Optimization of process parameters in Wire EDM of D3 tool steel using Taguchi method

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Abstract--D3Tool steel is a high carbon, oil hardened and high chromium tool steel. It possess high compressive strength and good dimensional stability. It is used in wide applications in industries like bushes, press tools, forming rolls, blanking dies, forming dies and punches. Wire EDM is a non conventional process of machining which is used for precision machining. It is a micro machining process used for manufacturing complex shapes with extremely close tolerances. The performance of Wire EDM is affected by various parameters. In this paper we attempt to optimize the machining parameters for achieving highest MRR (Material Removal Rate). For studying the performance characteristics we make use of L9 Orthogonal array, S/N ratio (signal to noise ratio). The process parameters considered for investigation are pulse on time, pulse off time, servo feed. Material removal rate was calculated using formulas. After the experimentation Taguchi Method is used to obtain optimum levels. The experimental analysis resulted into combination of pulse on time, pulse off time and servo feed to achieve maximum MRR.

Keywords- D3 Tool Steel, Taguchi Method, Orthogonal Array, MRR, S/N ratio.

1. INTRODUCTION

D3 tool steel is high Carbon /Chromium type tool steel, oil hardening which has high wear resistance. It hardens with very inconsiderable change in size. D3 alloy is deep hardened and it has high compressive strength. It is used in tooling applications, where high degree of accuracy is required in hardening i.e. forming and blanking dies, forming rolls, draw dies and powder metal tooling. Wire-EDM is an important operation in various manufacturing in certain industries, which gives importance to accuracy, precision and variety. Many researchers have tried to improve the performance characteristics i.e. the dimensional accuracy, material removal rate, surface roughness, cutting speed, kerf width and spark gap. Yet the overall potential utilization of process is not completely resolved. Optimization of different Wire EDM parameters for various materials are mentioned below. Patil, Solanki and Shekhawat.[1] showed effects of machining parameters on D2 tool steel proposed on WEDM using Taguchi method. Three process parameters were selected for investigation; Pulse on time, current, Pulse off time. For this experimentations L9 Orthogonal array was used. Current was the significant factor for surface roughness. G.Ugrasen, Ravindra, Prakash and Prasad [2] studied the optimization of cutting parameters in WEDM for HCHCr material using taguchi technique and grey relational theory. The objective of optimization was to attain good surface quality and minimum kerf width. Four process parameters were selected for this experimentation. They were pulse on time, gap voltage, pulse off time, wire feed. L16 Orthogonal array was used for experimentation. The results of this experiments showed that the response of the variable is affected by each control factor to different extent. P.K.Choudhury[3] experimented on Aluminium, which was the work piece material and copper was the electrode. The process parameters were pulse on time, discharge current, flushing pressure and polarity. L8 Orthogonal array was used for conducting experiments. From their results they concluded that according to ANOVA, polarity has high influence on MRR. Amitesh Goswami and Jatinder Kumar [4] did optimization in WEDM of Nimonic-80A material using utility concept and Taguchi approach. Following parameters were taken pulse on time, peak current, pulse off time, wire feed, wire tension, spark gap. They used L27 Orthogonal array. They investigated that MRR was obtained best at high reading of pulse on time. ShivkantTilekar, Das and Patowari[5] investigated process parameter optimization on WEDM on mild steel and aluminium by making use of taguchi method considering surface roughness and kerf width as response parameters. For experimentation spark on time, wire feed rate, spark off time and input current are used as input parameters. ANOVA shows that input current and spark on time has significant effect on mild steel and aluminium respectively for surface roughness.

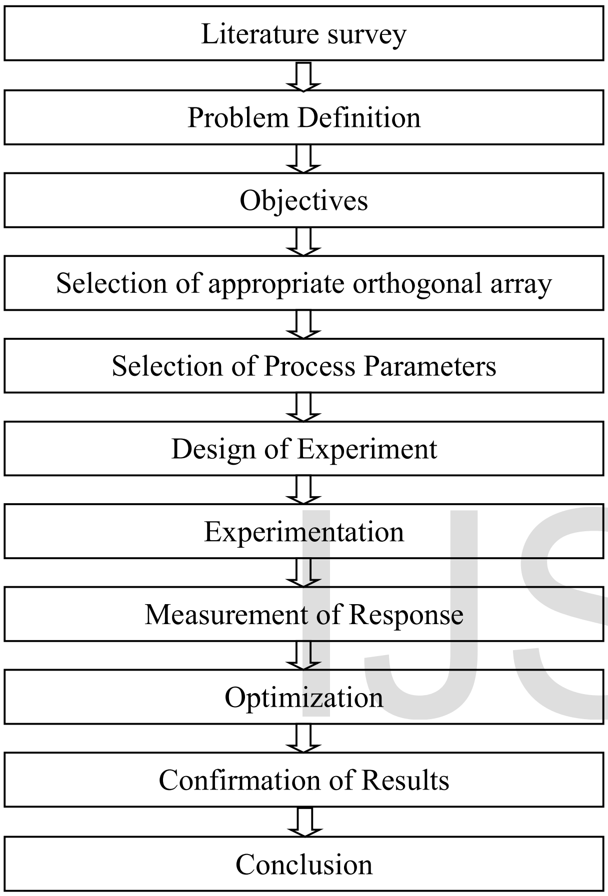


Fig. 1. Overall methodology chart

2. EXPERIMENTA DETAILS AND MEASUREMENTS

The Experimental studies were carried on ELECTRONICA HI-TECHJOB MASTER WEDM. The chemical composition of D3 tool steel workpiece used is given in Table 1. The dimensions of the workpiece used was 150mm x 40mm x 18mm. The electrode used was brass wire of diameter 0.25mm and dielectric distilled water (50kgf/mm^2 tensile strength). The value of cutting speed which were displayed on the monitor of machine were noted to calculate the MRR by using the following equation where 'Vc' is cutting speed in mm/min, 'b' is the width of the workpiece in mm, 'h' is height of workpiece in mm. The workpiece sizes are 40 x18 mm.

$$\mathbf{MRR = Vc * b * h \;\; mm^3/min \quad \ldots eqn(1)}$$

Elements	C	Cr	Fe	Mn	P
Percentage (%)	2.15	11.20	17	0.58	0.028
Elements	**Si**	**S**	**Ni**	**Mo**	
Percentage (%)	0.5	0.03	0.066	0.045	

Table 1 Chemical Composition of D3 Tool Steel

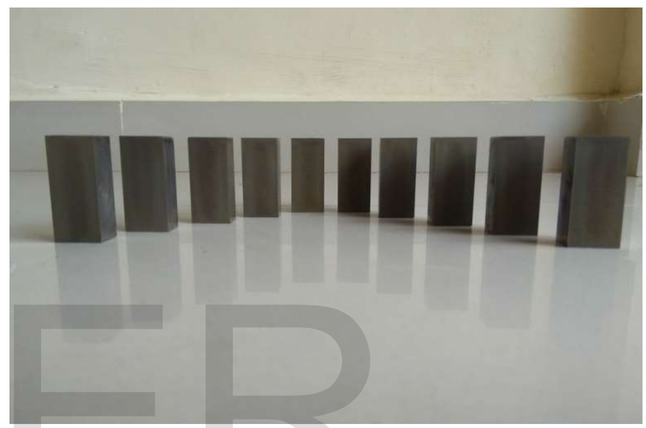


Fig. 2. The final machining is shown for D3 Tool Steel

3. TAGUCHI METHOD

The Taguchi Method is used for evaluation and implementation of improvement in process materials, equipments and facilities. This method is applied to various engineering applications like fabrication, service sector, computer aided design, etc. Taguchi method mainly includes a three stage approach i.e. system design, parameter design and tolerance design. In system design a functional prototype design is prepared which include product design and process design. In product design components materials are decided. In process design process sequence and production equipments and provisional process parameter values are decided. In parameter design performance characteristics are improved and it identifies the best process parameter values. The tolerance design carried out for analysis of tolerance which is recommended by parameter design for the best setting. The parameter design helps to achieve higher quality with minimum cost value. The steps involved are selection of

orthogonal array, conduction of experiments, analysis of data, identifying the best setting and confirmation of results.
The different levels selected for the parameters are shown in table no.2
The values of Pulse on time (TON) were 118, 122, 124 µsec . The values of Pulse off time (TOFF) were 50, 54, 56 µsec . The Servo feed (SF) of 2050, 2080, 2010 mm/min.

Level	L1	L2	L3
TON	118	122	124
TOFF	50	54	60
SF	2050	2080	2100

Table no. 2 Parameters and levels

In this method orthogonal array is used to lessen the number of experimentation and finding out the optimal parameters. According to Taguchi method, for three level of design L9 and L27 are the arrays which can be used. In this experimentation L9 OA is selected to save the time and cost of machining as Wire EDM is time consuming process. Total 9 experiments were conducted based on the combination of value of levels. Table no. 3 shows the L9 OA. After selecting the appropriate orthogonal array signal to noise ratio(S/N ratio) is calculated.

TON	TOFF	SF	Vc
118	50	2050	3.30
118	54	2080	2.80
118	56	2100	2.23
122	50	2080	3.80
122	54	2100	3.34
122	56	2050	2.51
124	50	2100	3.67
124	54	2050	3.15
124	56	2080	2.50

Table no.3A L9 Orthogonal array and measurement

Optimal machining performance is obtained by selecting S/N ratio for MRR as ‘Higher the better’. Following formula is given for calculating S/N ratio.

$$\mathbf{S/N = -10log(\frac{1}{n}(\frac{1}{Y_1^2} + \frac{1}{Y_2^2} + \frac{1}{Y_3^2} \ldots\ldots))} \qquad \ldots\mathbf{eqn(2)}$$

TON	TOFF	SF	MRR	S/N RATIO
118	50	2050	2376	67.51
118	54	2080	2016	66.08
118	56	2100	1605.6	64.11
122	50	2080	2736	68.74
122	54	2100	2404.8	67.62
122	56	2050	1807.2	65.14
124	50	2100	2642.4	68.43
124	54	2050	2268	67.11
124	56	2080	1800	65.10

Table no.3B S/N ratio

Table no. 3 shows experimental values of S/N ratio for MRR which is obtained from various set of experiments.
After calculations of S/n ratio mean S/N ratio is calculated for different levels.

Parameter	Level 1	Level 2	Level 3
TON	65.9	67.166	66.88
TOFF	68.226	66.936	64.783
SF	66.586	66.64	66.72

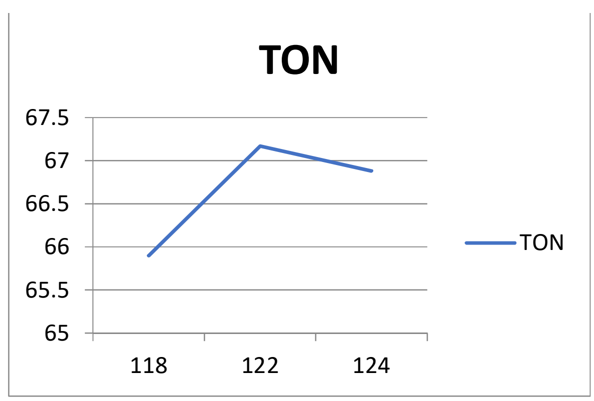
Table no.4 Mean S/N ratio for MRR

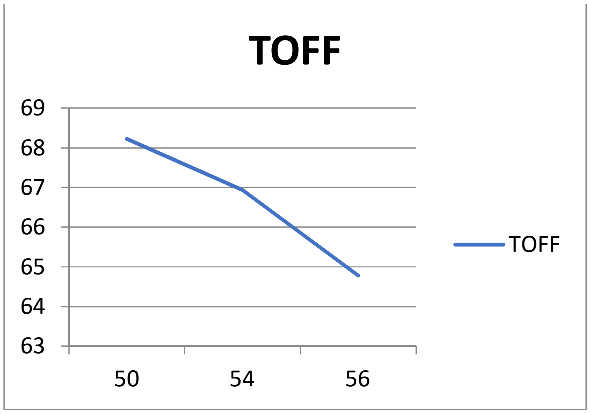
Table no. 4 shows the mean S/N ratio for process parameter in three levels. The mean S/N ratio of each level is obtained by calculating the average value of S/N ratio at each value of a process parameter. It is given by following formula.

$$\mathbf{Avg. = \frac{(P1 + P2 + P3)}{3}} \qquad \ldots\mathbf{eqn(3)}$$

4. MAIN EFFECT PLOT

In these plots the X-axis shows the value of each process parameter at 3 levels and Y-axis indicates the response values.





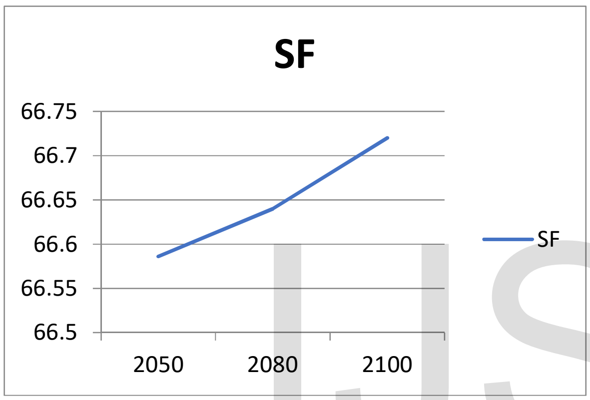


Fig. 5. Main Effect Plot for S/N ratio.

Optimal values of S/N ratio are shown with the help of Main effect plots.

5. CONCLUSION

Experiment results were developed by varying process parameter in Wire EDM. Taguchi method is used for optimizing the performance of the machine. The parameter design of Taguchi method provides minimum number of experiments and an efficient methodology for achieving higher MRR of D3 Tool steel. Hence it aims at reducing the cost and time. From the Main effect plot we can conclude that TOFF has the largest effect on material removal rate. The Main effect plot shows that material removal rate value decreases with increases in values of TOFF. For TON the MRR rises with increase in value up to the certain level and decreases with further increase in the value. From the experimental results of the mean S/N ratio it is observed that MRR value is maximum i.e. 68.226 at the level of TOFF (50µs). At TON (122µs) it was observed that the larger MRR was obtained (67.166) also for SF (2100mm/min) large value of MRR (66.72) was monitored. Hence optimum conditions for MRR observed were Pulse off time (50µs), Pulse on time (122µs) and servo feed (2100mm/min). Therefore by conducting this experiments we get optimal combinations of process parameter for MRR in WEDM .

6. REFERENCES

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