EFFECT OF PROCESS PARAMETERS OF MACHINING IN CNC WIRE-CUT EDM FOR ALUMINIUM

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ABSTRACT: The objective of this present work is to investigate the effect of input process parameters of wire electrical discharge machining on aluminium, which are now widely used in many Aerospace, Automotive, Marine, Rail, Building, Mechanical industries. The tool material damages the work piece due to chipping, presence of burrs. Wire cut Electrical discharge machining technique is a thermo electrical process capable of machining complex shapes and any hardness of conductive materials which are difficult to machine with traditional machining methods. As a part of the present research work, aluminium is to be machined in wire cut edm machine and the effect of five process parameters such as pulse on time (T_{on}), pulse off time(T_{off}) ,wire feed rate, table feed and servo voltage on Material removal rate and surface roughness is to be investigated. The experimental plan is based on Taguchi method using five factors each at three levels. The experiment was done with brass material of diameter 0.25 mm. Total no of 27 experiments were done. Different graphs were plotted to observe the effect of the input parameters on output parameters such as Material Removal Rate, Surface roughness. It was concluded that highest material removal rate was 21.164 mm^3/min which was due to high pulse on time and table feed and low pulse off time and servo voltage. Low surface roughness was 2.555 µm which was due to low pulse on time, pulse off time, table feed, wire feed rate and high servo voltage. Taguchi method is a good method to find out effect of process parameters on response parameters.

KEYWORDS: WEDM, Process parameters, T_{on}, T_{off}, Taguchi method.

INTRODUCTION

Machining is the process of material removal from a metal to produce a desired shape, size, accuracy of a desire product. The work piece used in the machining process can be of different shapes. It can be of flat sheet, hollow tubes, different type of beams etc [12]. Machining process requires man power, technical knowledge, machine tool etc. to do the machining work efficiently. It is impossible to get a finished product without a proper machining process. Two different types of machining process are used for machining operations. These are Conventional machining process and Non-conventional machining process.

In conventional machining process, machining process is done manually. The machine operator has the main work to do the machining operation. The more the machinist is experienced, the smoother the machining operation is done . In non-conventional machining process, all the work related to machining is done by machine. The machines are CNC controlled. The input is provided to the computer through key board. The computer executes the program and does the machining operation. The product produced through non conventional machining process is more finish and accuracy than conventional machining process.

Wire electrical discharge machining is now widely used in manufacturing industries. Accuracy , quality of the product have been improved to a higher level by this process[9].WEDM is a thermo- electric process in which material is removed by continuous sparks between work piece and wire electrode. The part and wire are immersed in a dielectric fluid, usually de ionized water, which also acts as a coolant and flushes the chips away [6]. In WEDM, there is no direct contact between work piece and tool as in conventional machining process, therefore materials of any hardness can be machined and minimum clamping pressure is required to hold the work piece. The selection of machining parameters in WEDM is an important task. Wire breakage, work surface damage can be occurred due to selection of improper selected parameters [9].The effectiveness of the whole process depends on number and different input process parameters. In this process, descriptions of various process parameters and their influence on respective responses have been presented.

LITERATURE REVIEW

Singh H. et.al [1] investigated the effect of different process parameters of WEDM on material removal rate using one factor experiment strategy by hot die steel. Different process parameters such as pulse on time, pulse off time, gap voltage, peak current , wire feed rate and wire tension were taken.
Sajuri Z. et.al [2] conducted the experiment to find the effect of wire electrical discharge machining cutting on fatigue strength of AZ61 magnesium alloy at room temperature. The surface high cycle fatigue tests were performed on both wire edm. Fractographic analyses were conducted on the tested samples to identify the mechanism of fatigue fracture. Wire edm cutting parameters affected the surface quality of AZ61 magnesium alloy.
Kumar R. et.al [3] analysed the current research trends in wire electrical discharge machining. Prediction of material removal rate and surface finish by machining AISID2 tool steel was done by developing mathematical models. Response surface methodology and artificial neural networks were used for the modelling of cutting speed and surface roughness.
Sivakiran S. et.al [4] studied the effect of machining parameters such as pulse on time, pulse off time, bed speed and current on material removal rate in WEDM. Linear regression was used to develop the relationship between control parameters and output parameters. EN 31 tool steel was used for the experiment.
Malik M. et.al [5] did an experiment to optimize the process parameters of wire edm. Grey relational taguchi method was used in this experiment. Material removal rate , electrode wire rate , surface roughness were the response parameters. It was concluded that pulse peak current was the most critical factor affecting MRR and duty factor was the least significant parameter.
Rao M.S. et.al [6] reviewed the effect of WEDM process parameters on different performance parameters. They also reviewed the various optimization method applied by the researchers and outlined the future trends in WEDM research.
Ariktla S.P.et.al [7] did the investigation of effect of input process parameters of WEDM on respoinse parameters. Titanium alloy was used for machining. Optical microscope was used to observe surface topography.
Nourbaksh F. et.al [8] investigated the effect of process parameters such as pulse width, servo voltage, pulse current, wire tension on performance parameters such as cutting speed, wire rupture, surface integrity in WEDM. Taguchi method was used in this experiment. The work piece used here was titanium alloy. SEM examinations were performed to understand the effect of different wires on work piece material surface characteristics.
Sivaraman B. et.al [9] developed optimal control parameters of machining in CNC Wire-Cut EDM for Titanium. Taguchi method was used to improve the multi response characteristics of MRR and surface roughness.

EXPERIMENTAL DETAILS

In wire electrical discharge machining, a thin wire is fed through the work piece which is submerged in the tank of dielectric fluid, generally deionised water [9]. The wire which is fed from the spool is taken through upper and lower guides. There is also a CNC controlled system in which all the operation are controlled through the computer.

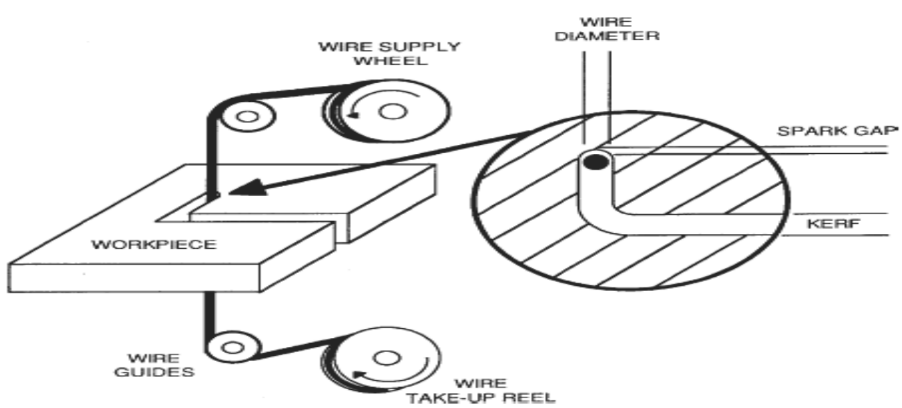

Figure. 1. Schematic diagram of WEDM [1]

This thesis work was done in Central Tool Room and Training Centre, Bhubaneswar and Central Institute of Plastic Engineering and Technology, Bhubaneswar. An Electronica manufactured Ecocut model CNC WEDM machine was used to do the experiments. The specification of the machine is (250*350*200) mm, weight is 2 Tonne and accuracy is 5 micron.

Figure. 2. Wire EDM machine in C.T.T.C, Bhubaneswar

The machine has four main components.

1. Computer Numerical Control
2. Power Supply
3. Dielectric System
4. Mechanical Section

Process Parameters

The process parameters are the factors which influence the response variable. Pulse on time, pulse off time, table feed, wire feed rate , servo voltage are the some of the process parameters used in WEDM.

Work piece material

Aluminium

Pure Aluminium is soft, ductile, corrosion resistance material. It is one of the lightest material having strength to weight ratio more than steel. Thermal conductivity of Aluminium is three times greater than steel.

Table. 1. Chemical composition of Aluminium[41]

Elements	Weight %
Al	99.7 %
Fe	0.05- 0.18 %
Si	0.03- 0.09 %
Cu	0.005 %

Methodologies

Minitab Software

It is a software which is used by many researchers to design different tables of experiment and find the result of calculation and graph of output. Different types of control chart can be made by this software.

Design of Experiment

By changing the process parameters which affect the machining process, the experiments are to be done to obtain best quality characteristics. Quality characteristics are the output values derived from the experiments.

Experimental procedure

First, a metal piece of Aluminium (350*10*20) mm was brought. Five factors such as pulse on time, pulse off time, table feed, wire feed rate and servo voltage were used. Three levels of these factors were taken. The table of factors and levels were given below:

Table. 2. Table of Factors and Levels

Input factor	Level 1	Level 2	Level 3
Pulse on time	3	6	9
Pulse off time	3	6	9
Table feed	4	8	10
Wire feed rate	2	4	6
Servo voltage	4	5	6

Total 27 experiments were done with the help of Minitab software. For doing experiments, the weight of the work piece by the help of weight measuring machine was measured. Then machining was done with the help of WEDM machine. Then surface roughness was measured with the help of surface roughness tester.

Figure. 3. Weight measuring machine in CTTC, Bhubaneswar

Figure. 4. Work piece machined in C.T.T.C,Bhubaneswar

Figure. 5. Surface roughness tester in CIPET, Bhubaneswar

Sl. No	Pulse on time	Pulse off time	Table feed	Wire feed rate	Servo voltage	Initial weight (gm.)	Final weight (gm.)	Diff.	Mach. Time (Min.)
01	3	3	4	2	4	248.4	248.1	0.3	8.15
02	3	3	4	2	5	242.6	242.5	0.1	9.17
03	3	3	4	2	6	237.2	236.9	0.3	11.09
04	3	6	8	4	4	231.4	231.2	0.2	7.00
05	3	6	8	4	5	225.9	225.7	0.2	8.30
06	3	6	8	4	6	220.4	220.2	0.2	11.08

07	3	9	10	6	4	214.8	214.6	0.2	7.34
08	3	9	10	6	5	209.2	208.8	0.4	9.22
09	3	9	10	6	6	203.5	203.4	0.1	12.21
10	6	3	8	6	4	197.8	197.6	0.2	4.27
11	6	3	8	6	5	192.4	192.3	0.1	5.31
12	6	3	8	6	6	186.9	186.6	0.3	7.20
13	6	6	10	2	4	181.2	181.1	0.1	5.18
14	6	6	10	2	5	175.8	175.5	0.3	6.49
15	6	6	10	2	6	170.3	170.1	0.2	9.02
16	6	9	4	4	4	164.7	164.5	0.2	7.39
17	6	9	4	4	5	159.3	159.2	0.1	9.00
18	6	9	4	4	6	153.8	153.7	0.1	10.35
19	9	3	10	4	4	148.3	148.1	0.2	3.30
20	9	3	10	4	5	142.7	142.6	0.1	4.26
21	9	3	10	4	6	137.2	137.1	0.1	6.25
22	9	6	4	6	4	131.6	131.4	0.2	6.46
23	9	6	4	6	5	126.1	126.0	0.1	7.08
24	9	6	4	6	6	120.6	120.4	0.2	8.44
25	9	9	8	2	4	115.2	115.0	0.2	4.53
26	9	9	8	2	5	109.8	109.6	0.2	6.08
27	9	9	8	2	6	104.4	104.2	0.2	8.38

Calculation

To measure the material removal rate , the formula used given below:

$$\text{Material Removal Rate} = \frac{\text{Weight loss from the work piece}}{\text{Density of the work piece} * \text{Machining time}}$$

RESULT AND DISCUSSION

The graph between pulse off time, table feed and wire feed rate with Material Removal Rate and Surface roughness were plotted.

Effect of input parameters on MRR

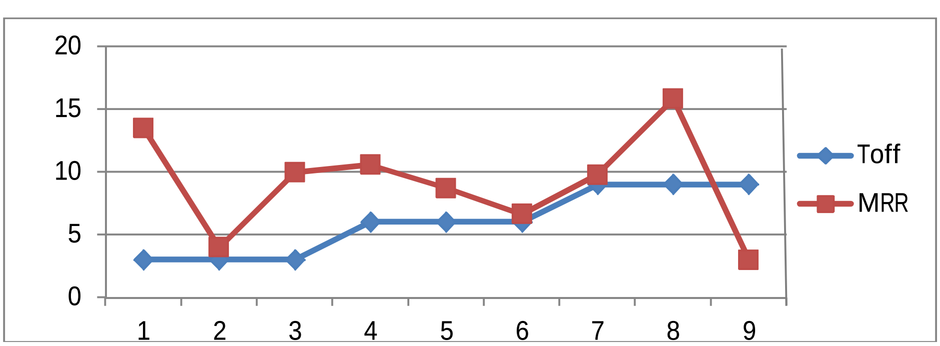

Figure. 6. Graph between T_{off} and MRR when T_{on} is constant = 3

This is the graph between pulse off time and Material Removal Rate. It is clearly seen that, when T_{off} is 3, then the value of Material Removal Rate is first decreased and then increased. The change in the value of the MRR is due to servo voltage value. For the first three experiments, the value of servo voltage is 4, 5, and 6. So when the value of servo voltage is increased from 4 to 5, then MRR is decreased and again when the servo voltage value is increased, the MRR value is decreased. After that when the value of pulse off time is 6, then MRR is decreased. Then when the pulse off time is 9, then the MRR is increased and then decreased.

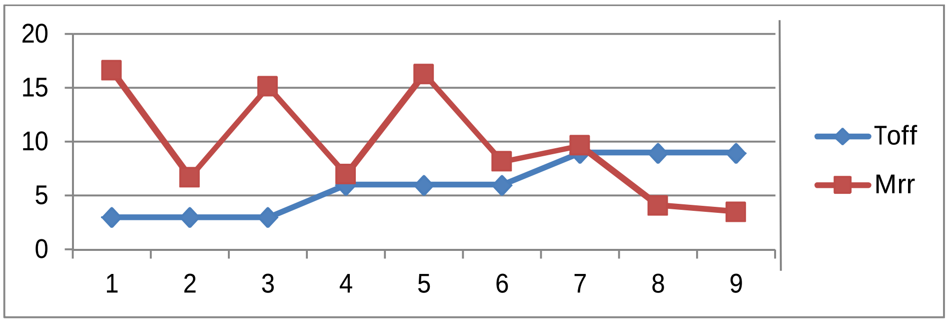

Figure. 7. Graph between Toff and MRR when Ton is constant = 6

When the Toff is 3, MRR is first decreased and then increased. When the Toff is 6, then MRR is increased and then decreased. When the Toff is 9, then MRR is reduced.

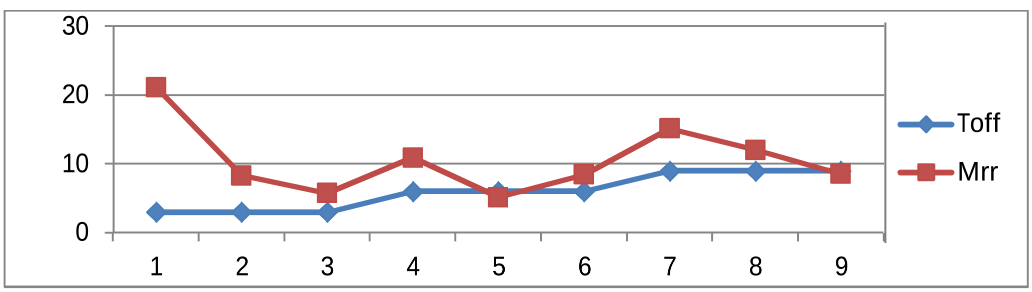

Figure. 8. Graph between Toff and MRR when Ton is constant = 9

It is observed that when Toff is 3, then the value of MRR is decreased .When the value of Toff is 6, then MRR value is decreased and then increased and when the value of Toff is 9, then MRR value is sharply decreased.

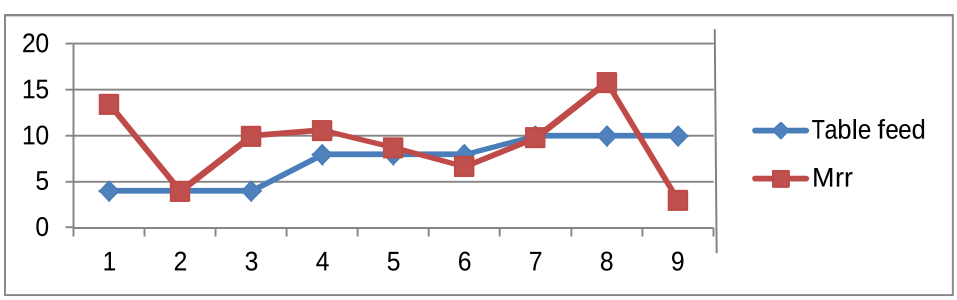

Figure. 9. Graph between table feed and MRR when Ton is constant = 3

When the table feed value is 4, then MRR value is sharply decreased and then increased. When the table feed value is 8, then MRR value is decreased and when table feed is 10, then MRR is increased and then decreased.
When the table feed is 8, MRR value is decreased and increased. When table feed is 10, MRR is increased and decreased. When table feed is 4, MRR value is first sharply decreased and then slowly decreased.
When table feed is 10, MRR is sharply reduced and then slowly reduced. When table feed is 4, MRR value is decreased and increased and when the value is 8, MRR is reduced.

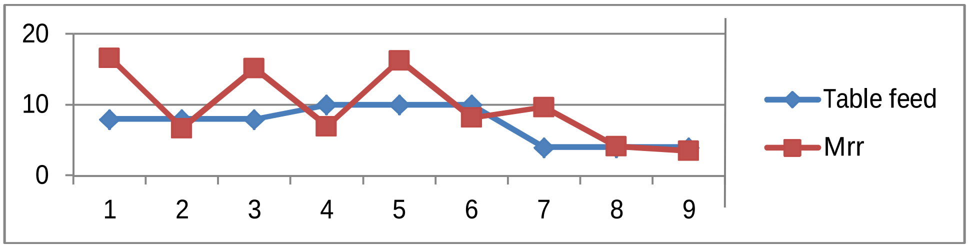

Figure. 10. Graph between table feed and MRR when Ton is constant = 6

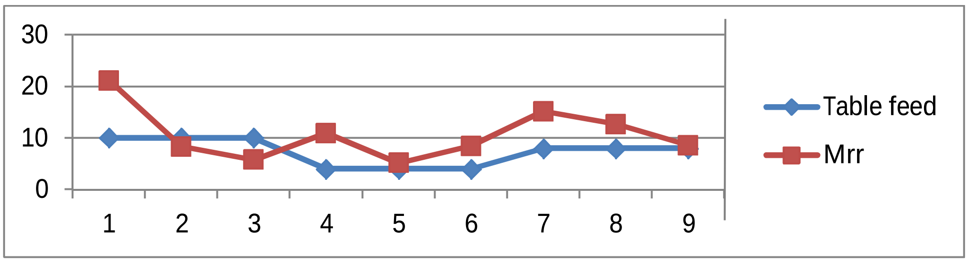

Figure. 11. Graph between table feed and MRR when Ton is constant = 9

Effect of input parameters on Surface roughness

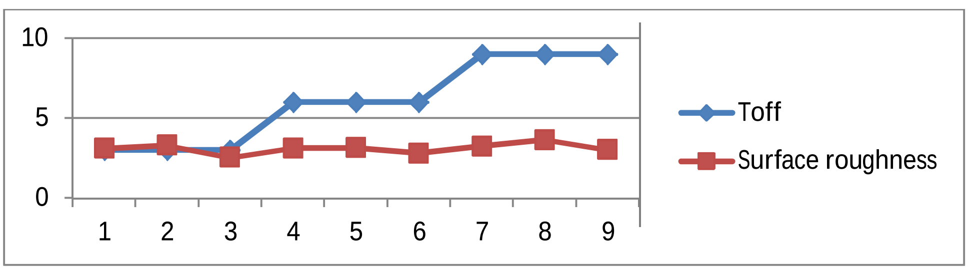

Figure. 12. Graph between Toff and surface roughness when Ton is constant = 3

When Toff is 3, surface roughness is increased slightly and then decreased slightly. When Toff is 6, surface roughness value is slightly increased and decreased. When Toff is 9, surface roughness value is slightly increased and decreased.

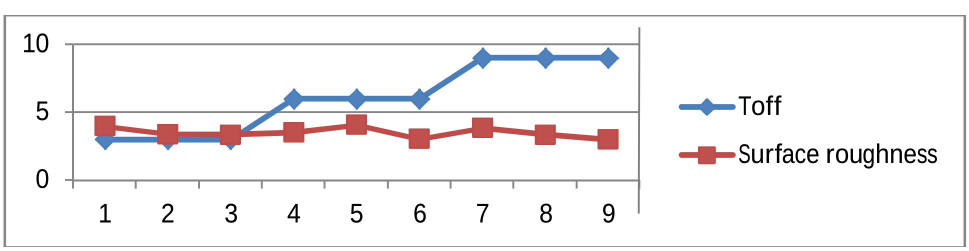

Figure. 13. Graph between Toff and surface roughness when Ton is constant = 6

When the value of Toff is 3, then surface roughness value is slightly decreased and then decreased very slightly that known to be as constant. When Toff is 6, then surface roughness is increased and then decreased. When Toff is 9, then surface roughness value is decreased.
With the increase of value of Toff is from 3 to 9 , the surface roughness value is decreased continuously.
When the table feed is 4, surface roughness is slightly increased and then decreased. When table feed is 8, surface roughness is just increased and then decreased and when table feed is 10, surface roughness is increased and then decreased.
When the table feed is 8, then surface roughness value is slightly decreased and then very slightly decreased. When the table feed is 10, then surface roughness value is increased and then decreased. When the value is 4, then surface roughness value is decreased.

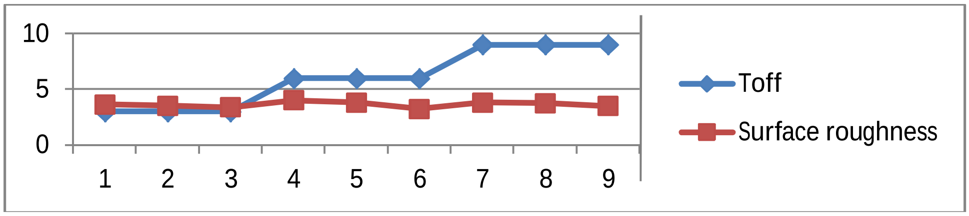

Figure. 14. Graph between Toff and surface roughness when Ton is constant = 9

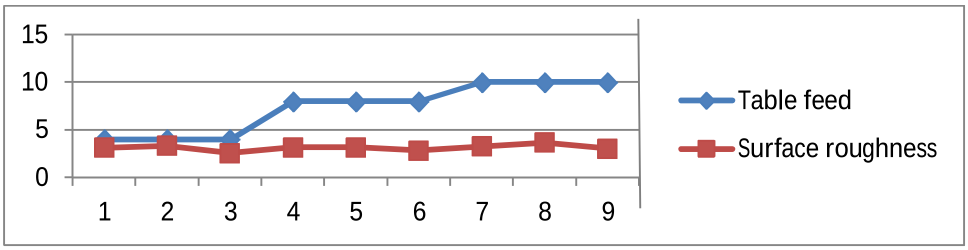

Figure. 15. Graph between the table fed and surface roughness when Ton is constant = 3

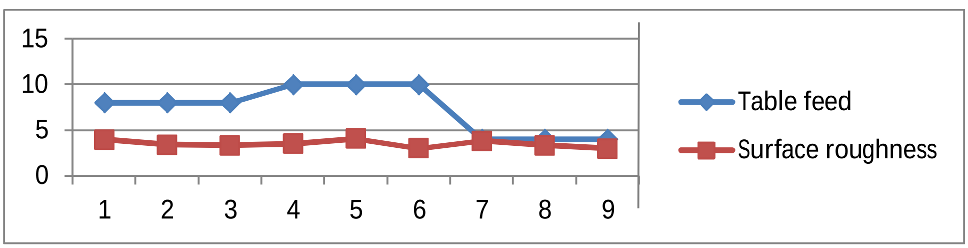

Figure. 16. Graph between table feed and surface roughness when Ton is constant = 6

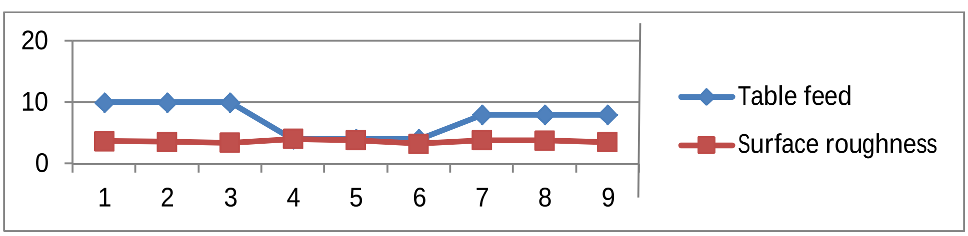

Figure. 17. Graph between table feed and surface roughness when Ton is constant = 9

When table feed is 10, surface roughness value is decreased. When table feed is 4, surface roughness value is decreased continuously. When the value is 8, then surface roughness value is decreased.

Confirmation Experiment

It is confirmed from the experimental value that 21.164 mm^3/min is the highest material removal rate and 2.555 µm is the minimum surface roughness value.

CONCLUSION

In this paper, different experiments were done to find the optimal input parameter combinations in WEDM for material removal rate and surface roughness by taking Aluminium material. The following conclusions were made for this present work.

1. The highest Material Removal Rate is 21.164 mm^3/min which is the 19^{th} experiment i.e. the highest MRR is obtained when Ton and table feed is high, Toff and servo voltage is low and wire feed rate is medium.
2. The lowest surface roughness is 2.55 µm which is obtained in 3^{rd} experiment. It was found when Ton, Toff , table feed , wire feed rate at it's lowest value or level and servo voltage was at it's highest value or level.

3. All the input parameters have effect on Material Removal Rate and surface roughness. But servo voltage has more effect on both of these.

It was found that, better machining result, good surface finish, less machining time can be obtained by controlling the input parameters.

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