PARAMETRIC MODELING FOR WIRE ELECTRICAL DISCHARGE MACHINING OF M42 HSS USING UNTREATED AND CRYOGENATED TREATED BRASS WIRE BY USING RESPONSE SURFACE METHODOLOGY

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Abstract - M42 super high speed steel is a finest cobalt high speed steel with a chemical composition intended for high hardness and better hot hardness. In the present work, the effect of shallow cryogenated brass wire on the M42 HSS is compared with the results of untreated wire on M42. The empirical modeling of process parameters of the WEDM has been carried out for the M42 HSS using a well known experimental design approach called response surface methodology(RSM). The parameters such as pulse-on, pulse-off, spark gap voltage and wire feed have been selected as input variables keeping others constant. The performance has been measured in terms of cutting speed(CS). There is increase in cutting speed value when we treat the M42 with cryogenated treated wire than the untreated wire.

Keywords - HSS, RSM, SEM, WEDM

I. INTRODUCTION

With the development in the technology, the scientists and technologists in the field of manufacturing are facing more and more challenges. Accompanying the development of mechanical industry, the demands for the alloy materials having high hardness, toughness and force resistance are increasing day by day. High speed steels are self hardening steels alloyed with W, Mo, Co, V and Cr. . Plain HSSs are broadly classified as T-type steels, which have tungsten as the major alloying element and M-type steels which have molybdenum is the major alloying element. M-types are most widely used for rotary tooling, especially drills, end-mills and taps. M-42 has the greatest hot strength[1]. M42 super high speed steel is a premium cobalt high speed steel. Its applications are twist drills, milling cutters, taps, reamers, broaches, saws, knives, and thread rolling dies. Machining of M42 with conventional techniques is extremely difficult because of its high strength, high fracture toughness and hardness. Therefore non-conventional machining processes based on chemical, electro-chemical, thermal, thermoelectric and mechanical energy are preferred over the conventional methods for the machining of the M42 HSS. Wire electric discharge machining (WEDM) is a non-conventional, thermoelectric process that can be used to cut complex and intricate shapes in all electrically conductive materials used in automobile ,tool and die, aerospace, dental, nuclear, computer and electronic industry with better precision and accuracy[2].

Cryogenic processing is the method of cooling a material to temperatures far below room temperature. Cryogenic treatment is done in a chamber, where the materials to be treated are steadily lowered in temperature from room temperature.

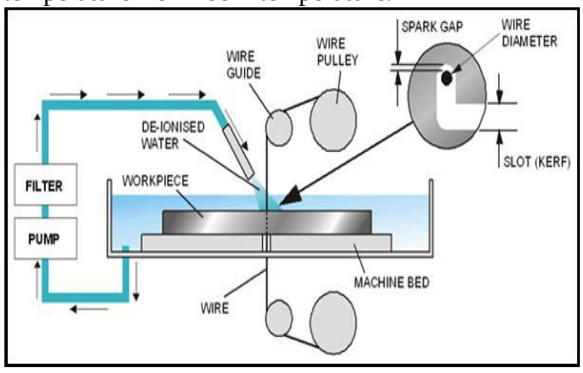


Figure 1 Schematic diagram of WEDM system (Guitrau, 1997)[3]

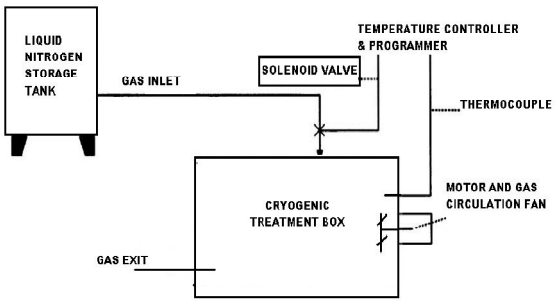


Fig 2: View of Cryogenic Processor

II. LITERATURE REVIEW

The literature review mainly focus upon the parametric modeling and optimization of various process parameters and various optimization techniques. Sarkar et al. (2008)[4] investigated modeling and optimization of wire electrical discharge machining(WEDM) of γ-TiAl in the trim

cutting operation. A second-order mathematical model, in requisites of machining parameters, was advanced for cutting speed, surface roughness and dimensional deviation using response surface methodology (RSM). Manjaiah M et al. (2014)[5] done investigations of effect of process parameters on the responses such as material removal rate and surface roughness of Ti50Ni40Cu10 SMA machined by WEDM using the Taguchi techniques to acquire optimum machining process parameters. The brass wires shown in Figure 3 are the amalgamation of zinc and copper, alloyed together in the assortment of 63 to 65% copper and 35 to 37% zinc (Schacht, 2004a)[6]

Aluminium brass wire electrodes are less susceptible to fracture than plain brass wires. These are commonly accessible in brand name names like Somal, TAF, etc. Tarr and Rhee (1977)[8] observed that when the alloy is subjected to the liquid nitrogen temperature, the thermal conductivity is enhanced by 3-4% without affecting the hardness from re- aging. Kamody (2001)[9] describes the effect of cryogenic treatment to minimize the instability effects of workpieces, which results in the regulation and compensation of wire burning action.

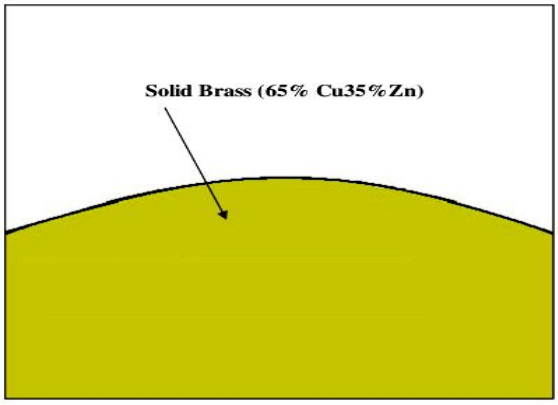


Fig 3: Plain Brass Wire Electrode (Toshiyuki et al., 2005)[7]

III. EXPERIMENTAL PROCEDURES

The experiments were carried out on a wire-cut EDM machine (ELEKTRA ECOCUT) of Electronica Machine Tools Ltd. In the present study commercially available M42 HSS is chosen as a work piece material. In all the experimental trials the M42 high speed steel(HSS) plate of 100mm x 80mm x 12mm size has been utilized as a work piece material

The chemical composition of the M42 is given above in table no. 1.

Element	C	Si	Cr	W	Mo	V	Co
Weight%	1.08	0.45	3.85	1.50	9.50	1.20	8.00

Table 1 Chemical composition of M42 HSS

A large number of process parameters influence the mechanism of WEDM process, while the machining is in progress. Table 4.4 shows the primary controllable process parameters available on the selected machine tool.

S No.	Control Parameters	Symbol	Range(mu)	Range (actual unit)
1	Pulse on time	T_{on}	110-120	0.6-1.1µs
2	Pulse off time	T_{off}	45-55	18-36µs
3	Spark gap voltage	SV	40-60	40-60V
4	Wire feed	WF	3-7	3-7 m/min

Table 2 Independent parameters and their values

Design of Experiment

RSM is a arrangement of mathematical and statistical techniques used in experimental study of relationships and optimization where numerous independent variables or factors manipulate a dependent variable or response.

			Factor 1	Factor 2	Factor 3	Factor 4	Response 1
Std	Run	Block	A:Pulse on time(mu)	B:Pulse off time(mu)	C:Spark gap voltage(V)	D:Wire Feed(m/min)	Cutting Speed(mm/min)
2	1	Block 1	120	45	50	5	1.04
15	2	Block 1	115	45	60	5	0.48
24	3	Block 1	115	55	50	7	0.4
7	4	Block 1	115	50	40	7	0.68
27	5	Block 1	115	50	50	5	0.53
6	6	Block 1	115	50	60	3	0.36
25	7	Block 1	115	50	50	5	0.53
20	8	Block 1	120	50	60	5	0.55
10	9	Block 1	120	50	50	3	0.78

16	10	Block 1	115	55	60	5	0.29
18	11	Block 1	120	50	40	5	1.02
11	12	Block 1	110	50	50	7	0.36
12	13	Block 1	120	50	50	7	0.71
4	14	Block 1	120	55	50	5	0.6
9	15	Block 1	110	50	50	3	0.34
28	16	Block 1	115	50	50	5	0.49
19	17	Block 1	110	50	60	5	0.24
5	18	Block 1	115	50	40	3	0.67
3	19	Block 1	110	55	50	5	0.27
22	20	Block 1	115	55	50	3	0.39
29	21	Block 1	115	50	50	5	0.49
21	22	Block 1	115	45	50	3	0.7
8	23	Block 1	115	50	60	7	0.34
13	24	Block 1	115	45	40	5	0.94
1	25	Block 1	110	45	50	5	0.49
17	26	Block 1	110	50	40	5	0.49
26	27	Block 1	115	50	50	5	0.5
14	28	Block 1	115	55	40	5	0.51
23	29	Block 1	115	45	50	7	0.67

Table 3 Design matrix and output responses-I for untreated brass wire

			Factor 1	Factor 2	Factor 3	Factor 4	Response 1
Std	**Run**	**Block**	**A:Pulse on time(mu)**	**B:Pulse off time(mu)**	**C:Spark gap voltage(V)**	**D:Wire Feed(m/min)**	**Cutting Speed(mm/min)**
2	1	Block 1	120	45	50	5	1.14
15	2	Block 1	115	45	60	5	0.54
24	3	Block 1	115	55	50	7	0.51
7	4	Block 1	115	50	40	7	0.74
27	5	Block 1	115	50	50	5	0.63
6	6	Block 1	115	50	60	3	0.46
25	7	Block 1	115	50	50	5	0.63
20	8	Block 1	120	50	60	5	0.55
10	9	Block 1	120	50	50	3	0.85
16	10	Block 1	115	55	60	5	0.39
18	11	Block 1	120	50	40	5	1.08
11	12	Block 1	110	50	50	7	0.47
12	13	Block 1	120	50	50	7	0.81
4	14	Block 1	120	55	50	5	0.63
9	15	Block 1	110	50	50	3	0.46
28	16	Block 1	115	50	50	5	0.59
19	17	Block 1	110	50	60	5	0.27
5	18	Block 1	115	50	40	3	0.75
3	19	Block 1	110	55	50	5	0.37
22	20	Block 1	115	55	50	3	0.49
29	21	Block 1	115	50	50	5	0.59
21	22	Block 1	115	45	50	3	0.78
8	23	Block 1	115	50	60	7	0.44
13	24	Block 1	115	45	40	5	1.04
1	25	Block 1	110	45	50	5	0.56
17	26	Block 1	110	50	40	5	0.59
26	27	Block 1	115	50	50	5	0.58
14	28	Block 1	115	55	40	5	0.62
23	29	Block 1	115	45	50	7	0.77

Table 5 Design matrix and output responses for cryogenated treated brass wire

Effect of Process Parameters on Response Characteristics

This segment presents the impact of process parameters on response characteristics i.e. cutting speed. It examines effect of pulse on and pulse off time on cutting speed response characteristics for untreated and cryogenated samples.

For non-cryogenated samples

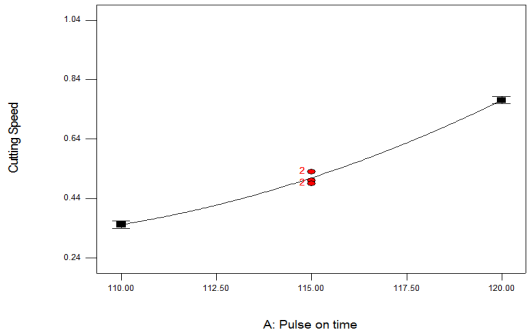


Figure 4 Effect of pulse on time on cutting speed

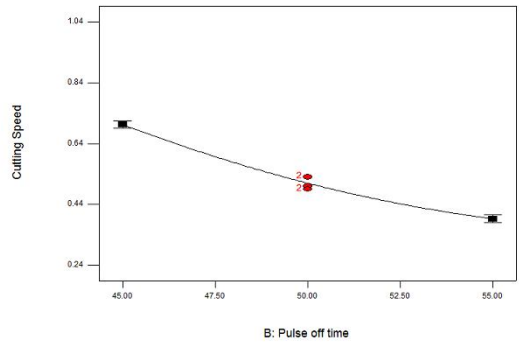


Figure 5 Effect of pulse off time on cutting speed

For Cryogenated samples

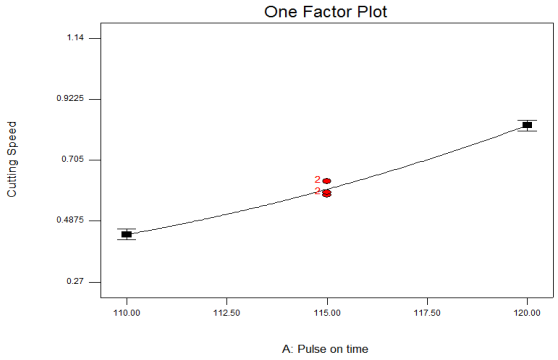


Figure 5.30 Effect of pulse on time on cutting speed

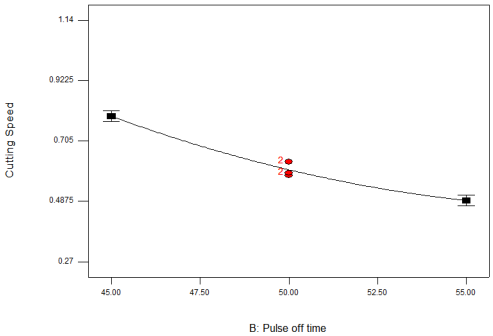


Figure 5.31 Effect of pulse off time on cutting speed

RESULTS & DISCUSSION

After the experimentation and analysis using Box Behnken Design(BBD), it has been found that pulse on time & pulse off time has a significant effect on the cutting speed in all the experimentation either on untreated or cryognated treated M42 HSS sample pieces. In case of non-cryogenated samples the cutting speed is increased appreciably from 0.35 to 0.77 mm/min as pulse on time was increased from 110mu to 120mu. This is because of the fact that higher value of pulse on time increases the span of discharge energy and it results into rapid melting and evaporation of material. Accordingly, substantial pieces of material are removed and subsequently, increment in cutting rate is acquired. The present result is in accordance with the result acquired in former studies (Tarang et al. 1995)[10]; (Sarkar et al. 2006)[11]. By decreasing the pulse off time the machining rate appreciably improved. Enlarged span of pulse off time decrease the number of discharges inside a given period(Saha et al. 2009)[12]. In case of cryogenated M42 HSS samples the same pattern of graphs has been obtained as in case of non cryogenate samples, but due to cryogenation of brass wire it is noticed that some energy leaves the lattice and create a more perfect and therefore stronger structure. Due to which in the experiments it has been seen that more and better cutting speed has been obtained. In case of samples which are machined with cryogenated brass wire the cutting speed is increased from 0.45 to 0.80 mm/min as pulse on time varies from 110 mu to 120 mu.

CONCLUSION

Following conclusions have been made in the present experimental and analytical work within the range of test conditions employed.

1. The use of shallow cryogenically treated wire electrode in WEDM for machining of M42 High Speed Steel(HSS) enhanced the cutting speed.
2. Less time is required for processing of same amount of workpiece material.
3. Superior surface finish of machined workpiece and less wire wear of wire is also obtained with cryogenically treated wire electrodes as compared with untreated wire electrode.
4. In the present research, the parametric optimization of process parameters with shallow cryogenic treated wire electrodes in WEDM indicates that the optimal settings of experimental results suggested by Box Behnken Design(BBD) lies well within the predicted range.

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