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STUDY ON EFFECT OF PLANETARY AND DIAGONAL TOOL ACTUATION STRATEGIES ON DISTORTION OF FEATURES MACHINED BY EDM PROCESS

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ABSTRACT

Electro Discharge Machining (EDM) is such an advanced machining process which has been widely used for the generation of complex features on hard to machine materials despite it results in inferior surface quality and distortion during generation of sharp features. This paper aims in carrying out an experimental study to understand the effect of two different tool motion strategies for the generation of a square cavity, viz. planetary and diagonal using EDM, on surface roughness as well as the distortion of the edges of the cavities that have been machined using these strategies. Effects of various electrical and non-electrical parameters on EDM responses have been studied. Current, pulse ON time, Gap Voltage and Duty factor are considered as the electrical parameters while tool kinematics parameters like tool path offset and scanning speed have been selected as the tool motion parameters. It has been observed that planetary strategy is preferable to diagonal strategy for the generation of non-circular cavities using EDM in terms of achievement of surface finish and relative better edge reproduction capacity.

Keywords: *EDM, Kinematics, Accuracy, Quality, Distortion, Roughness*

1.Introduction

Electro Discharge Machining (EDM) process is a thermo electric based machining process has been widely used in manufacturing industry as it can machine any electrically conductive material irrespective of its hardness. However, despite its wide acceptability, the process has limitations in terms of high machining time, low material removal rate and poor surface finish when compared to other non–conventional processes. Many techniques have been suggested by researchers to improve the efficiency of this process and incorporation of planetary or orbital tool movement is one among such technique.

In orbiting EDM, a relative motion between the tool and the workpiece is imposed in a prescribed path. These continuous movements create a larger gap between the tool and the work piece and promote advanced flushing caused by dynamic fluid pressures there by reducing the possibility of undesirable pulses [1]. It has been reported that orbiting processes could cut down tooling usages, reduce tool wear and improve surface finish [2].

Effect of various orbital strategies on surface finish has been reported by many researchers. Rajurkar and Royo [3] studied the feasibility of using orbital motion of the electrode along with R.F. control and reported improvement in surface integrity of the machined surface and machining rate. El - Taweel and Hewidy [4] studied the effect of helix and spiral mode tool actuation during the generation of circular cavity using EDM and observed that surface roughness decreases with increase in tool eccentricity. Further, they also reported that out of various helical modes given, helix mode provided the least surface roughness. Chen et al. [5] investigated the effect of different electrode route strategies viz., awl, spiral and straight dip and reported that awl type tool motion facilitates in machining of features with relatively better surface finish. However, even though different tool actuation methods have been reported to have a positive effect on feature quality, it is also understood that tool actuation parameters have relatively lower statistical significance on comparison with electrical parameters like current and pulse ON time [6].

Rebelo et al. [7] has also utilized the orbital motion of tool electrode for finishing and polishing of cavities generated on copper beryllium alloys by EDM. Maradia et al. [8] proposed a method in which the electrode orbiting is made stochastic with in the defined form contour and super finished surfaces having R_a < 0.06μm have been generated. Ferreira [9] demonstrated the generation of helical thread cavities in steel dies with surface micro finish for polymer injection for hollow worms having a minimum roughness of 0.09μm using helical EDM technique. Kumar et al. [10] utilized the concept of radial tool actuation in EDM for boring holes in hard to machine materials. It has been reported that even though high wear ratios can be obtained through

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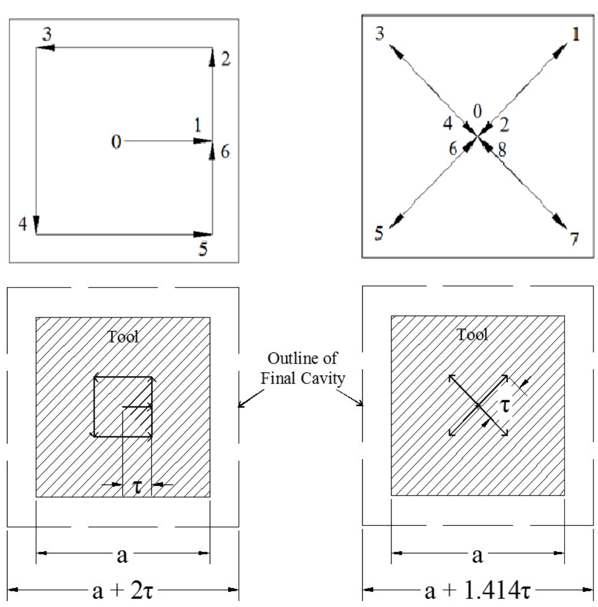
application of radial tool actuation, the surface quality is found to be lower.

During literature review, it has been observed that most of the works done in the area of orbital EDM is focused on the generation of circular cavities. Further, it has also been understood that very few works that discuss the effect of tool actuation as well as machining parameters on surface quality as well as feature accuracy.

In this paper, an attempt has been made to study the effect of tool actuation parameters as well as machining parameters on quality of non-circular features machined using EDM with different tool actuation strategies. cavity.

2. Tool motion strategies for Non-Circular cavity generation

To study the applicability of planetary or orbital movement in non-circular feature generation using EDM, square shaped feature has been opted for experimentation. For the generation of a square cavity, the tool motion strategies possible are planetary and diagonal. The tool paths for both these strategies are pictorially shown in Fig. 1(a & b).



(a) **(b)**

Fig 1. Tool motion strategies: (a) Planetary, (b) Diagonal

In planetary strategy, the tool is scanned along a path parallel to the edges of the final intended cavity as shown in Fig. 1(a). The path will be at a distance equal to the tool offset from the centre axis of the final cavity. In diagonal strategy, the tool is scanned from the centre of the axis towards the corners of the final cavity along the diagonal by a distance of tool offset. This motion is repeated towards all four corners in counter clockwise order as shown in Fig. 1(b). In both strategies, since motion along Z axis is also provided during the tool motion, the final tool path would look like a square shaped helix in the case of planetary strategy and "X" shaped in the case of diagonal strategy. Due to nature of the strategy, it can be understood that for the same tool path offset, planetary strategy will yield a bigger cavity than diagonal strategy.

3. Experimental Plan and Procedure

3.1 Parameter and Response selection

Two tool motion related parameters, viz. tool path offset and scanning speed of the tool and Four electrical parameters viz. gap voltage, pulse ON time, current and duty factor have been considered for experimentation. All parameters excluding current have been considered at three levels. Current has been considered at two levels. The experiments have been designed using one factor at a time methodology. The same experimental plan has been used for both strategies. The values of parameter levels considered are shown in Table 1.

In order to quantify the quality of the surface generated, Centre Line Average surface roughness (R_a) has been used. The measurements have been taken using Mitutoyo's SJ400 surface roughness tester. The roughness has been measured using a diamond tip stylus having a tip radius of 5µm. The measurements have been taken along an evaluation length of 4mm. Eight readings have been taken in the vertical walls of the cavity and the readings are averaged out for further analysis. The distortions along the internal edges of the machined cavities have been studied qualitatively using a vision measurement.

Table 1. Parameter Levels used for experimentation

Parameter	Unit	Level 1	Level 2	Level 3
Tool path offset	(mm)	0.5	1.0	1.5
Scanning speed	(mm/s)	0.05	0.09	0.13
Current	(A)	13	28	-
Gap voltage	(V)	40	70	100
Pulse ON time	(µs)	61	180	295
Duty Factor	-	0.2	0.5	0.7

3.2 Experimental Procedure

The experimentations have been carried out on Joemars AZ50R ZNC EDM with COC Orbit attachment which facilitates the generation of different tool paths. Stainless steel (SS304) has been used as the work piece material. Electrolytic copper square bars having cross sectional dimension of 8mm x 8mm have been used as the tool electrode material. A cavity of 6mm depth has been generated in all cases. On completion of machining, the surface of the work piece has been cleaned using 0.1N Sulphuric acid and rinsed using Acetone to remove the loose debris and acidic and dielectric stains, so that response can be evaluated accurately.

4. Results and Discussions

4.1 Effect of process parameters on surface roughness

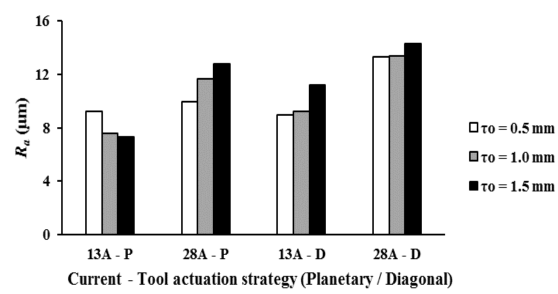
Fig. 2(a) shows that effect of variation of tool path offset on surface roughness of the feature generated. It can be observed that for most of the cases, the roughness is increasing with increase in tool path offset. As the tool path set increases, the pitting type erosion that occurs on the surface of the tool electrode also increases. This may contribute to roughening of the machined cavity walls. But in planetary strategy, when machining has been carried out at 13A, the response is observed to reduce with increase in tool path offset. It is also worth noting that the roughness of the cavity produced using diagonal strategy is very much higher than that produced using planetary strategy. In the case of effect of variation of scanning speed on surface roughness, no specific trend has been observed (Fig. 2(b)). Thus, it can be concluded that there is no significant effect of scanning speed on surface quality. At the same time, it also worth noticing that a higher scanning speed is preferable for a good finish when a higher discharge energy is used. This observation is similar for both planetary as well as diagonal strategies.

At higher discharge energy conditions, the amount of material removed from the work piece will be high. So, correspondingly, the debris formation at the inter electrode gap will be high which will lead to unstable machining conditions and result in secondary arcing. When the scanning speed of the tool electrode is high, the flushing at the inter electrode gap become more intense, resulting in the expulsion of debris from the machining zone and thereby facilitating evenly distributed sparking and improved surface finish.

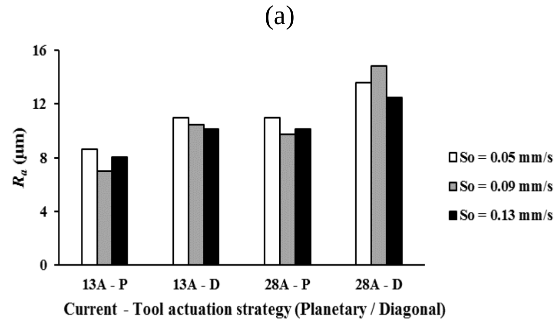
Fig. 3(a) shows the effect of Gap voltage on Surface roughness. As discharge energy in EDM process is a function of gap voltage also, an increase in the same would result in an increase in the amount of material removed by a single spark from the work piece material would increase thereby resulting in the formation of a bigger crater.

From Fig. 3(a) it can be observed that even though there is no significant effect of the gap voltage on surface roughness, the response is highest when the highest gap voltage condition is used for machining. This observation is found to be similar in features generated by both planetary as well as diagonal strategies.

Further, it can also be observed that the surface roughness of the cavity generated using diagonal strategy is very much higher than that generated using planetary strategy, for all current and gap voltage combinations considered. Effect of pulse ON time on surface roughness is graphically shown in figure 3(b).



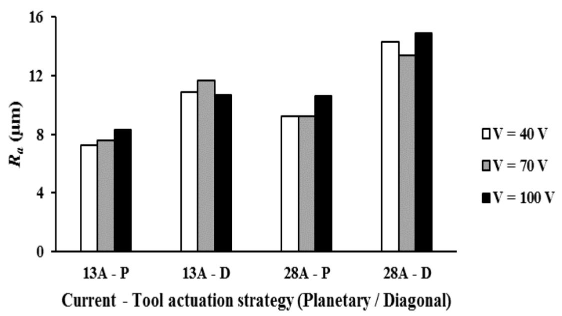
(a)



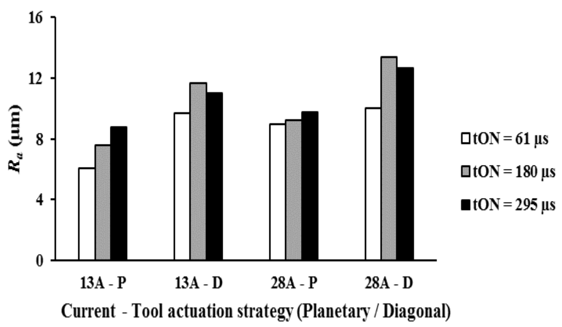
(b)

Fig. 2 Effect of (a) Tool path offset & (b) Scanning speed on Surface Roughness (R_a)

It can be observed that the response increases with increase in pulse ON time for lower current values for both strategies. At the same time, at higher current, the surface toughness is observed to increase initially and then decreases. This observation can be seen for planetary as well as diagonal strategies. The observation might be related to the change in the structure of plasma channel under different pulse ON time conditions. An increase or decrease of pulse ON time will result in a proportional change in the diameter of the plasma channel. This may result in change of material removal intensity, hence leading into lower material loss.



(a)



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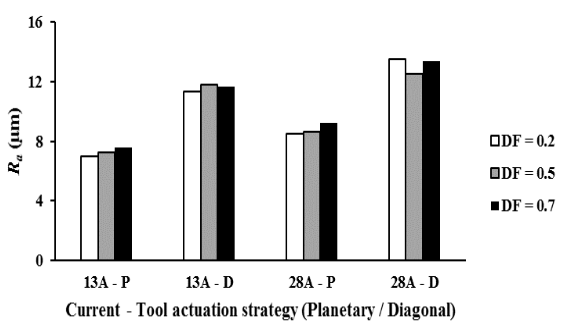

(c)

Fig. 3 Effect of (a) Gap voltage, (b) Pulse ON time and (c) Duty factor on Surface Roughness (R_a)

Graphical representation of effect of duty factor on surface roughness is shown in Fig. 3(c). It can be clearly observed that the variation of duty factor is not that significant on surface roughness. The response tends to increase slightly with increase duty factor in most of the cases considered. When duty factor is varied keeping pulse ON time constant, the time for flushing will be lower, this will lead to debris accumulation at the inter electrode gap and may result in secondary arcing. Such machining conditions may result in deterioration of surface quality.

4.2 Effect of process parameters on inside edge reproduction

Fig. 4 & 5 show the isometric view of the cavities generated under different conditions of process parameters. It can be inferred from both these figures that irrespective of all parameter variations, a high current level result in intense rounding of the internal edges of the cavities generated under both planetary as well as diagonal strategies.

From Fig. 4, it can be seen that with increase in tool path offset, the sharpness of the internal edges of the cavities tend to reduce. This can be seen clearly in the case of features machined with high current. Under high tool path offset conditions, the tool electrode is subjected to more sparking conditions, making it more prone to loss of material from the edges. This will ultimately result in production of features with dull edges. On comparing the features machined with planetary and diagonal strategies, it is worth noting that the sharpness of the edges produced using diagonal strategies under different tool path offset conditions are relatively low.

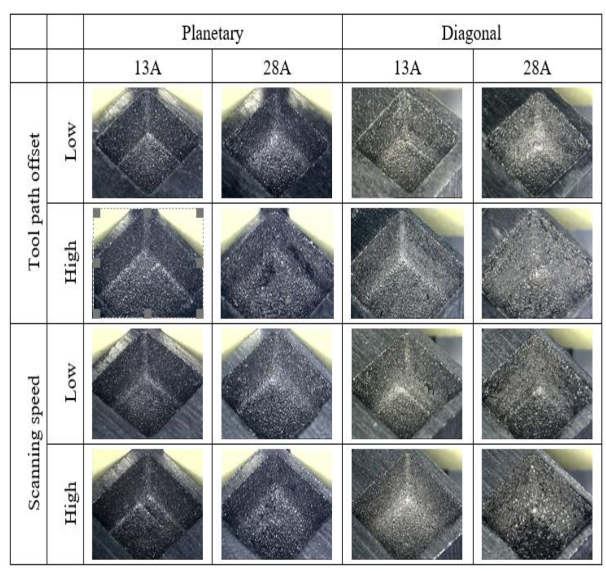

Fig. 4 Effect of tool actuation parameters on cavity distortion

Observations for variation of scanning speed of the tool electrode is also similar to that observed under variation of tool path offset. As high scanning speed of the tool electrode results in high machining time as the tool electrode may not get ample time to remove material during its traverse. This may result in to increases exposure of the tool electrode to the machining conditions, leading to high wear along the edges of the tool electrode. This might have resulted in to reduction in internal edge sharpness of features under such conditions using both strategies.

Further, an increase in scanning speed of the tool electrode, results in more turbulence in the machining zone. This may result in collision of debris particle with the workpiece as well as tool electrode surfaces, leading to occurrence of secondary discharges. Such conditions may result in unwanted material loss from the electrode surfaces, leading to generation of relatively dull features.

Fig. 5, which shows the effect of variation of electrical parameters on the distortion of internal edges and corners machined under planetary and diagonal strategies. It can be seen that a high level of gap voltage is preferable for generation of features with relatively better internal edges and corners. It can also be inferred from the figures that a higher pulse ON time facilitates in generation of sharp internal features. Further, in the case of variation of duty factor, it can be understood that a low duty factor yields effective generation of fine features in EDM with tool actuation.

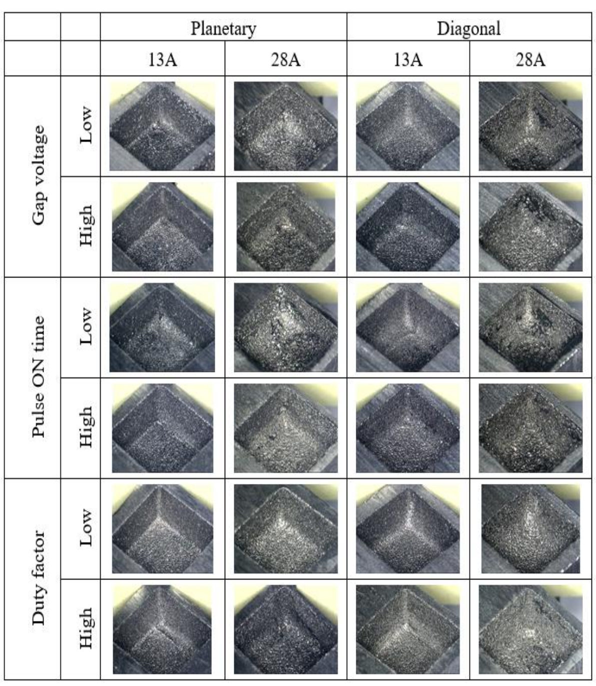

Fig. 5 Effect of Electrical parameters on cavity distortion

In the case of variation of gap voltage which is a function of inter electrode gap, a lower gap voltage will result in ineffective flushing at the machining zone due to relatively smaller gap. This may result in accumulation of debris in the machining zone, leading to the possibilities of occurrence of arcing and unanticipated material loss from the tool electrode surface.

Further, the relatively better internal edge reproduction under high pulse ON time conditions may be attributed to the better shape retention capacity of the electrode under such conditions. The high heat accumulation, which tends to occur under such conditions, make the dielectric fluid to dissociate and form a thick carbon layer on the tool electrode surface.

This will act as a protective layer for the electrode, thereby preventing material loss from the same. The better edge reproduction under low duty factor can also be justified on similar grounds. A low duty factor will facilitate effective flushing at the inter electrode gap, thereby reducing chances of any thermal distortion or arcing.

5. Conclusion

From experimentations, it is observed that tool motion strategies have a significant effect on Surface quality of the job machined using electro discharge machining process. Two strategies, viz. planetary and diagonal, have been used for the generation of a square cavity. It has been understood from the results that a higher current is not appropriate for machining sharp cornered features using EDM with tool actuation technique. Further, it has also been understood from the observations that planetary strategy is preferable to diagonal strategy for the generation of non-circular cavities with good surface quality as well as edge quality.

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