Experimental Analysis of Wire Electrical Discharge Machining of Aluminium Composite

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Abstract

It is commonly known that the aluminium alloy has a variety of uses in the automotive, aerospace, and marine sectors. In order to produce composite materials with optimal design, strength-to-weight ratios, corrosion resistance, fatigue resistance, and stiffness-to-weight ratios, Al_2O_3 or SiC can be utilised as reinforcement. Non-traditional machining techniques are used to prepare these composites because of their strength and the possible high cost of conventional machining. In the unconventional machining process known as wire EDM (Electrical Discharge Machining), electricity is utilised to create detailed shapes on conductive materials. A wire electrode is employed in this process. The current study examined how wire electrical discharge machining (WEDM) on Al-2024 Al_2O_3 composite affects Surface Roughness (SR) properties. Experiments were done with a Taguchi L16 orthogonal array (OA). Using this, the signal-to-noise (S/N) ratio technique is used to assess the effect of Wire EDM parameters on surface roughness. In the experiment, the surface roughness (SR) of the Al-2024 Al_2O_3 composite was examined in relation to the machining process parameters. The properties of surface roughness can be used to determine the best process parameter.

Keywords: Metal matrix composite; Wire-Electrical Discharge Machining; L16 Orthogonal Array; Surface Roughness;

1. INTRODUCTION

Wire-cut EDM (Wire EDM), also known as Spark EDM, is often used when minimal residual stress is required because it does not require significant shear to remove material. This form of EDM cuts with the assistance of a thin diameter wire that serves as an electrode. WEDM is an unconventional electro thermal machining method in which electrical energy is employed to produce an electrical spark and material removal happens owing to the thermal energy of the spark. The spark is created when the tool electrode and the work piece come into contact. The tool electrode and the work piece are kept at a certain distance from one another. Furthermore, a dielectric liquid is used to continually flow through the gap; the material removed is flushed out of the gap by this flowing dielectric liquid. These dielectric fluids have a high dielectric strength to stay nonconductive to electricity. Moreover, Wire Electrical Discharge Machining (WEDM) can fulfil the aim of high-speed machining with exceptional surface finish in tight tolerances in today's competitive environment. WEDM is a vital machining process for creating complicated forms on many types of conducting materials. The choice of machining parameters in a machining process has a considerable impact on the pace and quality of produced components. In WEDM, the selection of these factors is mostly determined by the operator's expertise and machining parameter tables supplied by machine-tool makers. Such a criteria, however, does not ensure either a fast production rate or adequate surface quality. As a result, a methodology for determining the best process parameters is required. The intention of the current work is to conduct an experimental analysis of the surface roughness of an aluminium composite generated by WEDM machining in relation to its input parameters, such as wire speed, current, pulse on time, and pulse off time.

The last published studies on the WEDM method that describe its use over aluminium, metal matrix composite, aluminium alloys and other materials are included in the literature review for this study. The literature review is separated into two distinct sections, the first of which describes the wire EDM method on various types of composites.The second section discusses the optimisation of process parameters for wire cutting on aluminium alloys. The literature study also includes a broad overview of computer-aided wire EDM. This literature review is illustrated in detail. **Satsangi, P. & Goyal, Piyush. (2019)** This article covered the demand for materials with high tensile strength and high impact strength rises as technology develops. WEDM is one of the widely used machining processes that is useful for cutting complex geometries in challenging materials. Because of its light weight and great strength, aluminium alloys are being used commercially more and more in the automotive and aerospace industries. In the present investigation, the work piece material was an Al 7000 series alloy micro WEDM, which is widely utilised in commercial applications. **Pramanik, Debal&Kuar, A. & Bose, Dipankar. (2019)** This article covered Wire Electrical Discharge Machining (WEDM), one of the non-traditional machining techniques with one of the quickest rates of broad growth. Its capabilities are so extensive that they can cover practically any conductive material machining application, including manufacturing, aerospace/aircraft, nuclear reactor, and the medical industries. **Nayak, BijayaBijeta&Sahu, Sasmita& Das, Diptikanta. (2020)**.There has been a growing demand for complex three-dimensional features and small devices manufactured of cutting-edge metal matrix composites in recent years. Taper cutting is a deep routed, non-contact spark eroding technique used in WEDM, which is a feasible way for machining complicated three-dimensional geometry using current metals, alloys, super alloys, and composites. In addition, an ANOVA analysis was run to discover which factors had the largest influence on the outcome.**Ramanan, G. & Reddy, M. Madhu&Manishankar, V... (2020)**. The effect of process parameters on machining quality in wire electrical discharge machining (WEDM) is investigated. This work examines the optimisation of process parameters in WEDM machining using the desirability approach based on response surface methodology (RSM). Influencing elements include pulse on time, servo speed rate, discharge current, and pulse off time.**Amritha, S. & Mallikarjuna, Shilpa & M R, Shivakumar&Madhoo, G. & Harshini, Y.P. & Harshith. (2021)**. An investigation of the mechanical and tribological behaviour of an aluminium metal matrix composite reinforced with alumina. Aluminium alloy has grown in popularity in the automotive and aerospace industries due to its ease of availability and manufacture. Materials science has grown in relevance in the realm of composites in recent years. Metal matrix composites are taking the lead in industrial applications in the field of composites.

2. MATERIALS AND METHODS

2.1 Materials

Aluminium 2024 is an alloy composed of copper, magnesium and other elements. Compared to any other metal, aluminium-alumina composite has the same properties as a strength, low density and good wear resistance. It was decided that alumina should be a material used to reinforce the metallic matrix. Due to its usage in the manufacturing of aluminium metal, abrasives due to its hardness, and refractory materials due to its high melting point, alumina, a combination of aluminium and oxygen with the chemical formula Al_2O_3, is important.

2.2 Methods

Taguchi L16 array is used for conducting experiments in wire EDM. Taguchi design of experiments is a strategy for designing experiments that attempt to generate high-quality goods or processes at a cheap cost by lowering variance caused by uncontrolled factors. Orthogonal arrays are used in Taguchi design of experiments to arrange the variables influencing the process and the levels at which they should be adjusted.

3. EXPERIMENTAL PROCEDURE

Al-2024 Al_2O_3 composite was used as a working material in this investigation in the form of a plate of size of 63 × 46 × 6 mm. 16 trials were conducted by employing a feed of cut for a length of 15 mm in a WEDM machine using various combinations of the process parameters. Experiments are done in CNC wire cut EDM DK7740 to process Al-2024 Al_2O_3 composite using molybdenum wire electrode (0.18 mm diameter) and demineralized (DM) water as a dielectric fluid. Fig. 1 represents the Wire EDM machine used for the experiment.

Fig. 1: Wire EDM Machine

The pulse-on time (Ton), pulse-off time (Toff), current (I), and wire speed are identified as the changeable process parameters based on the prior literature study on Wire EDM. These four parameters have been selected for the experiment which ranges are Ton (40-50) s, Toff (2-20) s, I (1-6) A, Wire speed (5-11) m/s. The surface roughness (SR) was obtained as an Ra value using a surface roughness meter (Mitutoyo SJ210 model) and analyzed using the average value of the SR values at four points perpendicular to the wire direction. Table 1 shows the layout of the L16 orthogonal array.

Table 1: L16 Orthogonal Array design

Expt no	Process parameters				Surface Roughness (μm)
	I (A)	Ton (s)	Toff (s)	Wirespeed (m/s)	
1	1	1	1	1	5.534
2	1	2	2	2	6.287
3	1	3	3	3	5.686
4	1	4	4	4	5.745
5	2	1	2	3	6.624
6	2	2	1	4	7.038
7	2	3	4	1	8.186
8	2	4	3	2	7.775
9	3	1	3	4	6.513
10	3	2	4	3	7.434
11	3	3	1	2	7.338
12	3	4	2	1	9.084
13	4	1	4	2	9.212
14	4	2	3	1	7.435
15	4	3	2	4	8.124
16	4	4	1	3	8.059

4. RESULTS AND DISCUSSION

The current study used the Taguchi S/N ratio technique to determine the influence of Wire EDM parameters on surface roughness. The signal-to-noise (S/N) ratio reflects the importance of an experimental finding. Because these responses must be minimised, the S/N ratio for surface roughness is calculated using the below Equation (the smaller the better). The equation for calculating S/N ratio is;

$$\lambda = -10 \log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} R_i^2\right) \quad i = 1,2, \ldots n$$

Where,

λ - S/N ratio

R_i – measure of response of i^{th} experimental run

n – number of experimental runs

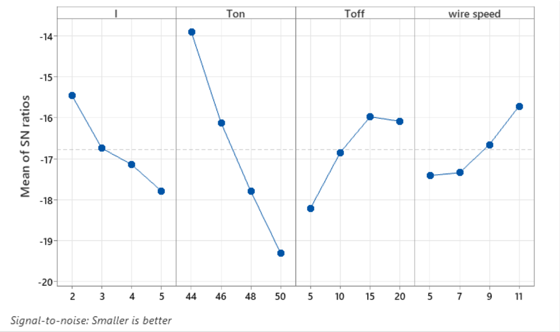

Fig 2: Main effects plot for S/N ratios

Table 2: Response Table for Signal to Noise Ratios

Level	I	Ton	Toff	wire speed
1	-15.45	-13.91	-18.22	-17.42
2	-16.75	-16.13	-16.85	-17.35
3	-17.15	-17.80	-15.98	-16.66
4	-17.80	-19.30	-16.09	-15.72
Delta	2.34	5.40	2.24	1.70
Rank	2	1	3	4

Fig 2 represents the graph between mean of S/N ratios to the values of each process parameter. From the graph it shows that Ton has the highest impact on the machining. Subsequently, current and Toff has impacted 2nd and 3rd rank respectivelywhereas wire speed has least impact on the machining. In addition, Table 2 depicts the delta rankings of process parameters and its respective rankings.

5. CONCLUSION

Overall, the study shows the influence of surface roughness test of aluminium-alumina composite using the WEDM process is determined. From the experimental investigations, optimal signal-to-noise ratios were obtained by the Taguchi L16 Orthogonal Array. Finally, it is concluded that pulse on time has the major response on the surface finish of the composite.

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