Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 3, June 2021: 4566 - 4579
Research Article

AN INVESTIGATION ON TI / 6063AL AND MRR IN WEDM BASED ON DOE METHOD

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Abstract

This experiment aims to optimize the WEDM (Wirecut Electric Discharge Machining) cutting process parameters while machining Titanium Ti/6063AL content. The hardness and strength of Ti/6063AL alloy make achieving a better surface finish and MRR a difficult task. The SR and MRR of Ti/6063AL were investigated, and a tremendous machined surface may be achieved by optimizing the machining limitations through different studies of the component while machining in WEDM. Using Taguchi's DOE method, machining parameters like Wire Feed Rate (WFR), Gap Voltage (GV), Pulse ON time (TON), and Pulse OFF time (TOFF) are used as input parameters to achieve an optimum result like SR and MRR. In this study, 9 experiments were carried out with 4 input parameters and three levels for each, and the MRR investigational results were analyzed using the Taguchi process. The optimum levels of a particular Input Process Parameter were effectively determined using MRR's Signal to Noise Ratio values.

Key words: Ti/6063 Al, WEDM, MRR, SR, CS

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1. Introduction

New materials that meet the requirements of aeronautical engineering applications, such as lightness, mechanical properties, and machinability, are constantly imposed. Titanium aluminide intermetallic alloys are promising materials for meeting today's most popular structural high-temperature requirements. They're known for their low density and high strength and also known for their strength stability, high modulus, oxidation resistance, and high creep. [1–3]. These alloys have potential uses in the aeronautics and aerospace industries.

Inconel 625 superalloys are also used in the aerospace and chemical industries because of their excellent mechanical properties [3]. The machining response like tool wear and MRR was Inconel 625 is a critical commodity in the automotive and aerospace industries. Inconel 625 is alloyed, melted, and processed to have maximum resistance to thermal fatigue and low cycle.
optimized by multiple objective optimization processes called on-dominating sorting genetic -algorithm-II, and the Pareto-optimal set of solutions was found [4]. The effects of OCV, duty cycle, current strength, and pulse on time were investigated.

SEM was used to determine the impact of input parameters on the process of SR and MRR (Ra)

[6]. Nimonic 80 A was studied for its MRR, surface integrity, and WWR. As the discharge energy increases, a melting explosion occurs, resulting in the creation of deeper and larger holes on the sample's surface, as seen in microstructure [7]. Cryogenic treatment of AISI4340 steel was studied in terms of mechanical properties and microstructure [8]. The latest methods for increasing tool life was a major economic constraint for industry, were documented by scientists. Cryogenic machining, when compared to any other machining method, yields the longest tool life, according to a current report. [9] The impact of the cryogenic process on the brass wire tool electrode in WEDM machining has only been studied in a few studies [10]. The 2nd order polynomial graphs for different system measurements have been attained after optimizing the impact of electric discharging machining process parameters on Inconel 718 and Inconel 625 performance characteristics. [11]. For the machining of commercially pure Ti, process parameters like wire form (zinc uncoated and coated brass wire), TON, TOFF, IP, WF, SV, and WOFF have been finalized, and SR and cutting speed has been analyzed as responses. [12]. carried out WEDM machining experiments on the superalloyNimonic C-263. [13.] Green EDM is being used in experiments to machine the superalloy Ti-6Al-4V. Tap water was chosen as the operational fluid because it has a low impact on human strength and the climate, while also providing a healthy machining environment for the operator and lowering machining costs. Taguchi's approach and Gray relational analysis were used to optimize experimental process parameters. [14].

2. ExperimentalMethodology

It is calculated to the optimum level of material properties in order to obtain a high dimensional accuracy and better surface quality achieved by the WEDM process. The WEDM selected regulated factors and their stages are revealed in Table 1. For these tests, the following controllable variables were chosen:

1. Pulse on Time(Ton)
2. Pulse off Time(Toff).
3. Wire feed rate(WFR)
4. Gap voltage(GV)

Table.1. Process Parameters & levels

Process parameters	**T_{OFF}**	**T_{ON}**	**GV**	**WFR**
Units	µs	µs	V	Mm/min
Level 1	5	7	45	3
Level 2	6	8	55	39
Level 3	9	7	65	7

The performance level was determined under the optimum machining conditions and also analyzed the controllable effect in variables or process parameters on performance characteristics

(MRR, Ra, and CS). The Taguchi process, a unique design technique, is used in this analysis. The Taguchi Procedure for Experimental Design and Analysis is a method for analyzing experimental designs. They are confirmation experiment, range of orthogonal array, data analysis, interactions to an orthogonal array, task of parameters, and determination of confidence intervals.

2.1 Taguchi's Design ofExperiments

Taguchi's DoE technique was used to determine the optimum setting of input parameters in this study. The experiments were carried out using Taguchi's L10 mixed form Orthogonal array (OA). In L9 OA, there are four criteria, each with three levels. The impact of significant parameters such as WF, TOFF, TON, and gap voltage on three output responses like surface roughness, cutting speed and MRR haS been investigated in this study.

2.2 TaguchiExperiment

There are four variables in this experiment, each with three different settings. A complete factorial experiment would necessitate 4^2=16 trials. Table 2 shows the results of a Taguchi test using aN L9 orthogonal array (8 measures, 3 variables, three stages).

2.3 MRR

The Maximum Material Removal Rate is a key indicator of the WEDM process's performance and cost- efficiency. However, increasing MRR can compromise the workpiece's surface integrity. MRR also worsens the bad surface finish. The MRR in WEDM may be calculated using the expression

Cutting Speed = Wire Travel Length / Total Time for Cutting (1) MRR = Cutting Speed x WorkPiece Height

Table.2. Taguchi experiment design

Experiment	1	2	3	4	5	6	7	8	9
A	A1	A1	A1	A2	A2	A2	A3	A3	A3
B	B1	B2	B3	B1	B2	B3	B1	B2	B3
C	C1	C2	C3	C3	C2	C1	C2	C3	C1
D	D1	D2	D3	D3	D1	D2	D2	D3	D1

2.4 TITANIUM Ti/6063 AL(Grade5)

It is estimated that titanium is used in 50 percent of the world's total. Heat treatment of titanium alloys Ti/6063 Al (Grade 5) will increase their strength. As a result, this alloy combines high strength with low weight and excellent corrosion resistance. The medical, marine, aerospace, and chemical processing industries all benefit from Ti/6063 Al's usability. Tables 3 and 4 demonstrate the mechanical properties and chemical composition of Ti alloys.

Table.3. Titanium alloy chemical composition

Elemen	**Fe**	**Al**	**O_2**	**N_2**	**V**	**Ti**	**C**

ts							
Specimen weight (%)	**0.30**	**5.9 – 6.87**	**0.5**	**0.08**	**4 – 5**	**Balance**	**0.09**

Table.4. Mechanical Properties of Ti

Description	Hardness Rockwell	Hardness, Brinell	Hardness, Vickers	Fatigue strength	Modulus of elasticity	Tensile Strength Yield	Hardness knoop	Tensile strength Ultimate	PR
Composition	**365**	**335**	**350**	**250 Mpa**	**114.7 Gpa**	**885 Mpa**	**365**	**955 Mpa**	**0.453**

3. Results andDiscussions

WEDM was used to cut the profile using a variety of parameters. Table 5 lists the parameters and their values. Experiments were carried out on the WEDM setup as shown, and data was collected on the effect of the most important process parameters on MRR. The experiment was carried out with 9 different combinations for profile1 according to the run conditions shown in Tab. 5.

Table 5 Different input parameter

S.NO	TON (µs)	TOFF (µs)	WF m/min	SPARK GAP SET VOLTAGE (V)	WT (g)	PC Amps
1	7	5	3	35	1300	1
2	6	5	4	50	1300	1
3	6	6	6	60	1300	1
4	7	4	4	60	1300	1
5	7	5	6	40	1300	1
6	7	6	2	50	1300	1
7	8	4	6	50	1300	1
8	8	5	2	60	1300	1
9	8	6	4	40	1300	1

3.1 Calculation of MRR

The Material Removal Rate was determined using a standard formula for each experiment. The diagram (Figure The picture for kerf width for profile – 1 is shown in Figure 1. In addition, the profile 1-9 was subjected to a Surface Roughness inspection. The following are the profile results that were collected.

1. Odometer measured the total length of wire travel for 1st profile = 122mm and the time taken for each experiment.

$$CS = \frac{\text{Length in mm}}{\text{Time taken in minutes}}$$

MRR = CS x Height of the Workpiece (mm^2/minute)

In Figure 2, it can be shown that the first profile has a SR of R 1.765 m.

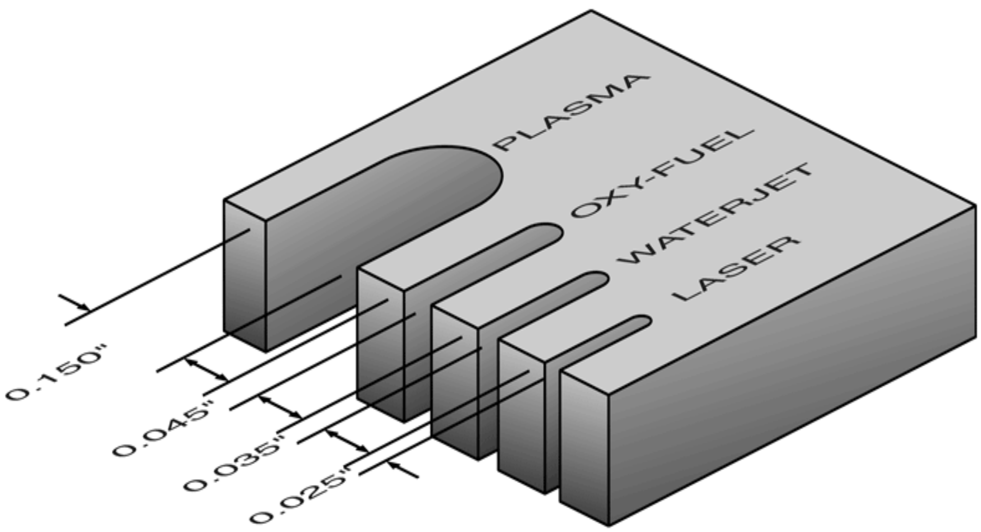

Figure1. Picture of kerf width for profile – 1

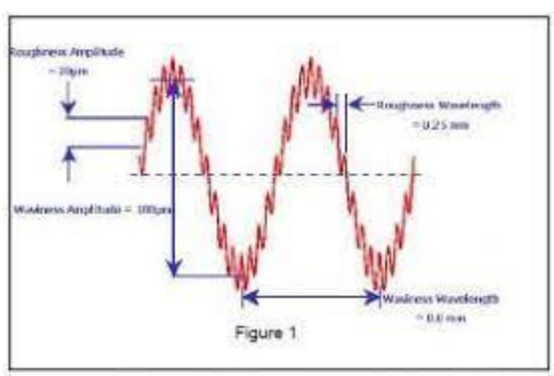

Figure2. SR measurement for 1st profile

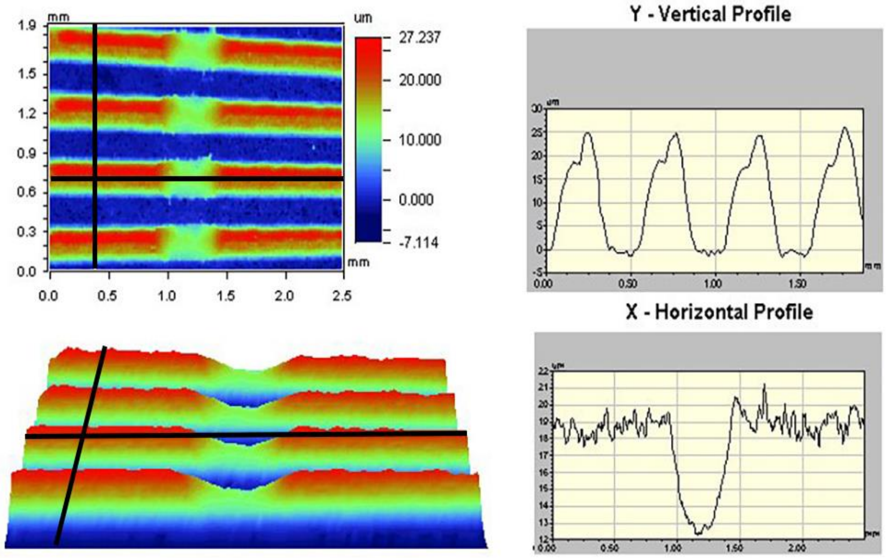

Figure3. SR measurement for 2nd profile

It can be shown in Figure 3 that the second profile has a SR of Ra =1.234 m.

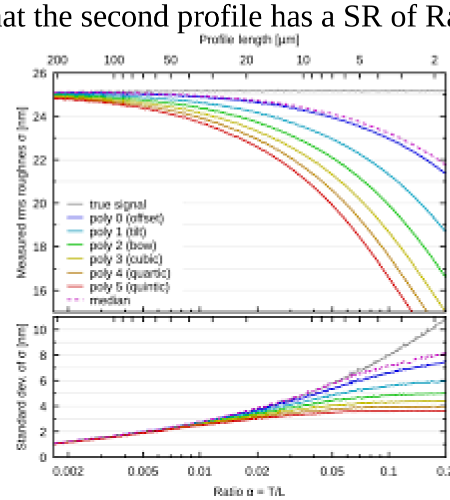

Figure4. SR measurement for 3rd profile

It can be shown in Figure 4 that the third profile has a SR of Ra = 1.300 m.

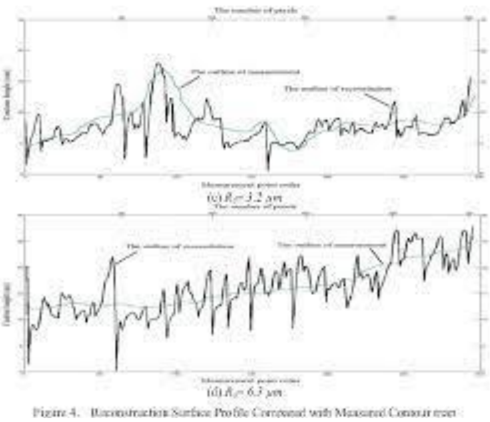

Figure5. SR measurement for 4thprofile

It can be shown in Figure 5 that the 4th profile has a surface roughness of Ra =1.123m.

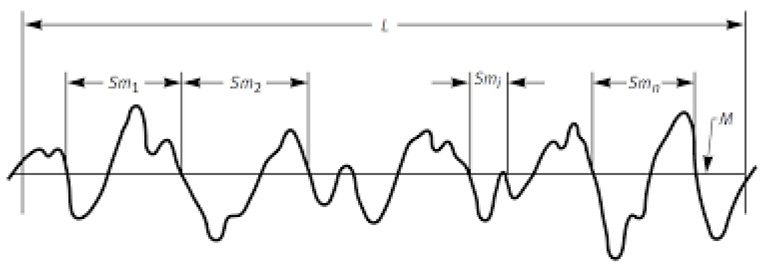

Figure6. SR measurement for 5th profile

It can be shown in Figure 6 that the 5th profile has a surface roughness of Ra =1.177 m.

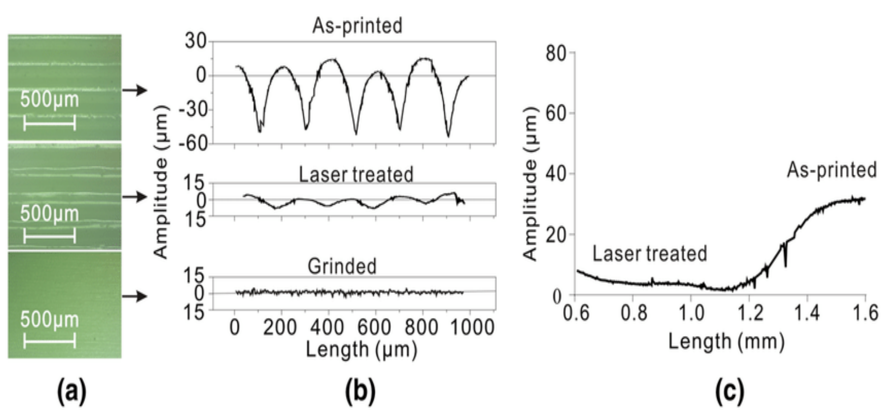

Figure7. SR measurement for 6thprofile

It can be shown in Figure 7 that the 6th profile has a surface roughness of Ra =1.356 m.

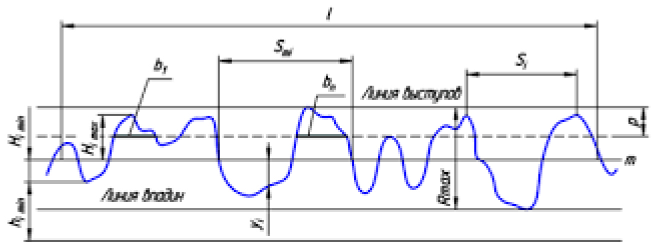

Figure8. SR measurement for 7th profile

It can be shown in Fig. 8 that the 7th profile has a surface roughness of Ra =0.876 m.

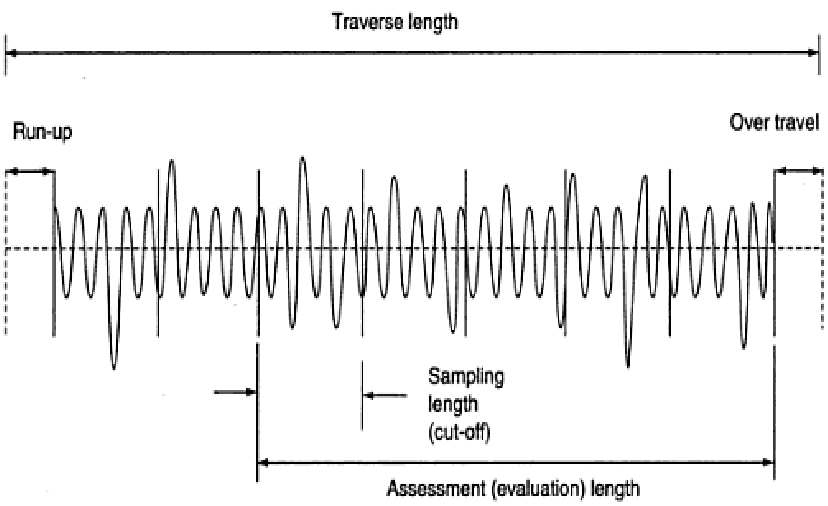

Figure9. SR measurement for 8th profile

It can be shown in Figure 9 that the 8th profile has a surface roughness of Ra =1.189 m.

Table.6. Experimental results

S.NO	TON (µs)	TOFF (µs)	WF mm/min	SPARK GAP SET VOLTAGE (V)	Cutting Speed (mm/min)	MRR (mm^2/min)	SR (µm)
1	5	6	1	35	4.01	4.99	2.103

2	7	4	4	50	3.61	6.49	1.193
3	8	4	6	60	4.04	7.27	1.283
4	6	5	4	60	2.89	5.19	1.085
5	7	5	6	40	2.97	5.35	1.182
6	8	5	2	50	3.16	5.68	1.243
7	6	6	6	50	2.59	4.66	0.985
8	7	6	2	60	2.89	5.19	1.136
9	8	6	4	40	2.97	5.35	1.170

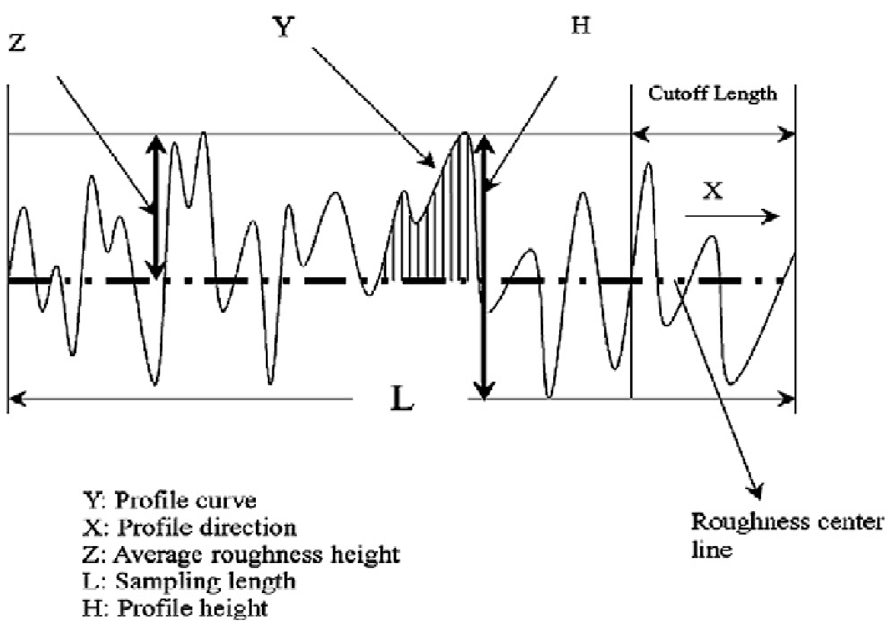

Fig10. SR measurement for 9thprofile

The surface roughness of the profile – 9 is calculated at Ra = 1.170 m, as shown in Figure 10. Table 6 shows the MRR, cutting speed and surface roughness. Figure 11 indicates that a higher signal-to-noise ratio corresponds to a higher MRR. The SNR is higher at D3, A1, C3, B3, and an MRR is best at this range. The non-linear signal to noise ratios was perfectly matched on a linear possibility plot with a p-value of 1.379, as shown in Figure 12.

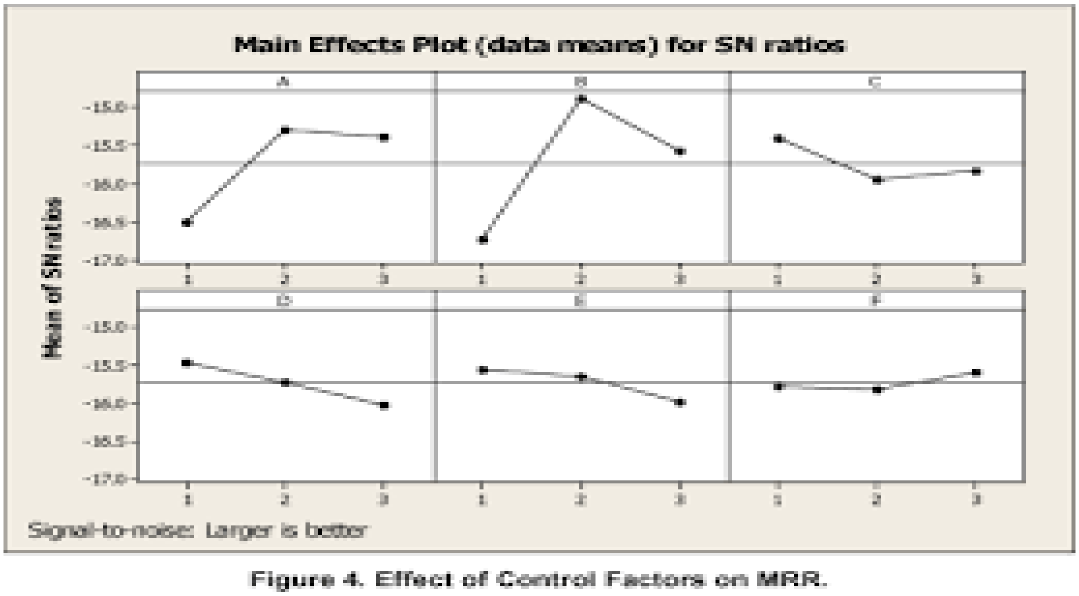

Figure11. Plot of main effects for MRR S/N ratios

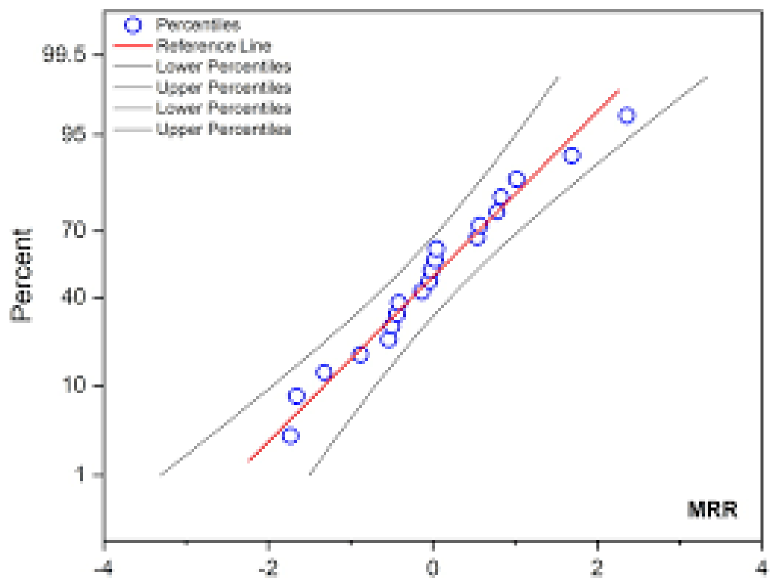

Figure12. NP plot for S/N ratios of MRR

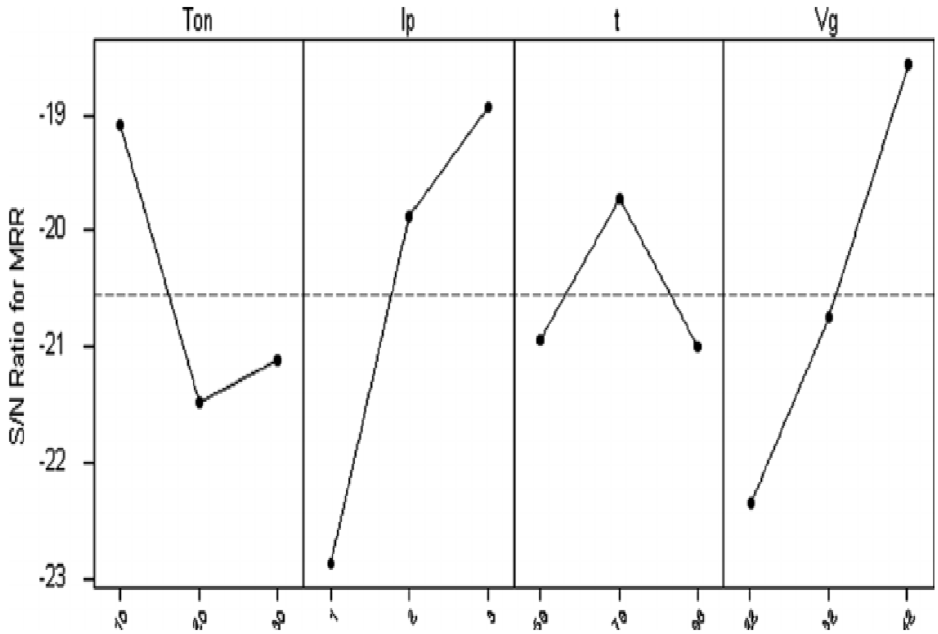

Figure13. S/N ratios of MRR Vs TON, TOFF on a contour plot

The contour plot for the signal to noise ratio for MRR in Fig 13 and also shows the higher S/N ratio and the better MRR. The S/N ratio in the greener area is the highest, resulting in higher MRR. The Surface Roughness is ideal for a lower signal-to-noise ratio, as shown in Figure 14. The SNR is lower at A1, B1, C1, D3, and Surface Roughness is at its best at this range. The graph above shows that cutting speed is directly proportional to MRR. The Pulse of Time is kept constant for the first 3 experiments while the PT differs.

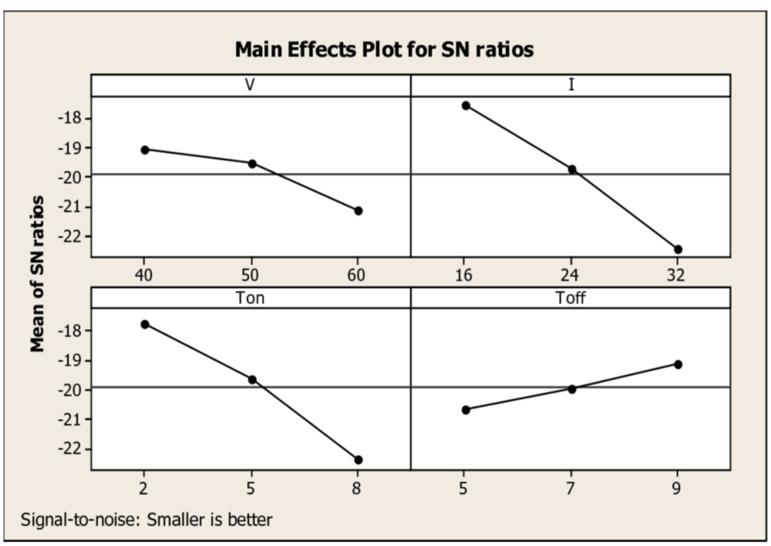

Figure14. Plot of main effects for SR S/N ratios

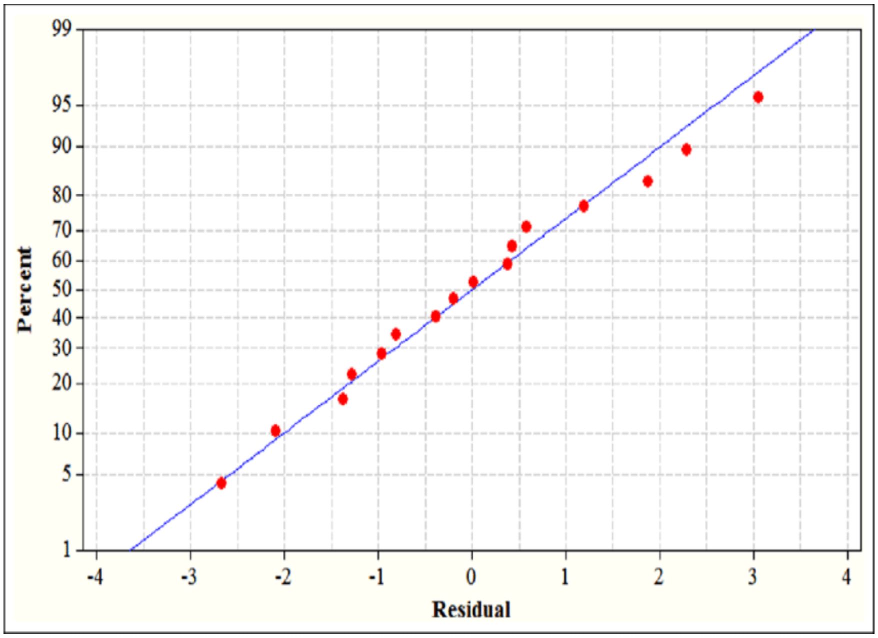

Figure15. NP plot for S/N ratios of SR

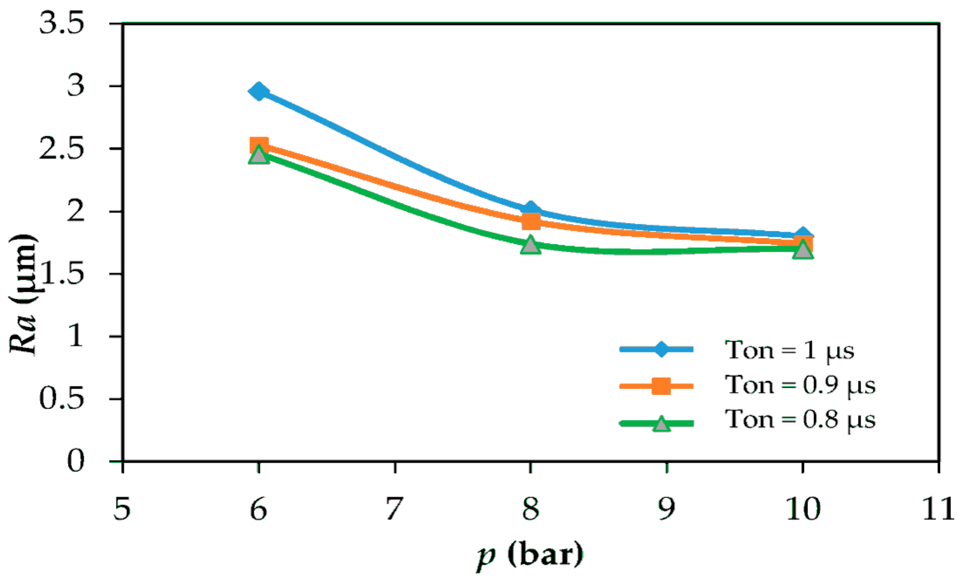

Figure16. S/N ratios of SR Vs TON, TOFF on a contour plot

At Ton = 9s, the maximum MRR of 6.98mm2/min is obtained. The pulse of time is marginally longer in the second series of three trials, and the MRR is lower than in the previous one, as shown in the table. The third set of trials suffers from the same problem. The cutting speed has a direct impact on SR. The SR is calculated as a high value of 1.459m for the high cutting speed, which correlates to a high MRR. High MRR 6.98 mm2/min is obtained for a high cutting speed of 3.99mm/min.

Conclusions

The effect of WEDM process parameters on Titanium Ti/6063 Al is discussed in this paper. WEDM for Titanium machining was investigated. Four process parameters have been chosen, each with three levels. For machined Titanium, the high metal removal rate (MRR) was measured. Confirmation studies have verified the optimal process levels using the multiple characteristic control schemes. Ton = 9 s, Toff = 5 s, WFR=7 mm/min, and GV=40 V are the best process parameters to use. CS = 3.99mm/min, MRR = 6.98mm2/min, and SR=0.876 m are the experimental values that correspond to this setting. MRR, Surface roughness, and cutting speed are the characteristics of process Parameters in WEDM. Taguchi Parameter Design will be used to analyze these parameters with various input process parameters. Furthermore, various process parameters achieving higher machining efficiency by obtaining a low surface roughness, cutting speed, and MRR.

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