PERFORMANCE INVESTIGATIONS OF ELECTRODE MATERIALS WITH INCONEL-718

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Abstract: Wire electrical discharge machining allowed success in the production of newer materials, especially for the aerospace and medical industries. Using WEDM technology, complicated cuts can be made through difficult-to-machine electrically conductive components. The high degree of the obtainable accuracy and the fine surface quality make WEDM valuable. Inconel is one of the newer materials that are developed to be hard, strong and temperature resistant which is widely used in turbo machinery industry due to their outstanding mechanical properties. However the challenge lies in optimum performance of WEDM and machining constraints with Inconel-718, so in this paper Inconel 718, was machined using WEDM and further with two different electrodes materials zinc coated brass and plain brass. Anova, is used to get the most influencing parameter out of discharge energy, pulse off, wire feed, wire tension, and flushing pressure on cutting rate, accuracy parameter kerf width. It has been found that discharge energy released is determining factor for both the response variables and there is considerable effect of electrode materials.

IndexTerms - WEDM, kerf width,cutting rate..

I. INTRODUCTION

In the recent years, wire electrical discharge machining (WEDM) has become an important non-traditional machining process, widely used in the aerospace and automotive industry. Intricate profiles used in prosthetics and biomedical applications can also be done in WEDM. It involves complex physical and chemical process including heating and cooling. The electrical discharge energy affected by the spark plasma intensity and the discharging time will determine the crater size, which in turn will influence the machining efficiency and surface quality. In WEDM, also known as wire cut EDM and wire cutting, a thin single strand metal wire usually brass is fed through the work piece and submerged in a tank of dielectric fluid, typically deionized water. Wire cut EDM is typically used to cut plates as thick as 300 mm and to make punches, tools, and dies from hard metals that are difficult to machine with other methods. The wire, which is constantly fed from a spool, is held between upper and lower diamond guides. The guides, usually CNC controlled, move in the x–y plane. On most machines, the upper guide can also move independently in the z–u–v axis, giving rise to the ability to cut tapered and transitioning shapes. The upper guide can control axis movements in x–y–u–v–i–k–l. This allows the wire cut EDM to be programmed to cut very intricate and delicate shape. The wire cut process uses water as its dielectric fluid, controlling its resistivity and other electrical properties with filters and deionizer units. The water flushes the cut debris away from the cutting zone. Flushing is an important factor in determining the maximum feed rate for a given material thickness[1]. Fig.1 represents the schematic diagram of WEDM.

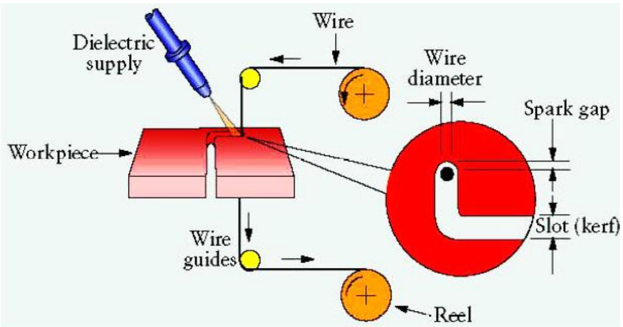

Figure 1: schematic diagram of WEDM

When machining Nickel-based superalloys, the significant challenges faced are that they have low thermal conductivity, Table 1. gives various properties of Inconel-718, that increases the thermal effects during machining, they often exhibit strong work hardening behavior, high adhesion characteristic onto the tool face altering cutting process parameters completely. In addition, they may contain hard abrasive particles and carbides that create excessive tool wear, and hence the surface integrity of the end products can be disappointing[2].Inconel 718 is a high-strength temperature-resistant (HSTR) nickel-based superalloy which exhibits good resistance to corrosion and oxidation along with high creep-rupture strength and fatigue endurance limit [3]. It is extensively used in the aerospace industry for manufacturing of gas turbine engine components such as turbine disks, blades, combustors and casings, nuclear power plant components such as reactor and pump, spacecraft structural components, medical devices, food processing equipment, extrusion dies and containers, casting dies, hot work tools and dies, etc. [4]

Machining of Inconel 718 Table 2.Showing typical composition with conventional techniques is extremely difficult because of its high toughness, hardness, work hardening tendency, low thermal conductivity, and presence of hard abrasive particles. Therefore, nonconventional machining methods based on chemical, electro-chemical, thermal, thermoelectric, and mechanical energy are preferred over traditional methods for the machining of Inconel 718. Wire electrical discharge machining(WEDM) is a non-conventional, thermoelectric process that can be used to cut complex and intricate shapes in all electrically conductive materials used in tool and die, automobile, aerospace, dental, nuclear, computer, and electronic industries with better precision and accuracy. The most important performance measures in WEDM are cutting rate and kerf width(cutting width). These measures, in turn, are influenced by numerous machining parameters such as discharge energy, pulse-off time, wire tension, wire feed rate, spark gap voltage, servo feed setting, average working voltage, and dielectric flushing condition[5]. Owing to a large number of process parameters and a complex nature of the process, even a highly skilled operator with as tate-of-the-art WEDM is rarely able to achieve the optimal performance. The improperly selected parameters may also result in serious consequences like short circuiting of wire and wire breakage that in turn reduces productivity. An effective way to solve this problem is to determine the relationship between the performance measures and the controllable input parameters. Also two types of wire electrodes are commonly used plain Brass and coated wire. Plain Brass was the successor to Copper wire and is still the most commonly used wire today. Brass, which is an alloy of Copper and Zinc, delivers a powerful combination of low cost, reasonable conductivity, high tensile strength, and improved flushability. Brass wire electrodes are extensively used on account of their ability to generate stable discharge, but their electrical conductivity is low.

Zinc coated Brass wires was one of the first attempts to present more Zinc to the wire's cutting surface. The addition of conductive alloying elements to the core surface of wire electrodes controls clarification and heat release. This wire consists of a thin (approximately 5 micron) zinc coating over a core which is one of the standard EDM brass alloys. Adding zinc to the wire electrode helps control electrical discharge properties, subsequently enhancing machining performance. Several inventors have focused their efforts toward enhancing wire electrode performance by controlling the above methods. This paper investigates the performance and effect of wire material in an attempt to address all the above issues.

Table 1: mechanical properties of Inconel- 718

Property Name	Value	Property Name	Value
Melting Point (k)	1260-1336^{0}C	Thermal Conductivity	11.4 W/Mk
Density(kg/m^3)	8192 kg/m^3	Ultimate tensile strength	1240 MPa
Specific Gravity	8.19	Specific heat	435 J/Kg K

Table 2: composition of Inconel 718.

ELEMENTS	Ni	Co	Cr	Mo	Fe	Si	Mn	C	Al	Ti
WEIGHT (%)	52.0	1.00	19.0	3.0	17.0	0.3	0.3	0.08	0.60	0.9

II. Experimental procedure:

Wire EDM of Inconel 718 alloy, was carried out on an Ultra cut WEDM, manufactured by Electronica Machine Tools. The machine tool used is shown in Fig. 2.Deionized water was used as dielectric. Zinc coated and uncoated brass of electrode of 250 micron diameter was employed. Inconel plate thickness 8 mm, with a (peculiar shape shown in figure 3) to check accuracy in terms of kerf width was selected. To evaluate the influence of parameters of Wire EDM process in terms of cutting performance characteristics such as Cutting rate, kerf width a ANOVA and residual plots are used here.

Figure 2: Experimental set up WEDM

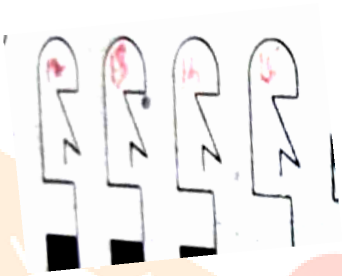

Figure 3: Experimental cut

Measurement of response variables

Cutting rate is calculated by using the following formula cutting rate = $K_f \times t \times$ cutting length[6]. The Kerf was measured using the Mitutoyo tools makers' microscope (100 X), is expressed as sum of the wire diameter and twice of wire workpiece gap. A typical Orthogonal Array mixed level design which gives the flexibility to choose different levels for every process parameters 'L18' is selected and the levels of process parameters are given Table 3. A. As for wire, we can have only two levels of plain brass and zinc coated. However with other parameters, we can keep three levels each. Discharge energy is found by Pulse on time x 336 [7]

Table 3
process parameter levels L18 OA

Parameters	levels	Values		
Wire Material	2	Brass	Zinc coated	
Discharge Energy	3	36.96	37.63	38.64
Pulse off	3	49	50	51
wire feed	3	3	4	5
wire tension	3	2	3	4
flushing pressure	3	4	5	6

III. Results and Discussion

The experimental results are collected for cutting rate and kerf width. Performance measures were statistically analyzed using analysis of variance, interaction plots and residual plots to determine the influence of electrode coating on response variables. In the present study all the designs, plots and analysis was carried out using Minitab 17 statiscal software.

A. Analysis of variance(ANOVA):

In the present study all the designs, plots and analysis have been carried out using Minitab17 software. The performance measures were statistically analyzed using analysis of variance (ANOVA). The analysis of variance was performed at 95 % confidence level. The associated P-value for the model is lower than 0.05 (i.e. =0.05), indicating that the model is statistically significant. It is used to establish statistically significant process parameter. Statistically, Larger F-value indicates that the variation of the process parameter makes a big change on the performance characteristics. According N.Tosun higher value of F-ratio shows that any small variation of the process parameter can make a significant influence on the performance characteristics. The results of ANOVA for the performance measure are presented in Table 4 and 5.

Table 4
Avova for Cutting rate

Control Factors	DF	Adj SS	Adj MS	F- Val	P-Val
Wire Material	1	0.14116	0.14116	2.11	0.196
Discharge Energy	2	6.22165	3.11082	46.56	0.000
Pulse Off	2	0.03453	0.01727	0.26	0.780
Wire Feed	2	0.03709	0.01854	0.28	0.767
Wire Tension	2	0.13832	0.06916	1.04	0.411
Flushing Pressure	2	0.18730	0.09365	1.40	0.317
Error	6	0.40089	0.06681		
Total	17	7.16093			
S	R-sq		R-sq(adj)	R-sq(pred)	
0.258485	94.40%		84.14%	49.62%	

According to ANOVA for cutting rate it is observed that with this process parameter configuration, discharge energy is the most significant process parameter with F-value of 46.56, and P-Val of 0.00<0.05, also the R-sq and R-sq(adj) values are within limits. And important to note is out of other all parameters wire material is next significant parameter with F-value of 2.11. Indicating the effect of coating.

Table 5
Anova for kerf width

Control Factors	DF	Adj SS	Adj MS	F- Val	P-Val
Wire Material	1	0.000004	0.000004	1.28	0.301
Discharge Energy	2	0.000573	0.000287	103.22	0.000
Pulse Off	2	0.000001	0.000001	0.26	0.779
Wire Feed	2	0.000001	0.000001	0.26	0.779
Wire Tension	2	0.000001	0.000001	0.26	0.779
Flushing Pressure	2	0.000003	0.000002	0.56	0.598
Error	6	0.000017	0.000003		
Total	17	0.000601			
S	R-sq		R-sq(adj)	R-sq(pred)	
0.0016667	97.23%		92.14%	75.05%	

According to ANOVA for kerf width, it is observed that with this process parameter configuration, discharge energy is the most significant process parameter with F-value of 103.22, and. and important to note is out of other all parameters wire material is second most significant parameter with F-value of 1.28 depicting the effect of coating

B. **Interaction Plots:**

The interactions among variables need be studied as not only individual parameters but their pooled combination need be understood to select a set of parameter range for optimization. Factors and their interactions that have strong effect on machining performance. One cannot conclude precisely without studying the interactions between various factors. The selection of interaction parameter was done S-N ratios, and the interaction of wire material and discharge energy is found for cutting rate and kerf width. Shown in figure 4.

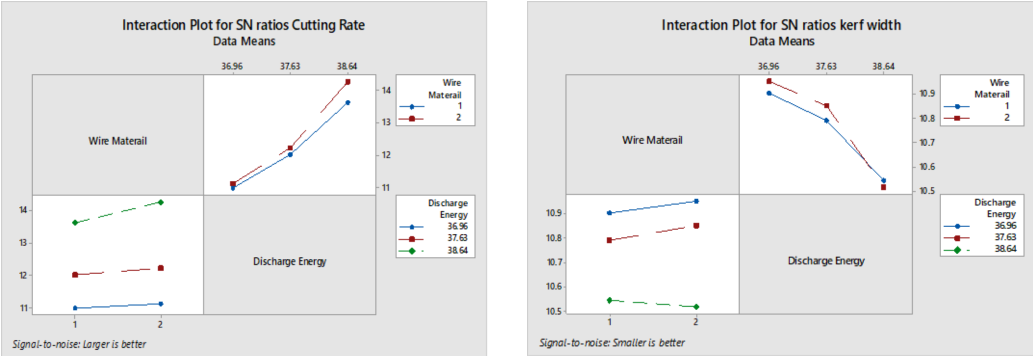

Figure 4: Interaction Plot for cutting rate and kerf width

From the interaction plot it is observed that there is no interaction for cutting rate between the two most influencing parameters wire material and discharge energy, however for the kerf with there is considerable interaction between these two parameters. Hence there is considerable influence of the coating on the electrode material.

C. Residual Plots

From the residual plots, figure 5, we get the reading outside from the normal probability plot. From the verses fit and versus order there is equal reading above and below the central line.

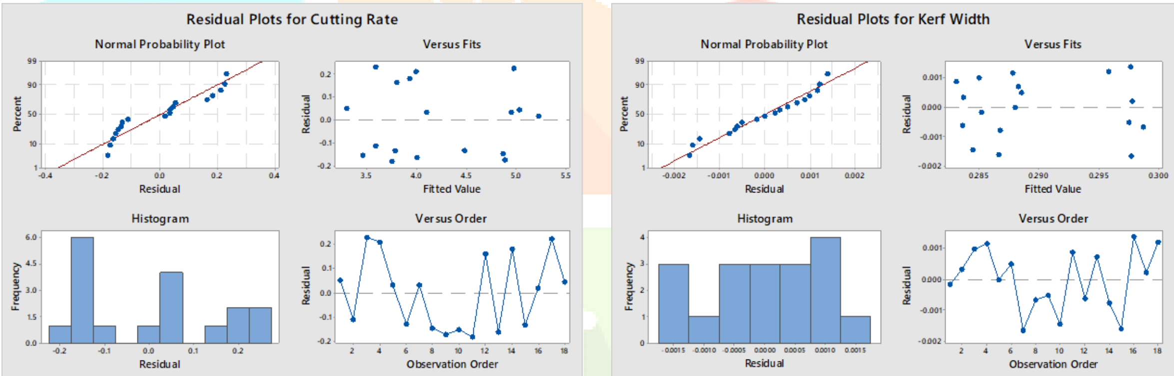

Figure 5: Residual plot for cutting rate and kerf width

IV. CONCLUSIONS

This paper described the machining of Inconel-718, with WEDM. It has proved its adequacy to machine Inconel 718 material. There is considerable influence of discharge energy on both the performance measures cutting rate and kerf width, however it is important to observe the next most influencing parameter is wire material.

V. ACKNOWLEDGEMENT

The author wish to acknowledge the TEQIP-II, of Dr. Babasaheb Ambedkar Technological University, Lonere for availability of funds for carrying experimentation work.

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