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Effects of Low Frequency Vibration Integrated with Workpiece on Quality Indicators in Wire Electrical Discharge Machining

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***Abstract*— *The improvement of productivity and surface quality in WEDM process is the interesting research area in the present situation. In the present study, an attempt has been made to introduce low-frequency vibration assigned to the workpiece for improving machining surface quality and productivity. SKD11 die steel was used as workpiece with brass wire as the electrode. The moving direction of the wire perpendicular to the impact direction of vibrations has been investigated. It has been found that the machining productivity has been improved. However the machining surface texture is not significantly affected with the proposed method*.

I. INTRODUCTION

Wire electrical discharge machining (WEDM) process is a very popular non-traditional machining method for machining surfaces with complex profiles of difficult materials. This could lead to reduce the complexity made with traditional machining [1]. Hence, an endeavor is essential to improve machining efficiency in WEDM process. The integrated vibration in WEDM is a new engineering solution that can significantly improve machining efficiency [2]. It is very important to analyze the effects of vibration on this machining process for better performance measures [3-5]. During the number of discharge points have been increased with the addition of ultrasonic vibrations. This created 30% higher cutting speed in the process [6]. A device has been designed to generate low frequency vibrations on the electrode wire for WEDM process [7]. The results showed that the cutting speed was 1.6 times higher than conventional WEDM. As the vibration frequency has been increased, the cutting time could be considerably reduced [8]. The important quality parameters such as cutting speed, and surface roughness were greatly improved. When the thickness of the workpiece exceeds 50 mm, the effect of the ultrasonic vibrations becomes ambiguous owing to lower discharge stability. The low-frequency vibration can be provided to workpiece with the help of a vibrator [9]. It could help to remove debris from the cutting zone in faster manner to optimize cutting speed and surface roughness [10]. The most important parameters influencing MRR are pulse dwell time, pulse generation time and vibration frequency [11]. A solution that integrates low-frequency vibrations with workpieces can be done more easily with lower cost [12].

From the literature survey, it has been found that only very few importance have been provided to low-frequency vibrations integrated with the workpiece in WEDM process to improve the process efficiency. In the present study, low frequency vibrations has been assigned to SKD11 workpiece in WEDM process. The motion of the wire has been controlled perpendicular to the motion of the vibration.

II. EXPERIMENTAL METHODOLOGY

SKD11 die steel is commonly used to manufacture small and medium-sized dies and cast dies. The workpiece specimens have been prepared with the dimensions of 15 mm X 200 mm X 10 mm as shown in Figure 1. The Brass wire electrode was used very commonly in WEDM process due to its high strength and good rigidity with the diameter of the electrode wire of 0.25 mm. The Deionized water was used as the dielectric medium. The experimental investigations were conducted in WEDM- CNC machine type (CW420HS). The workpiece was attached to the vibration protection fixture of the vibration unit to facilitate stable and accurate transmission of vibrations to the workpiece as shown in Figure 2. The vibration unit (Modal: Exciter 4824, Brüel & Kjær, Denmark) was used to investigate the vibrations. The amplitude of the vibrations for a chosen frequency value has been 0.75 µm. The selection of process parameters are shown in Table 1.

Figure 1. Workpiece is used

In order to evaluate the effectiveness of the optimal problem in vibration assisted WEDM process, the quality measures such as material removal rate (MRR), surface roughness (R_a) and radial overcut (ROC) were used. The weight of the workpiece was measured before and after machining using AJ 203 electronic balance (Shinko Denshi Co. LTD - Japan). The surface roughness was measured by a surface tester (Model: SV–2100, Mitutoyo, Japan) with the

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cutoff length 0.8mm. The microstructure-layer surface surveyed by photographing the cross-section of the machined surface layer using optical microscopy (Model: Axiovert-40MAT, Carl Zeiss, Germany).

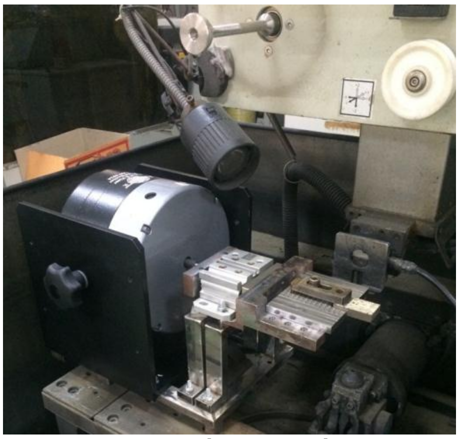

Figure 2. Actual experimental set up

Table 1. Selection of input parameters and performance measures

N0 EX.	Low frequency vibration (F)	The process parameters in WEDM	Performance measures in WEDM		
			MRR (mm^3/min)	R_a (µm)	ROC (mm)
1	0	Sc = 80V; Ton = 2 µs; Toff = 16µs; SV = 46V.	1.7157	1.245	0.268
2	100		2.1239	1.5825	0.278
3	200		2.2019	1.683	0.277
4	300		2.1499	1.84	0.279
5	400		2.2757	1.87	0.277
6	500		2.1574	1.734	0.275
7	600		2.0932	1.535	0.271
8	700		2.074	1.56	0.269
9	800		2.027	1.462	0.265
10	900		2.015	1.481	0.266

III. Results and Discussion

3.1. Effect of Vibrations on Material Removal Rate

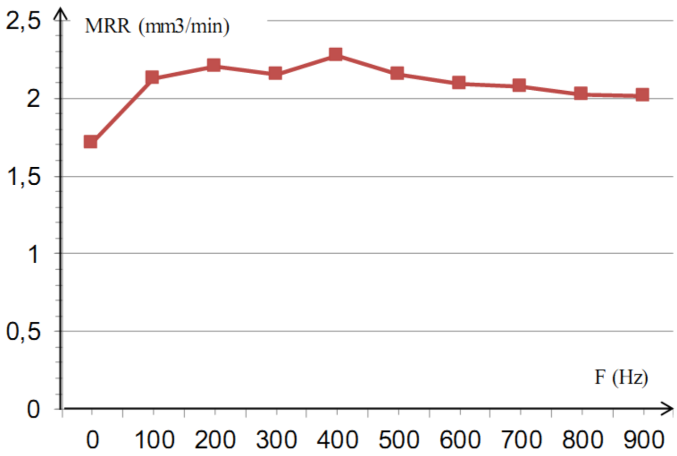

Figure 3. Effect of F on MRR

Figure 3 shows that the low-frequency vibration associated with the workpiece in WEDM machining has significantly improved machining productivity. It has been due to the ability of vibrations to increase in the frequency of sparks occurring in one pulse [8]. This could lead to an increase in the amount of workpiece material being melted and evaporated in one machining cycle. The vibrations incorporated into the workpiece could significantly improve chip ejection conditions from the machining area [8]. The process of forming and sparking at the machining area has been more stable by reducing short-circuit and arc discharges during the machining process. It has contributed to improving the machining productivity as compared with the non-vibrating WEDM, This has increased the MRR is significantly increased at 600Hz. However the MRR could be reduce when F = 700 - 900Hz. This may be due to the higher unstable during the higher frequency [7]. The vibration assisted WEDM process has increased the MRR than conventional WEDM process.

3.2. Effect of Vibrations on Surface Roughness

Figure 4 shows that the low-frequency vibration associated with the workpiece in WEDM machining has significantly affect the surface roughness. The vibrations has led to an increase in the size and number of sparks created by the sparks on the machining surface [7]. The rise of R_a on the machined surface after WEDM with perpendicular vibration was greater than in the parallel direction. The vibrations perpendicular to the wire displacement can produce arcing phenomena causing large dents on the machining surface with more particles adhering to the surface [13,14]. The higher R_a has been observed with vibration assisted WEDM process than conventional WEDM up to F = 300Hz. It was indicated that the change in machined surface roughness was negligible with the integration of vibrations into the workpiece.

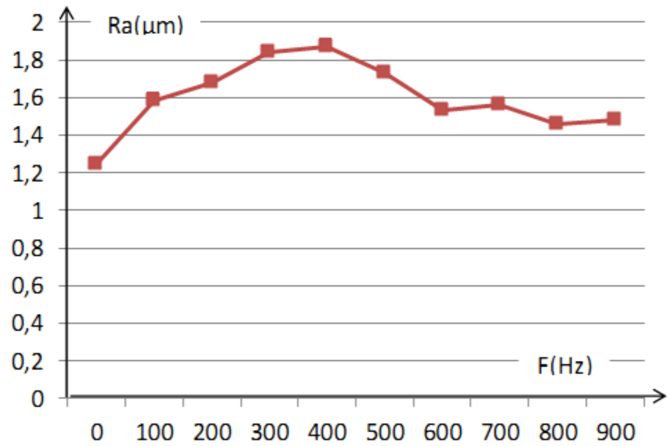

Figure 4. Effect of F on surface roughness (R_a)

3.3. Effect of Vibrations on Radial Overcut

Figure 5 shows the effect of the vibration frequency on the discharge gap size (ROC). It was observed that wire vibrations have a significant effect on ROC. The wire displacement in the direction perpendicular to the direction of vibration has strongly influenced ROC. This was due to the vibrations in this direction could increase the number of sparks along the width of the discharge gap [5]. As compared with WEDM

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without vibration, the size of the discharge gap was increased to maximum by 24µm. This has resulted in a greatly reduced machining accuracy.

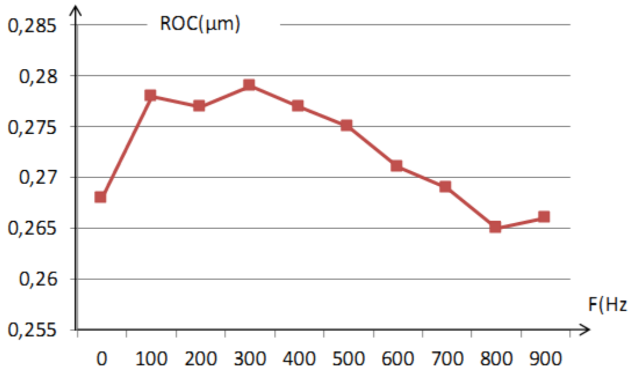
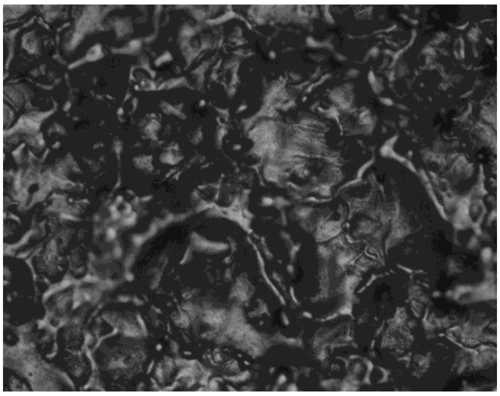


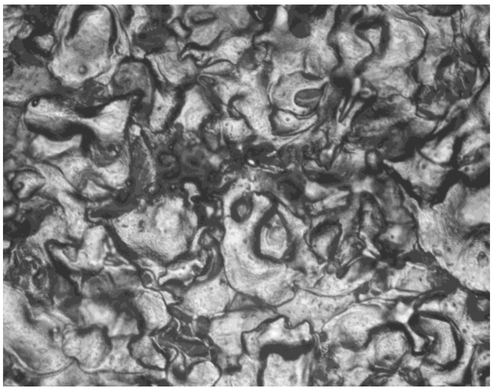
Figure 5. Effect of F on Radial overcut (ROC)

3.4. Effect of Vibrations on Machined Surface Quality

The surface morphology post-machined WEDM with and without vibrations integrated with the workpiece has shown in Figure 6. As compared with the non-vibrating WEDM, the number of craters on the surface machined with vibration has been more with the smaller size of the indentations. It may be that the vibration results in an increase in the discharge frequency in one pulse cycle [6].



a) F = 0Hz



b) F = 100Hz

Figure 6. Topography of machined surface after WEDM

IV. CONCLUSIONS

In the present study, the effects of low frequency vibrations on vibrations assisted WEDM process on machining SKD11 workpiece in WEDM process. From the experimental investigations, the following conclusions have been made as follows.

- Material removal rate (MRR) can significantly improved with the vibrations integrated to workpiece during the machining process.
- Surface Roughness (Ra) is not significantly changed with integrated vibrations parallel to the winding direction.
- The machining gap size can greatly increase with perpendicular vibrations of 24µm.

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