Experimental Analysis on Parameters Affecting the Material Removal Rate in Wire Electrical Discharge Turning using the Taguchi Method

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***Abstract*— Wire electrical discharge turning (WEDT) allows success in the machining of advanced materials, particularly for the cylindrical shape components used in the metrology, medical and aerospace field. Using WEDT technology, the micro dimension of geometrical features can be machined without constraints on difficult-to-machine electrically conductive materials. The high precision with large aspect ratio machining capability make WEDT valuable. The correct machining parameter selection is the most important aspect to take into consideration when machining by WEDT. Therefore, the purpose of this study was to rank, determine and optimise the machining parameters that affect the material removal rate (MRR) in WEDT process. As WEDT has as much as eleven control parameters in this study, representing a large number of machining, the Taguchi L-12 orthogonal array was used to obtain the required data with a minimum number of experiments. By using similar experimental data, the regression equation was developed to represent as fitness function for optimisation by genetic algorithm (GA). It was found that by selecting the fast feed of workpiece to machining zone, the faster material was removed and moreover, it dominated other machining parameters. The optimised parameters yield 1.398 mm³/min as the maximum value predicted for MRR recommended by GA.**

***Index Term*— Genetic Algorithm, Micro-cylindrical Machining, MRR, Taguchi, WEDT**

I. INTRODUCTION

Technology of machining with wire electrical discharge turning (WEDT) provides a satisfactory alternative to the conventional turning process, especially for the machining of high strength and brittle materials in applications of complex shapes and high precision part components as it does not possess any mechanical force during machining and it is not restricted by material properties. In principle, the WEDT is similar to the conventional wire electrical discharge machining (WEDM) as WEDT utilises the same principle of electrode wire travelling to erode the workpiece. However, in WEDT, the cylindrical workpiece is situated in a rotating manner as compared to the WEDM, whose workpiece is stationary.

Nowadays, the potential capability of WEDT has extended to the fabrication of micro cylindrical parts. Some researchers have contributed to the fabrication of micro cylindrical parts by WEDT such as the high aspect ratio of micro-pin [1], [2] and high accuracy of micro-cutting tool with complex geometries [3]. The machining performance of WEDT is defined and influenced by its machining parameters, which significantly affects the outcome of the process. Giridharan and Samuel [4] investigated the machining parameters such as the pulse-off time, servo feed as well as the spindle speed rotation to the discharge energy and modelled it to predict the material removal rate (MRR) and surface roughness. The models proposed by them are significantly reliable because the generated discharge energy was directly produced from the energy conversion of WEDT. Srivastava et al. [5] studied the effects of rotational spindle speed in WEDT towards surface integrity and the MRR while machining aluminium-based metal matrix composite. They found that the MRR and surface roughness reduced when the spindle speed increased and that the machined surface looked dull and contained the small craters.

According to literature, the most important performance measures in WEDT is the MRR, where it specifies the economics of machining and rate of production. Although the WEDT process can potentially machine down to micro dimensions, the machining characteristics and the rate of production have not been comprehensively recognised until today. In practice, it is very challenging to obtain the ideal performance of machines owing to the fact that there are too many controllable machining parameters [6], [7]. Some of the machines possess supplementary modes and controllers to regulate the machining conditions such as reverse polarity, arcing controller, rough-cut mode and finishing mode [8]–[10].

With the plethora of machining parameters and great differences in each machine, it is even more challenging to study the effects of machining parameters by conventional single-factor experiments. Numerous number of experiments are required, which will consume a lot of time at high costs. In addition, the pulse characteristics in WEDT are greatly different from WEDM machines due to the rotating of the workpiece; which can result in more frequent occurrences of arc pulses and arc regions - leading to the reduction in the MRR [11].

Due to this, a simple but reliable method based on a statistical approach was employed in the experiments to acquire information regarding the effects of various machining parameters on the MRR with a minimum number of experiments. To the authors' best knowledge, there are no published works studying the effects of machining parameters on the MRR statistically in the fabrication of micro cylindrical shape components by WEDT.

In this paper, a planned set of experiments was carried-out using the Taguchi L-12 orthogonal array and the effects of the machining parameters on the MRR was analysed. Afterwards, the machining parameters were optimised by using genetic algorithm (GA) approach. Titanium alloy was chosen as the workpiece material in this study due to its growing range of applications on micro-devices in the medical and metrology field. The topography of the machined surface was also analysed by scanning electron microscopy (SEM).

II. Methodology

A. Experimental Setup

The machining trials were carried out on a Mitsubishi Ra90 WEDM machine with assistance from the precise spindle unit in order to perform the micro-turning process as illustrated in Fig. 1. The de-ionised high pressurised water jets were applied to the machining zone to flush the debris away.

This WEDM machine has special features in which it is capable to control the degree of arc pulses and short pulses also known as stabilisers by machine manufacturers. In order to determine the effects of parameters in WEDT, all control machining parameters were investigated in this research study because the formation of arc and its regions highly occurred in WEDT as compared to WEDM, which altered the fundamental of spark erosion nature. Table I and Fig. 2 shows the details of the parameters and its function to the WEDT machining process.

The experimental setup was as follows: pure brass of 0.25 mm diameter is employed as wire electrode, titanium alloy grade 5 (Ti6-Al-4V, chemical composition percentage by weight, Aluminium= 6.9%, Vanadium= 4.1%, Carbon= 0.10%, Iron= 0.30%, Silicon= 0.15%, Oxygen= 0.20%, Nitrogen= 0.05%, Hydrogen= 0.015%, balance Titanium) with tensile strength of 1000 MPa and hardness of 36 HRC was chosen as the workpiece material. This kind of alloys is known to be challenging when processed by conventional machining [12]. The initial workpiece dimensions were 20 mm of length and 9.49 mm in diameter. The MRR of machined workpiece was taken as the response variable and calculated by obtaining the differences in the diameter of each workpiece before and after per unit machining time by using the Meiji Zoom stereo microscope as indicated in (1). R denotes the initial radius of the workpiece [mm], r denotes the final radius of the workpiece after machining [mm], l denotes the machining length [mm] and t denotes the machining time [min].

$$MRR = \frac{\pi l(R^2 - r^2)}{t} \ (mm^3/min) \quad (1)$$

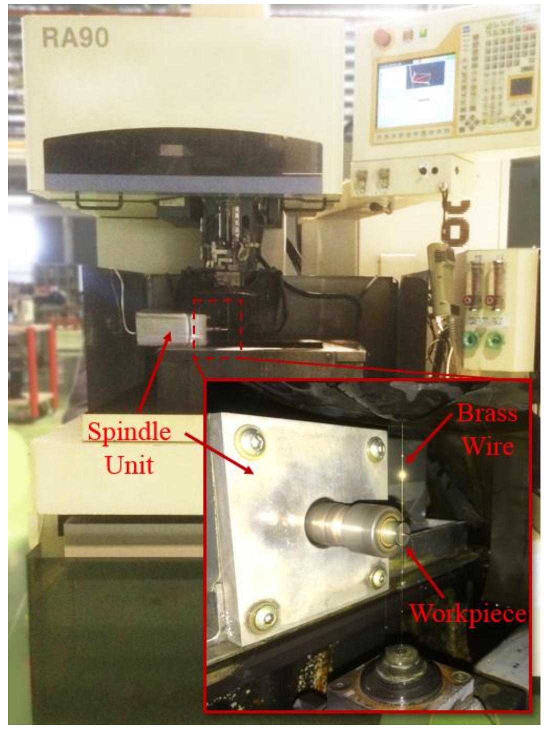

Fig. 1. WEDT Experimental setup

TABLE I
Mitsubishi RA90 Machining Parameter Descriptions

Machining Parameters	Descriptions
Voltage Open	Purposely for controlling the height of the gap voltage during no-load. The higher the value, the higher voltage be applied.
Intensity of Pulse	Purposely for controlling the size of the peak current that flows the gap specific to normal pulse.
Stabilizer-A	Purposely used to finely adjust the current specific to arc pulse.
Stabilizer-B	Purposely used to finely adjust the off-time.
Stabilizer-E	Purposely used to controls the short pulse and machining stability. Using high value will decelerate the machining, but then wire will be difficult to have breakage.
Voltage Gap	Controls the average machining voltage used as a target value when machining with optimum feed.
Wire Speed	Controls the wire feedrate. The higher the value, the faster the wire feed to machining zone.
Wire Tension	Controls the wire tension. The higher the value, the higher the tension of wire.
Rotational Spindle Speed	The number of turns a workpiece rotating around an axis per unit time (speed of revolution).
Table Feedrate	Controls the feedrate of machine table. The higher the value, the faster the movement of workpiece feed to machining zone.
Spindle Direction	Direction of the spindle rotation. Downward direction follows the direction of the wire travelling direction and upward is opposite to the wire travelling direction.

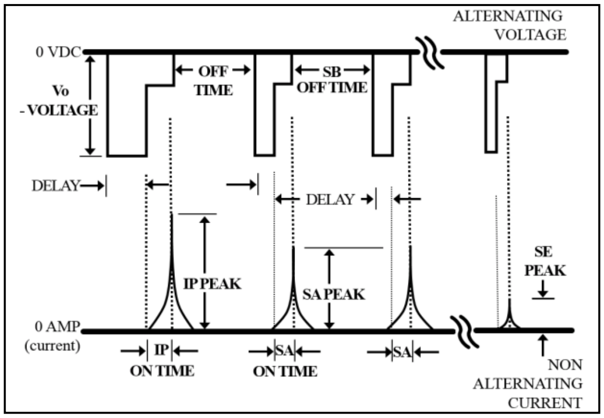

Fig. 2. Mitsubishi Ra90 theoretical pulse characteristics

B. Taguchi Orthogonal Array

In this present study, the behaviour of eleven machining parameters was evaluated and ranked according to the L-12 Taguchi orthogonal array design procedure by using the Minitab 16 statistical software. Each of the machining parameters consisted of two levels, which were level 1 and level 2 as indicated in Table II. Level 1 represented the minimum value while level 2 represented the maximum value of respective parameters. The Taguchi method offered simplicity in conducting an experiment with a large number of factors by conducting fewer experimental trials [13].

The application of the Taguchi method has been widely used by a great number of researchers since it became a reliable tool to diagnose the machining parameters that renders the quality of the products or processes while minimising the variations caused by external noise. In selection of the orthogonal array design for this method, selection depended on the number of parameters, interactions and their level.

Taguchi uses signal-to-noise (S/N) ratio to assess the quality the of the respective parameter. The term “signal” here refers to the desirable value and “noise” refers to the undesirable value. The aim of using S/N ratio as a measure of effectiveness was to develop products or processes that were insensitive to noise factors [14]. The S/N ratio indicated the degree of the predictable quality of a product or process in the occurrence of noise factors.

Machining parameters with a high S/N ratio always yields the optimum quality with less amount of variance. Taguchi categorised response characteristics into three special types, which included the larger-the-better, the smaller-the-better and the nominal-the-better [15].

The larger-the-better here refers to the responses of ideal quality of the products or processes as intended to be maximum. The smaller-the-better refers to the responses of ideal quality of the products or processes as intended to be minimum. The nominal-the-better refers to the responses of ideal quality of the products or processes equated with a particular nominal value.

In this study, the larger-the-better was considered to maximise the MRR, and the S/N ratio was expressed in (2). η represents the S/N ratio, *yi* represents the response value of the *i*th experiment, while *n* is the number of replications of each trials [16].

$$\eta = -10 \log \left[\frac{1}{n} \sum_{i=1}^{n} \left(\frac{1}{y_i^2} \right) \right] \quad (2)$$

Table III shows the design matrix of the L-12 Taguchi orthogonal array. L-12 design allows the evaluation of machining parameters on main effects only. Therefore, the interaction effect of machining parameters was assumed as negligible in this study. The trials were conducted randomly with three replications in order to attain the validity and accuracy of the experiment.

TABLE II
MACHINING PARAMETERS AND THEIR NOTATION, UNIT AND LEVELS

Parameter	Notation	Unit	Level 1	Level 2
Voltage Open	Vo	Notch	6	8
Intensity of Pulse	Ip	Notch	8	10
Stabilizer-A	SA	Notch	1	3
Stabilizer-B	SB	Notch	6	12
Stabilizer-E	SE	Notch	2	5
Voltage Gap	VG	volts	40	140
Wire Speed	WS	Notch	10	16
Wire Tension	WT	Notch	7	10
Rotational Spindle Speed	RSS	rev/min	50	2400
Table Feedrate	TF	mm/min	0.05	0.10
Spindle Direction	SD	-	Upward	Downward

TABLE III
EXPERIMENTAL DESIGN MATRIX USING L-12 ORTHOGONAL ARRAY

Trials	Vo	Ip	SA	SB	SE	VG	WS	WT	RSS	TF	SD
1	6	10	3	12	2	140	16	7	2400	0.05	Upward
2	8	8	1	12	5	140	10	10	2400	0.05	Upward
3	6	10	3	6	5	140	10	10	50	0.10	Upward
4	6	8	1	6	2	40	10	7	50	0.05	Upward
5	6	10	1	12	5	40	16	10	50	0.05	Downward
6	6	8	3	12	5	40	10	7	2400	0.10	Downward
7	8	8	3	12	2	40	16	10	50	0.10	Upward
8	6	8	1	6	2	140	16	10	2400	0.10	Downward
9	8	8	3	6	5	140	16	7	50	0.05	Downward
10	8	10	1	12	2	140	10	7	50	0.10	Downward
11	8	10	3	6	2	40	10	10	2400	0.05	Downward
12	8	10	1	6	5	40	16	7	2400	0.10	Upward

III. Results and Discussion

In general, the MRR result obtained is relatively high before an optimization as indicated in Table IV but it is still behind compared to macro sized machining by WEDT [17], [18]. Only slow feedrate can be applied in this study due to the volume of material being removed is about 30% more than machining macro sized of workpiece by WEDT [5], [11]. Large radial depth of cut used for obtaining final micro sized parts has restricted the feeding motion. Followings are the result in satisfying the research proposed objective.

A. Ranked of Parameter

A higher MRR is an indication of better productivity in WEDT process. The results of the MRR for each of the experiments based on orthogonal array and its corresponding S/N ratio are listed in Table IV.

The most important principle in the Taguchi method to evaluate the collected data is the S/N ratio. In this study, the S/N ratio should have a maximum value in order to obtain optimum process parameters. The response table (Table V) showed the average of each response characteristic for each level of the respective factors. This table tabulated the ranks among the process parameters that contributed to the MRR based on delta statistics. Delta statistics calculated the relative magnitude of efforts among the process parameters by minusing the lowest average from the highest average of each factor [19].

Therefore, the Minitab 16 software appointed ranks based on delta values; rank 1 to highest delta value, rank 2 to the second highest and, so on. The ranks represent the importance of each parameter to the MRR. The ranks and delta values showed that table feedrate had the greatest effect on the MRR, followed by pulse intensity, spindle direction, wire tension, voltage gap, stabilizer-E, stabilizer-A, stabilizer-B, rotational spindle speed, wire speed, voltage open.

TABLE IV
EXPERIMENTAL RESULT AND THEIR S/N RATIO

Trials	Material Removal Rate (mm^3/min)				Signal to Noise Ratio
	MRR 1	MRR 2	MRR 3	Mean	
1	0.711	0.704	0.711	0.709	-2.992
2	0.657	0.662	0.671	0.663	-3.569
3	1.366	1.371	1.374	1.370	2.736
4	0.676	0.674	0.679	0.677	-3.394
5	0.651	0.656	0.652	0.653	-3.704
6	1.272	1.298	1.334	1.301	2.284
7	1.326	1.321	1.324	1.324	2.435
8	1.296	1.308	1.310	1.305	2.310
9	0.674	0.674	0.679	0.676	-3.403
10	1.367	1.371	1.362	1.367	2.713
11	0.671	0.682	0.675	0.676	-3.403
12	1.337	1.349	1.355	1.347	2.588

TABLE V
RESPONSE TABLE FOR S/N RATIOS OF MRR

Parameter\Level	1	2	Delta	Rank
Voltage Open	-0.4601	-0.4398	0.0203	11
Intensity of Pulse	-0.5562	-0.3437	0.2125	2
Stabilizer-A	-0.5094	-0.3906	0.1188	7
Stabilizer-B	-0.4278	-0.4722	0.0445	8
Stabilizer-E	-0.3886	-0.5114	0.1228	6
Voltage Gap	-0.5326	-0.3674	0.1651	5
Wire Speed	-0.4389	-0.4611	0.0222	10
Wire Tension	-0.3674	-0.5326	0.1652	4
Rotational Spindle Speed	-0.4362	-0.4637	0.0275	9
Table Feedrate	-3.4110	2.5110	5.9220	1
Spindle Direction	-0.3660	-0.5340	0.1681	3

B. Parametric Influences and Analysis

The S/N ratio plots show all the effects of eleven process parameters toward the MRR in WEDT (Fig. 3, Fig. 4, and Fig. 5). In spark erosion machining, the pulse waveform played an important role in producing ideal plasma channels in removing the material. In this study, all the electrical parameters contributed to the creation of pulse characteristics as indicated in Fig. 2. Among the electrical parameters in this research study, pulse intensity dominated the other electrical parameters. By employing a high value of pulse intensity, it increased the discharge energy (Table V and Fig. 3). This increased the size of the discharge crater in terms of its depth and diameter, raised the MRR. In addition, voltage was also an important parameter to the pulse characteristics. In this study, there were two types of voltage, namely voltage open and voltage gap. Voltage open referred to the initial voltage applied during machining before the flows of amperage of current, while voltage gap referred to the average of voltage reduction after the flows of current. Astoundingly, voltage gap highly influenced the MRR rather than voltage open. One of the plausible reasons for this phenomenon may be related to the numerous occurrences of arc pulses and short pulses in WEDT as reported by Rees et al. [20] and Janardhan and Samuel [11]. According to Oßwald et al. [21], the arcing pulse occurs when the applied voltage does not rise above the average voltage gap. Therefore, the high value of applied voltage by parameter voltage open is inoperative as long as the arc pulse predominates the pulse characteristics during the machining. By applying a high value of voltage, the voltage open or voltage gap will increase the MRR.

Apart from this, as shown in Mitsubishi Ra90 machining pulse waveform (Fig. 2), stabilizer-E was used to control the short pulse and stabilizer-A to control arc pulse. As the notch value increased from 2 to 5 for stabilizer-E (Fig. 4), the MRR reduced because the normal pulses replaced by the short pulses, subsequently reducing the number of ideal plasma channels produced by normal pulses that had the capability to sufficiently remove the material. For stabilizer-A, the MRR increased by increasing the notch value from 1 to 3 (Fig. 3). Stabilizer-A was specified as the switch to finely adjust the current to control arc pulse. The occurrences of arc pulse in WEDT was quite frequent as compared to the conventional WEDM [11]. Thus, by increasing the notch value from 1 to 3 for stabilizer-A, this allowed the large amperage of current with arc pulse to erode the large volume workpiece materials. Knowingly, the arc pulse had adequate energy in generating sufficient plasma channel to erode the materials but was still lagging as compared to normal pulses in removing the materials [22]. All the results regarding the voltage, stabilizer-A and stabilizer-E has been reflected in the occurrences of arc and short pulses in WEDT as reported by Rees et al. [20] and Janardhan and Samuel [11]. They found that by introducing the rotating workpiece in conventional WEDM, it changed the pulse nature of spark erosion. They also found that WEDT pulses contained a lot of false discharge such as occurrences of shorts pulse, arcs pulse and arc regions.

Another interesting electrical parameter that was noteworthy for discussion in this research study was the relation of stabilizer-B to the off-time in pulse waveforms (Fig. 2). The higher the value, the more number of sparks fell off during the machining process, which resulted in less amounts of discharge occurrences and subsequently, reduced the MRR. However, the adequate amount of off-time offered the benefit of allowing the debris to be flushed away from the machining zone. Thus, this eliminated the chain-like bridge phenomenon and indirectly minimised the occurrences of short pulse.

In terms of non-electrical parameters in WEDT, table feedrate dominated the other non-electrical parameter, followed by spindle direction, wire tension, rotational spindle speed and wire speed (Table V). As shown in Fig. 5, table feedrate constituted the major effect of parameter to MRR. By increasing the table feedrate, the MRR increased. This result had similar agreements with Sun et al. [23], they indicated that the feeding speed possessed the most significant effect on the MRR in machining titanium alloy for micro cylindrical parts in WEDT. Table feedrate was certainly influenced by the MRR as the MRR was defined as the volume of material removed divided by the machining time. The calculation for the MRR used feedrate as an input value. The increase of the MRR was related to feedrate table because of the shorter machining time [24].

In addition to that, the upward spindle direction produced more MRR as compared to the downward direction. A possible explanation for this might be due to the reduction of the spark gap distance. According to Janardhan and Samuel [11], when the spark gap distance between rotating workpiece and wire electrode reduce, the ignition delay time has enough time to produce ideal plasma channel that can remove materials in excellent manner. Ignition delay time is an important time in the event of plasma channel before allowing the electrons and ions to flow through it during the discharge phase [25].

Wire tension also influenced the MRR results as the MRR slightly increased when using low tension of electrode wire. This result may be explained by the fact that the wire vibration turned occurred under the low wire tension. As a result, the wire had a tendency to deflect and over-remove the material dimension of workpiece. These circumstances were a drawback for precision machining despite the high material being removed.

In WEDT, rotating of the workpiece changed the pulse behaviour. When the workpiece rotated at a high speed, there was a reduction in the MRR. This was because, high rotational spindle speed led to distortions of gap equilibrium [26], occurrences of variation in total number of pulse and occurrences of false discharges [20]. Therefore, poor removal mechanism by plasma channel caused less appearances of normal pulses.

For wire speed, the MRR decreased by using faster wire electrode feeding. This result was most likely caused by the occurrences of vibrating electrode wires that diminish the dynamic stability of the wire and led to unfavourable sparking conditions [27]. Moreover, by applying fast wire feeding to the machining zone, it weakened the discharge state as the removal time for debris was shortened. This caused difficulty in flushing it away, thus, destroying the machining stability with occurrences of chain-like bridge by debris that ultimately reduced the MRR.

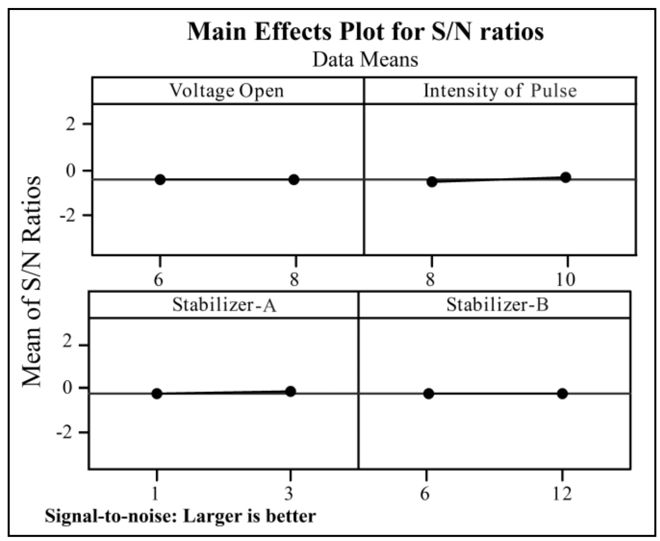

Fig. 3. Mean of MRR S/N ratios for voltage open, pulse intensity, stabilizer-A and stabilizer-B

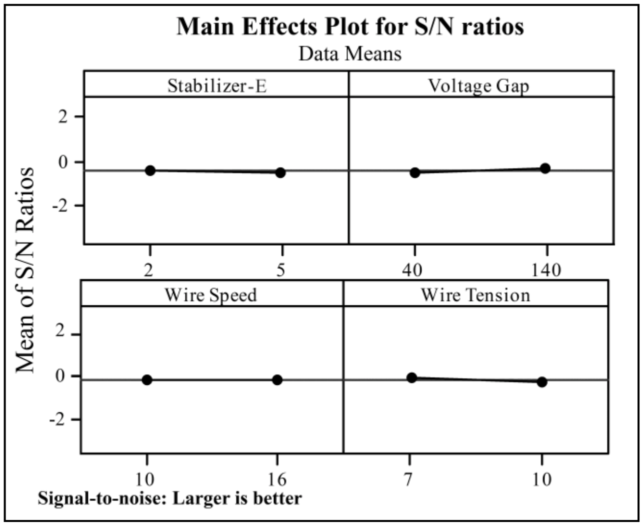

Fig. 4. Mean of MRR S/N ratios for stabilizer-E, voltage gap, wire speed and wire tension

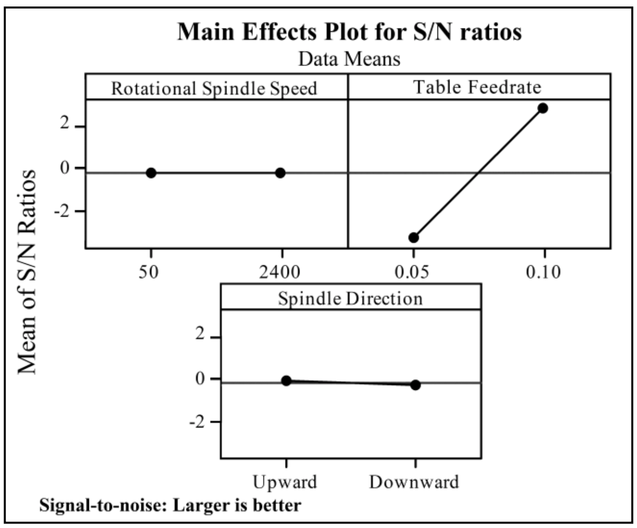

Fig. 5. Mean of MRR S/N ratios for spindle speed, table feedrate and spindle direction

C. Parameter Optimization

Some of the studied combination parameters has been shown to produce high MRR (Table IV). However, there are potentially other combination parameters that could yield higher MRR. In this section, the GA optimization approach was used to identify the optimum parameters in order to further improves the MRR. The problem fitness function is obtained through first-order derivative of regression analysis, as shown in (3);

$$MRR = -0.0566479 + 0.0031523 * Vo + 0.0146754 * Ip + 0.00372127 * SA - 0.00094726 * SB - 0.00251097 * SE + 0.0001864 * VG - 0.00114525 * WS - 0.00477662 * WT - 4.59008e^{-6} * RSS + 13.2036 * TF - 0.0186627 * SD \quad (3)$$

The maximization of the fitness function value of equation (3) is subjected to the boundaries of machining parameters. The range of values that present the boundaries of the optimization solution is shown as in (4). According to equation (4), the levels and boundaries for SD has been changed to the coded value in order to allows it to be analysed by Matlab GA solver, due to the fact that it is the only categorical parameter among the other parameters. In this study, the following GA parameters options are considered: Population type = double vector (250 size); Crossover function = two point; Migration= forward (20 interval with 0.2 fraction); Mutation function= constraint dependent; Scaling function= rank; Crossover fraction= 0.8 (default)[28].

$$\left.\begin{array}{ccccc} 6 & \leq & Vo & \leq & 8 \\ 8 & \leq & Ip & \leq & 10 \\ 1 & \leq & SA & \leq & 3 \\ 6 & \leq & SB & \leq & 12 \\ 2 & \leq & SE & \leq & 5 \\ 40 & \leq & VG & \leq & 140 \\ 10 & \leq & WS & \leq & 16 \\ 7 & \leq & WT & \leq & 10 \\ 50 & \leq & RSS & \leq & 2400 \\ 0.05 & \leq & TF & \leq & 0.10 \\ 1 & \leq & SD & \leq & 2 \end{array}\right\} \quad (4)$$

According to Fig. 6, it can be observed that the best value in maximizing MRR is 1.398 mm^3/min at the end of 205 iterations and its value obtained was higher than the studied combination parameters in Table IV. Furthermore, the optimal machining parameters proposed by GA has been carried out to performed on the actual experimental with the purpose to evaluate its validity. Table VI shows the optimal machining parameters and the results of confirmation experiment. It is found that the GA proposed machining parameter produced a little high up to 1.427 mm^3/min of MRR, but it is still in acceptable range as long the relative error percentage is small.

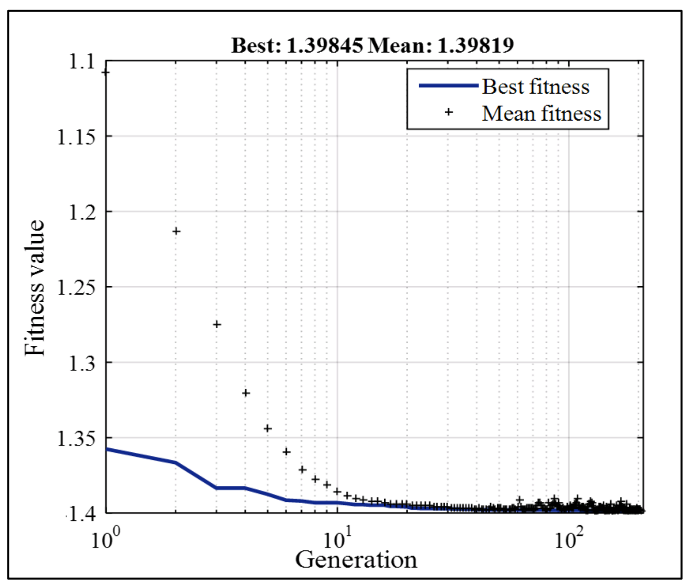

Fig. 6. Plot functions of the best fitness for MRR

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TABLE VI
THE OPTIMIZED PARAMETERS AND THE CONFIRMATION OF EXPERIMENT

Parameters	Optimum Level	Maximize Objective Function		
		Predicted by GA	Confirmation by Experiment	Relative error
Vo	8			
Ip	10			
SA	3			
SB	6			
SE	2			
VG	140	MRR= 1.398 (mm³/min)	MRR= 1.427 (mm³/min)	2.03%
WS	10			
WT	7			
RSS	50			
TF	0.10			
SD	Upward			

D. SEM Observations

During WEDT process, the discharged energy generates extreme temperatures led the materials to melted and vaporized. Every single discharge, a crater was formed on the machined surface that change the machined surface topography by effects of various process parameters. It was observed from Fig. 7 SEM micrographs of WEDT surface that it contains globules of debris, different size of craters and micro-voids. The surface topography of WEDT almost has similar figuration with surface topography of WEDM [10], but WEDT machined surface contains elongated craters because the effect of rotating workpiece makes the plasma arc column to simply slide over the machined workpiece and elongate the craters [23]. During machining, some of the molten material produced by the discharge energy was flushed away by the deionized water but the remaining molten material re-solidifies to form globules of debris as seen in Fig. 7. In this study, the occurrences of micro-void are caused by the gas bubbles expelled from the molten material during solidification due to the effects of cooling rate by de-ionized water.

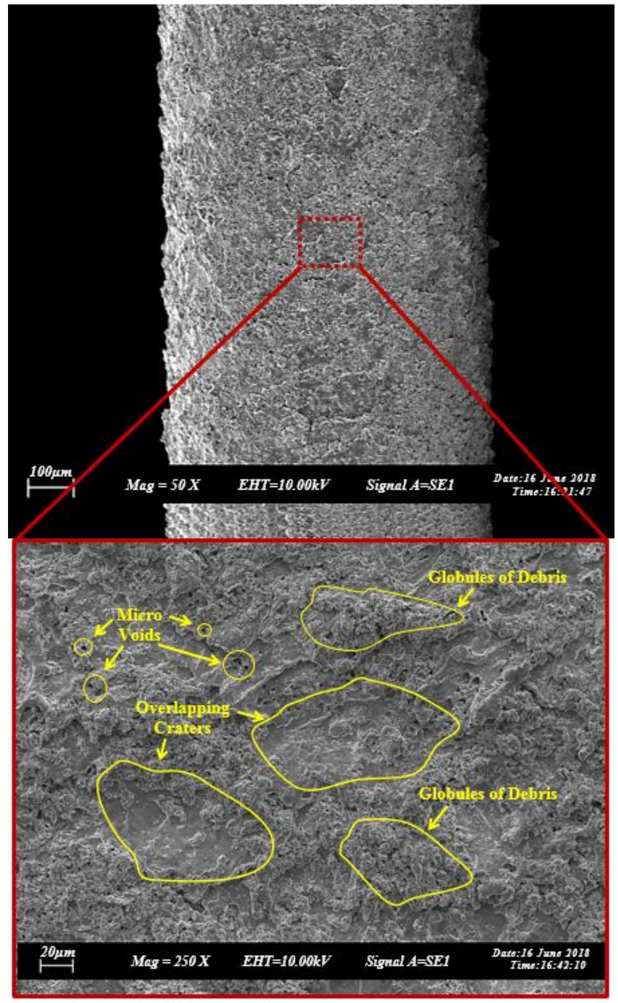

Fig. 7. SEM micrographs of machined surface under optimised machining parameters; Vo= 8 notch, Ip= 10 notch, SA= 3 notch, SB= 6 notch, SE= 2 notch, VG= 140 volts, WS= 10 notch, WT= 7 notch, RSS= 50 rev/min, TF= 0.10 mm/min and SD= upward direction, MRR = 1.427 mm³/min

IV. CONCLUSION

In this research work, the application of the Taguchi orthogonal array method was used to rank, screen and identify the effects of WEDT process parameters in the fabrication of micro-cylindrical parts made by titanium alloy. Almost all of the process parameters that were investigated in this research had influences on the MRR, but the most dominating parameter was the table feedrate. Though this study only covered a small range of levels, it can be extended by selecting a wide range of levels for each process parameter in order to cover a broad region of operability. The maximum value of MRR up to 1.398 mm³/min was discovered by GA approach with optimum machining parameters and the confirmation experiment was found highly acceptable with minimum error percentage of less than 2.5%. This study also supported the evidence from previous observations by researchers whose stated that the occurrences arcing phenomenon was quite severe on WEDT. With regards to the Taguchi method, future scholars can harness this approach for application in any engineering field that involves numerous control parameters with the benefit of minimising experimental trials, as offered by the Taguchi method.

ACKNOWLEDGEMENTS

The authors would like to thank the financial support of UTeM Zamalah Scheme as well as the facility support by the Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka (UTeM). This research is also supported by Malaysia Ministry of Education for [Fundamental Research Grant Scheme (FRGS); FRGS/2/2014/TK01/UTEM/03/2].

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