Investigation on EDM of SS316 using Copper and Brass Electrode for Improving MRR and TWR

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Abstract -*High-frequency vibration support EDM (Electrical Discharge Machining) become one of the finest ways to increase material removal rate in EDM process, due to the flush effect created by vibration. Nevertheless, using high-frequency vibration, especially in ultrasonic consumes a lot of setup cost. This work presents an effort to use a low-frequency vibration on work piece of (SS316) during EDM process. The vibration on the work piece happens with different variations of low-frequency and low-amplitude. The employment of low-frequency vibration in EDM process are used to increase the material removal rate, and decrease the surface roughness and tool wear rate.*

In our project stainless steel (SS316) grade materials is machined on spark EDM with 5mm copper electrode. The input process parameter are Pulse on time (μs) Current (A), Pulse off time (μs), Polarity, Dielectric pressure (kg/mm^2) were inspected using orthogonal array taguchi method L18. To advance the various output parameter like Material Removal Rate (MRR), Tool Wear Rate (TWR), Wear Ratio (WR),

Keywords:- SS316, EDM, Material Removal Rate.

1. Introduction

Since beginning humans have developed gradually their tools and energy sources to meet the requirements for making the life more easier and comfortable. In the early stage of mankind, tools were made of stone and wood. When iron tools were invented, strong metals and more advanced products could be produced. In 20th century products were made from the most durable and hard materials. In an attempt to meet the manufacturing challenges created by these hard materials, tools are more advanced now to include materials such as alloy steel, carbide, diamond, ceramics and cerment. Alike evolution has taken place with the same approach used to power the tools. At first, tools were fueled by either human or animal. As we harnessed the power from water, wind, steam and electricity, humans are able to extend their manufacturing skill with new machines with more efficiency and faster machining rates. Every time new tools, new materials, and advanced power sources are utilized, the efficiency and ability of manufacturing are greatly enhanced. Since 1940, a change in manufacturing process has been taken place that allows manufactures to meet the demands by increasing sophisticated designs and lasting, but in many cases nearly unmachinable materials .operator had displayed the continuous increase in strength of materials in aerospace industry. This manufacturing revolution is now, as it has been in the past, centered on the use of new manufacturing tools and new forms of energy source. The result has been the introduction of various new more powerful and efficient machines, forming and joining, known today as non-traditional manufacturing processes.

1.1 Conventional machining process

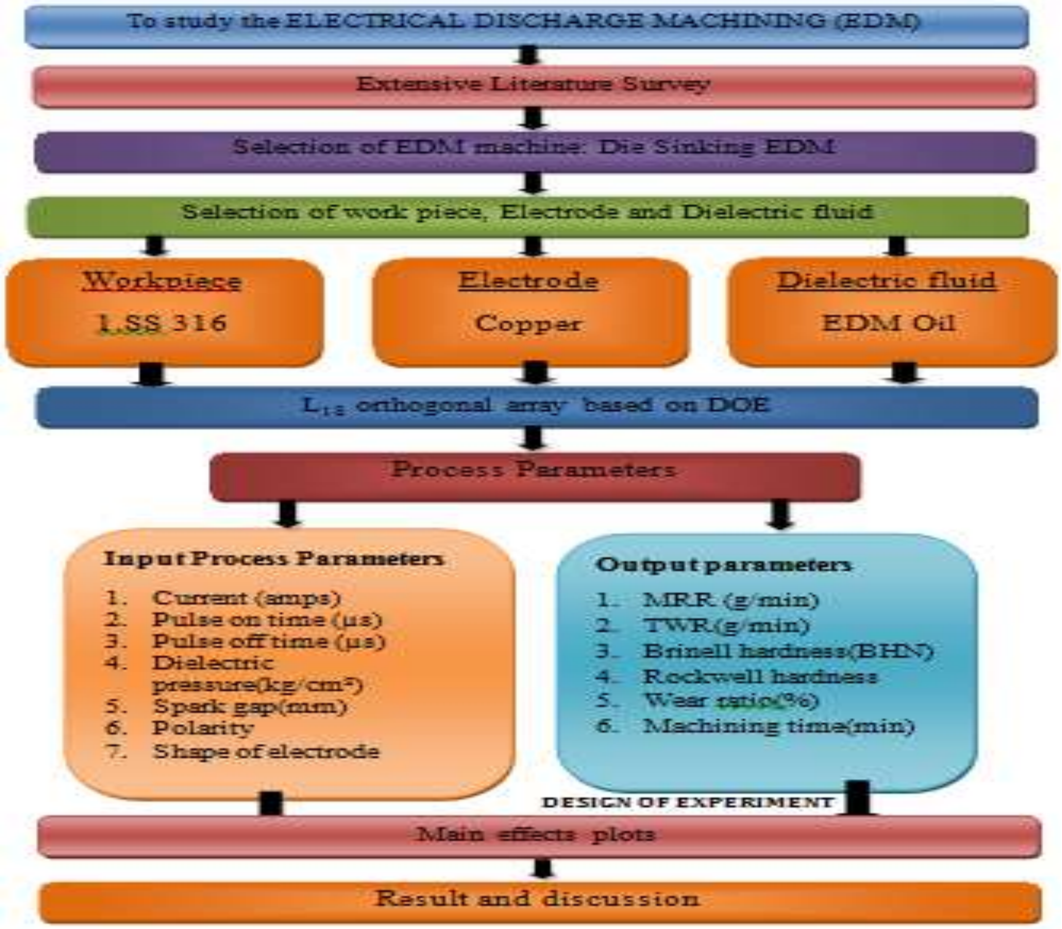
The conventional manufacturing processes are generally used for material removal and depend on electric motors, hard tool materials to perform tasks like sawing, drilling, broaching and sharp cutting. Conventional operations are operated with the energy from electric motors, hydraulics etc. In the same way, material joining is conventionally obtained with thermal, mechanical, electrical, chemical energy etc. In comparison, non-traditional manufacturing processes harness energy from sources consider till past standards. Material removal can now be done with high temperature plasmas, electrochemical reaction and high-velocity jet liquids and abrasives. Materials that have been extremely challenging to form, are now formed with magnetic fields, explosives and the shock waves from powerful electric sparks. Material-joining ability have been enlarged with the use of high-frequency sound waves and beams of electrons. There are more than 20 different non-traditional manufacturing processes machines have been invented and successfully implemented into production sectors.

E. Ferraris shows that this work presents an innovative method for the Electrical Discharge Drilling (EDD) of ultra-high aspect ratio (AR > 30) micro holes. It makes use of coating tools insulated on the sidewall. The concept is to promote the process stability of micro Electrical Discharge Machining deep drilling by preventing secondary sparks. The performance of standard and customized tools are compared and reviewed against the main criteria of machining time, tool wear and shape quality. Coating are also defined for capability process. Micro holes within 0.2 mm in diameter and obtain wi could be aspect ratio (AR) up to about 120.

F�io N. Le� investigates that Electrical discharge machining (EDM thin 1 h. A micro punching die is also realized by combining this strategy with micro wire EDM.) Fast hole-drilling machine is a highly developed technology used for making different shape of holes in parts such as fuel injectors, cutting tool coolants, plastic-mould vents, hardened punch ejectors and turbine blades. Hole sizes commonly vary between 0.3 and 3mm, with a diameter to length ratio of over 1:150. EDM fast hole drilling is a key manufacturing technology for gas turbine components, and Rolls-Royce currently operates over fifty machines using brass electrodes and deionised water dielectric in a range of factories. The process, however, leads to high production costs, mainly due to the high consumption of electrodes. Using fractional factorial and response surface design, a series of studies have been carried out with the purpose of optimising the drilling process through the evaluation of a water-based dielectric and an electrode material different from the standard materials of deionised water/brass, through analysis of drilling time, electrode wear, surface integrity and dimensional accuracy. The results showed that it is possible to obtain good drilling rates and achieve a reduction in electrode wear of nearly fifty percent.

S.Dhanabalan illustrates that work optimizes the blind-hole drilling of Al_2O_3/6061Al composite using rotary electro-discharging machining by using Taguchi methodology. Experimental results conform that the revised copper electrode with an eccentric through-hole has the optimum performance for machining from using various aspects. Three observed values, TWR, SR, and MRR, verify this optimization of the machining technique. In addition, seven independent parameters are chosen as variables in evaluating the Taguchi method and are categorized into two groups: (1) electrical parameters, like e.g., polarity, peak current, pulse duration, and powder supply voltage, and (2) non-electrical parameters, like e.g., rotational speed of the electrode, injection pushing pressure of the dielectric fluid, and the number of eccentric through-holes in the electrode. Moreover, Taguchi method analysis the reveals that the electrical group has a give more significant effect and then the non-electrical group on the machining characteristics. Furthermore, either the polarity or the peak current most prominently affects the EWR, SR or MRR amongst all of the parameters, whereas none of the non-electrical group has an equal affect. Also derived herein are semi-empirical equations are contain all of the machining characteristics.

II. EXPERIMENTAL METHODOLOGY



2.1 Introduction

This chapter deals with the selection of input Die sinking EDM parameters and output responses for this study. Then the procedures and specifications for machining process are explained. This chapter also deals with the measurement procedure for different output responses. Especially the measurements of SS316 material. The details of experimental design for SS31 Taguchi L$_{18}$ orthogonal array full factorial design are presented at the end.

Table 1. Chemical composition of SS316

%	SS316
C	0.08
Mn	2
Si	0.75
P	0.045
S	0.03
Cr	16-18
Mo	2-3
Ni	10-14
N	0.1

Table 2 Mechanical Properties of SS316

Properties	SS316 Steel
Density	8000 (kg/m^3)
Thermal Expansion	18 (10^{-6} /k)
Melting Point	1673 (K)
Thermal Conductivity	17 (W/m - k)
Specific Heat	530 (J/Kg - k)
Resistivity	81 (10^{-8} ohm .m)
Tensile Strength	620 (M pa)
Atomic Volume	0.0072 (m^3/k mol)
Poisson's Ratio	0.275
Bulk Modulus	152 G Pa
Ductility	0.51

The table 2 shows the mechanical properties of stainless steel 316

Tool material selection

- When selecting an electrode for EDM ,the most important thing is it's form and function of the material's conductivity. Conductivity promotes cutting efficiency
- Erosion resistance gives the electrode a longer working life and lowers the requirement of replacement
- The properties , which vary mostly by the type of alloy and materials used will be the deciding factors in selecting an electrode

Table.3 Showing Physical Properties of Copper Electrode

Physical properties	Value
Electrical resistivity (µ Ω/cm)	1.96
Electrical conductivity compared with silver (%)	92
Thermal conductivity (W/m K)	268-389
Melting point (C)	1083
Specific heat (cal/g C)	0.092
Specific gravity at 20 C (g/cm3)	8.9
Coefficient of thermal expansion (x 10 C-1)	6.6

The table 3.3 gives us the physical properties of copper electrode like melting point, specific gravity, coefficient of thermal expansion.

Fig 1 Die Sinking Electrical Discharge Machine (Make: OSCARMAX)

The fig 1 shows the physical setup of Die sinking electric discharge machine which is OSCARMAX model.

Table 4 EDM operating conditions for SS316

Working conditions	**Description**
Electrode material	Copper electrode
Dimension of hole	5 mm(Each Side)
Depth of drilling	2 mm
Workpiece polarity	Negative
Specimen material	SS316 Stainless Steel
Type of current	DC Power Supply
Discharge current (I, A)	3 - 10amps
Pulse on time (t_{on}, μ s)	3 - 40μs
Pulse off time (t_{off}, μ s)	1 - 5μs
Dielectric fluid	EDM oil
Fluid pressure (kg/cm^2)	1-5

RESULTS AND DISCUSSION

To find the material removal rate, tool wear rate, wear ratio, machining time, brinell hardness and Rockwell hardness. The input parameter used in experiments as in table 5

S.NO	INPUT PROCESS PARAMETER						
	POLARITY	CURRENT (amp)	PULSE ON TIME (μs)	PULSE OFF TIME (μs)	DIELECTRIC PRESSURE (kg/cm^2)	SPRAK GAP	SHAPE
1	POSITIVE	16	30	3	15	0.02	PENTAGONAL
2	POSITIVE	16	60	6	20	0.05	CIRCLE
3	POSITIVE	16	90	9	25	0.07	SQUARE
4	POSITIVE	21	30	3	20	0.05	SQUARE
5	POSITIVE	21	60	6	25	0.07	PENTAGONAL
6	POSITIVE	21	90	9	15	0.02	CIRCLE
7	POSITIVE	24	30	6	15	0.07	CIRCLE
8	POSITIVE	24	60	9	20	0.02	SQUARE
9	POSITIVE	24	90	3	25	0.05	PENTAGONAL

10	NEGATIVE	16	30	9	25	0.05	CIRCLE
11	NEGATIVE	16	60	3	15	0.07	SQUARE
12	NEGATIVE	16	90	6	20	0.02	PENTAGONAL
13	NEGATIVE	21	30	6	25	0.02	SQUARE
14	NEGATIVE	21	60	9	15	0.05	PENTAGONAL
15	NEGATIVE	21	90	3	20	0.07	CIRCLE
16	NEGATIVE	24	30	9	20	0.07	PENTAGONAL
17	NEGATIVE	24	60	3	25	0.02	CIRCLE
18	NEGATIVE	24	90	6	15	0.05	SQUARE

Table 5 Input process parameter of SS316

EXP.NO	WORKPIECE WEIGHT (g)		TOOL WEIGHT (g)	
	BEFORE MACHINING	AFTER MACHINING	BEFORE MACHINING	AFTER MACHINING
1	61.16	60.56	19.15	19.11
2	60.56	59.66	13.7	13.69
3	59.66	59.26	15.24	15.22
4	59.26	58.67	15.22	15.16
5	58.67	57.86	19.11	19.08
6	57.86	57.19	13.69	13.68
7	57.19	56.6	13.68	13.65
8	56.6	55.9	15.16	15.14
9	55.9	55.31	19.08	19.07
10	55.31	54.56	13.65	13.63
11	54.56	54.1	15.14	15.13
12	54.1	53.24	19.07	19.06
13	53.24	52.71	15.13	15.08
14	52.71	51.94	19.06	19.05
15	51.94	50.96	13.63	13.6
16	50.96	50.24	19.05	19
17	50.24	49.74	13.6	13.59
18	49.74	48.21	15.08	15.07

This table 6 shows the weight of material and tool before and after machining.

Table 6 Output process parameter of SS316

EXP.NO	MACHINING TIME	MRR	TWR	WEAR RATIO	ROCKWELL HARDNESS	BRINNEL HARDNESS
	(min)	(g/min)	(g/min)	%		BHN
1	5.28	0.113	0.007	16.14	40	144.5
2	4.45	0.202	0.002	101	81	144.9
3	5.35	0.074	0.003	24.66	59	144.5
4	3.31	0.178	0.018	9.88	51	144.5
5	4.36	0.185	0.006	30.83	49	144
6	4.2	0.159	0.002	79.5	35	144.9
7	2.59	0.227	0.011	20.63	30	144
8	3.18	0.22	0.006	36.66	21	144.5

9	5.39	0.109	0.001	109	44	144
10	42.21	0.017	0.0004	42.5	45	143.6
11	43.38	0.010	0.00023	43.47	49	144
12	44.08	0.019	0.00026	73.07	29	144
13	39.59	0.013	0.001	13	39	143.6
14	37.2	0.020	0.00026	76.92	52	143.6
15	44.36	0.022	0.00067	32.83	39	144
16	38.29	0.018	0.0013	13.8	51	144
17	37.48	0.013	0.00026	50	32	143.6
18	42.44	0.036	0.00023	156.52	47	144

Table 7 Output process parameter of SS316

The output parameter such as machining time, material removal rate, tool wear rate, wear ratio, brinell and Rockwell hardness values are tabulated.

Fig 2 Workpiece and Tool material after machining

S.NO	SHAPE	LOAD(KG)	LOAD (N)	PARAMETER	DIAL READING	ROCKWELL HARDNESS
1	PENTAGONAL	150	1471.5	1/16	Black	40
2	CIRCLE	150	1471.5	1/16	Black	81
3	SQUARE	150	1471.5	1/16	Black	59
4	SQUARE	150	1471.5	1/16	Black	51
5	PENTAGONAL	150	1471.5	1/16	Black	49
6	CIRCLE	150	1471.5	1/16	Black	35
7	CIRCLE	150	1471.5	1/16	Black	30
8	SQUARE	150	1471.5	1/16	Black	21
9	PENTAGONAL	150	1471.5	1/16	Black	44
10	CIRCLE	150	1471.5	1/16	Black	45
11	SQUARE	150	1471.5	1/16	Black	49
12	PENTAGONAL	150	1471.5	1/16	Black	29
13	SQUARE	150	1471.5	1/16	Black	39
14	PENTAGONAL	150	1471.5	1/16	Black	52
15	CIRCLE	150	1471.5	1/16	Black	39
16	PENTAGONAL	150	1471.5	1/16	Black	51

17	CIRCLE	150	1471.5	1/16	Black	32
18	SQUARE	150	1471.5	1/16	Black	47

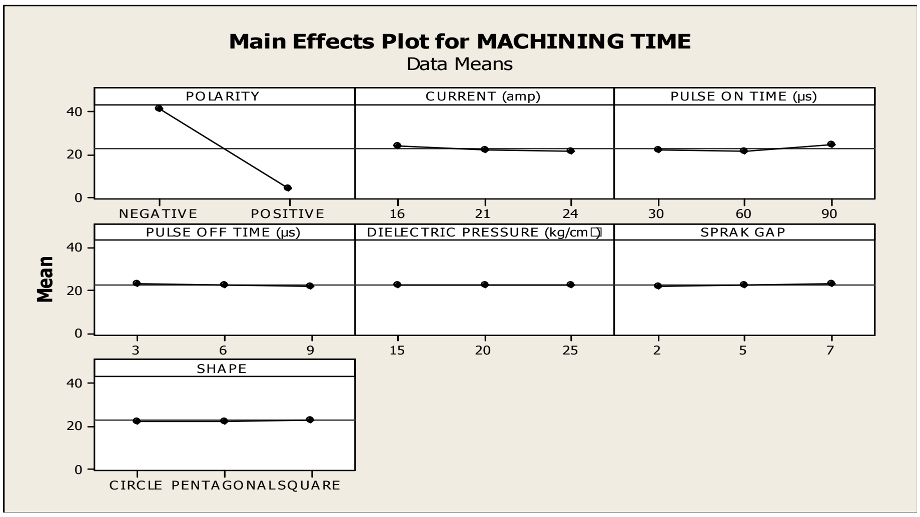
Table 8 Rockwell hardness test

S.N	SHAPE	LOAD (kg)	DIAMETER		MEAN	AREA (mm^2)	BRINELL HARDNESS (N/mm^2)
			d1	d2			
1	PENTAGONAL	500	20	20	20	3.46	144.5
2	CIRCLE	500	18	18	18	3.45	144.9
3	SQUARE	500	19	19	19	3.46	144.5
4	SQUARE	500	20	20	20	3.46	144.5
5	PENTAGONAL	500	21	21	21	3.47	144
6	CIRCLE	500	18	18	18	3.45	144.9
7	CIRCLE	500	22	22	22	3.47	144
8	SQUARE	500	20	20	20	3.46	144.5
9	PENTAGONAL	500	22	22	22	3.47	144
10	CIRCLE	500	23	23	23	3.48	143.6
11	SQUARE	500	21	21	21	3.47	144
12	PENTAGONAL	500	22	22	22	3.47	144
13	SQUARE	500	23	23	23	3.48	143.6
14	PENTAGONAL	500	23	23	23	3.48	143.6
15	CIRCLE	500	21	21	21	3.47	144
16	PENTAGONAL	500	21	21	21	3.47	144
17	CIRCLE	500	23	23	23	3.48	143.6
18	SQUARE	500	21	21	21	3.47	144

Table 9 Brinell Hardness test

1. Machining Time

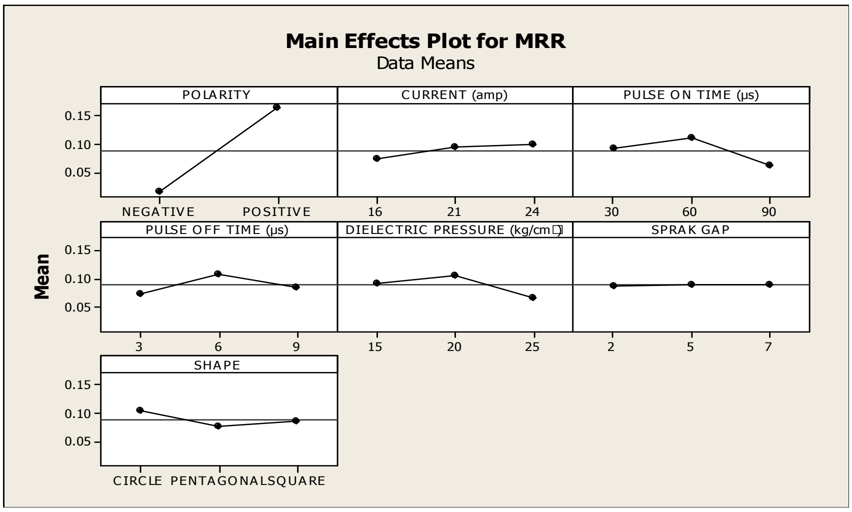
Fig 3 Main effects plot for Machining Time in SS316



In fig 3 Minimum Machining time is obtained at Tool-Positive, current level 3- 24 amp ,pulse on time at level 1-20(μ sec), pulse off time at level 3- 9(μ sec), the dielectric pressure at level 1-15 kg cm^2 , spark gap at level 1-(0.02mm) and shape at level 3 (Square)

2. Material removal rate

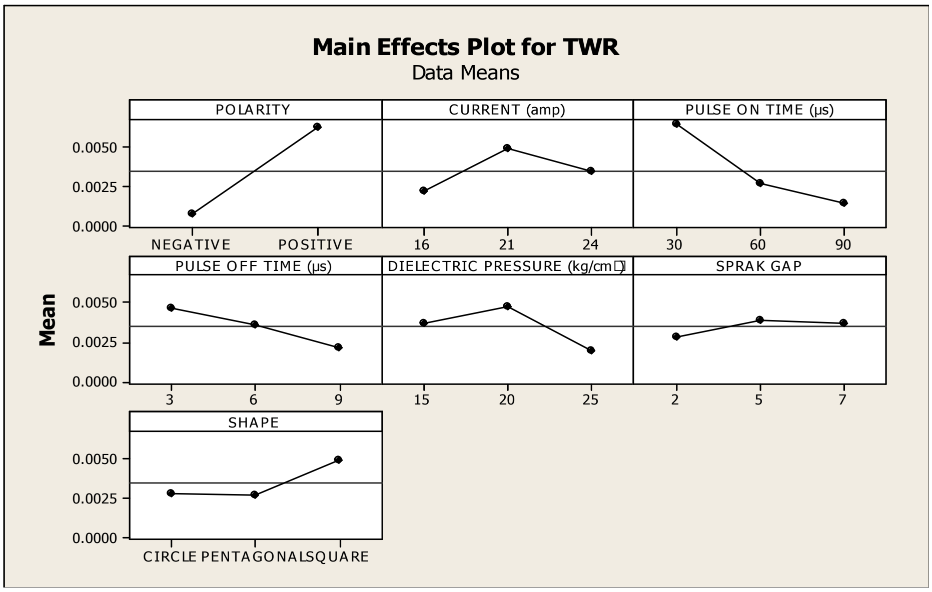
Fig 4 Main effects plot for Material removal rate in SS316



In fig 4 Maximum material removal rate is obtained at Tool-Positive, current level 3- 24 amp ,pulse on time at level 2-60(µ sec), pulse off time at level 2- 6(µ sec), the dielectric pressure at level 2-20kg cm^2 and spark gap at level 3-(0.07mm).

3 .Tool wear rate

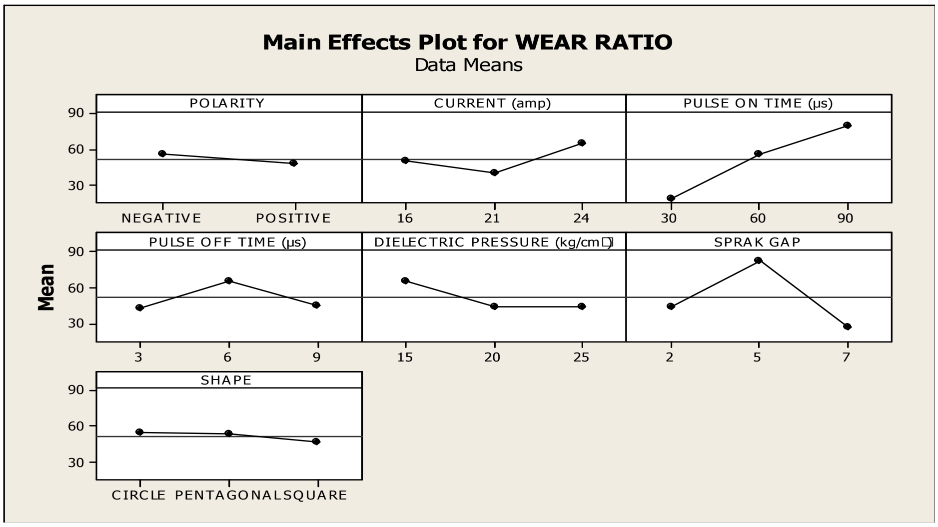
Fig 5 Main effects plot for Tool wear rate in SS316



In fig 5 Minimum tool wear rate is obtained at Tool-Negative, current level 1- 16 amp ,pulse on time at level 3-90(µ sec), pulse off time at level 3- 9(µ sec), the dielectric pressure at level 3-25 kg cm^2 , spark gap at level 1-(0.02mm) and shape at level 1 (Circle)

4 .Wear ratio

Fig 6 Main effects plot of wear ratio in SS316



In fig 6 Minimum wear ratio is obtained at Tool-Positive, current level 2- 21 amp ,pulse on time at level 1-20(µ sec), pulse off time at level 3- 9(µ sec), the dielectric pressure at level 3-25 kg cm^2 , spark gap at level 3-(0.07mm) and shape at level 3 (Square)

CONCLUSIONS

From this experiment on SS316 using Copper electrode we got maximum MRR, brinell and Rockwell hardness, minimum TWR, Wear ratio, Machining time.

- Minimum Machining time is obtained at Tool-Positive, current level 3- 24 amp ,pulse on time at level 1-20(µ sec), pulse off time at level 3- 9(µ sec), the dielectric pressure at level 1-15 kg cm^2 , spark gap at level 1-(0.02mm) and shape at level 3 (Square).
- Maximum material removal rate is obtained at Tool-Positive, current level 3- 24 amp ,pulse on time at level 2-60(µ sec), pulse off time at level 2- 6(µ sec), the dielectric pressure at level 2-20kg cm^2 and spark gap at level 3-(0.07mm).
- Minimum tool wear rate is obtained at Tool-Negative, current level 1- 16 amp ,pulse on time at level 3-90(µ sec), pulse off time at level 3- 9(µ sec), the dielectric pressure at level 3-25 kg cm^2 , spark gap at level 1-(0.02mm) and shape at level 1 (Circle)
- Minimum wear ratio is obtained at Tool-Positive, current level 2- 21 amp ,pulse on time at level 1-20(µ sec), pulse off time at level 3- 9(µ sec), the dielectric pressure at level 3-25 kg cm^2 , spark gap at level 3-(0.07mm) and shape at level 3 (Square)
- Maximum Brinnel hardness is obtained at Tool-Positive, current level 1- 16 amp ,pulse on time at level 3-90(µ sec) , pulse off time at level 3- 9(µ sec), the dielectric pressure at level 2-20 kg cm^2 , spark gap at level 1-(0.02 mm) and shape at level 3 (square)
- Maximum Rockwell hardness is obtained at Tool-Positive, current level 1- 16 amp ,pulse on time at level 2-60(µ sec) , pulse off time at level 2- 6(µ sec), the dielectric pressure at level 2-20 kg cm^2 , spark gap at level 2-(0.05mm) and shape at level 1 (Circle)

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