# INFLUENCE OF PROCESS PARAMETERS ON MATERIAL REMOVAL RATE IN WIRE ELECTRIC DISCHARGE TURNING PROCESS OF INCONEL 718

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## ABSTRACT

*The aim of the current research project work is to investigate the effect of the wire electrical discharge turning process parameters on material removal rate of INCONEL 718 nickel based super alloy by using Taguchi's method. L18 mixed type orthogonal array ($2^1 \times 3^7$) has been selected for experimentation under different process parameters such as rotational speed, pulse on time, pulse off time, servo voltage, wire feed rate, flushing pressure. A zinc coated brass wire of 250μm was used as wire electrode to turn the component and de-ionized water was used as dielectric fluid. The material removal rate has been obtained and analyzed by using Taguchi method. The effects of machining parameters on material removal rate have been studied.*

***Keywords:- Wire-EDT, INCONEL 718, MRR.***

## I. INTRODUCTION

Electric discharge machining process is considered under the categories of nontraditional machining process in which the erosion of material takes place by electrical discharge between an electrode and work piece produces an electric spark, hence it removes material in the form of debris, here only electrically conductive materials can be machined with this process [1,8]. The EDM has some major application in the field of aerospace, automotive industry, and surgical components also in the manufacturing of dies, punches and moulds [1,2]. The electric discharge machining is further modified on the basis of EDM working in order to achieve high dimensional accuracy and to cut intricate shapes, the modified forms are wire electric discharge machining (WEDM) and wire electric discharge turning (WEDT) process, Fig 1 shows the two dimensional line diagram of Wire-EDT and also experimental setup of Wire EDT have been shown in Fig 2, the WEDT is obtained by adding rotary axis to the Wire-EDM to turn hard material which is difficult to machine in conventional method. While machining the materials removed by means of electric spark generated between the inter electrode gap thereby it creates small crater on the surface of the material which leads to material removal [3-6,9]. A varies input parameters of wire electric discharge turning process have been shown in the form of Fish bone diagram in Fig 3. The material have identified for the experimentation was INCONEL 718 nickel based super alloy because of their growing application in the field of aerospace, nuclear, turbines, and fasteners etc, and also based on their properties like high corrosion resistant, high tensile strength wear resistant etc. The chemical compositions of INCONEL 718 super alloys have been given in Table 1.

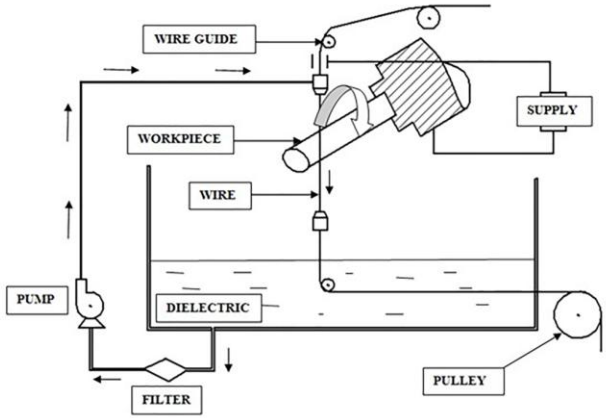


**Fig 1: Wire electric discharge turning layout**

The effects of selected machining parameters on Material Removal Rate of the wire EDT process was determined and analyzed according to Taguchi's approach, L18 orthogonal array of mixed design.

## II. EXPERIMENTAL WORK

The ECO CUT Wire electric discharge machine is externally fitted with turning setup to establish the Wire electric discharge turning process in order to produce cylindrical part for varies application, the experimental set up of Wire electric discharge turning process have been shown in Fig 2. In this work the INCONEL 718 has been used as a work-piece material, it has been kept at 50mm length, 10mm diameter. Zinc coated brass wire of 250μm as wire electrode and de-ionized water is used as a Dielectric fluid for experimentation. The Performance of Wire- EDT is evaluated on the basis of material removal rate (MRR). The material removal rate can be evaluated by using the equation (1) given below [6].

**Table 1**: Material composition of INCONEL 718 super alloy [7]

| Alloy% | Ni+Co | Cr | Cb+Ta | Mo | Ti | Al | Co | C | Mn | Si | P | S | B | Cu | Fe |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min | 50.00 | 17.00 | 4.75 | 2.80 | 0.65 | 0.20 | - | - | - | - | - | - | - | - | - |
| Max | 55.00 | 21.00 | 5.50 | 3.30 | 1.15 | 0.80 | 1.00 | 0.08 | 0.35 | 0.35 | 0.016 | 0.015 | 0.006 | 0.30 | Balance |

$$MRR=\frac{Wtb-Wta}{t*\rho} \quad \text{-----------------} \ (1)$$

Where:

Wtb-Weight of work-piece before machining in mg

Wta-Weight of work-piece after machining in mg

t-Machining Time in min

ρ-Density of INCONEL 718= 8.19g/cm$^3$

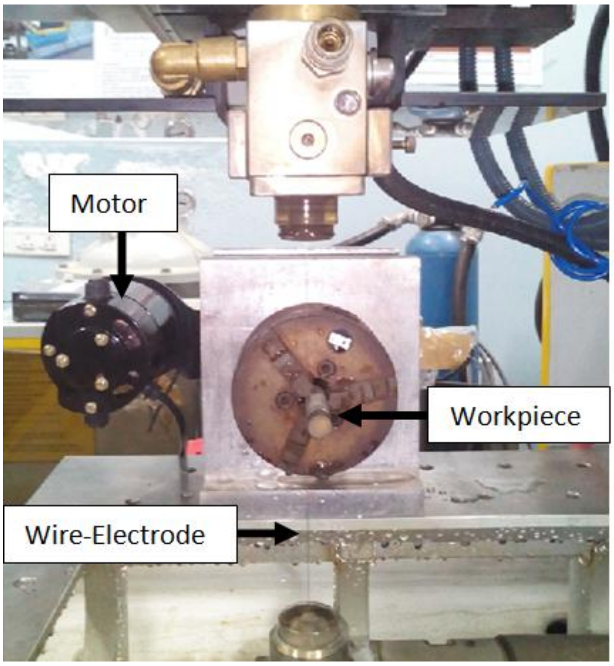


**Fig 2: Wire Electric Discharge Turning setup**

This paper makes use of Taguchi's method for designing the experiments. Hence L18 mixed orthogonal array ($2^1$ x $3^7$) was selected for the investigation. The machining parameters and their levels selected based on the degree of freedom of process parameters and their levels and degree of freedom of orthogonal array. In the investigation the six parameters are identified and selected for experimentation, such as rotational speed, pulse on time, pulse off time, servo voltage, wire feed rate and flushing pressure, here the rotational speed was considered as two levels factor and remaining five parameters was in three levels. The process parameters and their levels have been given in Table 2, Table 3 have been given fixed process parameters considered in the operation and Table 4 has been shown the layout of L18 orthogonal array and response variable [10,11].

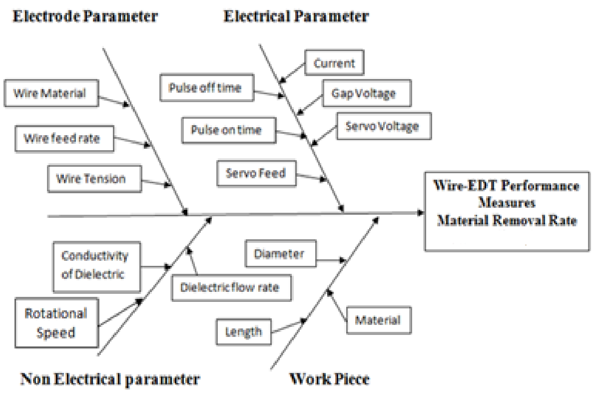


**Fig 3: Fish bone diagram for Wire-EDT**

**Table 2: Machining parameters and their levels**

| Parameters | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| Rotational speed (rpm) N | 150 | 250 | - |
| Pulse on time (µs) Ton | 108 | 116 | 124 |
| Pulse off time (µs) Toff | 24 | 32 | 40 |
| Servo voltage (Volt) SV | 18 | 36 | 54 |
| Wire feed rate (m/min)Wf | 2 | 4 | 6 |
| Flushing Pressure (bar)Pf | 1.8 | 2.0 | 2.2 |

**Table 3: Fixed Parameters**

| Parameters | Value |
|---|---|
| Peak voltage(V) | 11 |
| Peak current (A) | 12 |
| Wire Tension (daN) | 06 |
| Servo Feed (mu) | 2150 |
| Wire material | Zinc coated brass (250µm) |
| Dielectric fluid | De-ionized water |

**Table 4: L18 orthogonal array layout with response**

| Exp | N | $T_{on}$ | $T_{off}$ | SV | Wf | $P_f$ | MRR |
|---|---|---|---|---|---|---|---|
| 01 | 150 | 108 | 24 | 18 | 2 | 1.8 | 1.2231 |
| 02 | 150 | 108 | 32 | 36 | 4 | 2.0 | 0.3840 |
| 03 | 150 | 108 | 40 | 54 | 6 | 2.2 | 0.5571 |
| 04 | 150 | 116 | 24 | 18 | 4 | 2.0 | 0.9426 |
| 05 | 150 | 116 | 32 | 36 | 6 | 2.2 | 0.6090 |
| 06 | 150 | 116 | 40 | 54 | 2 | 1.8 | 1.3036 |
| 07 | 150 | 124 | 24 | 36 | 2 | 2.2 | 1.2560 |
| 08 | 150 | 124 | 32 | 54 | 4 | 1.8 | 2.0321 |
| 09 | 150 | 124 | 40 | 18 | 6 | 2.0 | 1.9065 |
| 10 | 250 | 108 | 24 | 54 | 6 | 2.0 | 0.6130 |
| 11 | 250 | 108 | 32 | 18 | 2 | 2.2 | 0.5656 |
| 12 | 250 | 108 | 40 | 36 | 4 | 1.8 | 0.6279 |
| 13 | 250 | 116 | 24 | 36 | 6 | 1.8 | 1.6903 |
| 14 | 250 | 116 | 32 | 54 | 2 | 2.0 | 2.3068 |
| 15 | 250 | 116 | 40 | 18 | 4 | 2.2 | 2.3347 |
| 16 | 250 | 124 | 24 | 54 | 4 | 2.2 | 1.3065 |
| 17 | 250 | 124 | 32 | 18 | 6 | 1.8 | 2.3779 |
| 18 | 250 | 124 | 40 | 36 | 2 | 2.0 | 3.1014 |

## III. RESULTS AND DISCUSSIONS

### 3.1 Effect of Rotational speed on MRR

Fig 4 depicts the material removal rate versus rotational speed plot to understand the effect of input parameter on response; from the Fig 4, it is observed that by increasing rotational speed of the spindle or work-piece the material removal rate increases i.e. material removal rate is directly proportional to rotational speed, this is because by increasing the rotational speed the work-piece have been more exposed in to the spark region, and also it takes less time to machine the work-piece, so that the material removal rate get increases by increasing the rotational speed.

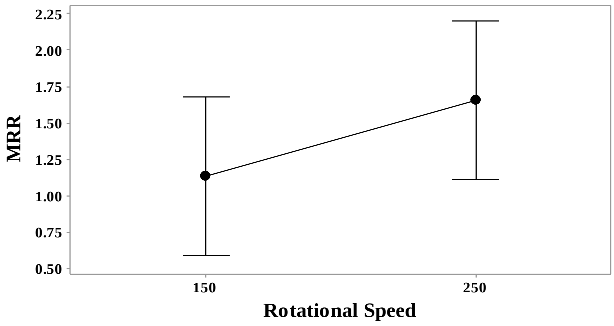


**Fig 4: Material removal rate Vs Rotational speed**

### 3.2 Effect of Pulse on time on MRR

The Material removal rate versus pulse on time plot has been shown in Fig 5. Fig 5 shows the direct effect of pulse on time on material removal rate, which means that by increasing pulse on time the material removal rate increases similarly by decreasing pulse on time the material removal rate decreases. This is because by increasing pulse on time power input to the machine become more so that the duration of each spark gets increases hence spark intensity become high therefore it removes more materials from the work-piece.

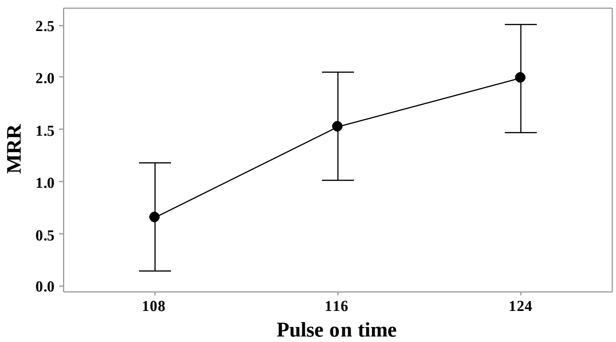


**Fig 5: Material removal rate Vs pulse on time**

### 3.3 Effect of pulse of time on MRR

Fig 6 have been shown to study the influence of pulse off time on response variable, the pulse off time also shows direct effect on material removal rate, similar to the effect of rotational speed and pulse on time on response variable which is already discussed in the above. Here by increasing pulse off time increases the material removal rate this is because, by increasing pulse off time it increases the time taken for next spark that delay in spark generation helps to flush the debris or chips present in between inter electrode gap and also it avoids the fusion of debris so that MRR get increases.

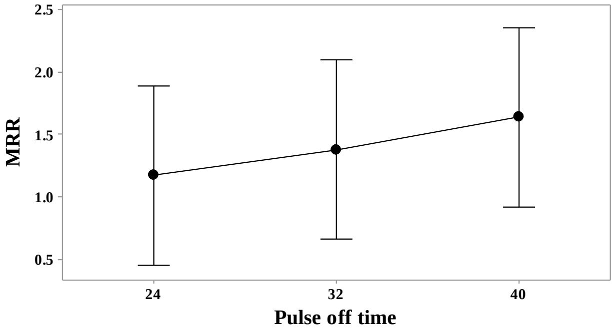


**Fig 6: Material removal rate Vs pulse off time**

### 3.4 Effect of servo voltage on MRR

The effect of servo voltage on material removal rate plot have been shown in Fig 7, from the plot it understand that by increasing servo voltage the material removal rate decreases from level 1(18V) to Level 2(36V) further it shows almost constant effect, this is because; the inter electrode gap is maintained by means of servo voltage, if the servo voltage magnitude is low that means that the gap between electrode and work-piece is less, this is the case the intensity of spark towards the work-piece is high, similarly if the servo voltage magnitude is high that shows gap between wire electrode and work-piece become large in this case the spark intensity is less because of large gap. Based on above theory by increasing servo voltage from Level 1- Level 2 to Level 3 the material removal rate gets decreases.

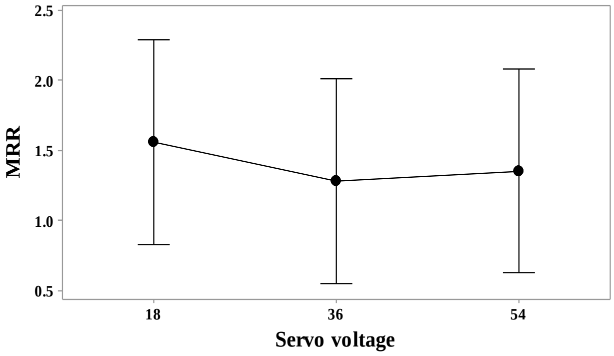


**Fig 7: Material removal rate Vs servo voltage**

### 3.5 Effect of wire feed rate on MRR

Fig 8 have been presents the plot for material removal rate versus wire feed rate, from the Fig 8 it is understood that by increasing wire feed rate the material removal rate decreases visa versa. This is because by increasing wire feed rate produce abrupt spark that leads to system become unstable, as a result the material removal rate decreases from Level 1 to Level 2 further it shows constant effect on MRR.

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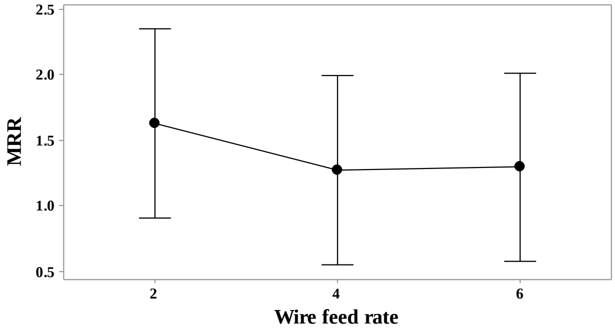


**Fig 8: Material removal rate Vs wire feed rate**

### 3.6 Effect of flushing pressure on MRR

The effect of flushing pressure on material removal rate have been shown in Fig 9, from the Fig it is observed that the effect of flushing pressure on MRR become constant from level 1 to level 2 further at Level 3 the material removal rate get decreases, this is because by increasing flushing pressure from 1.8 bar to 2 bar the material removal rate shows constant, here the chips present in between the inter electrode gap are clearly removed that helps to increase the material removal rate without fusing, at level 3 further increase in flushing pressure reduces the intensity of spark between the gap so that it reduces material removal rate.

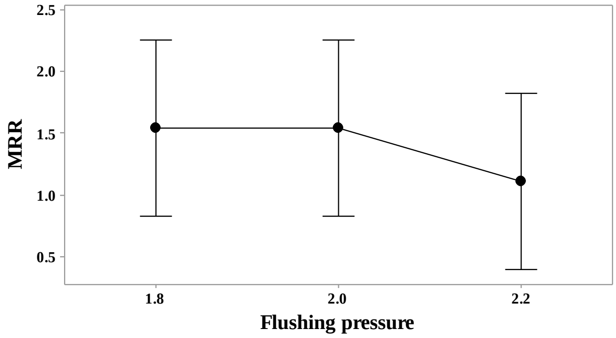


**Fig 9: Material removal rate Vs flushing pressure**

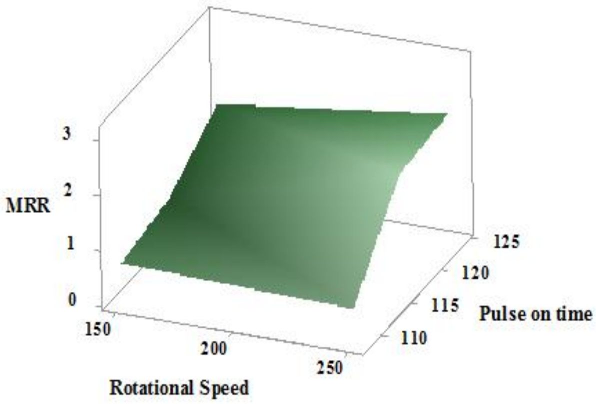


**Fig 10: Surface plot of MRR Vs pulse on time, rotational speed**

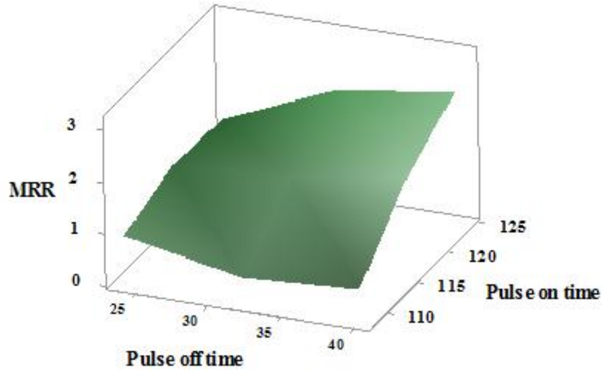


**Fig 11: Surface plot of MRR Vs pulse on time, rotational speed**

Fig 10 shows the material removal rate variation with respect to two input parameters, as can clearly seen from Fig 10, the material removal rate value increases with higher pulse on time and rotational speed values on the other hand by decreasing the value of pulse on time and rotational speed the material removal rate decreases

Fig 11 depicts the material removal rate results with pulse on time and pulse off time; from the Fig 11 it can be shown that the value of material removal rate increases with increases in pulse on time and pulse off time.

## IV.CONCLUSION

The Wire Electric Discharge Turning process has been carried out with the help of Taguchi's L18 orthogonal array experimental design. The experiments were conducted by considering the rotational speed, pulse on time, pulse off time, servo voltage, wire feed rate and flushing pressure as a input machining parameters, based on the experimentation the following conclusions can be drawn.

- The material removal rate increases by increasing rotational speed of the spindle.
- The material removal rate increases with increase in pulse on time and pulse off time.
- The material removal rate decreases by increasing servo voltage and wire feed rate up to some extent then it shows constant MRR.
- Material removal rate is constant up to Level 2 then it decreases by increasing flushing pressure.

## REFERENCES

[1] Mohammad Jafar Haddad, Alireza Fadaei Tehran, Investigation of cylindrical wire electrical discharge turning (CWEDT) of AISI D3 tool steel based on statistical analysis [J]. Journal of materials processing technology 198 (2008) 77–85

[2] P. Matoorian, S. Sulaiman, M.M.H.M. Ahmad, An experimental study for optimization of electrical discharge turning (EDT) process [J].journal of materials processing technology 204 (2008) 350–356.

[3] Aminollah Mohammadi, Alireza Fadaei Tehrani, Ehsan Emanian, Davoud Karimi, Statistical analysis of wire electrical discharge turning on material removal rate [J]. Journal of materials processing technology 205 (2008) 283–289.

[4] Jun Qu, Albert J. Shih, Ronald O. Scattergood, Development of the Cylindrical Wire Electrical Discharge Machining Process, Part 1: Concept, Design, and Material Removal Rate [J]. Journal of Manufacturing Science and Engineering (2002)124.

[5] Priyaranjan Sharma, D. Chakradhar, S. Narendranath, Evaluation of WEDM performance characteristics of Inconel 706 for turbine disk application, Materials and Design 88 (2015) 558–566.

[6] M.J. Haddad, A. Fadaei Tehrani, Material removal rate (MRR) study in the cylindrical wire electrical discharge turning (CWEDT) process [J], journal of materials processing technology 199 (2008) 369–378.

[7] UNS N07718, W. Nr. 2.4668

[8] Mohit Datt, and Daljinder Singh, Optimization of WEDM Parameters using Taguchi and ANOVA Method, International Journal of Current Engineering and Technology,2015,15(6), 2277 – 4106.

[9] Parveen Kr. Saini, Mukesh Verma, Experimental Investigation of Wire-EDM Process Parameters on MRR of Ti-6al-4v Alloy, International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, 4(5)-2014

[10] Gaurav Raghav, B.S. Kadam, Manjeet Kumar, Optimization of Material Removal Rate in Electric Discharge Machining Using Mild Steel, International Journal of Emerging Science and Engineering (IJESE) ISSN: 2319–6378, 1(7)-2013

[11] K. Kumar, R. Ravikumar, Modeling and Optimization of Wire EDM Process, International Journal of Modern Engineering Research (IJMER),3(3)- 2013 ,1645-1648.