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Optimization of WEDM Process Parameters on Surface Roughness and Study of Physical behaviour using SEM for Machining Aluminium Alloy Al 7075 using Brass Coated Copper Wire

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Abstract

Wire Electrical Discharge Machining is one of the most effective Non-Conventional Machining method available to machine intricate shapes which are very difficult to machine with conventional machining methods, on electrically conductive materials having varying hardness. In this research work, an attempt has been made to study the effect of process parameters of WEDM on the Surface roughness. Input process parameters considered in this work are Pulse on time (T_{ON}), Pulse off time(T_{OFF}), Wire Feed (WF), Wire Tension(WT) and the Surface Roughness as response. Al 7075 Aluminium alloy was taken as work material and Brass coated copper wire as electrode to machine and the values of roughness obtained by varying the input process parameters were analysed using Taguchi method (L 27 orthogonal array). The measured values have been used to develop the mathematical model and the accuracy of the model was tested using Analysis of Variance (ANOVA) technique. Based on the predicted values the interaction graphs, were drawn between the Surface roughness and the process parameters taken for this study. It was construed that the pulse-on time has the highest impact on the Surface roughness followed by the Wire feed, Wire tension and the Pulse-off time. The surface roughness got increased with increase in wire feed. Finally optimum parameters have been arrived to achieve better surface roughness. WEDMed surface was also examined by using scanning electron microscope (SEM) and evinced that the physical behaviour of these process parameters on Surface roughness. Copyright © VBRI Press.

Keywords: WEDM, optimisation, surface roughness, RSM, GA, Al 7075, SEM, brass coated wire.

Introduction

WEDM is an important Non Traditional Machining process employed for machining materials of less machinability ratio to any intricate shape. The only constraint is that the material should be electrically conductive material. It is hard to access the optimum machining parameters since it depends upon so many factors such as machining parameters, work piece, wire characteristics etc., improper selection of parameters may lead to undesirable effects like rough surface finish, less material removal rate and occurrence of wire breakage frequently.To achieve good surface finish, optimisation of parameters are absoultely necessary. The main objective of this proposed study is to achieve minimum surface roughness by optimising input process parameters...... Several researchers have undergone investigations on optimisation of WEDM process parameters, Pratik AR et(al) , were studied the WEDM parameters Wire tension, Pulse on time and Peak current on the material removal rate by adopting Response Surface Methodology on AISI D2 cold work steel work material, it is widely used in die and mold making industries [**1**]. Anmol Bhattiya *et al.*, in WEDM process used Brass wire electrode to machine high carbon high chromium steel by adopting Taguchi method and optimised the input process parameters to achieve minimum Surface roughness. The optimised process parameters were Peak current (220 A), Pulse on time (131 Micron secs), Pulse off time (131micron secs) and wire tension (2gf) [**2**]. Arun Kumar *et al.*, investigated the effect of WEDM process parameters pulse ON time, pulse OFF time, pulse duration and servo feed on the output parameters MRR and Surface finish by adopting Response Surface Methodology (RSM) and the Analysis of variance (ANOVA). The results shown that pulse On time played a major impact on MRR (62.8%) and Surface finish (72.81%) [**3**]. Pradeep Kumar *et al.* examined to optimise the WEDM process parameters Pulse on time, Pulse off time and Peak current by adopting Taguchi L9 orthogonal array with ANOVA technique to achieve maximum Surface finish. Pulse on time played a significant effect by contributing 92.35 % and Peak current is insignificant

[4]. Anmol Madaan *et. al.*, revealed that the relation between various WEDM process parameters Pulse on time, Pulse off time, Peak current and Wire tension on the output parameter Surface roughness, P20 Tool Steel was taken as the work material and Taguchi's design of experiments, Analysis of Variance (ANOVA) and L9 orthogonal array have been used for analysis. It was observed that Pulse off and Peak current were the most dominant factors while comparing with Pulse on time and Wire tension [5]. Copyright © VBRI Press.

Experimental method

Work material

Al 7075 Aluminium Alloy is used widely in marine, aerospace, automobile and in die making industries because of its low weight to high strength ratio. It contains high Tensile strength, Shear strength, Yield strength and Fatigue strength. **Table 1** illustrates the Chemical Composition of Al 7075 Aluminium Alloy by weight.

Table 1. % of Aluminium Alloy Al 7075 Composition by weight.

Al %	Zn%	Mg%	Cu%	Cr %	Others %
90	5.6	2.5	1.6	0.23	0.07

Machine tool

In WEDM, a very thin circular wire (0.02-0.3 mm) made up of Brass or Copper or Molybdenum as electrode and the wire is strecthed between two rollers. Part of the wire is eroded by the spark. The predominent feature of the moving wire is to machine any complicated and complex shapes. When DC supply is made through, to remove the metal, a high energy spark is produced between the work piece and the which produces high temperature and causes the work piece metal to be melted, eroded and some portion got vapourised. Dielectric fluid is circulated by a pump over the cutting area to carry away the removed materials. **Fig. 1** shows the experimental setup of Wire Electric Discharge Machining.

Fig. 1. WEDM machine setup.

Specimen, tool and dielectric fluid used

A rectangular block of Al 7075 Aluminium Alloy Length 200 mm, Width 16 mm and Thickness 10 mm was taken as work material. The experiment was performed on WEDM machine with 0.25 mm dia Brass Coated Copper Wire as electrode and Deionized water as Dielectric Fluid.

Fixed and variable parameters considered in this experiment

The input power 230 V, Dielectric fluid pressure 1 machine unit(low), Pulse Peak Voltage 2 machine unit, Servo Voltage 20 V and Servo Frequency 2100 cycles/sec were kept as fixed parameters. The variable parameters were Pulse On (T_{ON}), Pulse Off (T_{OFF}), Wire Feed (WF) and Wire Tension (WT) in the range of 120-128 µsec, 50-58 µsec, 1-3 m/min and 5-9 gm respectively. Three level four parameters were chosen.

Experimental values

Table 2. Experimental Results of R_a using L27 orthogonal array matrix.

Ex. No	Pulse On (A)	Pulse off (B)	Wire Feed (C)	Wire Tension (D)	Surface Roughness (R_a)
1	128	54	2	5	1.83
2	120	54	1	7	1.56
3	124	58	2	9	1.72
4	124	58	1	7	1.68
5	124	50	2	5	2.45
6	124	54	2	7	2.02
7	120	58	2	7	1.76
8	128	54	3	7	2.01
9	128	54	1	7	1.88
10	124	54	3	5	1.97
11	124	54	3	9	1.96
12	120	54	2	5	1.63
13	120	54	2	9	1.9
14	124	54	2	7	2.06
15	128	54	2	9	1.85
16	128	50	2	7	2.72
17	124	50	1	7	2.12
18	124	50	3	7	1.47
19	120	54	3	7	1.24
20	128	58	2	7	1.43
21	124	54	2	7	1.69
22	124	54	1	5	2.01
23	120	50	2	7	2.06
24	124	54	1	9	1.8
25	124	50	2	9	2.35
26	124	58	2	5	2.1
27	124	58	3	7	2.5

Fig. 2. Surface Roughness Tester.

Results and discussions

Response Surface Methodology (RSM)

The Surface roughness R_a measured by surface tester **Fig 2** and the same was tabulated in the **Table 2**. The relationship between the parameters and the response was obtained by RSM in Minitab. ANOVA results were tabulated in **Table 3** $R_a = -163.215 + 2.067{*}T_{ON} + 1.190{*}T_{OFF} + 1.046{*}WF + 0.919WT - (0.007{*}T_{ON}{*}T_{ON}) - (0.003{*}T_{OFF}{*}T_{OFF}) + (0.110{*}WF{*}WF) - (0.026{*}WT{*}WT) - (0.006{*}T_{ON}{*}T_{OFF}) + (0.002{*}T_{ON}{*}WF) - (0.001{*}T_{ON}{*}WT) - (0.032{*}T_{OFF}{*}WF) - (0.009{*}T_{OFF}{*}WT) - (0.004{*}WF{*}WT)$ Eq. 1

Table 3. ANOVA for R_a

Source	DF	Seq SS	Adj MS	F
Regression	14	0.734158	0.052440	141.68
Linear	4	0.339383	0.114621	77.42
Pulse on	1	0.073633	0.088760	239.80
Pulse off	1	0.070533	0.059477	160.69
Wire Feed	1	0.010208	0.003746	10.12
Wire Tension	1	0.185008	0.011398	30.79
Square	4	0.271950	0.067988	183.68
Pulse on*Pulse on	1	0.069360	0.066008	178.33
Pulse off*Pulse off	1	0.017640	0.014008	37.85
Wire Feed*Wire Feed	1	0.126150	0.064533	174.35
Wire Tension*Wire Tension	1	0.058800	0.058800	158.86
Interaction	6	0.122825	0.020471	55.31
Pulse on*Pulse off	1	0.036100	0.036100	97.53
Pulse on*Wire Feed	1	0.000225	0.000225	0.61
Pulse on*Wire Tension	1	0.000225	0.000225	0.61
Pulse off*Wire Feed	1	0.065025	0.065025	175.68
Pulse off*Wire Tension	1	0.021025	0.021025	56.80
Wire Feed* Wire Tension	1	0.000225	0.000225	0.61
Residual Error	12	0.004442	0.000370	
Lack-of-Fit	10	0.004442	0.004568	7.63
Pure Error	2		0.000444	
Total	26	0.738600		

S = 0.0192390 PRESS = 0.025584
R-Sq = 95.40% R-Sq(pred) = 92.54% R-Sq(adj) = 94.70%

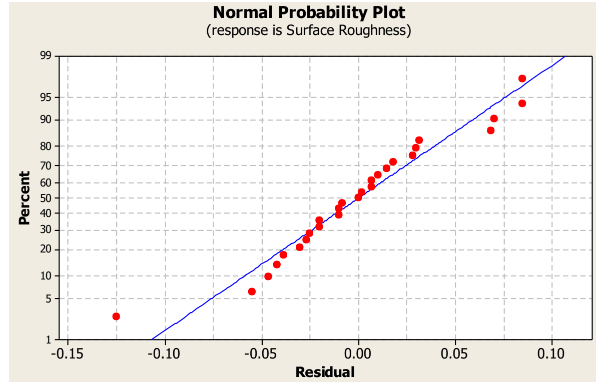


Fig. 3. Fitness of the experiment.

Fig. 3 shows the fitness of the experiment, it was evident that there was no much difference between experimental value and expected values arrived from RSM. **Fig. 4** shows the effect of SN Ratio.

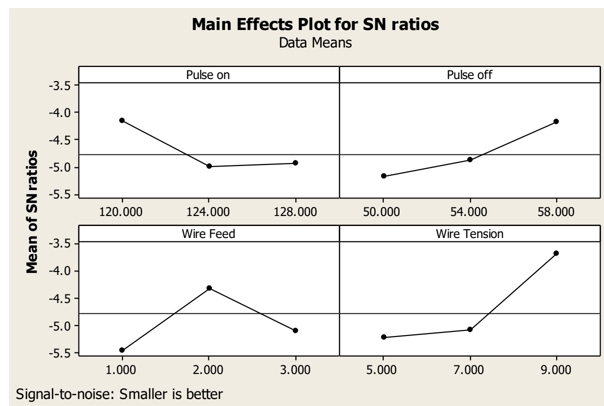
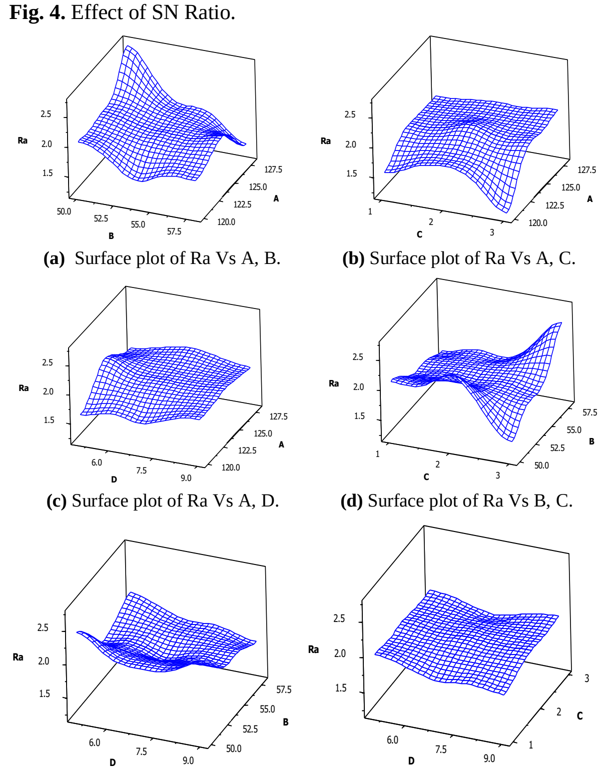


Fig. 4. Effect of SN Ratio.



(a) Surface plot of Ra Vs A, B. **(b)** Surface plot of Ra Vs A, C.

(c) Surface plot of Ra Vs A, D. **(d)** Surface plot of Ra Vs B, C.

(e) Surface plot of Ra Vs B, D. **(f)** Surface plot of Ra Vs C, D.

Fig. 5. Surface plot of R_a Vs input parameters.

Fig. 5 shows the effects of input parameters on R_a for moderate T_{ON} and T_{OFF}, the Surface roughness R_a was minimum and for the minimum T_{ON} and maximum $T_{OFF,}$ the Surface Roughness R_a was maximum. For minimum WF the R_a value was minimum and as it increases the R_a value also gradually increases and the starts decreasing. For minimum WT, R_a value was minimum and gradually increased and attains the peak for the maximum value of WT. **Fig. 7** shows the best fit solution predicted R_a as 1.87 µm for T_{ON}-122, T_{OFF}– 55, WF-1 and WT-6.

Surface topography

Surface topographic analyses were performed on WEDMed surface by VEGA3TE SCAN SEM machine at Government College of Engineering, Salem/ Tamilnadu in order to investigate the surface condition of the machined work piece. **Fig. 6** shows the SEM micro graphs of WEDMed surface under various magnifications of WEDMed surface at T_{ON} -122, T_{OFF} – 55, WF-1 and WT-6. SEM images were noted for the optimal Values hence the surface is better with less number of craters and cracks.

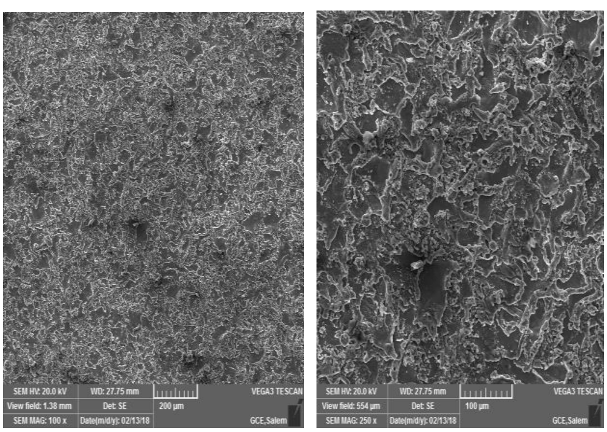


Fig. 6. SEM micro graphs.

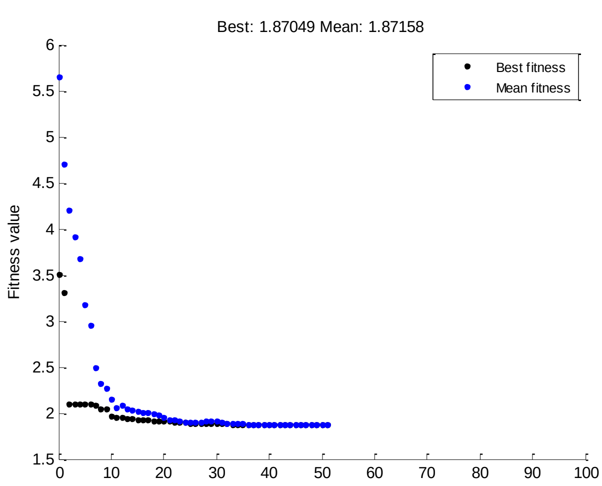


Fig. 7. Optimal solution of R_a by GA.

Conclusion

This work elucidates the effects of WEDM process parameters while machining of Al 7075 Alloy by using Brass Coated Copper Wire, a quadratic regression equation obtained for R_a by Response Surface Methodology and the same was used in Genetic Algorithm to obtain the best fit R_a. The following conclusions were derived based on the results obtained during machining of Al 7075 Alloy with Brass Coated Copper Wire.

- The best Surface Roughness value of 1.87 was obtained for the optimized value of Pulse On (T_{ON}) value 122 µsec, Pulse Off (T_{OFF}) value 55 µsec, Wire Feed (WF) 1 m/min and for Wire Tension (WT) value 6 gm.
- It has been noted that the Surface roughness got increased with minimum value of Pulse On time and maximum value of Pulse Off time
- The Surface roughness was minimum for minimum Wire feed and Wire tension.
- When the Wire Feed and Wire Tension are minimum, the Surface roughness was maximum.
- SEM images were used to analyse the physical behaviour of selected process parameters on Surface roughness.

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