Study on Wire Electrical Discharge Machining of Inconel-625

Claver Nsanzumuhire*, Bernard W. Ikua and Karanja Kabini

***Abstract*—** Wire Electrical Discharge Machining (WEDM) is one of the non-conventional methods for machining of materials that are difficult to machine using conventional means. In WEDM, the optimum machining process parameters are governed mainly by the properties of workpiece material. Determination of these parameters presents a challenge to machining process planners. Improperly selected parameters for WEDM may result in low Material Removal Rate (MRR), short-circuiting of wire, wire breakage and poor surface finish. In this paper, the effect of Pulse-on time, Gap voltage and Wire Feed Rate on Surface Roughness (SR) and Material Removal Rate in WEDM of Inconel-625 is analyzed. Experiments are carried out for a wide range of input parameters and analysis is carried out on their effects on machining performance. The results show that both MRR and SR increase with increase in Pulse-on time. Also, the best surface finish (Ra = 3.5 μm) is obtained when the Pulse-on time is below 15 μ sec. The maximum MRR is obtained at a Pulse-on time ranging between 20-25 μsec.

***Keywords*—**Gap Voltage, Material Removal Rate, Pulse-on time, Surface Roughness, Wire Electrical Discharge Machining, Wire Feed Rate.

I. INTRODUCTION

Inconel-625 is a nickel-alloy based material which has the properties such as high fatigue strength, resistance to chloride stress, high hardness and oxidation resistance [1]. These properties make this material suitable for applications in marine, aerospace, and power generation industries [2]. Due to its very high hardness, the material is very difficult to machine by conventional machining methods such as turning, milling or grinding. For this reason, wire electrical discharge machining is one of the alternative methods used to machine the material.

The wire EDM is an electro-thermal process that utilizes a continuously travelling wire electrode to erode material from the workpiece submerged in a dielectric fluid. Debris is flushed away from the machining zone by the dielectric fluid. Tension is applied on the wire to maintain the spark gap and to avoid tapering of the cut surface. A schematic of the wire EDM process is shown in Figure 1.

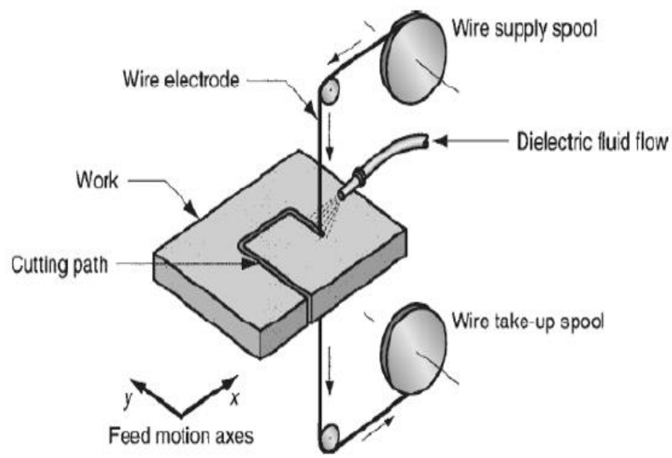

Figure 1: Schematic diagram of wire EDM [3]

II. LITTERATURE REVIEW

A great deal of research has been reported in literature, on optimization of WEDM processes. Abbas and Solomon [4] investigated the influence of two factors namely duty cycle and peak current in the wire EDM of Inconel-625. In their study, Taguchi orthogonal array was used to optimize these parameters for minimum surface roughness. It was reported that surface roughness increased with the increase in Pulse-on time and decreased with increase in Pulse-off time.

Saravan and Babu [5] conducted a study on the wire EDM of Inconel-625, in which they investigated

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influence of peak current, wire tension, wire diameter, Pulse-on time and Pulse-off time on material removal rate, surface finish and corner accuracy. It was reported that for optimum material removal rate, good surface finish and improved corner accuracy, the Peak current, wire tension, wire diameter, Pulse-on time and Pulse-off time should be 7 A, 1400N/mm^2, 0.25mm, 8 μs and 17μs, respectively.

Tonday and Tiga [6] investigated the effect of cutting parameters on material removal rate and surface integrity in WEDM of Inconel-625. The process parameters considered were peak current, Pulse-on time, Pulse-off time and wire tension. The study used Taguchi technique and analysis of variance (ANOVA) to analyze the influence of these parameters on output parameters. As a result, the research concluded that wire tension had no effect on both MRR and surface roughness. Also, Pulse-on time was found to have the highest impact on both the output parameters, whereas Pulse-off time had the greatest impact on MRR. It was found that the peak current had the largest impact on the surface roughness.

Singh et al., [7] conducted an experimental study on metal removal rate and surface characteristics in wire EDM of Inconel-625. In this work, the input parameters were peak current, Pulse-on time and Pulse-off time. It was reported that the increase in current and Pulse-on time increased MRR and surface roughness

Abhishek and Rahul [8] investigated the machining performance of wire EDM of Inconel-625. In their research, application of fuzzy inference systems coupled with Taguchi's philosophy was demonstrated to be an efficient method for simultaneous optimization of process parameters on MRR and SR. It was reported that the optimum values of gap voltage, peak current, Pulse-on time and flushing pressure should be 90 V, 5 A, 200 μs and 0.6 bars respectively.

From the foregoing, it can be seen that much work has been done on the effect of discharge current, Pulse-off time, duty cycle, wire tension and wire diameter, mainly using Taguchi orthogonal arrays and fuzzy inference systems. The main focus has been on how these parameters affect MRR, surface roughness and corner accuracy. However, the influence of Pulse-on time, feed rate and gap voltage were not considered. This research seeks to investigate the effect of Pulse-on time, feed rate and gap voltage on MRR and SR. Also, an algorithm for optimization of wire EDM of Inconel-625 will be developed.

III. METHODS

2.1. **Equipment used in the study**

Machining experiments were conducted on the AWT6S wire EDM machine. The surface roughness was measured using surface roughness tester (MITUTOYO SJ-30) and the kerf width was measured using a profile projector (Mitutoyo PJ311). The MRR was obtained from the volume of the material removed for a given machining time. Photographs of the equipment used are shown in Figures 2-4.

Figure 2: Photograph of wire EDM

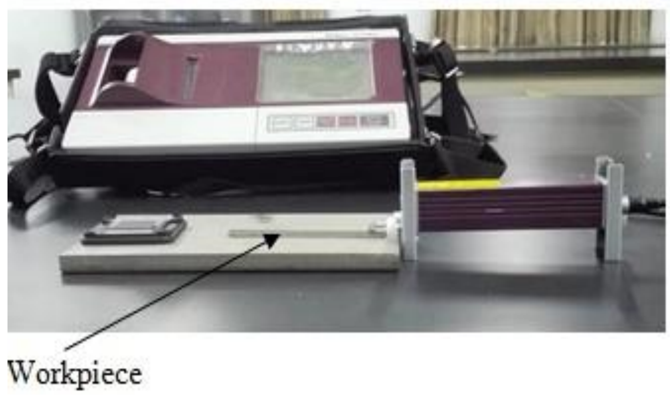

Figure 3: Set up for measument of surface roughness using surface roughness tester

Figure 4: Set up for measument of gap width using profile projector

The specifications of the Wire Electrical Discharge Machine, wire EDM, surface roughness tester and profile projector are shown in table 1.

Table 1: Specifications of equipment used

Wire EDM	Model	AWT6S
	Dielectric fluid	Deionized water
	Pulse-on time range(μs)	1-24
	Pulse-off time range (μs)	1-50
	Wire feed rate range (mm/min)	1-200
	Gap voltage range (V)	1-150
Surface roughness tester	Model	PJ-301
	Stylus travel distance (mm)	4.0
	Stylus travel speed (mm/s)	0.5
Profile projector	Model	PJ-311
	Screen diameter(mm)	300
	Rotation (degrees)	360

Experiments were made using design of experiments (DOE) method and they involved machining of straight cuts. Straight cuts were chosen to allow for ease of measurement of surface roughness.

The machining experiments were conducted with workpieces of 10 mm thickness, at constant wire feed rate and gap voltage of 100.5 mm/min and 75.5 V respectively. The variable parameter was the Pulse-on time which was varied from 1-24 μsec.

The MRR was obtained as

$$MRR = V/t \tag{1}$$

Where V is the volume of material removed on machining for a duration of time t. As indicated in figure 5, it is seen that the obtained surface roughness was 3.39 μm. The upper part of the figure indicates the surface roughness parameters recorded by the machine based on the roughness profile as indicated from the bottom part of figure.

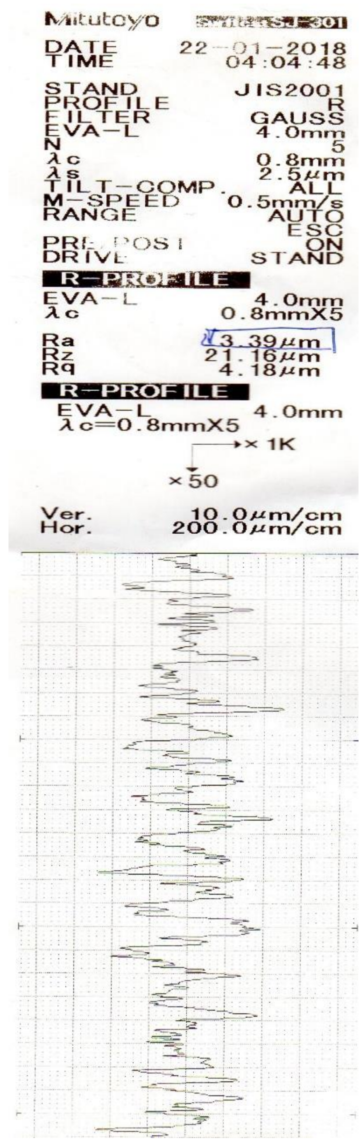

Figure 5: Typical surface roughness profile

IV. RESULTS AND DISCUSSION

Figure 5 shows a typical trace of surface roughness profile as obtained from the surface roughness tester.

The influence of Pulse-on time on SR is shown in Figure 6. It is seen in this figure that the SR is hardly affected by the Pulse-on time for up to Pulse-on time of 15 μs, above which the SR begins to increase with increase in Pulse-on time. This means that holding other factors constant, for good surface finish, the Pulse-on time should not be above 15 μs.

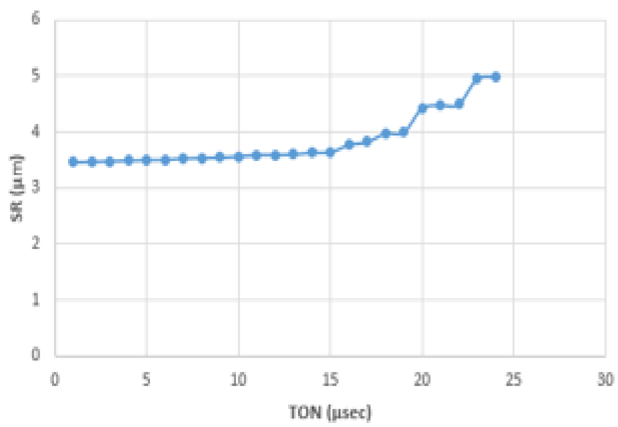

Figure 6: Influence of Pulse-on time on SR

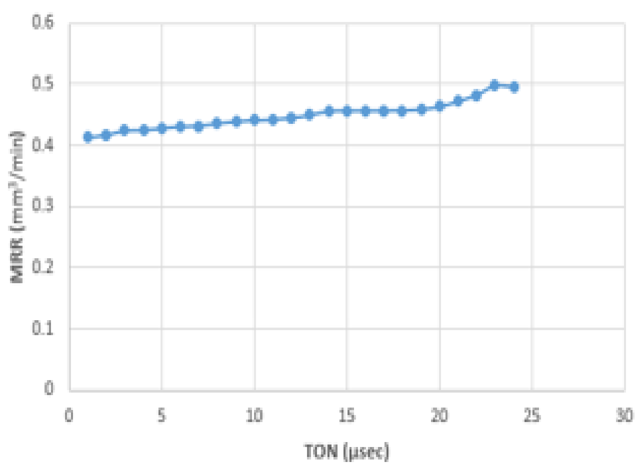

Figure 7: Influence of Pulse-on time on MRR

Figure 7 shows the influence of Pulse-on time on MRR. It is seen in this figure that the MRR increases gradually with increase in pulse-on time. This shows that to maximize on MRR, the Pulse-on time must be high. This however, would compromise on the SR, as was seen in Figure 6. Therefore, it is important to obtain an optimum value of Pulse-on time, which will give an acceptable SR and MRR.

Towards this, an algorithm for optimization of the WEDM process is necessary.

V. CONCLUSION

The effect of Pulse on-time on response variables such as material removal rate and surface roughness has been presented. It was established that both MRR and SR increase with the increase in Pulse-on time. However, the required higher MRR is compromised by the unexpected high SR. As recommendations, the effect of other machining parameters such as gap voltage and wire feed rate on the machining process should be investigated as well. An optimization algorithm should also be developed to optimize the machining process.

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