Investigation on EDM of SS316 Using Brass and Copper Electrode for Improving Material Removal Rate and Tool Wear Rate

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Abstract

At the outset period of humankind, instruments were made of stone for the thing being made. Exactly when iron contraptions were envisioned, beneficial metals and more current articles could be made. In twentieth century things were created utilizing the most solid and hence, the most machine proficient materials. With a ultimate objective to address the amassing troubles made by these materials, contraptions have now progressed to join materials, for instance, blend steel, carbide, gem and stoneware creation. An equivalent advancement has happened with the methods used to control our instruments. From the start, mechanical assemblies were powered by muscles; either human or animal. Nevertheless as the powers of water, wind, steam and force were harnessed, mankind had the choice to moreover widen delivering capacities with new machines, more unmistakable accuracy and speedier machining rates. Each time new instruments, gadget materials, and power sources are utilized, the viability and capacities of makers are massively overhauled. Since 1940's, a disturbed in collecting has been happening that eventually allows makes to fulfill the requirements constrained by dynamically refined plans and strong in any case all around practically un machinable, materials. This gathering revolt is by and by, as it has been beforehand, focused on the usage of new mechanical assemblies and new kinds of energy.

I. Introduction

Since beginning of humanity, people have progressed gadgets and fuel sources to control these mechanical assemblies to meet the necessities for making the presence more less difficult and enchanting. First and foremost period of humanity, contraptions were made of stone for the thing being made. Right when iron instruments were envisioned, useful metals and more present day articles could be made. In twentieth century things were delivered utilizing the most strong and in this manner, the most un machine able materials. With a ultimate objective to address the gathering troubles made by these materials, devices have now evolved to consolidate materials, for instance, composite steel, carbide, gem and stoneware. A similar headway has happened with the procedures used to control our mechanical assemblies. From the start, instruments were powered by muscles; either human or animal. Regardless as the powers of water, wind, steam and force were harnessed, mankind had the alternative to furthermore extend creating capacities with new machines, more conspicuous accuracy and faster machining rates. Each time new instruments, device materials, and power sources are utilized, the capability and limits of makers are immensely improved. Since 1940's, a disturbance in collecting has been happening that before long allows manufactures to satisfy the requirements constrained by logically complex plans and solid notwithstanding generally speaking practically un machinable, materials. Seller had shown the reformist development in strength of material with year quick headway of material in plane business. This amassing distress is as of now, as it has been previously, focused on the usage of new gadgets and new kinds of energy. The result has been the introduction of new amassing measures used for material departure, outlining and joining, alluded to now as non-regular collecting measures.

1.2 Unconventional machining process

Non-traditional amassing measures is described all in all of cycles that take out excess material by various methodology including mechanical, warm, electrical or engineered energy or blends of these energies yet don't use a sharp cutting instruments as it ought to be used for standard collecting measures. Inconceivably hard and delicate materials are difficult to machine by traditional machining cycles like turning, infiltrating, embellishment and handling. Nontraditional machining measures, in like manner called advanced creating measures, are used where standard machining measures are not achievable, agreeable or judicious in light of special reasons as outlined underneath.

- Very hard sensitive materials difficult to prepare for standard machining
- When the workpiece is exorbitantly versatile or thin
- When the condition of the part is exorbitantly erratic

A couple of sorts of non-customary machining measures have been made to meet extra required machining conditions. Right when these cycles are used fittingly, they offer various advantages over non-customary machining measures. The typical non-ordinary machining measures are depicted in this part.

1.3 Electrical Discharge Machining (EDM)

Electrical delivery machining (EDM) is conceivably the most by and large used non-ordinary machining measures. The major interest of EDM over ordinary machining cycles, for instance, metal cutting using different mechanical assemblies and beating is that this technique utilizes thermoelectric collaboration to disintegrate undesired materials from the workpiece by a movement of discrete electrical shines between the workpiece and the cathode.

The standard machining measures rely upon harder gadget or grinding material to dispose of the milder material while non-traditional machining cycles, for instance, EDM uses electrical shimmer or atomic ability to break up unwanted material to make needed shape. Thusly, the hardness of the material isn't, now a decision part for EDM measure. A schematic of an EDM association is shown in Figure 2, where the instrument and the workpiece are immersed in a dielectric fluid. EDM kills material by delivering an electrical stream, routinely set aside in a capacitor bank, across a little opening between the device (cathode) and the workpiece (anode) usually in the solicitation for 50 volts/10amps.

2. Literature Review

Selvarajan et al investigates that Electric Discharge Machining (EDM) is a particularly promising machining cooperation of earthenware. This investigation is an out of the perspective in-vestigation of EDM on Si₃N₄-TiN with Copper cathode. Ceramics are used for removal dies and bearing balls and they are more capable, effective and even have longer life than conventional metal blends. Inferable from high hardness of terminated composites, they are for all intents and purposes hard to be machined by normal machining as it inside and out depends upon relative hardness of equipment with work piece. However EDM offers basic machinability got together with striking surface finish. Information limits of head significance like stream (I), beat on(Pon) and off time(Poff), dielectric pressure(DP) and opening voltage(SV) are thought about using L25 balanced group. With help of mean effective plots the relationship of yield limits like Material Removal Rate(MRR), Tool Wear rate(TWR), Surface Roughness(Ra), Radial overcut(ROC),Taper point (α),Circularity(CIR), Cylindricity (CYL) and Perpendicularity (PER) with the thought about data limits and their individual effect were analyzed. The immense machining limits were gotten by examination of contrast (ANOVA) taking into account Gray Relational Analysis(GRA) and worth of backslide coefficient was settled for each model. The results were also surveyed by using demonstrative examination which outlined that radiance dissolving association could sufficiently be improved.

Ravinder Kumar shows that Micro electric delivery machining (μ -EDM) is a for the most part used cycle for machining of hard to machine materials. The occasion of arcing and shortcircuiting in smaller than expected electric delivery exhausting (EDD) is a normal issue which confines the perspective extent achieved during the association. The current assessment is based on the improvement as needs be credits by taking out the occasion of arcing and shortcircuiting. These issues can be tended to by changing the gadget anode math. Notwithstanding the way that, EDD using shaped gadget cathodes further foster response credits as shown by the past examinations, nonetheless time spent in terminal assembling ought to moreover be considered as it impacts the overall convenience. Considering the composing related to EDD using framed instrument anodes, the proposed cathode has been found to possess least terminal creation energy for instance 9 min for an anode length of 3.2 mm. Along these lines, the proposed terminal is good for making openings of high point extent with least anode make time. The proposed anode was in like manner found to be convincing in shedding the social affair of debris in the machining zone. Additionally, the need of flushing during the cycle has been totally shed making it a self-flushing terminal. The instrument of removal of junk is throughout explained reliant upon the photos found using a quick camera. The introduction of the proposed cathode was surveyed with respect to response ascribes, for instance, material departure rate, device wear rate, perspective extent, fix point and corner clear of the entered opening. A liberal addition of 300% in point extent was recorded using the arranged terminal when diverged from the solid barrel formed anode for the initial estimation of 0.8 mm

3. Design of Experiment

This is deals with the assurance of data Die sinking EDM limits and yield responses for this assessment. Then the methods and subtleties for machining measure are explained. This part moreover deals with the assessment system for different yield responses. Especially the assessments of SS316 material. The nuances of test plan for SS31 Taguchi L18 even display full factorial arrangement are presented close to the end.

3.2 Work piece selection

3.2.1 Stainless steel 316

Solidified steel contains an extension of molybdenum that gives it further created utilization block. This is particularly clear for pitting and split utilization in chloride conditions.

The table 3.1 shows that substance association of SS316 contains carbon, silicon, phosphorous, sulfur, manganese, chromium, etc

Table 3.1 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 3.2 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 3.2 shows the mechanical properties of tempered steel 316 contains thickness, flexibility, mass modulus, etc

3.2.2 Application

From the outset made for use in paper production lines solidified steel 316 is by and by regularly used in:

- Food getting ready equipment
- Chemical and petrochemical equipment

Fig-3.1 Workpiece and Tool material before machining

From Fig 3.1 shows that condition of workpiece and tool material before machining

3.3 Tool material selection

- When picking EDM terminals, the fundamental thoughts nearby its construction and limit are the material's conductivity (or resistivity) and it's breaking down obstacle. Conductivity propels cutting efficiency, since electric stream is the "cutting gadget".
- Erosion resistance (a factor of relaxing point, hardness, and basic decency) gives the cathode a more broadened help life and cuts down the repeat of replacement.
- These properties, which shift simply by the kind of blend or material used, ought to be the principle thought while picking a cathode.

3.3.1 Copper electrode

- Copper and copper composites have favored EDM wear impediment over metal, be that as it may are more difficult to machine than either metal or graphite.
- It is moreover more exorbitant than graphite. Copper is, regardless, a normal base material since it is uncommonly conductive and strong.
- It is useful in the EDM machining of tungsten carbide, or in applications requiring a fine fulfillment.

Table 3.3 Showing Physical Properties of Copper Electrode

Physical properties	Value
Electrical resistivity ($\mu \Omega/\text{cm}$)	1.96
Electrical conductivity compared with silver (%)	92
Thermal conductivity (W/m K)	268-389
Melting point ($^{\circ}\text{C}$)	1083
Specific heat (cal/g $^{\circ}\text{C}$)	0.092
Specific gravity at 20°C (g/cm ³)	8.9
Coefficient of thermal expansion ($\times 10^{-6} \text{ }^{\circ}\text{C}^{-1}$)	6.6

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

3.4 Machine setup and specification

3.4.1 Die sinking EDM

- Die Sinking EDM (electrical transport machining) infiltrating, in any case called quick Die sinking EDM entering, opening popper, and start Hole EDM drilling, was once relegated to a "last inn" method for Drilling openings. After a short time turning EDM entering is used for creation work.
- Drilling speeds have been created of up to two inches every Minute. Openings can be exhausted in any electrical Conductive material. Whether or not hard or fragile, including carbide.
- A Die sinking EDM machine has been used for Die sinking EDM measure.

From table 3.4 gives the working and specification of die sinking EDM used for doing experiments.

Table 3.4 Die Sinking EDM set up and its specifications

Parameters	Dimensions
EDM Drilling	Machine Model SD350
Work Table	600 mm x 300 mm
Table Travel (X)	350 mm
Table Travel (Y)	300 mm
Spindle Servo Travel (Z1)	345 mm
Second Travel Auxiliary Head Travel (Z2)	200 mm
Electrode Guide Travel (Z3)	150 mm
Working Fluid Tank Capacity	20 Litre Pure Water
Maximum Workpiece Weight	400 Kg
Machine Weight (Net)	800 Kg
Power Source	380 V
Max Power Consumption	3.5 KVA
Max Machining Current	35 A
Servo Speed (Stability)	Adjustable

Table 3.5 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} , μs)	3 - 40 μs
Pulse off time (t_{off} , μs)	1 - 5 μs
Dielectric fluid	EDM oil
Fluid pressure (kg/cm ²)	1-5

This table 3.5 shows the operating condition of SS316 in which the die sinker EDM works and table 3.6 shows the parameters and levels of spark EDM.

Table 3.6 Parameters and levels of spark EDM

Symbol	Parameter	Unit	Level 1	Level 2	Level 3
A	Current	Amp	16	21	24
B	Pulse on time	μs	30	60	90
C	Pulse off time	μs	3	6	9
D	Spark gap	mm	0.02	0.05	0.07
E	Dielectric pressure	Kg/cm ²	15	20	25
F	Shape of electrode	-	Circle Square Pentagonal	Circle Square Pentagonal	Circle Square Pentagonal
G	Polarity	-	Straight polarity Reverse polarity	Straight polarity Reverse polarity	Straight polarity Reverse polarity

3.4.2 Dielectric Pressure

During the EDM cooperation the workpiece and the cathode are brought down in the dielectric oil, which is an electrical encasing that assists with controlling the curve release. The dielectric oil, that gives a method for flushing, is coordinated through the twist opening. This kills suspended particles of workpiece material and terminal from the work depression.

3.4.3 Distilled water

Refined water can't avoid being water that has had enormous quantities of its defilements disposed of through refining. Refining incorporates warming up the water and a while later uniting the steam into an ideal holder.

3.5 Selection of Orthogonal Array

L18 symmetrical exhibit with six variables and three levels is the intended to direct the tests. The plan of trial is shown in Table 3.7 EDM working condition for SS 316 alloy material.

Table 3.7 Design of Experiment

Exp. No.	L ₁₈ Orthogonal Array						
	1	2	3	4	5	6	7
1.	1	1	1	1	1	1	1
2.	1	1	2	2	2	2	2
3.	1	1	3	3	3	3	3
4.	1	2	1	1	2	2	3
5.	1	2	2	2	3	3	1
6.	1	2	3	3	1	1	2
7.	1	3	1	2	1	3	2
8.	1	3	2	3	2	1	3
9.	1	3	3	1	3	2	1
10	2	1	1	3	3	2	2
11	2	1	2	1	1	3	3
12	2	1	3	2	2	1	1
13	2	2	1	2	3	1	3
14	2	2	2	3	1	2	1
15	2	2	3	1	2	3	2
16	2	3	1	3	2	3	1
17	2	3	2	1	3	1	2
18	2	3	3	2	1	2	2

3.6 Experimental plan

In this work, the data limits that have been considered are stream, beat on and beat off time, dielectric fluid squeezing component and opening voltage and these are critical factors in EDM machining.

3.6.1 Current (amp)

The current tends to the different power levels that the EDM generator is prepared for giving. The value of this factor (I) addresses, for the present circumstance, the most outrageous worth of the delivery current power, that is, the zenith power.

The power regards used in the programming of the EDM machine are power levels of the current.

3.6.2 Pulse On time (μ s)

The range of time (μ s) that the current is allowed to stream per cycle. Material clearing is directly comparative with the proportion of energy applied during this on time. This energy is obliged by the apex current and the length of the on time.

3.6.3 Pulse Off time (μ s)

The term of time (μ s) between the glimmers (as such, off-time). This time allows the fluid material and to be wash out of the bend opening.

This limit is affecting the speed and the robustness of the cut. Thusly, if the beat off-time is unnecessarily short, it will cause shimmers to be unstable.

3.6.4 Dielectric pressure (kg/cm^2)

In EDM, a liquid medium that fills the opening between the terminal and work piece and goes probably as a cover until a specific opening and voltage are refined. Used to take out chips and cool the anode/wire and work piece.

It then ionizes and transforms into an electrical course, allowing a stream (shimmer) to travel through it to the work piece. It moreover serves to cool the work and to flush away the particles made by the glimmer.

3.7 Output parameters

These are following respects be assessed/resolved: MRR, TWR, VR and Machining Time dimensional characteristics viz. circularity and cylindricity. The assessments/calculations of these yields are explained in the going with entries.

3.7.1 Material removal rate

For each put down of stopping points, the machining tests were driven. The weight of the work piece before machining and the greatness of the work piece in the wake of machining were assessed using electronic harmony of cutoff 300 grams and exactness 0.001 grams.

The time taken for completing the experiment was also measured using stop watch. The MRR was then calculated using the following formula.

$$\text{MRR (g/min)} = \frac{W_b - W_a}{t}$$

Where,

W_b -Weight of the work piece before machining (g)

W_a - Weight of the work piece after machining (g)

Fig 3.3 shows the weighing machine in which weight of the material and tool is calculated before and after machining.

Fig 3.3 Showing Precision Electronic Balance

3.7.2 Tool wear rate

The wear in cathode is fundamental to be assessed and controlled considering the way that it impacts dimensional accuracy of feature that is machined. Contraption wear depends after dissolving point of the anode materials. Instrument wear rate (TWR) is wear in the terminal per unit time and it is resolved using eqn.

$$\text{TWR (g/min)} = \frac{W_b - W_a}{t}$$

Where,

W_b -Weight of the tool before machining (g)

W_a - Weight of the tool after machining (g)

t - Machining time (min)

3.7.3 Wear ratio

The Wear proportion might be communicated as proportion of wear pace of hardware and work-piece. It is communicated and determined with the assistance of following condition:

$$\text{WR (\%)} = \text{MRR/TWR}$$

Where,

MRR-Material removal rate (g/min)

TWR-Tool wear rate (g/min)

3.7.4 Rockwell Hardness Test

The Rockwell hardness test system contains indenting the test material with a gem cone or hardened steel ball indenter. The indenter is compelled into the test material under an essential minor weight commonly 10 kg f. Right when equilibrium has been reached, an appearance contraption, which follows the advancements of the indenter accordingly responds to changes start to finish of passageway of the indenter is set to a datum position.

The fig 3.4 and 3.5 shows the genuine game plan of brinell and Rockwell hardness machine in which hardness of material is resolved.

Fig 3.4 Rockwell hardness

3.7.5 The Brinell Hardness Test

The Brinell hardness test strategy contains indenting the test material with a 10 mm distance across cemented steel or carbide ball presented to a pile of 3000 kg. For milder materials the store can be diminished to 1500 kg or 500 kg to avoid outrageous space. The full weight is regularly applied for 10 to 15 sec.

Fig 3.5 Brinell hardness

$$BHN = \frac{P}{\frac{\pi D}{2} [D - \sqrt{D^2 - d^2}]}$$

Where:

P is the test load [kg]

D is the diameter of the ball [mm]

d is the average impression diameter of indentation [mm]

4. Conclusion

In the latest field of development respect to welding and machining, plasma twist welding and machining have a monster accomplishment. Due to its further created weld quality and extended weld yield it is been used for precision welding of cautious instruments, to customized fix of fly engine sharp edges to the manual welding for fix of parts in the gadget, die and structure industry. Regardless, due to its high equipment cost and high making of ozone, it's been overshadowed by other improvement welding gear like laser bar welding and electron bar welding. To vanquish the referred to issue, it is been not unexpected that soon it will get with its base cons.

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