Journal of Applied Science and Engineering Methodologies
Volume 4, No.1 (2018): Page.547-555
www.jasem.in

An Experimental Analysis of Process Parameters in EDM with Stainless Steel 316 using Taguchi Design

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Abstract : *Metal removal mechanism in Electrical Discharge Machining is mainly a thermal phenomenon where thermal energy is produced in plasma channel, and is dissipated though work piece, tool and dielectric. The process is mostly used in situations where machining of very hard materials, intricate parts, complex shapes. The objective of this work is the optimization of the cutting parameters for Electric discharge machining of AISI 316 stainless steel to achieve the better surface finish using Taguchi's methodology. Taguchi Parameter Design is a powerful and efficient method for optimizing quality and performance output of manufacturing processes, thus a powerful tool for meeting this challenge. This work discusses an investigation into the use of Taguchi Parameter Design for optimizing surface roughness generated by a EDM operation.*

Keywords: *EDM parameters,, Surface roughness, MRR, Taguchi method*

1. Introduction

The growing trend to use slim, light and compact mechanical components in automobile, aerospace, medical, missile, and nuclear reactor industries has led to the development of high strength, temperature resistant, and hard materials during last few decades. It is almost impossible to find sufficiently strong and hard tools to machine aforesaid materials at economic cutting speeds. Moreover, machining of complex shapes in these materials with low tolerances and high surface finish by conventional methods is even more troublesome. Hence, there is great demand for new machining technologies to cut these 'difficult-to-machine' materials with ease and precision. Among modern machining processes, electric discharge machining (EDM) has become highly popular in manufacturing industries due to its capability to machine any electrically conductive material into desired shape with required dimensional accuracy irrespective of its mechanical strength. In this method, three control factors viz. pulse on, pulse off and Current rating were investigated at three different levels and the EDM operations are done on Electronic M2S machine. Experiments carried out using L9 Orthogonal Array with three different levels of control factors .The experimental results were analyzed, conformed and successfully used to achieve good surface finish and minimum machining time and maximum material removal rate of SS316 work piece materials.

1.1 Principle of EDM

Despite the fact that the material removal mechanism of EDM is not absolutely identified and is still contentious, the most widely established principle is the transformation of electrical energy into thermal energy through a sequence of distinct electric discharges. Fig. 1.1 shows a representative diagram of a typical EDM setup. Build-up of suitable voltage across tool and work-piece (cathode and anode respectively) that are submerged in an insulating dielectric, causes cold emission of electrons from the cathode. These liberated electrons accelerate towards the anode and collide with the dielectric fluid, breaking them into electrons and positive ions. A narrow column of ionized dielectric fluid molecules is established connecting the two electrodes. A spark generates due to the avalanche of electrons. This results in a compression shock wave.

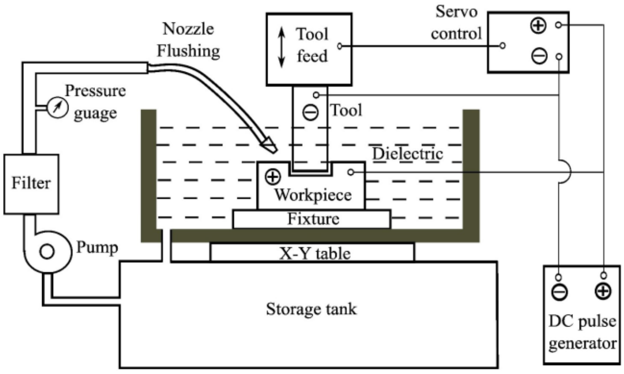

Fig. 1.1 A typical EDM setup

3.EDM PROCESS

3.1. THEORIES OF MATERIAL REMOVAL

The removal of material in electrical discharge machining is based upon the erosion effect of electric sparks occurring between two electrodes. Several theories have been forwarded in attempts to explain the complex phenomenon of "erosive spark". The following are the theories;

1.Electro-mechanical theory
2.Thermo-mechanical theory
3. Thermo-electric theory

3.1.1. ELECTRO-MECHANICAL THEORY

This theory suggests that abrasion of material particles takes place as a result of the concentrated electric field. The theory proposes that the electric field separates the material particles of the work piece as it exceeds the forces of cohesion in the lattice of the material. This theory neglects any thermal effects. Experimental evidence lacks supports for this theory.

4.GENERAL EXPERIMENTAL SETUP

4.1. EXPERIMENTAL SETUP

Electrodes were machined to a cylindrical shape of 20 mm width and 40 mm length. rectangular piece of 32 mm diameter and thickness 15 mm of SS316 has to be planned.

Figure 4.1: General Experimental Setup

4.2. ELECTRODE MATERIALS

Graphite Electrode

Graphite is the most commonly used material for electrode. Graphite was introduced in EDM industry around 50 years ago. General Electric was the first, well known manufacturer to introduce graphite in EDM industry. It was known by its trade name “Gentrode”. Unlike other metal based electrode material, graphite has certain unique properties which keep it above others as a suitable material for EDM electrode. Its heat resistivity is thousands of degrees higher than other materials. It does not melt like other materials; instead it turns straight into gas from solid state. This is also a disadvantage because, instead of creating chips and staying under the di-electric, it causes a dusty cloud to form in work place. This is hazardous if not followed precaution. Vacuuming the dust is a good idea to prevent from breathing graphite in while at work place. Graphite, despite being the best option as an electrode material, has some limitations in molecular level. It is porous so when immerged in di-electric fluid it can cause problematic impurities. Trapped moisture can create steam when cutting which damages the electrode. Due to this problem, it is better to use denser graphite which shows little penetration even after long hours of soaking. One other way of using graphite without facing problem is to heat the electrode in oven for an hour at 121°C.

4.2.1 Graphite Grades

Grain size and density defines the quality of graphite as an electrode. It also determines its price and cutting efficiency. Graphite with finer grain size results on better finishing and wear resistance, but graphite with larger grin size costs less.

1. **Sub-Micron**: This grade of graphite is the most expensive one and has the grain size of less than one micron i.e. Angstrofine graphite.

2.**Premium**: Graphite with less than or equal to 5 microns, i.e. Ultrafine, falls under premium grade of Graphite.

3.P**erformance**: Superfine to fine Graphite with 10-20 microns size is high performance Graphite.

4.**General purpose**: Graphite with grain size of larger than 20 microns are general purpose Graphite.

Property	Unit	Material
Density	g/cc	1.86
Electrical resistivity	(µ.ohm. cm)	850
Average particle size	Micron (µm)	20
Hardness	HB	95
Fluxural strength	Mpa	76

Table : 4.1. Properties of Graphite electrode

4.3. WORK MATERIAL

Type 316 is an austenitic chromium nickel stainless steel containing molybdenum. This addition increases general corrosion resistance, improves resistance to pitting from chloride ion solutions, and provides increased strength at elevated temperatures. Properties are similar to those of Type 304 except that this alloy is somewhat stronger at elevated temperatures. Corrosion resistance is improved, particularly against sulfuric, hydrochloric, acetic, formic and tartaric acids; acid sulfates and alkaline chlorides.

4.3.1 WORK MATERIAL DETAILS

Work material –SS316
Work material size–32 Dia-12 mm thickness

4.3.2 CHEMICAL PROPERTIES

Material	C%	M%	Si%	Cr%	S%	P%	N%
SS 316	0.08	2	0.75	18	0.03	0.045	0.1

Table 4.2 Chemical properties

4.4 PROCESS PARAMETER USING DOE

s.no	Pulse on time	Pulse off time	Gap current
	µs	µs	amps
1	60	30	8
2	80	40	12
3	100	50	16

Table 4.4: Process parameters and their levels

4.5 AN ORTHOGONAL ARRAY L_9 FORMATION

Design	T on[µs]	T off [µs]	Amps
$A_1B_1C_1$	60	30	8
$A_1B_2C_2$	60	40	12
$A_1B_3C_3$	60	50	16
$A_2B_1C_2$	80	30	12
$A_2B_2C_3$	80	40	16
$A_2B_3C_1$	80	50	8
$A_3B_1C_3$	100	30	16
$A_3B_2C_1$	100	40	8
$A_3B_3C_2$	100	50	12

Table :4.5 Orthogonal array L9 formation

5.6 EXPERIMENTAL DATA

S.NO	T ON	T OFF	AMPS	RA	MRR	MT
				µm	gm/min	min
1	60	30	8	3.671	0.016	26
2	60	40	12	7.093	0.027	19
3	60	50	16	5.33	0.032	15
4	80	30	12	3.884	0.036	17
5	80	40	16	8.757	0.022	21
6	80	50	8	8.558	0.019	24
7	100	30	16	6.24	0.032	14
8	100	40	8	6.247	0.025	22
9	100	50	12	4.855	0.044	11

Table: 4.6 Experimental Data of the PMEDM process

5.7 SURFACE ROUGHNESSES (ANALYSIS OF RESULT)

Table: 4.7 Surface Roughness and S/N Ratios Values for the Experiments

NO	Design	T On	T Off	Amps	RA	SNRA1
1	$A_1B_1C_1$	60	30	8	3.671	-11.296
2	$A_1B_2C_2$	60	40	12	7.093	-17.017
3	$A_1B_3C_3$	60	50	16	5.33	-14.535
4	$A_2B_1C_2$	80	30	12	3.884	-11.786
5	$A_2B_2C_3$	80	40	16	8.757	-18.847
6	$A_2B_3C_1$	80	50	8	8.558	-18.647
7	$A_3B_1C_3$	100	30	16	6.24	-15.904
8	$A_3B_2C_1$	100	40	8	6.247	-15.913
9	$A_3B_3C_2$	100	50	12	4.855	-13.724

5.7.1 RA -PROCESS PARAMETER

LEVEL	T ON	T OFF	AMPS
1	-14.28	-12.99	-15.29
2	-16.43	-17.26	-14.18
3	-15.18	-5.64	-16.43
DELTA	2.14	4.26	2.25
RANK	3	1	2

Table: 4.8 Response Table -Smaller is better

SOURCE	DF	SS	MS	F	P	% contri
T ON	2	4.722	2.361	0.64	0.608	17
T OFF	2	11.628	5.814	1.59	0.389	43
AMPS	2	3.402	1.701	0.46	0.683	13
ERROR	2	7.322	3.661			27
TOTAL	8	27.074				100

Table: 4.9 Analysis of Variance for RA

Regression Equation
Ra = 6.071 - 0.706 Pulse-On_60 + 0.996 Pulse-On_80 - 0.290 Pulse-On_100 - 1.472 Pulse-Off_30 + 1.295 Pulse-Off_40 + 0.177 Pulse-Off_50 + 0.088 Amps_8 - 0.793 Amps_12 + 0.705 Amps_16

Main Effects Plot for SN ratios

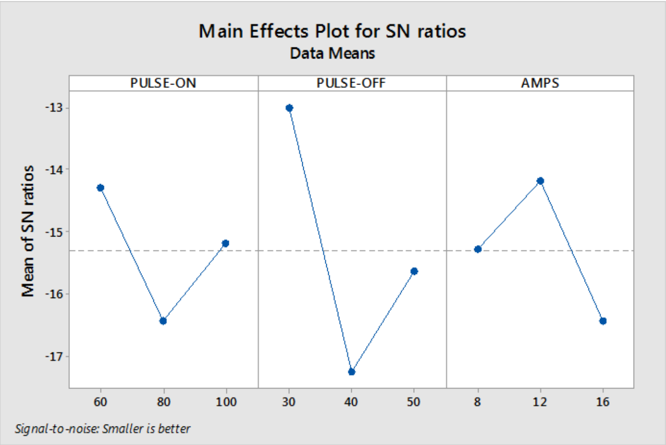

Figure :4.1 Main effects plot for SN ratios

5.8 MACHINING TIME (ANALYSIS OF RESULT)

NO	Design	T On	T Off	Amps	MT	SNRA1
1	$A_1B_1C_1$	60	30	8	26	-28.3
2	$A_1B_2C_2$	60	40	12	19	-25.575
3	$A_1B_3C_3$	60	50	16	15	-23.522
4	$A_2B_1C_2$	80	30	12	17	-24.609
5	$A_2B_2C_3$	80	40	16	21	-26.444
6	$A_2B_3C_1$	80	50	8	24	-27.604
7	$A_3B_1C_3$	100	30	16	14	-22.923
8	$A_3B_2C_1$	100	40	8	22	-26.849
9	$A_3B_3C_2$	100	50	12	11	-20.828

Table: 4.10 Machining Time And S/N Ratios Values for MT

5.8.1 MACHINING TIME FOR EACH LEVEL OF THE PROCESS PARAMETER

LEVEL	T ON	T OFF	AMPS
1	-25.80	-25.28	-27.58
2	-26.22	-26.29	-23.67
3	-23.53	-23.98	-24.30
DELTA	2.69	2.30	3.91
RANK	2	3	1

Table: 4.11 Response Table for Signal to Noise Ratios-MT-Smaller is better

5.CONCLUSION AND RESULT

The aim of the research work was to investigate the mach inability of SS316. In this study three process parameters are varied viz. Pulse on time, Pulse off time and ampere rating constant dielectric pressure to study the influence on the responses MRR, Machining timing and Ra. Machining Timing &MRR were merge on the same parameter. Based on the experimental results the following conclusions are drawn:

5.1.1OPTIMAL CONTROL FACTOR

1. Surface Roughness-A3 (Pulse on time -100μs)B1(Pulse off time 3 μs)C2(Amps-12)
2. Machining Timing- A2 (Pulse on time -80μs) B3(Pulse off time -50 μs)C1(Amps-8)
3. Material Removal Rate- A2 (Pulse on time -80μs) B3(Pulse off time -50 μs)C1(Amps-8)

Minimum Surface finish and machining timing were held at through lower level pulse on time and lower rating of amps.MRR were held through lower level pulse on time and Maximum rating of amps.

5.1.2 Percentage contribution of Process parameter

1. Surface Roughness- Pulse off time 43%
2. Machining Timing -Amps 64%
3. Material Removal – Amps 59 %

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