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Research Paper

Study of wire-electrical discharge machining parameters of titanium alloy by using taguchi method

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Abstract

Machining of Titanium alloys is difficult due to their chemical and physical properties namely excellent strength, chemical reactivity and low thermal conductivity. Traditional machining of such materials leads to formation of continuous chips and tool bits are subjected to chatter which leads to formation of poor surface on machined surface. In this study, Wire-EDM one of the most popular unconventional machining process which was used to machine such difficult-to-cut materials. Effect of Wire-EDM process parameters namely peak current, pulse-on- time, pulse-off-time, servo voltage on MRR and SR was investigated by Taguchi method. 0.25 mm brass wire was used in this process as electrode material. A surface roughness tester (Surftest 301) was used to measure surface roughness value of the machined work surface. A multi-response optimization technique was then utilized to optimize Wire-EDM process parameters for achieving maximum MRR and minimum SR simultaneously.

Keywords: *Titanium Alloy; Wire-EDM; Brass Wire; Taguchi Methodology; Multi-Response Optimization; Surface Roughness Tester.*

1. Introduction

Titanium and its alloys are having excellent chemical and mechanical properties and hence they were found as component materials which are used in aerospace and non-aerospace applications [1]. Having physical properties such as excellent strength and light weight in nature these materials are used in preparation of automobile structures and engine components of aerospace industries. Due to their low elasticity and chemical reactivity with the tool materials, it is not east to cut Titanium alloys. Hence, development of advanced machining process for Titanium alloys arises in order to achieve better surface finish and tool life [2]. Wire-EDM which is a unconventional machining process was introduced to produce different variety of components with intricate shapes [3]. It is the process in which temperature is generated because of the electric spark developed between the two electrical conductors [4]. In this process, pulse generator unit will generate series of electrical pulses which are applied between the two conductors of electricity. The material is removed from the work surface because of the small spark energy developed in the narrow gap. Electro-erosion of work-piece is occurred because of large number of such developed tiny discharges [5].
Wire-EDM is a newly developed machining process which consists of varies number of electrical and non-electrical machining parameters [6]. Because of varies process parameters and difficult mechanism, achieving optimum performance from the machine is always a challenging task [7]. Therefore, a systematic approach is badly required and a demand for research studies was established, to find out the optimum parameter setting.

A good number of researches have been carried out in this area to find better optimal parameters while machining Titanium and its alloys [8-10]. Different types of optimization techniques are used by different authors for optimization of machining parameters. M.S. Hewidy et al [11] have used RSM technique to optimize WEDM machining parameters for minimum wire wear ratio and surface roughness. They have conducted 31 experiments on Inconel 601 material on a Wire-EDM machine. Peak current, Duty factor, Wire tension and Water pressure were taken as machining parameters and found that peak current as the significant parameter. Neeraj Sharma et al. [12]
Have used optimization technique to optimize process parameters namely Pulse-on-time, pulse-off-time, SV, IP and WT for maximum MRR and minimum SR. They have conducted experiments according to Central composite design (CCD). Vinod Kumar et al [13]. Have conducted experiments on Nimonic-90 using wire as electrode material to evaluate Surface roughness and Dimensional shift.
In the present study, effect of machining parameters namely IP, T_{on}, T_{off} and SV on performance characteristics was investigated. Taguchi method was used to identify significant parameters on output responses namely MRR and SR. A multi criteria decision analysis, which is a multi- response optimization technique, was used to optimize the machining parameters in this paper for achieving maximum material removal rate and minimum surface roughness.

2. Plan of experimentation

In the present work, work piece material selected was Ti-6Al-4V alloy. It was considered for optimizing process parameters with multiple performance characteristics namely material removal rate (MRR) and surface roughness (SR). Machining parameters considered were: IP, T_{on}, T_{off} and SV. Orthogonal array Taguchi L_9, as shown in Table (1) has been used by the author [14]. Taguchi method, which is a robust design methodology, is used for the conduction of experiments.

Table 1: Experimental Results after Machining Process from A.V.S Ram Prasad. [14]

S NO	IP	Ton	Toff	SV	MRR	SR
1	10	105	75	40	2.91	1.8
2	10	115	85	50	3.37	1.98
3	10	125	95	60	3.76	2.34
4	15	105	85	60	4.5	2.48
5	15	115	95	40	6.25	2.71
6	15	125	75	50	7.15	2.9
7	20	105	95	50	6.32	2.41
8	20	115	75	60	7.42	3.1
9	20	125	85	40	6.05	2.79

3. AHP TOPSIS and experimental results

The procedure for the selection of good alternative from those available alternatives by TOPSIS method is given below:

Step 1. Table 1 shows experimental values which describes about input parameters. Output characteristics namely MRR mm^3/min ()nd SR R_a ()µm) investigated were also shown. Hence these output values are taken as input values in to decision matrix and source for this data is obtained from the Wire-EDM machining process.

Step 2. The next step is to determine all the important data required for the attributes in the form of decision matrix as given in Table 2.

Table 2: Decision Matrix (x_{ij})

S NO	MRR	SR
1	2.91	1.8
2	3.37	1.98
3	3.76	2.34
4	4.5	2.48
5	6.25	2.71
6	7.15	2.9
7	6.32	2.41
8	7.42	3.1
9	6.05	2.79

Step 3. Formation of normalised decision matrix as shown in Table 3, by using the following equation and considering the decision matrix values as shown in above Table.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad \text{i=1, 2......9; j=1, 2.} \tag{1}$$

Where

i = number of experimental runs.

j =performance characteristics.

x_{ij} normalised value of i-th experimental run associated with j-th performance characteristics.

Table 3: Normalised Decision Matrix (r_{ij})

S NO	MRR	SR
1	0.107516	0.236878
2	0.202851	0.260565
3	0.226326	0.307941
4	0.270869	0.326365
5	0.376207	0.356632
6	0.43038	0.381636
7	0.38042	0.317153
8	0.446632	0.407956
9	0.364168	0.36716

Step 4. Calculation of weighted normalized decision matrix as shown in Table 4 by using weights which are obtained by AHP method. Weights for different parameters (w_j) or MRR= 0.5, SR=0.5.

$$r_{ij} =* \text{ i=1, 2....9; j=1, 2.} \tag{2}$$

Table 4: Weighted Normalized Decision Matrix

S.NO	MRR	SR
1	0.087581	0.118439
2	0.101425	0.130283
3	0.113163	0.15397
4	0.135434	0.163182
5	0.188103	0.178316
6	0.21519	0.190818
7	0.19021	0.158576
8	0.223316	0.203978
9	0.182084	0.18358

Step 5. Calculation of ideal best (V^+) nd ideal worst solutions (V^-) f jth output parameter have the optimal performance:

$$V^+ = \{[\max(S_{ij} \,|\, j \in J] \text{ or } [\min \; S_{ij}) \square \; j \grave{o} J']i = 1,2,\ldots\ldots.9 \tag{3}$$

$$V^- = \{[\min(S_{ij} \,|\, j \in J] \text{ or } [\max \; S_{ij}) \square \; j \grave{o} J']i = 1,2,\ldots\ldots.9 \tag{4}$$

Where V^+ epresents an ideal best solution (0.223316, 0.118439).

Similarly, V^- epresents ideal worst solution (0.087581, 0.203978).

Step 6. Determine computed distance measures.

The performance of these output values is measured as the important alternative distance s_{ij}^+ rom the V^+ alues and the bad alternative distance s_{ij}^- rom the V^- alues.

The following equations given below shows the performance of each alternative under the best and worst conditions

$$s_i^+ = \sqrt{\sum_{j=1}^{2} \left(D_{ij} - s_i^+\right)^2} \tag{5}$$

$$s_i^- = \sqrt{\sum_{j=1}^{2} \left(D_{ij} - s_i^-\right)^2} \tag{6}$$

Where j= 1, 2.

Step 7. Calculation of closeness coefficient and rank for alternatives.

Closeness coefficient $C_i = \frac{s_i^-}{s_i^- + s_i^+}$ (7)

Table 5: Closeness Coefficient Values

SNO	s_i^+ .			RANK
1	0.135735	0.085539	0.386575	7
2	0.1224650	0.074984	0.379765	8
3	0.115742	0.056171	0.326741	9
4	0.098616	0.062883	0.389369	6
5	0.069464	0.103746	0.598969	4
6	0.072834	0.128286	0.637858	2
7	0.052029	0.112223	0.683236	1
8	0.085539	0.135735	0.613425	3
9	0.077094	0.096679	0.556353	5

The closeness coefficient values as shown in Table 5 have been computed by using equation (7). Therefore, a higher value of the relative closeness coefficient value means that the corresponding machining parameters are closer to the optimal levels. In other words, the optimization of machining parameters associated with the complex multiple performance characteristics can be converted into optimal resolution of single relative closeness value. Table 5 presents the results of worst and best alternative distances, relative coefficient values and their ranks. The results show that experiment value 7 has the highest relative closeness coefficient value. The optimum parameter setting obtained by using AHP-TOPSIS method for Wire-EDM was 20 Peak current, 105 Pulse on time, 95 Pulse off time and 50 Servo voltages.

4. Conclusion

AHP-TOPSIS is employed to carryout multi-objective optimization in Wire-EDM of Ti-6Al-4V workpiece. All the four process parameters namely Peak current, Pulse on time, Pulse off time and Servo voltage of workpiece material have been studied simultaneously to optimize all important machining criteria keeping other process parameters constant. By using AHP-TOPSIS method Closeness Coefficient Values were found for the maximum MRR and minimum Surface Roughness. The optimum parameter setting obtained by using AHP-TOPSIS method for Wire-EDM was 20 Peak current, 105 Pulse on time, 95 Pulse off time and 50 Servo voltage.

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