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Effects of Low-Frequency Vibration Integrated With WorkpieceOn Quality Indicators In Wire Electrical Discharge Machining

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Abstract

The improvement of productivity and surface quality in the WEDM process is an 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 a workpiece with the 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 machining productivity has been improved. However, the machining surface texture is not significantly affected by the proposed method.

I. Introduction

Wire electrical discharge machining (WEDM) is a very popular non-traditional machining method for machining surfaces with complex profiles of difficult materials. This could lead to reducing the complexity made with traditional machining [1]. Hence, an endeavor is essential to improve machining efficiency in the 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 discharges, points have been increased with the addition of ultrasonic vibrations. This created a 30% higher cutting speed in the process [6]. A device has been designed to generate low-frequency vibrations on the electrode wire for the 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 ultrasonic vibrations' effect becomes ambiguous due to lower discharge stability. The low-frequency vibration can be provided to the workpiece with the help of a vibrator [9]. It could help remove debris from the cutting zone faster 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 ata lower cost [15].

From the literature survey, it has been found that only very few importance have been provided to low-frequency vibrations integrated with the workpiecein the WEDM process to improve the process efficiency. In the present study, low-frequency vibrations have been assigned to the SKD11 workpiece inthe 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 withdimensions of 15 mm X 200 mm X 10 mm, as shown in Figure 1. The Brass wire electrode was used very commonly in the 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 the 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 is shown in Table 1.

To evaluate the effectiveness of the optimization problem in the vibration-assisted WEDM process, quality measures such asmaterial removal rate (MRR), surface roughness (R_a), and radial overcut (ROC) were used. The workpiece's weight was measured before and after machining using AJ 203 electronic balance (Shinko Denshi Co. LTD - Japan). The surfaceroughness was measured by a surface tester

(Model: SV–2100, Mitutoyo, Japan) with the cutoff length 0.8mm. The microstructure-layer surface surveyed by photographing the machined surface layer's cross-section using optical microscopy (Model: Axiovert-40MAT, Carl Zeiss, Germany).

Figure1.A workpiece is used.

Figure2.Actual experimental setup

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

A. Effect of vibrations on Material removal rate

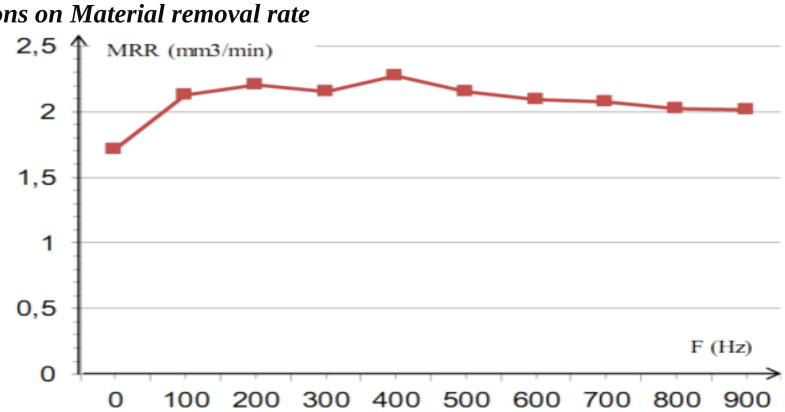


Figure 3.Effect of F on MRR

Figure 3 shows that the low-frequency vibration associated with WEDM machining work has significantly improved machining productivity. It has been due to vibrationsto 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 workpiececould 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 machining productivity as compared with the non-vibrating WEDM. This has increased the MRR is significantly increased at 600Hz. However, the MRR could be reduced 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 the conventional WEDM process.

B. Effect of vibrations on Surface roughness

Figure 4 shows that the low-frequency vibration associated with the workpiece in WEDM machining has significantly affected the surface roughness. The vibrations have led to an increase in the sparks' size and number created by the sparks on the machining surface [7]. Ra's rise 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 a 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.

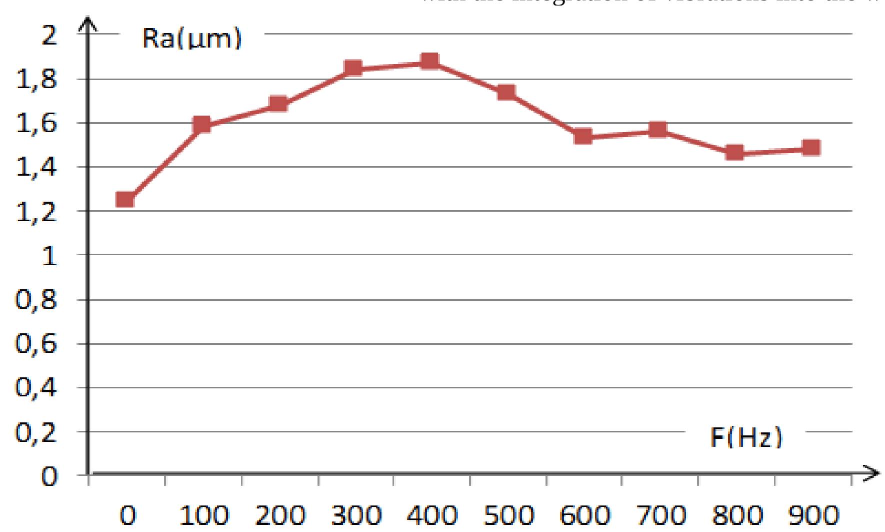


Figure 4.Effect of F on surface roughness (R_a)

C. 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 that could increase the number of sparks along the discharge gap [5]. As compared with WEDM without vibration, the size of the discharge gap was increased to maximum by 24µm. This has resulted in a greatly reduced machining accuracy.

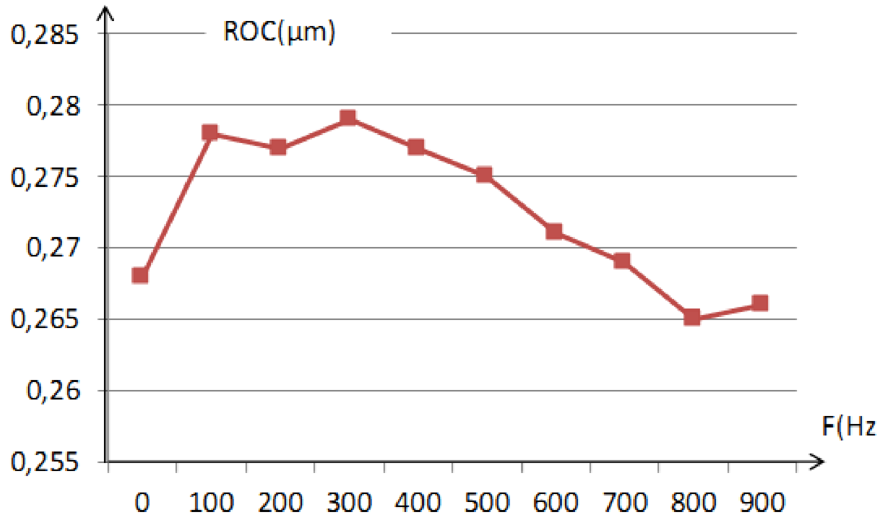
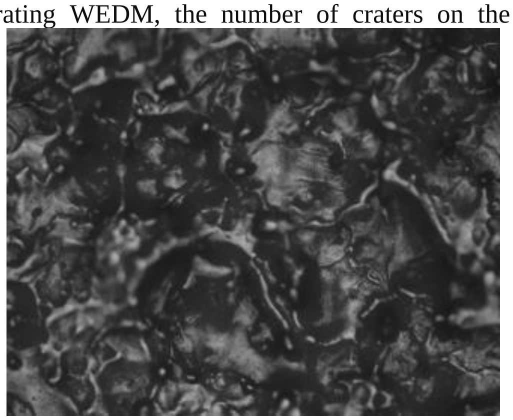


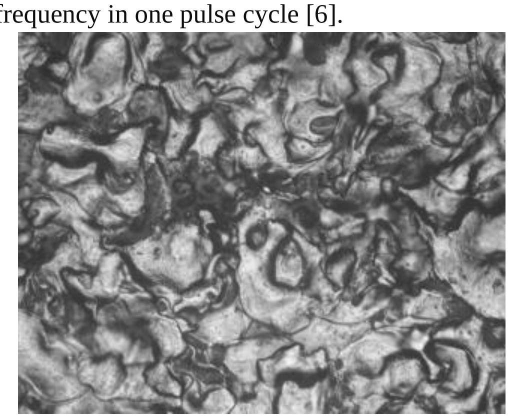
Figure5. Effect of F on Radial overcut (ROC)

D. Effect of vibrations on Machined surface quality

The surface morphology post-machined WEDM with and without vibrations integrated with the workpiece, as 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. The topography of machined surface after WEDM

IV. Conclusions

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

- The material removal rate (MRR) can significantly be improved with theworkpiece's vibrations 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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