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STUDY OF SURFACE INTEGRITY OF A SURFACE MACHINED BY ELECTRO DISCHARGE MACHINING

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ABSTRACT

During machining of metals by electrical discharged machining (EDM) process a large amount of heat is generated by which the surface characteristics of the metals are affected. But this phenomenon is unavoidable during the machining of metals by EDM process and some technical problems remain unsolved in the area of surface integrity of the machined workpiece. This paper describes effect of process parameters namely Current, Duty Factor and Aspect Ratio on the surface generated by electro discharge machining. Copper electrodes are used to create blind holes in SS 304 work piece material. The detailed analysis of the SEM micrographs is carried out to understand the effect of process parameters on surface integrity. It is found that current is the most significant parameter that affects the surface integrity. Effect of all the three parameters on generated surface profile is critically discussed.

Keywords: *Advanced Machining Process, EDM Process, Surface Integrity, Aspect Ratio*

1. Introduction

EDM is a thermal process that uses spark discharges to erode electrically conductive materials. A shaped electrode defines the area in which spark erosion will occur, thus determining the shape of the resulting cavity or hole in the work piece. The electrically conductive work piece is positioned in the EDM machine and connected to one pole of a pulsed power supply. An electrically conductive electrode, shaped to match the dimensions of the desired cavity or hole, is connected to the remaining pole of the power supply. The electrode and work piece are then positioned in such a way that a small gap is maintained between the two. To provide a controlled amount of electrical resistance in the gap, an insulating (dielectric) fluid is flooded between the electrode and work piece [1]. Response Surface Methodology (RSM) of experimental design is an emerging technique which helps in carrying out the analysis of experiments with least experimental effort [2]. This method has been applied to various experimental analyses in electro discharge machining process in recent times. Parametric optimization has been carried out using RSM in electro discharge machining by many researchers [3,4,5,6].

The intense heat generated and associated with each discharge during machining results in local severe temperature gradients in the machined surface on cessation of the discharge, the surface layers cool quickly and develop a residual tensile stress that is often sufficient to produce cracks in the machined surfaces [7]. The structure of this thermally affected layer is quite different from the parent material and although it is beneficial in terms of enhanced abrasion and erosion resistance, the defects within it such as voids, cracks, induced stress, etc cause an overall deterioration of the component’s mechanical properties [8]. Among the surface defects, cracking is the most significant since it leads to reduction in the material resistance to fatigue and corrosion, especially under tensile loading condition [9]. If the quality of EDMed product is to be improved, it is essential to develop an in-depth understanding of the relationship between the predominant EDM machining parameters and the resulting machined surface integrity.

Table 1 Input Factors and Their Levels

Factor	Low level (-1)	Center level (0)	High level (+1)
A: Current(Amp)	13	17	21
B: Duty Factor	0.5	0.65	0.8
C: Aspect Ratio	1	2	3

The authors have carried out study on optimization of MRR based on process parameters mentioned in Table 1 using Response Surface Method

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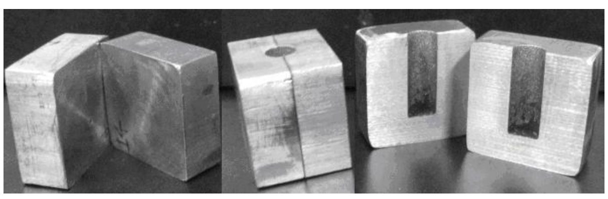
in their prior work [10]. In present study, an attempt has been made to understand the effect of these process parameters on surface integrity.

2. Experimental Details

SS 304 is used as work piece material in the experimentation. Cubes of 25 mm size are cut. These pieces are cut into two equal halves and then ground on surface grinder to create fine surface. These pieces are held tightly and electrode is positioned exactly at centre so as to create half cavity on each part of the piece. This is done to get easy view of the internal surface. Electrolyte Copper is used as electrode material. Electrode having 7mm diameter and 25mm length are turned from round bar of 12mm.



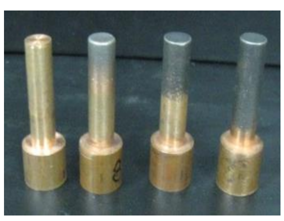


Fig. 1 Workpiece and Electrode Material

Experimentation has been carried out using Face centered Central Composite Design of Response Surface Method where total 20 experimental runs are required [11] which consist of (i) 8 factorial points and 3 center points and (ii) 6 axial/star points and 3 center points are carried out. Table 2 shows complete design matrix with coded variables as well as actual value of these variables.

3. Study of Surface Integrity

Images of the surface generated by EDM process for various combinations of input parameters as mentioned in table 2 have been captured using the Scanning Electron Microscope Hitachi - S3400. Effect of current, duty factor and aspect ratio are discussed in the following sections:

3.1 Effect of current

Current is the most significant parameter that affects the quality characteristics in EDM process. The SEM images shown in Fig. 2 to 4 describe the surface quality obtained for machining at various currents for Duty Factor = 0.65 & Aspect Ratio = 2.

Table 2: Experimental Combinations using RSM [10]

S. No.	Current	Duty Factor	Aspect Ratio
1	13	0.5	1
2	21	0.5	1
3	13	0.8	1
4	21	0.8	1
5	13	0.5	3
6	21	0.5	3
7	13	0.8	3
8	21	0.8	3
9	17	0.65	2
10	17	0.65	2
11	13	0.65	2
12	21	0.65	2
13	17	0.5	2
14	17	0.8	2
15	17	0.65	1
16	17	0.65	3
17	17	0.65	2
18	17	0.65	2
19	17	0.65	2
20	17	0.65	2

It is clear that the bulges and curves at the bottom corner increase with current. For the current value of 13 A, large amount of recast layer is formed (Fig. 2) across the machined surface. For current value of 17A (Fig. 3), the recast material is deposited in form of clusters of many tiny sized bulges instead of depositing as a layer. This may be the reason for higher roughness. Further, small sized cracks are visible on the surface which shows that material is not properly removed from the surface. This may be due to improper flushing. Fig. 4 shows the image of work piece surface obtained for current value of 21A. It is clearly visible that large secondary arcing is taking place. This occurs due to poor flushing. Further, relatively larger bulges are also visible. A typical bulge is visible which leads to an idea that these bulges may be hollow in nature.

3.2 Effect of duty factor

The images shown in Fig. 5 to 7 are for surfaces machined with Duty Factor values of 0.5, 0.65, 0.8 at I= 17 A and Aspect Ratio = 2. In a prior work, authors have carried out ANOVA where it is found that Duty Factor is not a significant factor for MRR [10]. In the same lines, it found that no significant changes are visible on the machined surface with variation in duty factor. But it can be noted that crater size is increasing slightly with increase in duty factor. The size of river lines is also found increasing with the increase in duty factor.

3.3 Effect of aspect ratio

The value of aspect ratio considered is 1, 2 and 3. Generally, it is seen that as aspect ratio increases flushing becomes difficult. This makes material removal difficult. It is found that as aspect ratio increases it becomes more and more difficult to effectively remove the eroded particles from the area. These eroded particles that fall in between the sparks give rise to secondary sparking resulting in more carbon deposition on surface. Further, it can also be noticed that at the bottom the surface is found slightly curved instead of sharp corner.

The reason behind such observation can be the side wear and corner wear of the tool electrode occurring at higher current and higher aspect ratio which in turn results in generation of such curved surface. Further, it is found that recast material is deposited in form of a layer in lower aspect ratio (Fig. 8) while this recast material takes shape of bulges as aspect ratio increases. This would probably result in increasing roughness of the machined surface.

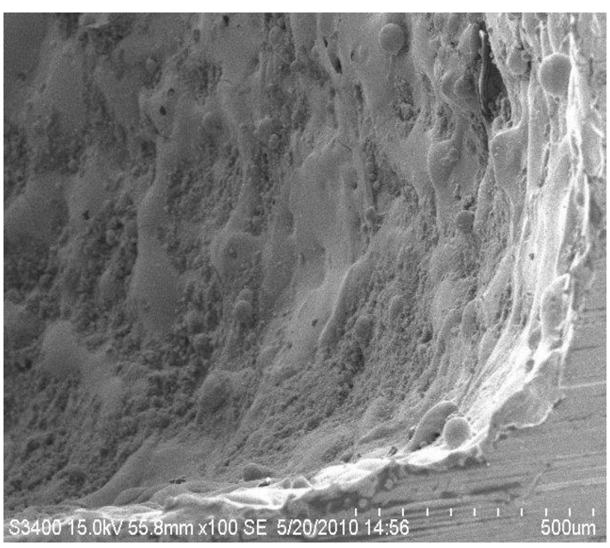


Fig. 2 Image of Bottom Part for I = 13A, DF =0.65, AR = 2

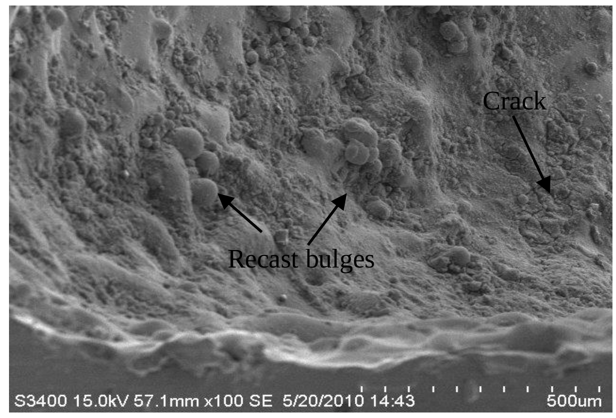


Fig. 3 Image of Bottom Part for I = 17A, DF =0.65, AR = 2

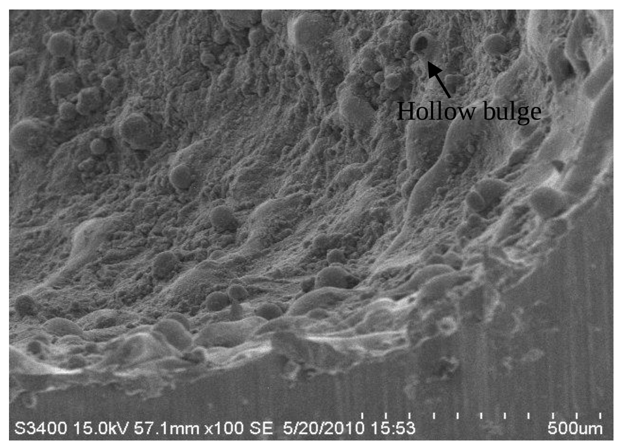


Fig. 4 Image of Bottom Part for I = 21A, DF =0.65, AR = 2

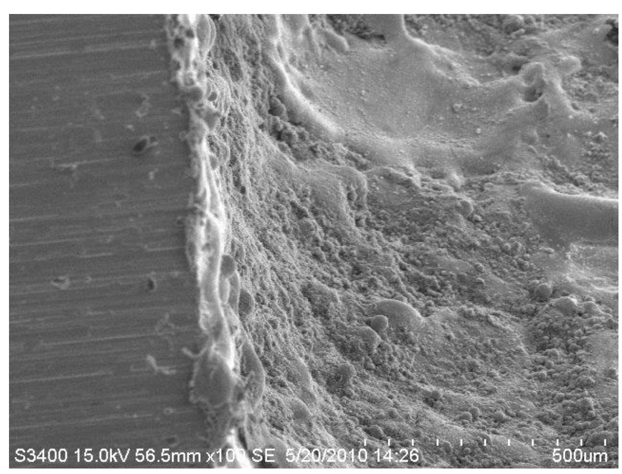


Fig. 5 Image of Bottom Part for DF =0.5, I = 17A, AR = 2

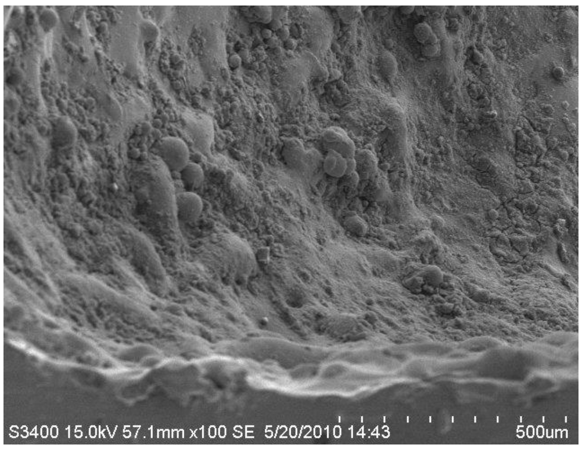


Fig. 6 Image of Bottom Part for DF =0.65, I = 17A, AR = 2

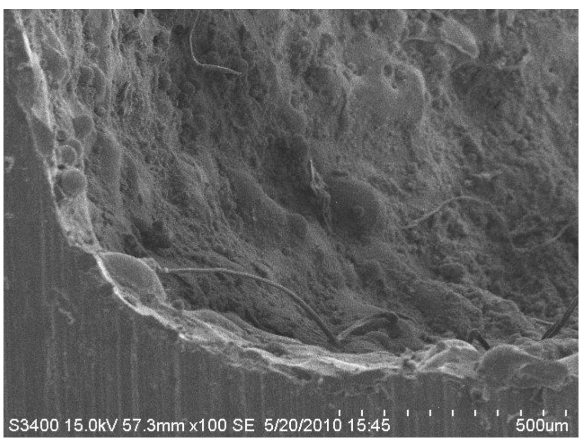


Fig. 7 Image of Bottom Part for DF =0.8, I = 17A, AR = 2

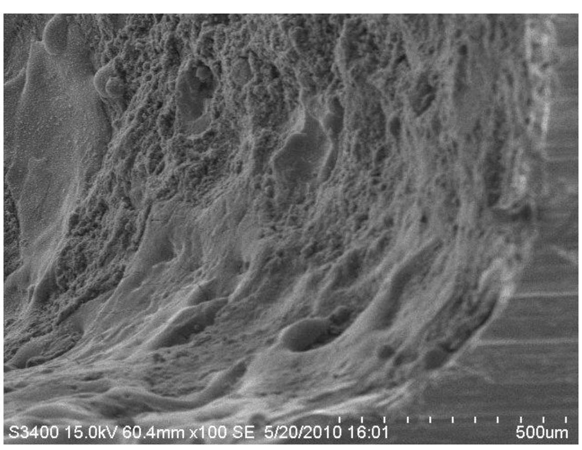


Fig. 8 Image of Bottom Part for AR = 1, I = 17A, DF =0.65

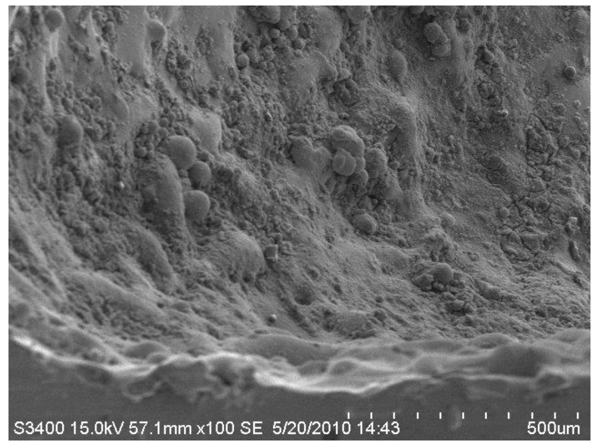


Fig. 9 Image of Bottom Part for AR = 2, I = 17A, DF =0.65

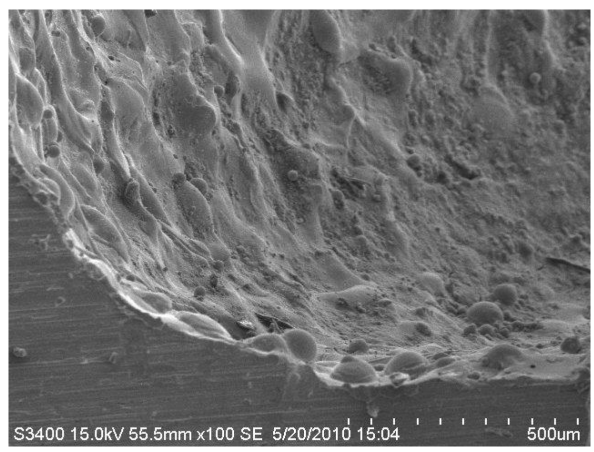


Fig. 10 Image of Bottom Part for AR = 3, I = 17A, DF =0.65

4. Conclusion

Generally, it found that recast layer is formed due to poor flushing especially at higher depths. But here it is seen that recast layers are formed more when aspect ratio is less. Further investigations are required to study the reasons behind such observations.

The analysis of the experimental observations highlights that surface integrity in EDM is greatly influenced by current, duty factor as well as aspect ratio. Current being the most significant factor in MRR also, it has major effect on surface integrity. Large variation is noted with variation in current. Hence, optimization of MRR can not be proper, if surface integrity is not taken care of. As duty factor is influential, it can be understood that Pulse ON time is also an influential process parameter. It is also seen that as depth increases, there is substantial variation in surface characteristics. This may be due to poor flushing at higher depths. But the effect of aspect ratio i.e. increase in depth needs further investigation.

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