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Effects of Roughing Parameters in WEDM on Groove Width and Gap

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ABSTRACT

Wire electrical discharge machining (wire-EDM) is very important in the manufacturing, due to its growing industrial and research applications. Inaccurate geometry in corner and especially sharp-curved corner cutting is one of the major problems in this process. Creation of exact geometry and high dimensional accuracy has been subject of many research works. In the present research, actual cutting slots on straight and curved paths are studied in roughing operation. Experiments are designed using the Full Factorial Method by considering frequency of discharges, wire tension and radius of curvature as variables. By employing statistical techniques in analysis, influences of these parameters on width of the cut of slot, on both straight and curved paths, are evaluated. Practical results for straight side gap and curved corner average gap are achieved, for each set of parameters. Because of concavity of wall on inner arc and convexity of wall on outer arc, measuring errors appear in the measurement of slot width at the curved corner. In addition, depletion of material and accumulation of material are observed at entrance and exit of the curved path, respectively. By calculating variable side gap on a curved corner, practical wire diversion and machining error are obtained.

KEYWORDS:

WEDM, Machining Error, Corner Radius, Groove Width, Wire Diversion

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1- Introduction

Wire EDM is a complicated machining process with a random nature. The performance of WEDM, especially in achieving dimensional and geometrical accuracy, highly depends on machining parameters. To investigate the accuracy, the cutting path should be analyzed. In spite of the high accuracy of the WEDM control systems, it is very difficult to generate accurate arcs when the arc diameter is small. There is always a high risk of wire vibrations or deflections and consequently, deviations from the pre-defined cutting path. The reason goes back to the inevitable unbalanced process forces on the flexible wire such as electrostatic, electromagnetic, electrodynamic and plasma explosion forces; and dielectric pressure, especially on small arcs. The maximum difference between the programmed and deflected-wire paths is defined as wire-lag.

Among initial investigations about the error of machining of the corners, study of Dekeyser and Snoeys [1] is the most valuable. They found that the errors in corners were due to wire lag, wire vibrations and possibly increased discharge at corners. Some researchers attempt to modify the cutting parameters, such as discharge power; thus the wire deflection could be significantly reduced and geometrical and dimensional accuracy and straightness of the work-piece wall could be increased [2]. The main drawback here is the increase of machining time. In order to increase the accuracy, Obara et al. [3] propose a combination of power control with path correction in corners at the roughing stage. In this approach, the power control is implemented to reduce the wire bending, while the path regeneration is to compensate the errors. They claim that this method requires the least time for the corner machining. In another work, Obara et al. [4] investigate several controlling methods for reducing the machining time in the corners and finally suggest a combination of increase in the off-time pulse duration, control of servo voltage, and path compensation techniques.

Cutting slot width may help to predict and analyze the machining error in WEDM. As a necessary but not enough criterion, constant slot width along the cutting path can result in uniform residual material and less machining error. Various parameters such as open-circuit voltage, discharge frequency, wire tension, sparks energy, dielectric flushing-pressure, wire-feed speed, work-piece thickness and material, wire diameter and material and dielectric material and contamination have been investigated for this purpose. Tosun et al. [5] investigate the influence of open-circuit voltage, discharge frequency, wire-feed speed and dielectric flushing on cutting slot width. They show that among these parameters, the open-circuit voltage is the most effective. Yang et al. [6] experimental studies indicate that increasing the wire tension and discharge frequency give more uniform slot cutting.

The present paper investigates the effects of the discharge frequency and wire tension on the straight-cutting accuracy, and discharge frequency, wire tension and corner radius on small-radius curved-cutting accuracy for a single stage roughing operation. Cutting groove width and lateral-gap size between the wire and work-¬piece are analyzed for these two paths. This paper discusses a novel subject about variable spark gap for various points of the wire perimeter. By calculating the variable gap size around the wire in a curved path, the wire diversion and machining error are obtained. These results extract that in curved corner cutting, on the top of the variable gap error, there is a wire deviation error to the path inner arc.

2- Methodology

The experiments are performed on 1.2510 (AISI: O1) tool steel with 54×59×9 mm^3 dimensions. Charmilles Robofil 200 wire cut machine and SW25X wire (with 0.25mm diameter) recommended by Charmilles are used for cutting. The pieces are accurately adjusted on the machine table with the least distance of lower and upper machine jaws from the work-piece bottom and top surfaces, respectively. Environmental conditions are kept constant and steady. After cutting, the slot width is measured by an ARCS Video Measure System (VMS). To ensure repeatability, tests are repeated three times. Cutting slot width and lateral-gap size between wire and work-piece depend on various parameters. Based on the vast experience of the present authors and conclusions on the literature, among the influencing parameters, the discharge frequency (controlled by pulse off-time), wire tension and cutting path curvature can have the highest effects on the slot width and lateral-gap size. Therefore, they have been considered for the evaluations. Table1 presents different levels chosen for the variables.

In this study, Design Of Experiments (DOE) methodology is applied for preparing required data. Based on the full factorial method, the DOE prepares

Table 1. Levels of variable parameters used in the experiments (Bold values are recommended by the manufacturer).

Parameters	Levels	Parameters values		
13	18	13	18	-
0.43	2.00	10	12.5	15
10	12.5	150	300	450

the plenary data of a process and Minitab®15.1.0.0 software were employed for data analysis and graphics. Experimental results and statistical analysis show the effects of discharge frequency and wire tension on the straight groove width as well as the effect of the discharge frequency, wire tension and corner radius on the curved groove width. Higher frequency is associated with higher power and as a result of higher material removal rate and a wider cutting slot. The wire tension adjustment is important for the straightness of the slot. Higher wire tension causes less wire deflection and vibration and consequently a narrower cutting slot. The path curvature is decreased by increasing the corner radius.

3- Results and Discussion

The experimental results reveal the influences of three cutting parameters i.e. the discharge frequency, the wire tension and the arc radius on the accuracy of the straight path and small radius arc cutting in the WEDM roughing. Relationships were derived for actual cutting slot size and lateral spark gap size on the straight and curved paths. Three lateral spark gap sizes on the curved path (apparent spark gap, inner spark gap, and outer spark gap) were calculated. Then, wire path diversion and total cutting error at inner arc were obtained. It can be concluded that: Higher discharge frequency and less wire tension cause larger lateral spark gap and consequently wider cutting slot in both the straight and curved paths as is shown in Figure 1 and Figure 2.

The spark gap is variable around the wire leading-perimeter when it travels on a curved path. Wider gap at the inner arc and closer gap at outer arc are produced. Any change in variables which reduce the difference between the inner and outer arc discharge gaps improve the corner cutting accuracy. Obviously this is achieved by decreasing the discharge frequency and increasing the wire tension and arc radius. The wire bending due to non-symmetric lateral discharge

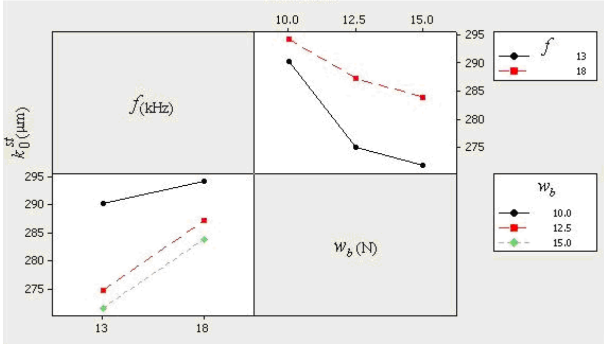

Figure 1. Effects of the discharge frequency and wire tension on the straight slot width (k_0^{st})

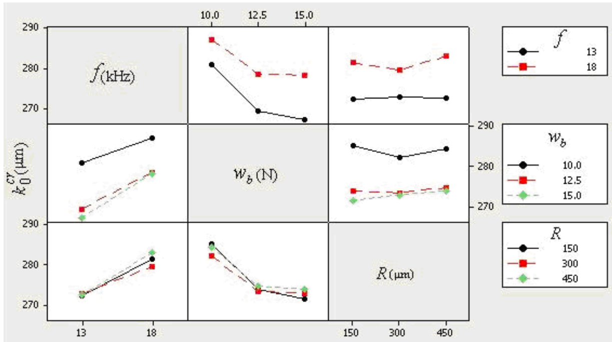

Figure 2. Effects of the discharge frequency, wire tension and the curvature radius on curved slot width (k_0^{cr})

forces of the corner cutting produces concave wall at the inner arc and convex wall at outer arc. These cause an error in the slot width measurement by the optical shadowgraph methods. Depletion of material at entrance and accumulation of material at the exit of the inner arc are observed which are result of sudden changes in type of traveling movement as well as laterally unbalanced forces.

4- Conclusions

Investigating the actual cutting slot on the straight and curved paths in the roughing shows the higher discharge frequency and less wire tension cause large lateral spark gap and consequently wide cutting slot. The corner radius does not have any significant effect on the cutting slot. Statistical analysis clarifies the effects of above parameters on the straight and curved cutting slots and also their associated experimental models. The concavity of the inner and convexity of the outer walls of the cutting slot cause an error in the width measuring. The spark gap is variable for various points of the wire perimeter because these points have different linear feeds on the arc path. In curved corner cutting, on the top of the variable gap error, there is a wire deviation error to the path inner arc. Practical wire deviation and total convex arc machining error compared to the straight path are calculated for each experimental setting using the experimental results. In addition, accumulated materials are observed at end of the arc path. This study concludes that the cutting slot widths in both straight and curved path are almost the same. Therefore, machining error on the curved corners are not due to the slot width variations.

5- References

[1] Dekeyser, W.L., Snoeys, R. , "Geometrical accuracy of wire-EDM. 9th Int. Symp. on Electro Machining", (ISEM-9), Japan, pp. 226– 232, 1989.

[2] Hsue, W.J., Liao, Y.S., Lu S.S. , "A study of corner control strategy of wire-EDM based on quantitative MRR analysis", Int. J Elect Machining, Vol. 4, 33-39, 1999.

[3] Obara, H., Kawai, T., Ohsumi, T., Hatano, M. , "Combined power and path control method to improve corner accuracy of rough cuts by wire EDM (1st report) ", Int J Elect Machining, Vol. 8, 27– 32, 2003.

[4] Obara, H., Kawai, T., Ohsumi, T., Hatano, M. , "Combined power and path control method to improve corner accuracy of rough cuts by wire EDM (2nd report) ", Int J Elect Machining, Vol. 8, 33– 38, 2003.

[5] Tosun, N., Cogun, C., Tosun, G. , "A study on kerf and material removal rate in wire electrical discharge machining based on Taguchi method", Journal of Materials Processing Technology, Vol. 152: pp. 316–322, 2004.

[6] Yang, C.T., Song, S.L., Yan B.H., Huang, F,Y. , "Improving machining performance of wire electrochemical discharge machining by adding SiC abrasive to electrolyte", International Journal of Machine Tools and Manufacture, Vol. 46: pp. 2044– 2050, 2006.