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# Effect of wire related parameters and servo feed on process performance characteristics during WEDM of combustor material

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**Abstract.** Generally, Ni based superalloys are used as combustor material owing to its high temperature resisting properties. These materials are also having high strength and hence, they are difficult-to-machine. Producing components of these materials with complex shapes employing traditional machining techniques is practically near to impossible. This problem can be addressed by using WEDM technique. The current research aims to study the effect of wire related parameters and servo feed on material removal rate (MRR) and wire wear rate (WWR) during WEDM of waspalloy. Experimentation has been conducted as per one-factor-at-a-time (OFAT) approach and optimum solution is obtained by graphical analysis. It is observed that wire feed rate of 4 m/min, wire tension of 11 machine unit, and servo feed of 2050 mm/min provide highest value of material removal rate.

**Keywords.** WEDM, Waspalloy, MMR, WWR

## 1. Introduction

Combustor or combustion chamber is the most crucial component of gas turbine. It is utilized to burn fuel. Thus, it experiences a severe mechanical condition. Generally, combustors are made of high-strength, high-temperature-resistance materials namely Ni based super alloys. These materials are having low machinability and found difficult to process by conventional techniques. In contrast, since last decade wire electric discharge machining (WEDM) is emerged as one of the most potential non-traditional machining processes to develop tricky profiles with close tolerances on uncanny materials. In WEDM, material is removed by melting and vaporization by high temperature ranging up to 6000-10000 $^0$C. This high temperature is generated by a series of electric sparks between tool electrode and work piece dipped in a dielectric as shown in Figure 1.

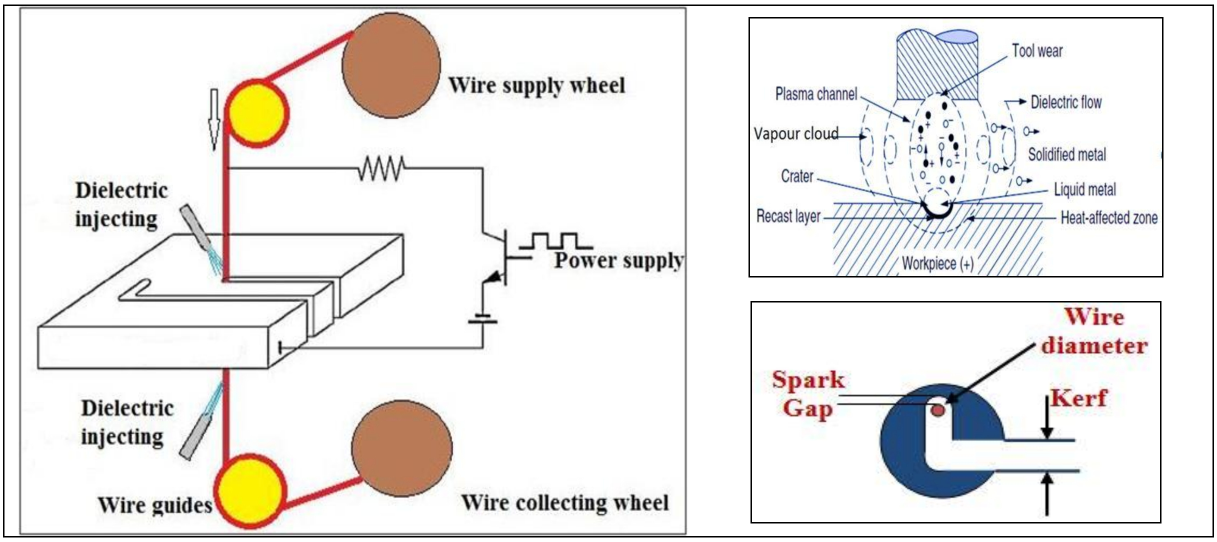



**Figure 1.** Schematic diagram illustrating the process principle of WEDM

The detail description of the process is available in literatures [1-3]. Till date a number of research works has been carried out on WEDM. A comparative study on WEDM employed for different materials is illustrated in Figure 2. It is evident from Figure 2 that most of the research work carried out on either steel alloys or aluminium alloys; limited research work has been reported on Ni based super alloys. Therefore, it is very much essential to explore WEDM of Ni based super alloys from the industrial point of view. Beside this, in this process, wire-electrode contributes approximately 70% of the machining cost [4]. Thus, to achieve economical machining, investigation on wire related parameters is essential. In current research, experimentation has been conducted to explore the effects of wire related parameters and servo feed on measures of process performances.

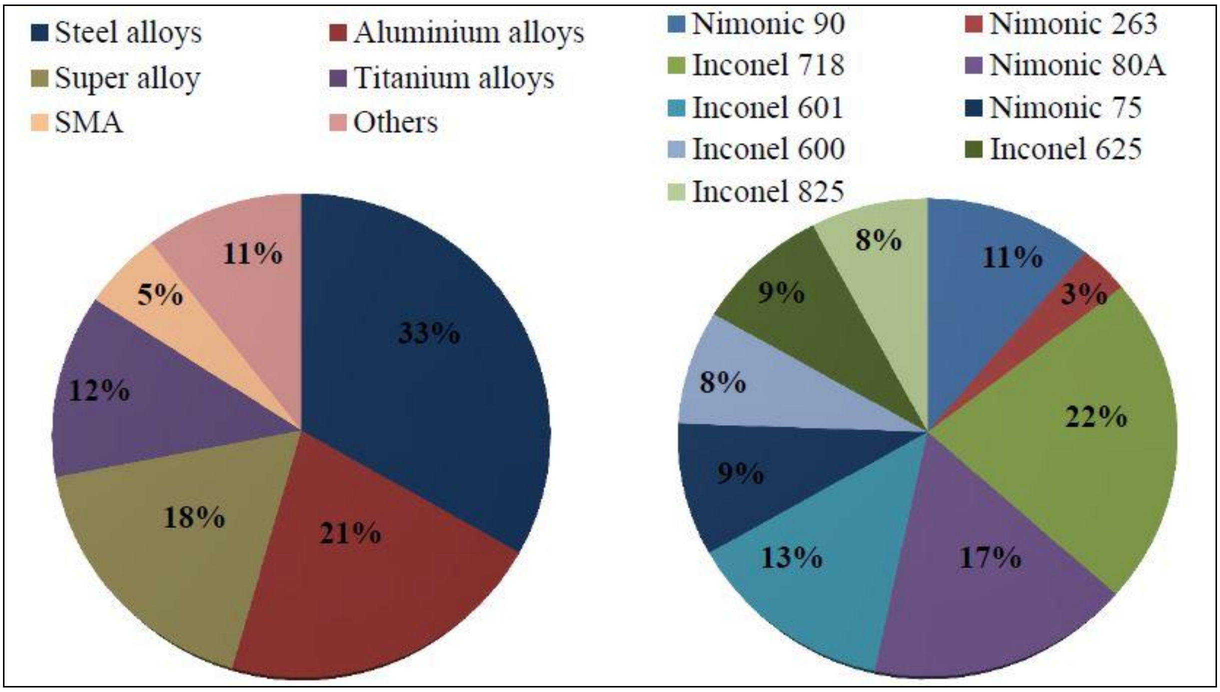


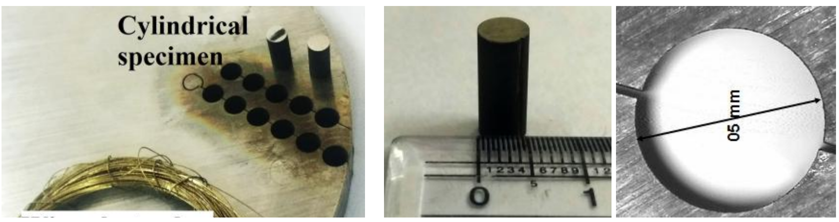

**Figure 2.** Comparative study of published research work on WEDM

## 2. Experimental Details

Experiments are conducted on Electronica Sprintcut-734 machine (*Make: Electronica Machine Tool*). The machine setup consists of four main components:

- Power supply system
- Dielectric system
- Positioning system
- Drive system

The detailed functions of components are available in references [5-6]. In present research, wasp alloy is employed as work piece material. It is a Ni based super alloy (*Cr: 18-21%; Co: 12-15%; Mo: 3.5-5%, Ti: 2.75-3.25%, Ni: Balanced*); utilized as combustor material for gas turbines owing to its excellent strength at elevated temperature (~1000 $^{0}$C). Wire feed rate (WF), wire tension (WT), and servo feed (SF) are decided as input process parameters. Beside this, pulse-on time, pulse-off time, peak current, servo voltage, water pressure and wire-electrode are kept fixed for experimentation. The ranges and levels of input and fixed parameters are presented in Table 1. MRR and WWR are opted as process performance characteristics for current study. Experimentation has been conducted as par one-factor-at-a-time (OFAT) approach and optimum solution is obtained by graphical analysis. In OFAT approach, response of the process is observed after varying only one input parameter and keeping the other parameters at mid level. A cylindrical work piece of diameter 5mm and height 12 mm is cut to carry out the experimentation. The photographic view of the cylindrical pieces cut from the work piece is demonstrated in Figure 3.



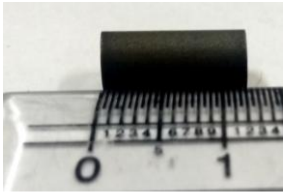



**Figure 3.** Photographic view of work sample

**Table 1.** Ranges and levels of parameters employed in experimentation

| *Input parameters* | | *Fixed parameters* | |
|---|---|---|---|
| **Parameter** | **Range (Levels)** | **Parameter** | **Value** |
| Wire feed rate (m/min) | 2-14 (2, 4, 8, 11, 14) | Pulse-on time | 115 μs |
| | | Pulse-off time | 50 μs |
| Wire tension (mu) | 2-14 (2, 5, 8, 11, 14) | Peak current | 130 A |
| | | Servo voltage | 50 V |
| Servo feed(mm/min) | 2000-2100 (2000, 2050, 2100) | Water pressure | 1 kg/cm$^2$ |
| | | Wire-electrode | Brass wire |

MRR defines the amount of material removed per unit machining time. It is quantified using Equation 1.

$$MRR\ (mm^3/min) = \frac{cutting\ length \times height\ of\ workpiece \times wire\ diameter}{machining\ time} \quad (1)$$

WWR is characterized by weight loss of the wire per unit machining time. The weight of unit length of used-wire and unused-wire are measured using high-precision electronic weighing machine (*accuracy = 0.0001 g*) and WWR is determined using Equation 2.

$$WWR\ (mm^3/min) = \frac{mass\ of\ unused\ wire - mass\ of\ used\ wire}{machining\ time} \times \frac{1}{wire\ density} \quad (2)$$

## 3. Results and discussion

Experimentation has been conducted to study the influence of WF on MRR and WWR. The experimental outcomes are presented in Table 2. Maximum MRR of 5.604 mm$^3$/min is obtained when WF = 04 m/min where, WF of 14 m/min is responsible for lowest MRR. On contrary, WF of 14 m/min provides lowest value of WWR. Therefore, it is practically difficult to select optimum WF. To address this problem, wear ratio (WR) is quantified. WR is the ratio of MRR and WWR; it should be maximum. It is evident that WF of 4 m/min provides higher value of WR; hence, it is selected as optimum WF for current research.

**Table 2.** Experimental results showing effect of wire feed rate

| **Expt. No.** | **Wire feed rate** (m/min) | **MRR** (mm$^3$/min) | **WWR** (mm$^3$/min) |
|---|---|---|---|
| 1 | 02 | 5.345 | 1.250 |
| 2 | 04 | **5.604** | 1.303 |
| 3 | 08 | 5.104 | 2.353 |
| 4 | 11 | 5.153 | 2.251 |
| 5 | 14 | 5.086 | 1.158 |

The effect of WT on MRR and WWR is explored by carrying out experimentation with five different values of WT as presented in Table 1. The experimental results related to effect of WT is shows in Table 3. It is clear from Table 3 that maximum MRR of 5.861 $mm^3$/min is obtained for WT of 11 mu. Although, maximum WWR of 5.565 $mm^3$/min is recorded when WT = 11 mu. Like previous case, WR has been quantified. It is found that 14 mu provides higher value of WR; hence, it is opted as optimum solution.

Experimental results showing the effect of SF are presented in Table 4. For present experimentation SF is varied from 2000-2100 mm/min in step of 50 units. It is evident that no machining is occurred when SF = 2000 mm/min. The maximum MRR of 5.104 $mm^3$/min is recorded for SF of 2050 mm/min. However, SF of 2100 mm/min is responsible for lower value of WWR (i.e.1.096$mm^3$/min). It is examined that higher value of WR is recorded for SF of 2100 mm/min. Therefore, it can be reported that 2100 mm/min is optimum SF for present study.

**Table 3.** Experimental results showing effect of wire tension

| Expt. No. | **Wire tension** (mu) | **MRR** ($mm^3$/min) | **WWR** ($mm^3$/min) |
|---|---|---|---|
| 1 | 02 | 5.626 | 4.324 |
| 2 | 05 | 5.568 | 2.261 |
| 3 | 08 | 5.104 | 2.589 |
| 4 | 11 | **5.861** | 5.565 |
| 5 | 14 | 5.325 | 1.821 |

**Table 4.** Experimental results showing effect of servo feed

| Expt. No. | **Servo feed** (mm/min) | **MRR** ($mm^3$/min) | **WWR** ($mm^3$/min) |
|---|---|---|---|
| 1 | 2000 | Not working | |
| 2 | 2050 | 5.104 | 1.184 |
| 3 | 2100 | 4.908 | 1.096 |

Figure 4 presents the effect of WF and WT on prime response parameter of current study (i.e., MRR). It is observed that there is no significant change in MRR owing to change in WF or WT. For instance, the change in MRR is not more than 10% in any case. It indicates that WF and WT are not having significant influence on MRR. This investigation is in accordance with past research work [7].

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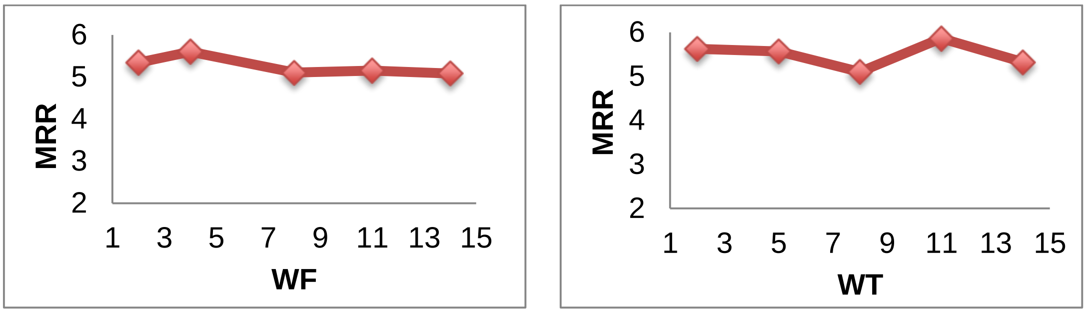


**Figure 4.** Effect of WF and WT on MRR

The effect of WF and WT on WWR is depicted in Figure 5. It is evident that no proper trend is observed. Figure 6 shows the quantified values of WR for different value of WF, WT, and SF. The value of input parameter responsible for higher value of WR is selected as optimum for further study.

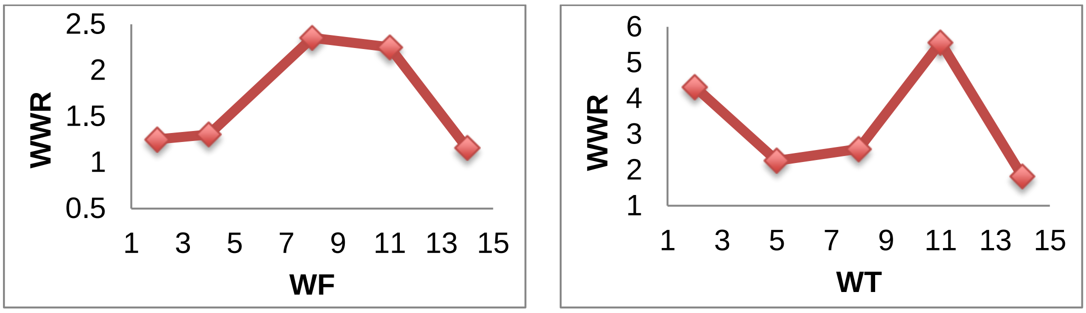


**Figure 5.** Effect of WF and WT on WWR

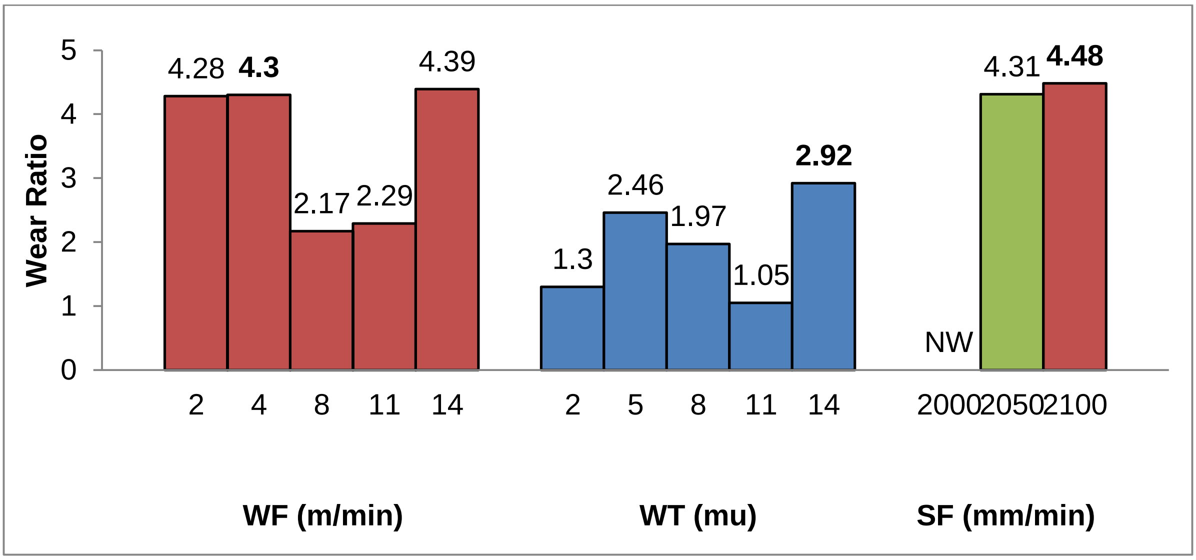


**Figure 6.** Effect of WF, WT and SF on WR

Unused-wire and used-wire are also analysed using optical microscope. The photographs obtained from optical microscope are illustrated in Figure 7. The wear out portion in case of used-wire is clearly visible.

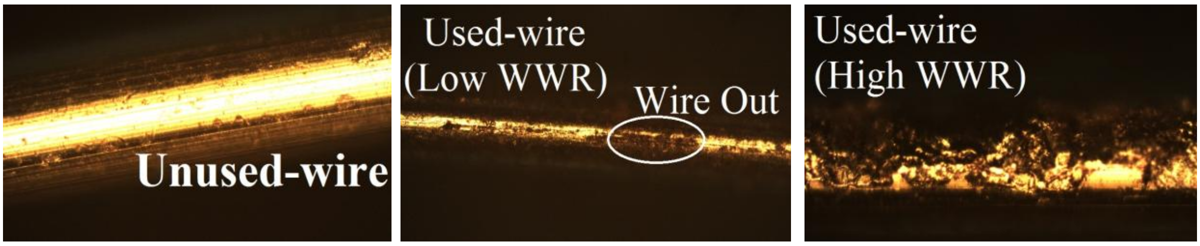


**Figure 7.** Photographs of wire-electrode captured by optical microscope

## 4. Conclusion and future scope

In current research, WEDM has been attempted on combustor grade waspalloy material to explore the effect of WF, WT and SF on MRR and WWR. It is evident from experimental results that WF, WT and SF are having significant influence only on WWR. The effect of input parameters on MRR is not significant. Maximum 10% change in MRR can be observed employing different levels of input parameters. It is found that, 4 m/min as WF, 14 mu as WT and 2100 mm/minas SF are optimum for the present study. The future research could include the study of effect of other process parameters on surface quality of wire electric discharge machined waspalloy parts.

## 5. References

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