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Analysis of Machining Characteristics of Micro_EDM

Aniket Gupta[1,*] and Suruchi[2]

[1]Department of Mechanical Engineering, Chandigarh Engineering College, Jhanjeri-140307, Punjab, India

[2]Department of Agriculture, Chandigarh Engineering College, Jhanjeri-140307, Punjab, India

*Email: aniketj1019@cgc.ac.in

Abstract: Micromachining is the ability to make features with sizes between one micrometer and one thousand micrometers, and when the volume of material taken away is at the micron level. In specific, it is used to make microstructures and elements that are very small. In order to produce better results in terms of productivity and greater machining efficiency, micromachining is frequently carried out via the use of non-traditional machining techniques. Industrial products with a higher proportion of functionalities and lower overall dimensions are increasingly needed to meet the requirements of the new world. Since it is the most crucial method, micro-machining is used more than any other in the production of such tiny parts and components. In this study RSM-based central composite design approach was used to study the different parameters like MRR and TWR during machining of SS 304 stainless steel, grade 304.

Keywords: EDM, alloys, machining, Micro-EDM

Introduction

Fundamentals of micro-EDM deals with the basic features of micro machining process along with the process parameters, electrical parameters and performances. It operates according to the fundamental concept of spark erosion machining, in which the removal of materials is accomplished by the process of melting and vaporization in the discharge gap that exists between the tool and the workpiece. Materials that are very abrasive and electrically conductive are often used for this function. Erosion of materials can be accomplished through the processes of heating, melting, and in which the dielectric fluid, to produce vaporization of the workpiece, such as hydrocarbon oil or de-ionized water, is introduced between the tool electrode and workpiece. These occurrences are brought upon by plasma. Voltage sufficient to overcome dielectric breakdown strength of tiny gap is required to start the discharge. When ionization of cations and anions takes place between the tool electrode and the workpiece electrode, dielectrics serve as catalysts. To prevent electrolysis, the insulating effect of the dielectric medium on the electrodes must be considered throughout the EDM process. In order to achieve a gap size of between 10 and 100 micrometers, the dielectric must have a smaller dielectric constant than that of the electrode shape. This will allow for more accurate machining features to be produced. On the other hand, in order to prevent a short circuit from occurring, a certain gap width is required. This is particularly the case when electrodes are used that are sensitive to vibration (such as wire-electrodes) or deformation. It is required for the subsequent pulse discharge in EDM to take place at a position that is sufficiently far from the site of the discharge that came before it in order to achieve stable circumstances. A location like this may be one in which the gap is narrow or where it is polluted by debris particles, both of which have the potential to reduce the dielectric breakdown strength of the liquid. As a result, the amount of time that passes between pulse discharges needs to be sufficient enough for the plasma to be deionized and the dielectric breakdown strength to return to its pre-discharge level before the next pulse voltage is applied. This is necessary in order for the next pulse discharge to be successful. If this is not avoided, discharges will continue to take place in the same region with each pulse, leading to an increase in temperature and an uneven eroding of the work piece.

Therefore, it is understood that micro-EDM is a thermal non-conventional machining process based on the

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phenomena of material removal by melting and vaporization with the help of controlled values of process parameters to obtain the desired performances.

Mechanism of Material Removal in Micro-EDM

The electro discharge machining technique uses thermo-electric phenomena as the foundation for the material eroding that takes place. EDM is able to remove material because of the erosive effects that are produced when a very small discharge energy is generated due to spark discharge occurring between the tool and workpiece electrodes in the vicinity of dielectric fluid. This occurs when a spark discharge takes place between the tool and workpiece electrodes. Sparks of very little duration are produced, which contribute to the development of an ionization process between these two electrodes. A little amount of material from both electrodes melted as a result of the generator's release of electrical energy, which was then turned into chemical energy. The length of the pulse comes to an end, and then the pause time starts. Within the space that separates the electrode and the workpiece, a powerful electric field is generated. The presence of contaminants within the dielectric fluid creates a bridge between the electrode and the workpiece that has a high conductivity. The bridge and the dielectric fluid work together to help break the potential that exists between the electrode and the workpiece when the voltage is increased. Ionization of the dielectric material results in the formation of a plasma channel. As a result, both the temperature and the pressure in that location quickly increased. At the point where the spark contacts the electrode and the workpiece, a trace quantity of material is removed in the form of vapor. During the sparking process, bubbles quickly increase and rupture until the voltage is removed from the circuit. After then, the plasma channel will collapse, and the dielectric fluid will enter the gap in order to remove the molten metal particles. This will be accomplished by flushing them away. The peak current or strength of the spark, the duration of the ON time and the OFF period, the duty factor, and the gap distance between the electrodes all have a role in determining the pace at which material is removed. When the voltage between the electrodes is raised, the intensity of the electrode potential in the volume between the electrodes is larger than the dielectric strength (in some places). Dielectric breakdown occurs as a result, allowing current to flow across the electrodes themselves. As a direct result of this, electrode material is being removed. Liquid dielectric is normally pumped into the inter-electrical space when the current is switched off. This allows the debris particles to be removed while the dielectric insulation is being treated. The material removal process is shown in Fig. 1 as a physical phenomenon.

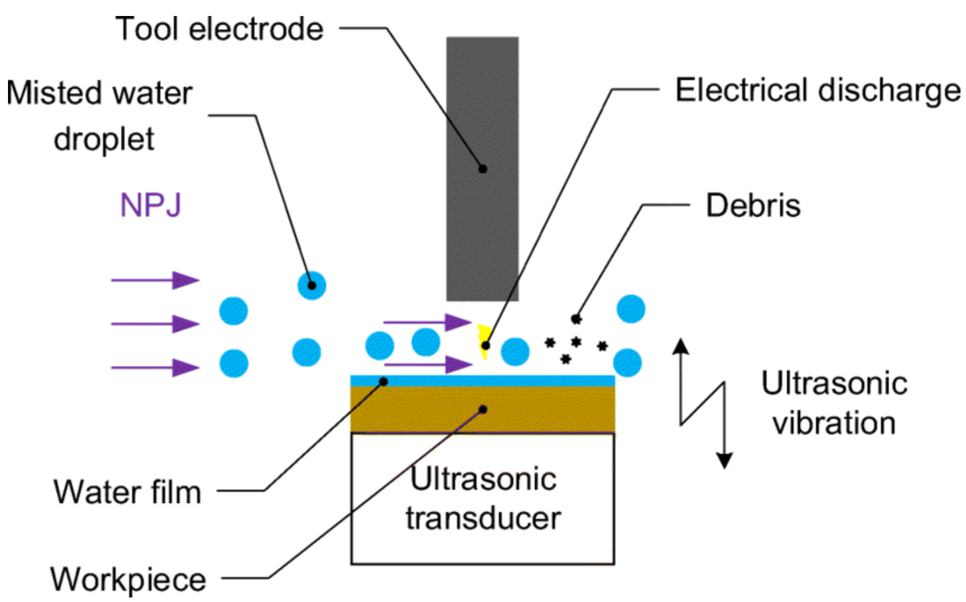

Fig. 1 Material Removal Mechanism in Micro-ED

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To investigate the machining characteristics, experiments were performed on SS 304 stainless steel grade with micro copper tool as tool electrode. At first, micro-EDM set up has been prepared with conventional machining chamber considering EDM oil as dielectric. A total of (20 × 3) 60 experiments were conducted and values of machining characteristics such as MRR, TWR and overcut were measured and analyzed.

Experimental Planning

Using Response Surface Methodology's central composite design (CCD), the initial studies incorporated peak current and pulse on time as process parameters. The inquiry included conducting 60 (203) tests. The workpiece is made of SS 304 stainless steel, grade 304, and has a thickness of 350 micrometers. The tool electrode comprised of a copper tool with a diameter of 430 micrometers. SS 304 is the most often used kind of stainless steel. For the most part, steel does not include iron. The principal non-iron components are chrome (18% to 20%) and nickel (8% to 10.5 percent). Austenitic stainless steel is the most common kind. Although carbon steel has a higher electrical and thermal conduction than stainless steel, it lacks almost all magnetic characteristics. Corrosion resistance is superior than that of normal steel, and it is widely used because of its versatility in shaping. Corrosion-resistant stainless steel, such as 304, is resistant to a wide range of corrosive environments and several corrosive chemicals. Mechanical properties of SS 304 may be seen in Table 1. EDM oil is acting as a dielectric fluid in this investigation. Plunging pressure (P) was regarded a fixed parameter whereas other machining components, such as gap voltage, pulse off time, and polarity (Po), were considered adjustable factors in the micro-EDM process. Pilot studies were carried out to define the ranges of variable process parameters, such as peak current, pulse on-time, and flushing pressure, as a starting point. No through microholes could be drilled below the minimum process parameters specified for experimentation..It's demonstrated in Table 1 and 2 that RSM-based central composite design approach was used to code and measure numerous process parameters, as well as to set up the experiment.

Before and after machining, the weights of both the workpiece and the tool were measured, and the MRR and TWR were determined. Overcut measurements were made using an optical microscope to quantify the size difference between the micro tool and micro through holes on a workpiece.

Table 1. Mechanical properties for 304 stainless steel alloy

Properties	Values
Tensile Strength (MPa)	540 - 750
Proof Stress (MPa)	230 Min
Elongation A50 (mm)	45 Min %
Density	8 g/cc
Melting Temperature	1400-1455^{0}C
Thermal Conductivity	16.2 W/m-K
Hardness	123BHN

Table 2. Experimental conditions for micro-EDMing of SS 304

Fixed process parameters	Range / Values Specified
a) Gap Voltage	45 V
b) Work Time	02 sec
c) Lift Time	05 sec
d) Pulse off-Time	06µsec
e) Polarity	Positive {Tool Electrode (+) and Workpiece Electrode (-)}
Controlled Process parameters	
a) Peak current (A) :-	1-5 A
b) Pulse On-Time :-	1-5 µsec
c) Flushing Pressure :-	0.09-0.27 kg/cm^2

Table 3. Experimental Conditions based on Central Composite Design of RSM

Expt. No.	Peak Current (A)	Pulse On Time (µsec)	Dielectric Flushing Pressure (kg/cm^2)	Peak Current (A)	Pulse On Time (µsec)	Dielectric Flushing Pressure (kg/cm^2)
	Coded Values			Actual Values		
1	0	0	0	3	3	0.18
2	0	0	+1.682	3	3	0.27
3	1	-1	-1	4	2	0.12
4	0	+1.682	0	3	5	0.18
5	-1	+1	-1	2	4	0.12
6	-1.682	0	0	1	3	0.18
7	0	0	0	3	3	0.18
8	0	0	0	3	3	0.18
9	0	0	0	3	3	0.18
10	+1	+1	-1	4	4	0.12
11	+1	-1	+1	4	2	0.24
12	+1.682	0	0	5	3	0.18
13	-1	-1	+1	2	2	0.24
14	0	0	0	3	3	0.18
15	+1	+1	+1	4	4	0.24
16	0	-1.682	0	3	1	0.18
17	-1	+1	+1	2	4	0.24
18	0	0	-1.682	3	3	0.09
19	-1	-1	-1	2	2	0.12
20	0	0	0	3	3	0.18

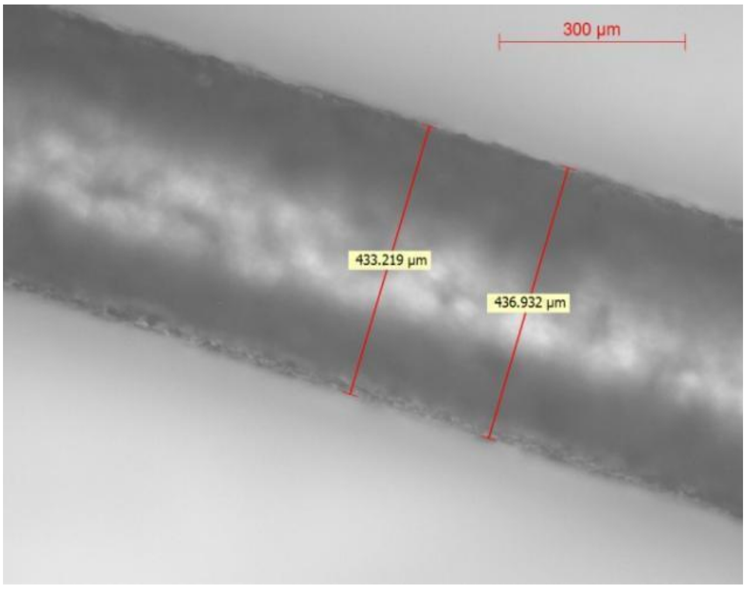

Fig. 2. Optical image of copper micro tool

Experimental Results

Based on the designed experimental conditions by RSM technique, all the experiments were performed after setting all the process parameters (variable and constant) at different combinations. The experimental procedure was followed to obtain data from necessary measurements. Among these measures were the decrease in weight of the workpiece and tool, the amount of time it took to machine it, the sizes of the through microholes, and so on the experimental approach was used to get the data. Twenty-three times a day, a total of sixty experiments were conducted out. The real data were acquired by taking the average of the three experimental runs that were included in each set of experimental data. These actual data were then used for the purposes of conducting analyses and modeling of the performance characteristics. MRR, TWR and Overcut were calculated as per the formula mentioned earlier and had been shown in Table 3.

Table 4 Experimental Results during micro-EDMing of SS 304

Expt. No.	MRR (in μg/min)	TWR (in μg/min)	Overcut, (in μm)
1	398	280	70.00
2	360	660	79.25
3	399	570	83.75
4	487	1080	75.00
5	422	460	55.00
6	380	260	45.00
7	398	700	62.00
8	400	930	61.00
9	410	790	60.00
10	412	920	84.25
11	623	900	70.00
12	717	1160	85.00
13	277	210	63.75
14	398	960	66.68

15	630	830	75.00
16	460	490	65.63
17	280	550	69.12
18	267	590	68.75
19	408	270	53.21
20	398	710	65.25

After the calculation of values, all three machining characteristics have been analyzed with the help of surface plots for each process parameters obtained using MINITAB software. Microscopic images of micro cylindrical holes machined with micro-EDM process have been obtained and analyzed from the view of quality perspective by Leica V4 Optical Microscope.

Conclusion

It is possible to micromachine any conductor material, regardless of its hardness, using Micro Electro Discharge Machining (-EDM), a thermo-erosive process. To create a spark, electrodes on both the tool and the workpiece are separated by about 20 meters to create a dielectric field.. A detailed experimental investigation is needed to understand the practicality of micro-EDMing on sophisticated materials in a range of contexts. Currently, researchers are investigating and optimizing microEDM machining features for a wide array of innovative engineered materials. With the micro electro discharge machining in the micro domain at various machining settings in mind, this was done.

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