wire. Dielectric System, Type, viscosity, and different flow characteristics. Include for a variety of works. The study is made to find the optimum conditions of the parameters in order to get less surface roughness, maximizing cutting speed, controlling wire rupture without affecting the MRR. It is found that there is an improve- ment in surface finish from the confirmation experiment with the application of regression models and optimization design of experiments models explored during the cutting tests. The mathematical models developed for machining performance characteristics can be successfully used for evaluating MRR and minimum kerf width for different cutting parameters with wire cut EDM process.

The object is optimized with Taguchi method by using the different Electrical parameters: Peak current, Dielec- tric pressure, pulse on time, pulse off time and supply Gap voltage, Voltage and polarity, Average gap current. Non- electrical parameters: Wire tension, Wire feed rate, Wire speed; work feed rate, machining time, gain and rate of flushing. Electrode based parameters: Material and size of the wire. Dielectric System: Type, viscosity, and other flow characteristics.

Aluminium, Copper & Brass work material by using Taguchi method a better surface characteristic like MRR and R_a was determined by using analysis of variance can be achieved during machining the surface roughness val- ues for different incremental values of machining impulse indicate that the values are comparatively less as compared to others. This task was done by considering T-ON, ma- chining speed, wire feed rate and off-set distance as pa- rameters. The task can be extended by considering other parameters like wire tension, dielectric flush rate etc. en- hanced machining quality. Surface quality can be im- proved by adopting multipass machining. World today's requirement is to produce products at low cost also best quality. So the proceess to formulate for selection of wire cut EDM process parameters for getting uniform kerf width, better quality surface finish, MRR, better utilization of Wire electrode for good quality surface characteristics, optimal cutting speed and machining work-piece of differ- ent thickness can be adopted for practical applications. This will bring a lot of process improvement, better pro- duction and efficient incorporation of the wire cut EDM process by achieving machined parts of a very high degree of surface characteristic. Orthogonal arrays and taguchi method helps in optimization of machining parameters on kerf and the MRR in wire cut EDM operations.

An optimum combination for the minimum kerf and maxi- mum MRR canbeobtainedbyusingtheanalysisofsignal-to- noise (S/N) ratio.

The cutting voltage and machining impulse (T-ON) are the most significant and significant machining parameters, with respect to control MRR.

(i) Mediumforbetterworkingconditionsandadvantages.

(ii) The wire Cut EDM research area can be divided in different area just like Performance measurement im- provement, Development in wire cut EDM, Control of process and optimizing the process parameter on dif- ferent type of work piecematerial.

(iii) From this work it understood that there is a need for increasing the accuracy of the prediction of optimal process parameter, which may be solved by hybridiza- tion for developing an expert system to provide optimal process parameters to achieve desired performance measuresfordifferentmaterialsinWirecutEDM.

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