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Research Article

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To Study the Effect of Process Parameters on Surface Roughness during Electric Discharge Machining of Al6061t6 Work Piece with Graphite Electrode

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Abstract In most industries, Manufacturing with machining plays a greater role because the formation of parts need surface finish during the machining process. The non-conventional machining processes are only method to machine hard materials. Electric Discharge Machining (EDM) is one of such processes used for removing the material in hard materials. It is non tradition by means of thermal energy instead of cutting force. In this study, experiments are carried out to find the optimum values of the parameters for addressing the issue of surface roughness in aluminium parts produced with graphite electrode in EDM.

The experiments are carried out on ZNC-250 die-sink electric discharge machine for drilling of Aluminium T061 work piece using Graphite rod as electrode. In order to understand the response of the system, experiments were conduct out at three levels of Current (I), Pulse-on Time (T_{on}), Pulse-off Time (T_{off}) and Servo Voltage (V).

From the measured value of Surface Roughness (SR), it is found that the surface finish deteriorates with increase in current. Current is found to be the highest effect factor which has highest upshot on the Surface Roughness followed by pulse off time and last by pulse on time.

Keywords Surface Roughness, Pulse on time, Pulse off time, Current

1. Introduction

In production, metal forming and machining are the two main processes. In metal forming, the shapes are produced by material displacement without material removal, whereas the desired shape is obtained in the machining processes by removing extra material from the initial stock. In most of the industry, manufacturing with machining contributes to a greater extent as even the formed parts require finishing by material removal.

Electric discharge machining (EDM) is one of the most widely used non-conventional machining processes. Electro Discharge Machining (EDM) is an electrically thermal non-conventional machining process, where electrical energy is used to generate an electrical spark and removal of material mainly due to the thermal energy of the spark EDM is now developed into the most important accepted technologies, since many complicated 3D shapes can be machined using an uncomplicated size tool electrode. In the manufacturing industry, electro-discharge machining (EDM) is commonly used for the production of mold and die components. This machine is used because the ability of the machining process is very accurate in creating complex or simple shapes within parts and assemblies. The cost of machining is much more due to the machine for its initial investment and maintenance, but it is a highly desirable machining process when high accuracy is required.

EDM has been substituting traditional machining operations. Now today EDM is a popular it is one of the main methods used in die production and there is no direct physical contact between the electrodes so that no mechanical stresses developed on the work piece. Electric discharge machining is also known as thermal erosion process where tool and work piece do not come in to the contact with each other during machining process. The progression of events constitutes the process of material erosion from the work surfaces.

2. Review of Literature

Hung (1994) explored the feasibility of applying the EDM approach to silicon carbide particle-reinforced cast Aluminium matrix composite. In order to predict the effect of process parameters on MRR, re-cast sheet, and SR, they built a statistical model [6]. The presence of SiC particles has been revealed to result in decreased MRR. This is because the Aluminium matrix is insulated and protected from vaporization by these particles. MRR and recast layer depth have been stated to be mainly regulated by input power and the current alone dominates the machined surface finish.

Shahzad (2010) investigated the effect of process parameters like pulse on time, discharge current and diameter of electrode on material removal rate (MRR), tool wear rate (TWR) and over cut. The experiments were done using AISI P20 tool steel as workpiece and U-shaped copper tool as electrode with internal flushing system. The S/N ratios was used for minimizing the TWR and maximizing the MRR and Taguchi method was used for optimization of the process parameters [12]

Guu, Y.H. (2005) reviewed electronic discharge machine research shows that it is a important machining process both process of electrical and thermal occur simultaneously, and that most significant areas of interest in electronic discharge machining research are enhancing the machining performance such as surface roughness and electrode material removal rate by different ways [5].

Hocheng (1997) conducted a preliminary analysis of the SiC / Al composite MRR and surface roughness. For single and continuous discharge, material removal characteristics were tested. The study starts with a single discharge and a relationship between the crater size and the given discharge parameters has been found. Two heat conduction models were used for the calculation of the crater size [10]. The material removal rate has been greatly enhanced, as expected. For efficient machining of SiC / Al, broad current and short on-time is recommended.

Karthikeyan (1999) focused on the mathematical simulation of Aluminium-silicon carbide particulate composites for electric discharge machining. They studied the effects on the MRR, TWR, and SR of the percentage volume of SiC, current and pulse length. With an increase in the current, the MRR rises and with an increase in the percentage volume of SiC and the pulse length decreases[7]. With an increase in the current and the percentage amount of SiC, the TWR inscreases but decreases with an increase in the length of the pulse. With an increase in the current, the percentage volume of SiC and the pulse length, the surface roughness increases.

RiazAhamed (2009) worked on applying (EDM) did a study, focused on optimization of electrical discharge machining process parameter for maximization of material removal rate during machining of NiTi alloy[1]. They revealed that work electrical conductivity, gap current and pulse on time were important parameters that have an effect on the material removal rate. The optimized surface roughness obtained based on optimum setting of input parameter.

Kathiresan (2010) studied EDM using a copper electrode. Studies showed that the current and %age weight of silicon carbide significantly affected the MRR and surface roughness[7]. With an increase in the current and decrease in the %age weight of silicon carbide, the MRR increases. With a reduction in the current and an improvement in the %age weight of silicon carbide, the surface finish increases. In comparison with Aluminium 6061, Mouangue Nanimina et al. investigated machining efficiency characteristics on AMMC strengthened with 30 % Al_2O_3. To evaluate their effects on the reinforced MMC's MRR and TWR, main process parameters such as current, pulse on and pulse off were varied. A high peak current and on time value has been shown to increase Al6061 MRR rapidly rather than AMMC while decreasing with the increase in off time. At low peak current and on-time, instrument wear was greater than off-time.

Velmurugan (2011) investigates the impact on the machining of hybrid Al6061 metal matrix composites reinforced with 10 %SiC and 4 % graphite particles by parameters such as current, pulse on time, voltage and flushing pressure on MRR, tool wear rate and SR. With an increase in current, pulse time, and flushing pressure of the dielectric fluid, the metal removal rate of the composite increases as it decreases with an increase in voltage. With the rise in current and voltage, the tool wear rate of the formed composite increases and decreases with the increase in pulse time and flushing pressure of the dielectric fluid. During electrical discharge machining, the surface roughness of the composite increases with an increase in current, pulse duration, voltage and flushing pressure [13].

Non-conventional manufacturing processes are characterized as a group of processes that extract excess material through different techniques or combinations of these energies involving mechanical, thermal, electrical or chemical energy, but do not use sharp cutting tools as they need to be used for traditional manufacturing processes. With chip forming, material removal may occur or even no chip formation may take place. The key attraction of EDM over conventional machining methods, such as metal cutting using various instruments and grinding, is that this technique uses a thermoelectric approach to erode undesired materials from the work piece through a series of discrete electrical sparks between the work piece and the electrode.

In AJM, for example, chips are of microscopic size and electrochemical machining material removal occurs due to atomic level electrochemical dissolution in the case of electrochemical machining material removal. As in traditional machining processes, material in the form of chips is often extracted by applying forces to the work material with a wedge-shaped cutting tool that is harder than the machining material.

Sandhu HS, Mehta V, Manchanda J, Phull GS (2015) concluded that negative polarity performs higher material removal rate and it has lesser tool wear when graphite electrodes are used. It was also analyzed that the discharge current and the pulse on time have a direct impact on the material removal rate and the surface roughness, being the highest values of material removal rate and surface roughness [11].

Muthuramalingam (2015) gave a review on the influence of electrical process parameters in EDM process. This study examines an overview of the EDM method, the modeling of process parameters and the effect of process parameters on performance measurements such as material removal rate, surface roughness, and electrode wear rate, such as input electrical variables, pulse shape and discharge energy.

Kumar (2017) analyzed the work to maximize the Material Removal Rate (MRR) and minimize the Surface Roughness (SR) value. Discharge current (I), source voltage (V), pulse-on time (Ton) and pulse-off time (Toff) are the process parameters considered in their experimental work. They have applied the Taguchi method and ANOVA analysis based on DOE and Taguchi to optimize the two process performance factors mentioned above, that is SR and MRR [12].

In order to achieve the best (optimum) desired outcome under the given specified experimental conditions, optimization is used for results. The most important aim of the decision is either to minimize the effort / time needed or to maximize the product’s desired results / benefits or economic benefits. The conventional method of selection of combinations of parameters in EDM does not provide adequate or desirable results. EDM process parameter optimization has been treated as a single-objective optimization process and a multi-objective problem for optimization. Experiment design (DOE) approach such as the Taguchi process is used to actually minimize the experimental runs [9]. According to this, electrical discharge machining (EDM) is the best tool for optimizing process parameters-pulse on time, pulse off time, current, voltage etc.

3. Experimentation and Data Analysis

To achieve the desired objective or objective when researching specific fields of interest, some kind of suitable approach or technique would be required to achieve that mission. It is therefore examined, according to the reviewed literature that statistical or mathematical techniques have proven to be the researchers' best option for many years to optimize their findings or to predict the nature of various parameters with the output value [8]. These approaches can include design of experiment, analysis of variance (ANOVA), correlation approach, Taguchi technique procedure, regression technique, and many more. For optimization or to obtain the best set of results, these techniques are extremely important because without such techniques, it is tedious to assume the effect of various parameters on the output values with accuracy.

The experiment is planned for various combinations of cutting variables using fractional (Taguchi experiment design) and total factorial experiment design (DOE). Variance analysis (ANOVA), correlation and regression technique are used to study the output characteristics as per DOE at different conditions.

4. Proposed plan of work (Methodology)

It can be analyzed from the literature review that there are several independent parameters in the machining process that impact the surface roughness (SR). After the machining process, the surface roughness will be measured using the surface roughness tester MITUTOYO SURFTEST 210.

Figure 1: Surface Tester

In this study In order to reduce the surface roughness (SR) in Aluminium 6061 T6 with the aid of adjusting the input parameters-current, voltage and pulse on time and pulse off time for operation on the EDM, with graphite electrode tool. Applying Taguchi method for analysis and optimization of variables.

The materials to be used in experiment are given below:

Table 1: Material required in experiment

S. No.	Object	Material
1.	Tool (Electrode)	Graphite
2.	Work piece	Aluminium 6061 T6

5. Tool (Electrode) Material:

The exceptional features of Graphite make it the ideal substrate for electrodes. In manufacturing and other uses, such as mould making, general engineering and micro machining, graphite is mainly used for electrical discharge machining (EDM).

- Fast and simple machining, no deburring
- Increased removal rate and high wear resistance compared with copper
- Lightweight with a 4 times lower density than copper
- Elevated thermal stability and high thermal shock resistance

It can be seen from the literature review that the graphite electrodes have resulted in the smoothest surface roughness. It appears that the greater the electrical conductivity, the greater the flow of current. Consequently, it affects the roughness of the work piece. The larger currents were used, the higher the acquired surface roughness value.

6. General Characteristics Aluminium 6061 T6:

In many of the manufacturing operation, especially involving Aluminium 6061T6 , shearing is one the fastest process to reduce the raw stocks into desired lengths and other dimensions. The shear edges needs to be sharp and capable of retaining sharpness even after long periods of use. The material properties that are generally of most interest when choosing the optimum material for a particular cutting application include:

- Wear resistance
- Toughness or shock resistance
- High working capacity

- Anti corrosive
- Low cost and easily available

Table 2: Chemical Composition of Aluminium 6061 T6

S. No.	Element	Composition %
1.	Aluminum	95.8-98.6
2.	Chromium	0.04 – 0.35
3.	Copper	0.15-0.4
4.	Iron	Max 0.7
5.	Magnesium	0.8-1.2
6.	Manganese	Max 0.15
7.	Silicon	0.4 – 0.8
8.	Titanium	Max 0.15
9.	Zinc	Max 0.25
10.	Remaining	Max 0.15

Table 3: Mechanical properties of Aluminium 6061 T6

Density g/cm^3	Elastic modulus (E), GPa	Coefficient of thermal expansion, µm/°C	Thermal conductivity, W/Mk	Hardness	Tensile strength, MPa
2.70	68.9	23.6	151-202	95	124-290

7. Experimental setup

As per objective of the complete set of experimental work will be performed on Electric Discharge Machine available in the workshop of department of Mechanical Engineering CTAE.

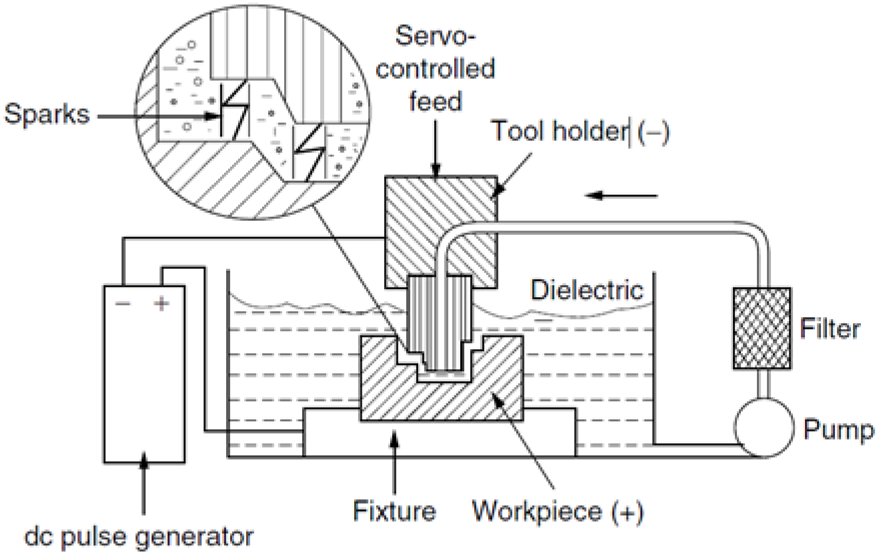

Figure 2: Line Diagram of Experimental Setup

8. Measurement of Independent parameters

This is implies to analyse the effect of surface roughness experimentally. The experimental phase will be conducted by adjusting the various process variables-current, voltage, pulse on time and pulse off time; for each, three levels will be taken.

Table 4: Input Variables

S. No.	Symbols	Input Variables	L 1	L2	L3	Units
1.	T_{on}	Pulse on time	50	70	90	micro sec
2.	T_{off}	Pulse off time	5	10	15	micro sec
3.	V	Servo Voltage	2	2	2	Volt
4.	I	Current	2	4	6	Amp

For measuring the surface roughness various parameters will be arranged as shown in table.

Table 5: Surface roughness verses T_{on} and T_{off}

I = 2 amp	5 (T_{off})	10 (T_{off})	15 (T_{off})
50 (T_{on})	2.378	2.272	2.132
70 (T_{on})	2.859	2.685	2.393
90 (T_{on})	2.932	2.632	2.430

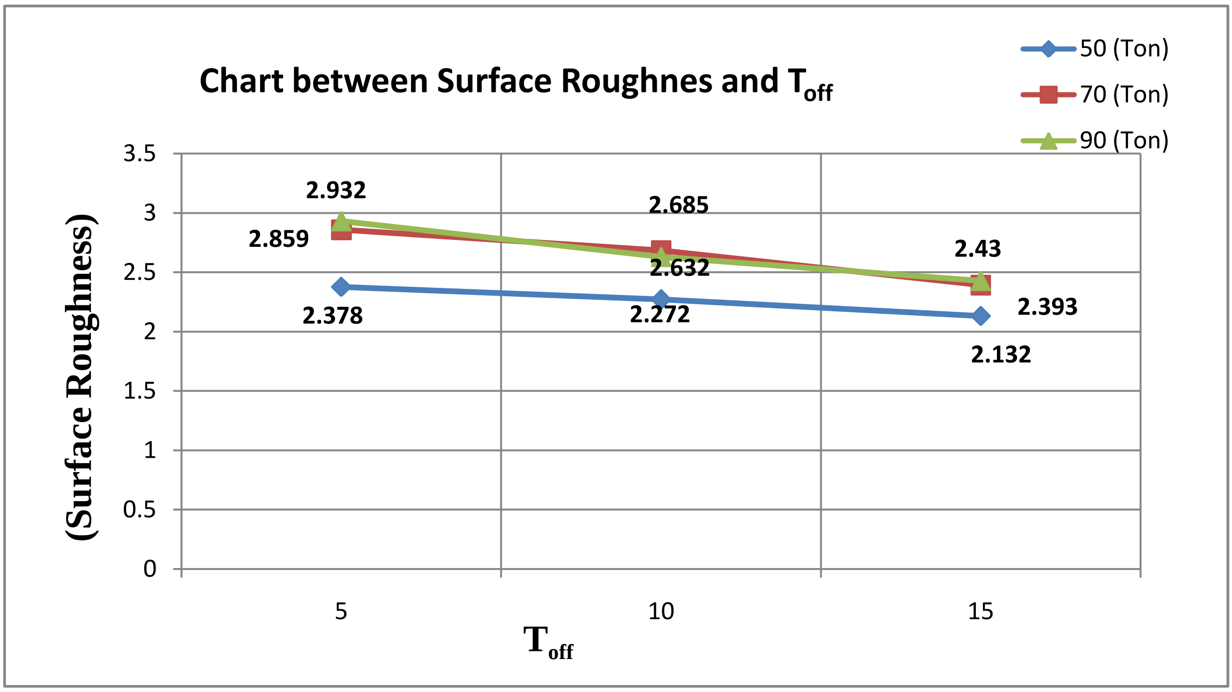

Figure 3: Changes of Surface roughness with pulse on time (T_{on}) and pulses off time (T_{off})

The figure 3 shows the combine upshot of pulse on time (T_{on}) and pulse of time (T_{off}) on surface roughness. As shown in figure 3 at current (I) is 2 ampere and 50 micro sec pulse on time , when is pulse off (T_{off}) time changing from 5 micro sec to 15 micro sec the surface roughness changes from 2.378 micro m to 2.132 micro m respectively. Similarly it is having same effect when pulse on time (T_{on}) is 70 micro sec and 90 micro sec hence it may be concluded that as pulse off time (T_{off}) increase as surface roughness decrease and pulse on time (T_{on}) is increase then the surface roughness is also increases.

Table 6: Surface roughness verses T_{on} and T_{off}

I = 3 amp	5 (T_{off})	10 (T_{off})	15 (T_{off})
50 (T_{on})	3.609	3.239	3.124
70 (T_{on})	3.562	3.344	3.323
90 (T_{on})	3.892	3.336	3.167

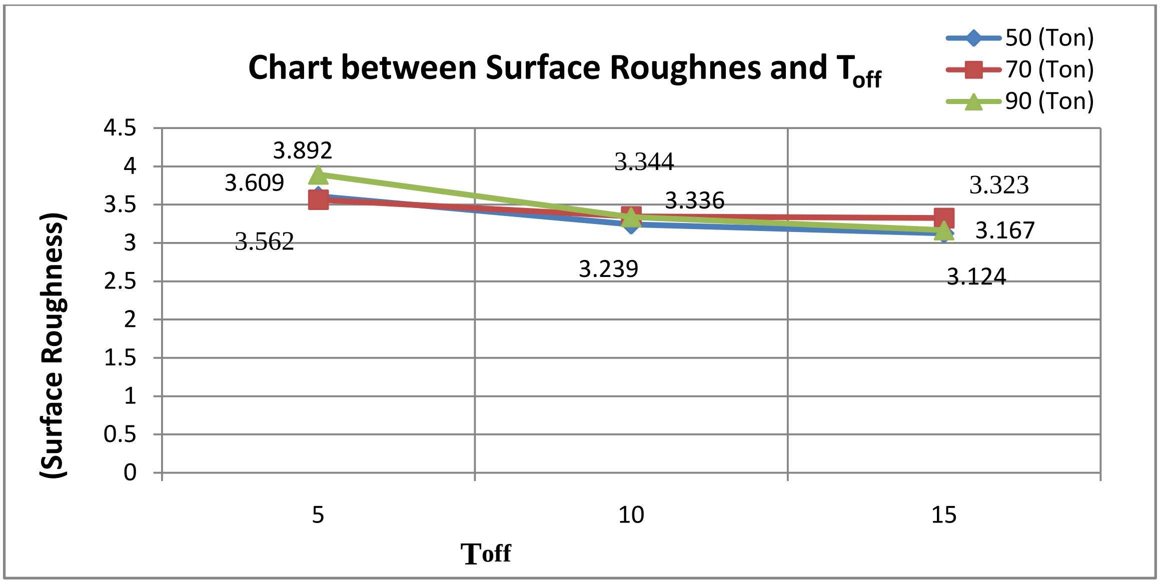

Figure 4: Changes of surface roughness with pulse on time (T_{on}) and pulses off time (T_{off})

The figure 4 shows the combine upshot of pulse on time (T_{on}) and pulse off time (t_{off}) on surface roughness. As shown in figure 4 at current (I) is 3 ampere and 50 micro sec pulse on time , when is pulse off (T_{off}) time changing from 5 micro sec to 15 micro sec the surface roughness changes from 3.690 micro m to 3.124 micro m respectively. Similarly it is having same effect when pulse on time (T_{on}) is 70 micro sec and 90 micro sec hence it may be concluded that as pulse off time (T_{off}) increase as surface roughness decrease and pulse on time (T_{on}) is increase then the surface roughness is also increases.

Table 7: Surface Roughness verses T_{on} and T_{off}

I = 4 amp	**5 (T_{off})**	**10 (T_{off})**	**15 (T_{off})**
50 (T_{on})	4.423	4.211	4.122
70 (T_{on})	4.989	4.942	4.632
90 (T_{on})	4.936	4.723	4.626

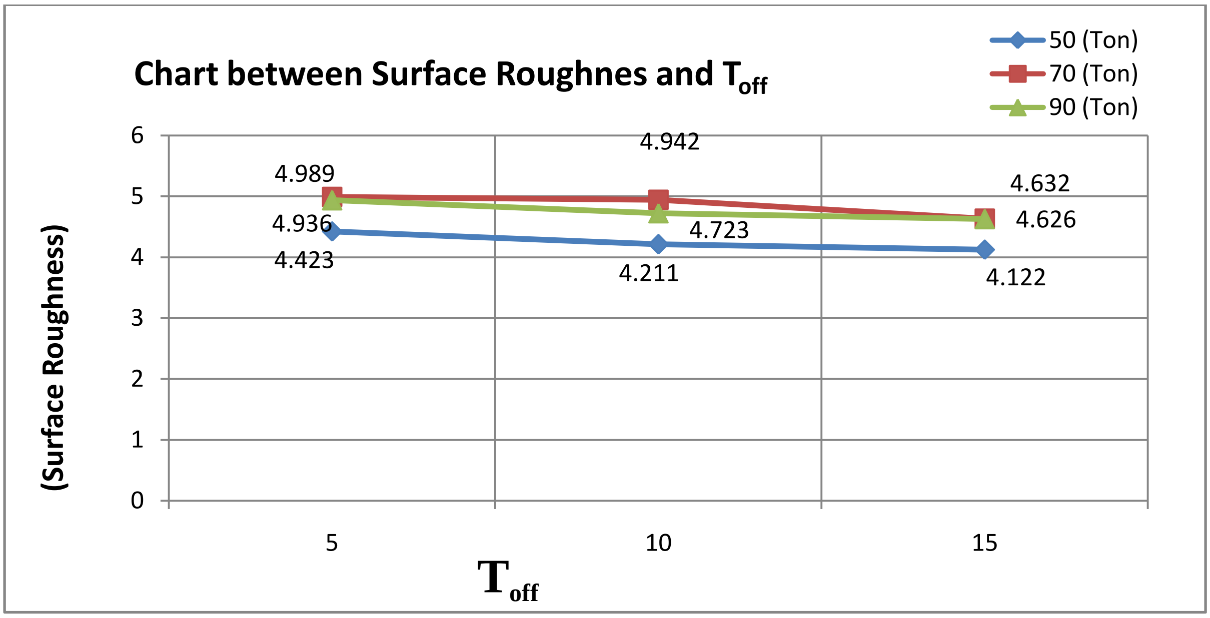

Figure 5: Variation of surface roughness with pulse on time (T_{on}) and pulses off time (T_{off})

The figure 5 shows the combine effect of pulse on time (T_{on}) and pulse off time (t_{off}) on surface roughness. As shown in figure 5 at current (I) is 4 ampere and 50 micro sec pulse on time , when is$_f$ pulse off time (T_{off}) changing from 5 micro sec to 15 micro sec the surface roughness changes from 4.423 micro m to 4.122 micro m respectively. Similarly it is having same effect when T_{on} is 70 micro sec and 90 micro sec hence it may be concluded that as pulse off time (T_{off}) increase as surface roughness decrease and pulse on time (T_{on}) is increase then the surface roughness is also increases.

9. Conclusions

The analysis of the output parameters and experimental results for three levels of current, pulse on time and servo voltage were carried out. These techniques give the relation between input parameter and output parameter.

As per analysis for the surface roughness the value of current is increase with increasing the pulse on time (T_{on}) surface roughness is also increase mean while the value of pulse off time (T_{off}) will also increase at the same time the value of surface roughness is decreasing.

The current is the highest effecting parameters which have highest effect on the surface roughness then pulse off time and lowest pulse on time.

From the measured value of Surface Roughness (SR), it is shows that the surface finish deteriorates with increase in current. Current is found to be the highest effecting parameters which have highest effect on the surface roughness followed by pulse off time and last by pulse on time.

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