Optimization of Process Parameters of WEDM Process for Machining D2 Tool Steel

Sayyed Amer Ali[1], Shantisagar Biradar[2], Swpnil Dhole[3]

[1, 2, 3] Department of Mechanical Engineering, MSS, College of Engineering & Technology, Jalna (Maharashtra)

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Abstract - *This paper presents an investigation of WEDM process using molybdenum wire as electrode on D2 tool steel. WEDM is a thermal machining process that utilizes spark discharges to erode a conductive material. Optimum machining conditions were obtained with maximum cutting rate and minimum surface roughness as objective. It was observed that with increase in peak current, cutting speed and surface roughness increases. Response surface methodologies D optimality test was used to determine the optimal machining parameters, among which the peak current for cutting speed and the gap voltage for surface roughness were found to be the most significant. The obtained optimal machining conditions are peak current of 16 A, voltage of 190 V, Pulse on time of 115 µs, Pulse off time of 40 µs and Wire tension of 6 N which is validated by confirmation test.*

***Key Words*:** WEDM, D2 tool Steel, Optimization

1. INTRODUCTION

Wire electrical discharge machining (WEDM) is one of the most extensively used non-conventional material removal processes. WEDM has evolved over time from being just used for manufacturing tools and dies to the machine of exotic space age alloys including Inconel, titanium, Carbide, Polycrystalline diamond compacts and Conductive ceramics. It can machine anything regardless of its hardness, the only condition being the material should be electrically conductive. Parts that have complex geometry and tolerances don't require manufacturer to rely on different skill levels or multiple equipment. Substantial increases in productivity are achieved since the machining is unattended, allowing operators to do work in other areas. Most workpieces come off the machine as a finished part, without the need for secondary operations.

D2 tool steel has been selected as a work piece by taking into account its various engineering applications such as in manufacturing of punching tools, mandrels, mechanical press forging die, plastic mould and die-casting dies, aircraft landing gears, helicopter rotor blades and shafts. Among non-conventional machining processes, the WEDM is one of the method capable of machining D2 tool steel with desired accuracy.

WEDM is non-conventional machining process, widely used for machining electrically conductive materials, more specifically hard materials. The WEDM has many advantages, such as non-contact with the work piece during the machining process and ability to machine any conductive material, regardless of its hardness. Researchers worked in area of WEDM machining to investigate effect of process parameters. Bikash Choudhuri et al. (2018) made an attempt to model the performances of WEDM process on H21 tool steel using response surface methodology. The effect of various process parameters (pulse on time, pulse off time, current, gap voltage and wire tension) on the performance characteristics of WEDM is studied. Longer pulse on-time results in less consumption of wire but lower surface finish with more surface defects [1]. S. Banerjee et al. (2018) examined the influence of process parameters of WEDM on MRR of EN47 spring steel. Taguchi methodology along with L27 orthogonal array is used to optimize the MRR by considering four process parameters i.e. Pulse-on time, Pulse-off time, Wire feed and gap voltage. The ANOVA result indicates that pulse-on time is the most influencing parameter whereas pulse off time and gap voltage are found to be quite remarkable parameters to control the MRR [2]. Anshuman Kumar et al. (2017) used Taguchi method couple with multi objective Simulated Annealing (SA) for WEDM process on machinability of Inconel 718 alloy. The highly effective parameters on both the kerf and the MRR were found as voltage and Ton variable, whereas current was less effective factors among all. [3]. Somvir Singh Nain et al. (2017) linear, non-linear and ANN-linear regression based modelling technique to determine the surface roughness (SR), waviness (Wa) and material removal rates (MRR) of wire electrical discharge machining (WEDM) on Udimet-L605. Based on experimental result it was found that surface roughness decrease with increase in servo voltage and pulse-off-time [4].

2. EXPERIMENTAL SET-UP

Experiments have been conducted using ELEKTRA SPRINTCUT 734 WEDM. The WEDM machine is shown in Fig. 1

Fig -1: WEDM Machine

Machining parameters and their level chosen for this study are presented in Table 1.

Table 1: Machining parameters and their levels

Factor		Unit	Levels 1	Levels 2	Levels 3	Levels 4	Levels 5
			-2	-1	0	1	2
Peak current	Ip	Amp	15	17	19	21	23
Gap voltage	V	Volt	190	210	230	250	270
Pulse on time	Ton	µSec	110	115	120	125	130
Pulse off time	Toff	µSec	40	45	50	55	60
Wire feed rate	WF	N	6	7	8	9	10

3. RESULT AND DISCUSSION

The analysis was made using the popular software specifically used for design of experiment applications known as MINITAB. In present study, it is desirable to maximize Cutting rate and to minimize surface roughness.

A. Analysis of cutting rate

The peak current determine the status of input energy in the WEDM process. From the surface plot it can be seen that increase in peak current leads to an increase of cutting speed. Fig 2 shows that the cutting rate is directly proportional to the peak current. Cutting speed decreases with increase in voltage.

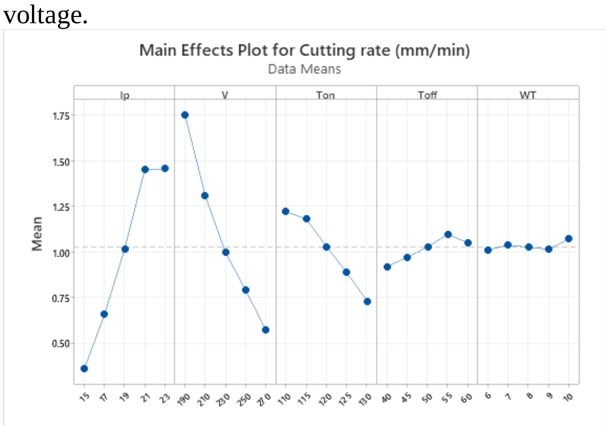

Fig. 2. Main Effect Plot for cutting speed

B. Analysis of surface roughness

The discharge energy increases with the pulse on time and peak current and larger discharge energy produces a larger crater, causing a larger surface roughness value on the work piece. Fig 3 shows that the surface roughness is directly proportional to the peak current, but it is decreases with increase in voltage.

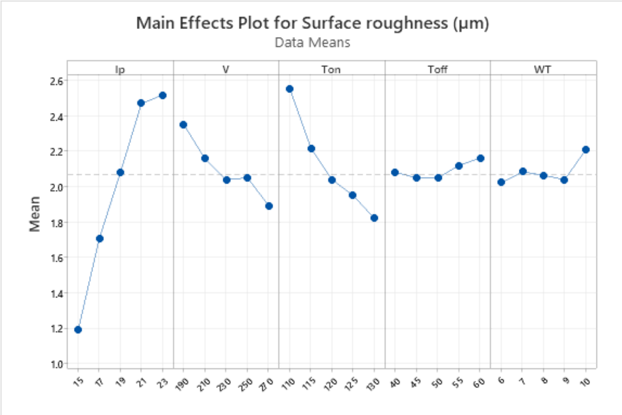

Fig. 3 Main Effect Plot for surface roughness

RSM's D-optimal Method

Response Optimizer helps to identify the factor settings that optimize a single response or a set of responses. For multiple responses, the requirements for all the responses in the set must be satisfied. Response optimization is often useful in product development when you need to determine operating conditions that will result in a product with desirable properties.

Table 2 Response Optimization for cutting rate and Ra

Parameters	Goal	Lower	Target	Upper	Weight	Import
Cutting rate	Maximum	0.36	2.15	2.15	1	1
Surface Roughness	Minimum	1.19	1.19	2.83	1	1

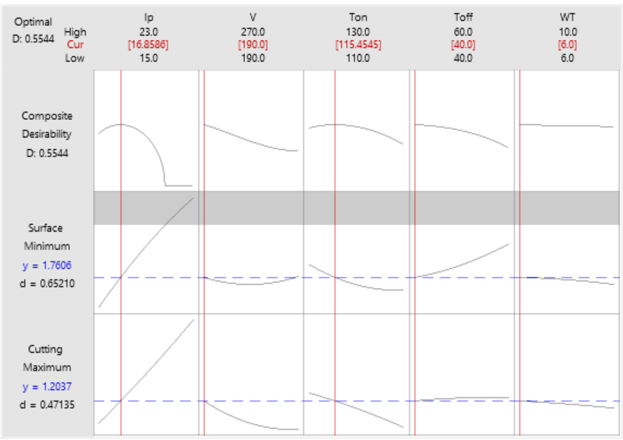

Fig. 4 Optimization Plot for cutting rate and surface Ra

From the plot it is observed that the composite desirability is obtained as 0.5544 reflecting the setting of input variables marked by red color will provide optimum responses value

- **Global Solution**

Peak current = 16 Amp
Gap voltage = 190 Volt
Pulse on time = 115 µsec
Pulse off time = 40 µsec

Wire tension = 6 N

- **Predicted Responses**

Cutting rate = 1.2037 mm/min,
Surface Roughness = 1.7605 µm

4. CONCLUSIONS

WEDM experiments were successfully performed on D2 Tool Steel using molybdenum wire. The cutting rate and surface roughness are evaluated. It is observed that increase in peak current drastically reduces the machining time to at the same time surface roughness is high. From the response surface optimizer, the optimum value of cutting rate is 1.2037 mm/min and surface roughness is 1.7605 µm at peak current = 16 Amp, Gap voltage = 190 V, Pulse on time = 115 µsec, Pulse off time = 40 µsec, Wire tension = 6 N which is validated by confirmation test.

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