IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 9, September 2016

Experimental Investigation to assess the Effect of Electrode Bottom Profiles during Machining Monel 400 through EDM Process

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Abstract: This paper presents the experimental investigation to determine the parametric setting for the effective and efficient machining of Monel 400 alloy by EDM process. The metal removal rate and Surface roughness has been measured for each experiment to study the effects of tool profile i.e. Flat, Convex, and Concave shape, peak current, pulse on time and pulse off time on performance during machining. The experiments have been conducted Electrical Discharge Machine model S-35; SPARKONIX is available at M/s 3M Tools, Industrial Area Phase 9, Mohali. The machining results were obtained by variation of Pulse ON Time ranging from 4 to 6 µs, Pulse OFF Time ranging from 3 to 7 µs, Input Peak Current ranging from 10 to 20 Amp, by changing the tool profile i.e. Flat, Concave and Convex. The optimum combination parameters for machining of Monel 400 alloy using EDM for higher MRR are Concave shape of tool, 20amp current, 4µs of Pulse on time, 3µs of Pulse off time. The optimum combination parameters for machining of Monel 400 alloy using EDM for lower surface roughness are Concave shape of tool, 10amp current, 4µs of Pulse on time, 3µs of Pulse off time.

Keywords: EDM, Tool Profile, Monel 400, MRR, surface structure.

1. INTRODUCTION

Monel-400 is one of the most important nickel based alloys that contains about 60-70 percent nickel, 20-29 percent copper and small amounts of iron, manganese, silicon and carbon. Monel-400 is characterized by its good corrosion resistance, good weldability and high strength. Therefore, it has been used extensively in many applications such as chemical processing equipment, gasoline and fresh water tanks, crude petroleum stills, valves and pumps, propeller shafts, marine fixtures and fasteners, electrical and electronic components, de-aerating heaters, process vessels and piping, boiler feed water heaters and other heat exchangers, and etc. It also has higher maximum working temperatures than nickel (up to 540 °C, and its melting point is 1300–1350 °C), which makes it the preferred metal for boiler feed water heaters and other heat exchangers.

Lee et.al (2004) found that the crack formation on the machined work piece could be attributed to the presence of the residual stresses induced during the machining processes. Studies were conducted to investigate the relationship between machining conditions and surface cracking with an objective of establishing machining conditions which prevent the occurrence of such cracks.
Patel et.al (2009) reported that the process parameters like discharge current and pulse-on time have considerable effect on the surface roughness and surface integrity of the machined surface while machining ceramic-composites and play dominant role in causing surface and sub-surface damages. **Khan et.al (2009)** conducts the experiments by varying the electrode profile. They show that electrode profile has a definite effect on the machining performance of any work material. MRR was the maximum for the electrodes having bottom profile round shaped, followed by the square, triangular and the diamond shaped electrodes. **Zhang et.al (2011)** reveals that the nature and characteristics of the recast layer formed at the machined surface of the work piece has strong relationship with the type of dielectric used during EDM. Formation of micro-cracks and micro voids within the recast layer, formation of oxides and carbides in the recast layer and the roughness of the machined surface are attributed to the type of dielectric used in EDM. **Manohar et.al (2014)** concluded that the adverse effects caused due to the erosion of flat profile electrodes on the machined surfaces could be overcome by employing convex profile electrodes. Concave profile electrodes almost simulate the condition of eroded flat-profile electrode. Convex profile electrodes produce machined surfaces of better quality in terms of higher surface finish, thinner recast-layer and closer geometry, in addition to higher MRR compared to flat profile or concave profile electrodes.

Monel 400 is classified as difficult-to-machine materials. The conventional processes of machining keeping very low feed to ensure that during machining there are the least structural changes generally do machining of Monel 400. The problems of machining characteristics for Monel 400 with conventional machining processes are summarized below (a) The heat generated during machining of Monel 400 cannot dissipate quickly due to poor thermal conductivity; so that most of the heat is concentrated on the cutting edge and tool face. (b) The contact length between the chip and the tool is extremely short. This implies that the high cutting temperature and the high stress are simultaneously concentrated. (c) Serrated chips are generated during machining, which create fluctuations in the cutting force.

Therefore, there is a crucial need for reliable and cost-effective machining processes for Monel 400. Keeping in view the difficulties associated with conventional machining of Monel 400, this work is an attempt toward machining of the same with EDM.

2. EXPERIMENTAL WORK

Electrical discharge machining is to be used for the experimental investigation. Monel 400 will to be used as work piece materials. Following are the various parameters of EDM, which are the considered for analyzing the machining of performance criteria e.g. material removal rate, and surface structure. Experiments will be conduct based on Taguchi's method with four factors at three levels each. The metal removal rate and Surface roughness has been measured for each experiment to study the effects of tool profile i.e. Flat, Convex, and Concave shape, peak current, pulse on time and pulse off time on performance during machining. The machining results were obtained by variation of Pulse ON Time ranging from 4 to 6 µs, Pulse OFF Time ranging from 3 to 7 µs, Input Peak Current ranging from 10 to 20 Amp, by changing the tool profile i.e. Flat, Concave and Convex.
The factors will be study and their levels chosen are detailed in the Table 1. Table 2 shows the format for L_9 (3^3) orthogonal array i.e. matrix which will be used for conducting experiments.

Table 1: EDM Parameters and Their Levels

S. No	Input Parameters	Units	Levels		
			1	2	3
1	Tool Profile		Flat	Concave	Convex
2	Peak Current	Amp	10	15	20
3	Pulse On-Time	µs	4	6	8
4	Pulse Off-Time	µs	3	5	7

Table 2: L_9 (3^3) Orthogonal Array

Experiment No.	Column			
	Tool Profile	**Peak Current**	**Pulse On Time**	**Pulse Off Time**
1.	1	1	1	1
2.	1	2	2	2
3.	1	3	3	3
4.	2	1	2	3
5.	2	2	3	1
6.	2	3	1	2
7.	3	1	3	2
8.	3	2	1	3
9.	3	3	2	1

MRR of each sample was calculated from weight difference of work piece before and after the performance trial:

MRR is calculated by
= Diff. of weight of workpiece before and after machining /Time of machining

Where: W_1= Initial weight of work piece material (gms)
W_2= Final weight of work piece material (gms)
T = Time period of trails in min

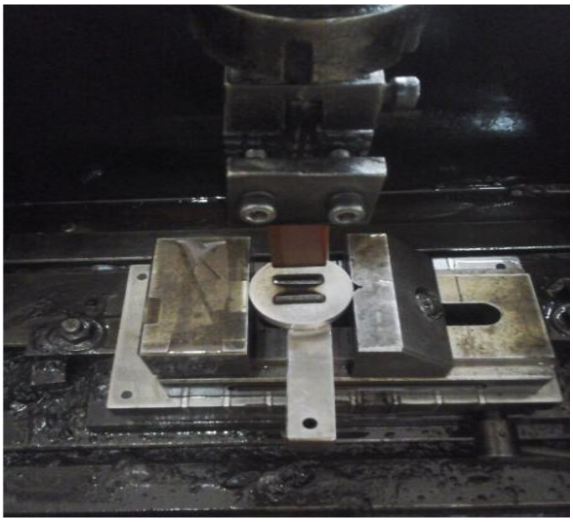

Fig 1: Machining of concave profile on Monel 400 by EDM

Fig 2: Flat, Concave and convex profile on Monel 400 by EDM

3. RESULTS AND DISCUSSION

The effects of process parameters i.e. tool profile i.e. flat; convex, and concave shape, peak current, pulse on time and pulse off time on material removal rate, and surface roughness on EDM has been analyzed for exploring the research finding for the better combination of parameters and control over machining of Monel 400.

Table 3: Experimental result for MRR, and SR

S. No	Tool Profile	Current (Amp)	Ton (µs)	Toff (µs)	MRR (mg/ min)	SR (Ra)
1	1	1	1	1	2.212	1.260
2	1	2	2	2	2.561	1.829
3	1	3	3	3	3.245	2.425
4	2	1	2	3	11.124	1.246
5	2	2	3	1	12.979	1.525
6	2	3	1	2	16.322	1.861
7	3	1	3	2	7.963	1.465
8	3	2	1	3	8.703	1.673
9	3	3	2	1	11.733	1.836

Figure 3 (a) shows the effect of variation of Tool Profile on Mean of SN Ratios of MRR. Graph plotted by utilizing the MRR results obtained by variation of Tool Profile i.e. flat; convex, and concave shape, variation of Peak Current 10 to 20, variation of Pulse On-time 4 to 8µs and Pulse Off-time 3 to 7 µs. It is clear that there is increase in MRR with the change of Tool Profile from level1 to level2 i.e. flat to concave profile and then decreases from level2 to level3 i.e. concave to convex profile.

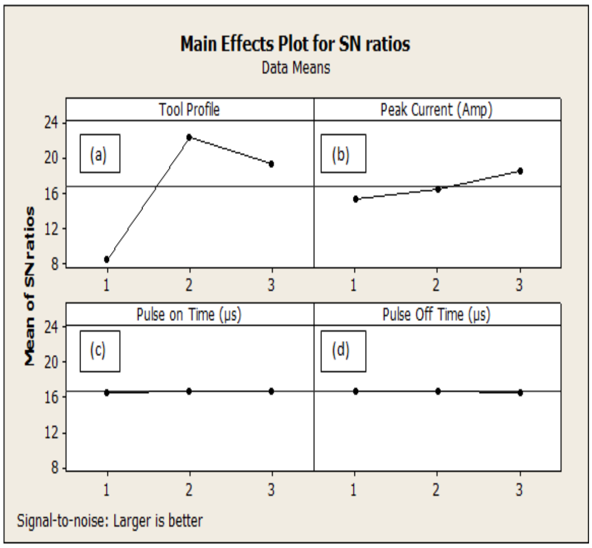

Fig 3: Mean of SN ratio of graph for MRR

Figure 3 (b) shows the effect of variation of Peak Current on Mean of SN Ratios of MRR. Graph plotted by utilizing the MRR results obtained by variation of Tool Profile i.e. flat; convex, and concave shape, variation of Peak Current 10 to 20, variation of Pulse On-time 4 to 8µs and Pulse Off-time 3 to 7 µs. It is clear that there is increase in MRR with the increase in Peak Current from level1 to level2 i.e. 10 to 15 and then increases further from level2 to level3 i.e. 15 to 20 with decrease in Peak Current.

Figure 3 (c) shows the effect of variation of Pulse On-time on Mean of SN Ratios of MRR. Graph plotted by utilizing the MRR results obtained by variation of Tool Profile i.e. flat; convex, and concave shape, variation of Peak Current 10 to 20, variation of Pulse On-time 4 to 8µs and Pulse Off-time 3 to 7 µs. It is clear that there is small increase in MRR with the increase in Pulse On-time from level1 to level2 i.e. 4 to 6 µs and than remains constant from level2 to level3 i.e. 6 to 8 µs.

Figure 3 (d) shows the effect of variation of Pulse Off-time on Mean of SN Ratios of MRR. Graph plotted by utilizing the MRR results obtained by variation of Tool Profile i.e. flat; convex, and concave shape, variation of Peak Current 10 to 20, variation of Pulse On-time 4 to 8µs and Pulse Off-time 3 to 7 µs. It is clear that MRR remains constant with the increase in Pulse Off-time from level1 to level2 i.e. 3 to 5µs and than decreases minutely at the end from level2 to level3 i.e. 5 to 7µs.

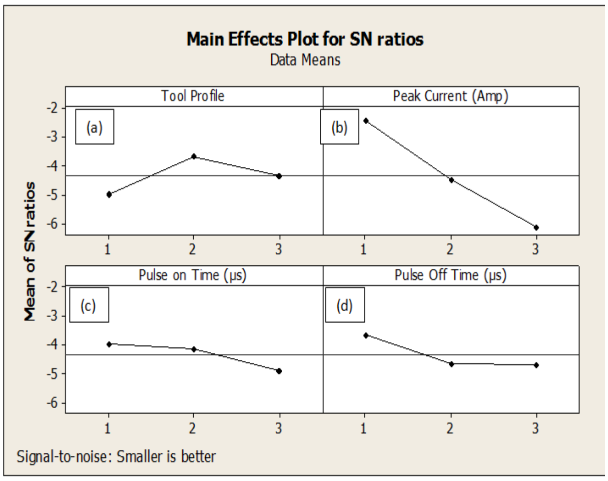

Fig 4: Mean of SN ratio of graph for Surface Roughness (Ra)

Figure 4 (a) shows the effect of variation of Tool Profile on Mean of SN Ratios of Surface Roughness (Ra). Graph plotted by utilizing the Surface Roughness (Ra) results obtained by variation of Tool Profile i.e. flat; convex, and concave shape, variation of Peak Current 10 to 20, variation of Pulse On-time 4 to 8µs and Pulse Off-time 3 to 7 µs. It is clear that there is increase in Surface Roughness (Ra) with the change of Tool Profile from level 1 to level 2 i.e. flat to concave profile and then decreases from level 2 to level 3 i.e. concave to convex profile.

Figure 4 (b) shows the effect of variation of Peak Current on Mean of SN Ratios of Surface Roughness (Ra). Graph plotted by utilizing the Surface Roughness (Ra) results obtained by variation of Tool Profile i.e. flat; convex, and concave shape, variation of Peak Current 10 to 20, variation of Pulse On-time 4 to 8µs and Pulse Off-time 3 to 7 µs. It is clear that there is decrease in Surface Roughness (Ra) with the increase in Peak Current from level 1 to level 2 i.e. 10 to 15 and then decreases further from level 2 to level 3 i.e. 15 to 20 with decrease in Peak Current.

Figure 4 (c) shows the effect of variation of Pulse On-time on Mean of SN Ratios of Surface Roughness (Ra). Graph plotted by utilizing the Surface Roughness (Ra) results

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Figure 4 (d) shows the effect of variation of Pulse Off-time on Mean of SN Ratios of Surface Roughness (Ra). Graph plotted by utilizing the Surface Roughness (Ra) results obtained by variation of Tool Profile i.e. flat; convex, and concave shape, variation of Peak Current 10 to 20, variation of Pulse On-time 4 to 8µs and Pulse Off-time 3 to 7 µs. It is clear that Surface Roughness (Ra) decreases with the increase in Pulse Off-time from level 1 to level 2 i.e. 3 to 5µs and than decreases minutely from level 2 to level 3 i.e. 5 to 7µs.

4. CONCLUSIONS

1. It is noted that the maximum mean of material removal rate (MRR) is 16.322mg/min which is at 20amp current, 4µs of Pulse on time, 5µs of Pulse off time, for concave shape of tool.
2. The optimum combination parameters for machining of Monel 400 alloy using EDM for higher MRR are Concave shape of tool, 20amp current, 4µs of Pulse on time, 3µs of Pulse off time.
3. It is noted that the minimum mean of Surface roughness (SR) is 1.246Ra which is at 10amp current, 6µs of Pulse on time, 7µs of Pulse off time, for concave shape of tool.
4. The optimum combination parameters for machining of Monel 400 alloy using EDM for lower surface roughness are Concave shape of tool, 10amp current, 4µs of Pulse on time, 3µs of Pulse off time.

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