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Fabrication of Macro-Arrayed Structure using Reverse EDM: A Multi-objective Optimization

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Abstract

In the past few years, applications like surface texturing and fin-like structures for heat dissipation demands development of arrayed structures. At micro-scale, micro reverse electro-discharge machining (M-REDM) proved its ability to fabricate such arrayed structure. Very few attempts have been made at the macro level. In this research, an attempt has been made to check the feasibility of fabrication of macro-rod arrayed structure of Ø 5 mm × 4 mm using reverse EDM (REDM) on AISI D2 steel. Pulse ON time (T_{on}), pulse current (I_p) and gap voltage (V_g) were selected as process parameters while material removal rate (MRR), tool wear rate (TWR), surface roughness and taper angle were chosen as response variables. The experimental investigation has been planned using Taguchi L_9 orthogonal array and process parameter optimization carried out using various multi-attribute decision making (MADM) methods i.e. simple additive weighting (SAW), weighted product method (WPM) and grey relational analysis (GRA) to get the best suitable alternative among them. From the results obtained during experimentation, it can be seen that the MRR and surface roughness was mostly affected by I_p whereas TWR was mostly affected by T_{on} having the highest contribution among all process parameters. Taper angle in the range of 3° to 5° was observed. Optimized set of process parameters obtained using WPM and GRA method is in accordance with each other whereas SAW method ranked it second best alternative which is as follows: T_{on} = 155 µs; I_p = 9 A and V_g = 40 V.

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1. Introduction

Non-traditional machining processes have been developed to produce the complex shape with better surface finish, precise tolerances in hard and difficult-to-cut materials. Among them, electro-discharge machining (EDM) is used extensively in the industry. EDM is a thermoelectric in nature in which work material erodes by series of discrete but controlled electrical sparks between the workpiece and electrode immersed in a dielectric fluid [1]. Need based number of variants of EDM process are developed and tried at micro scale as well. Micro reverse EDM (M-REDM) is one of the variants which can be a promising technique to fabricate arrayed features on hard and difficult-to-cut material.

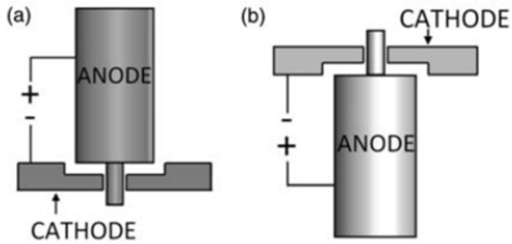

Fig.1. (a) Normal REDM; (b) Inverted REDM [2]

In case of reverse EDM (REDM), a cathode (electrode) contains the required number of cavities pre-machined by a suitable machining process. A bulk rod (anode) of relatively large diameter is aligned over these cavities and fed through at a controlled feed. Erosion from anode surface takes place wherever material to material interface is present which results in replication of pattern of cavities from the cathode surface to the anode surface. Cross-section of the fabricated features on anode resembles the cross-section of cavities pre-machined on the cathode. The aspect ratio of the fabricated structures can be controlled by controlling the displacement of the moving electrode along the Z-axis [2, 3]. Based on the positions of the electrodes, two variants of the REDM are defined. These are normal and inverted REDM processes which can be seen in Fig. 1 (a) and (b). The inverted REDM is found to be a better configuration as the machining time required for fabricating similar feature is lower than the normal REDM [2].

Talla et al. [4] studied the feasibility of REDM process in the fabrication of arrayed features of Ø 3 mm and height 2 mm on mild steel utilizing response surface methodology (RSM) based experimentation. Peak current, pulse-on time and flushing pressure were chosen as process parameters whereas dimensional accuracy in terms of taper and cylindricity error, MRR, surface roughness, microhardness and surface morphology were analyzed. Patil et al. [5] tested the feasibility of REDM to produce macro-scale features and effect of various process parameters like pulse-on time, pulse current and gap voltage on dimensional accuracy of the feature has been analyzed. They found I_p as the most influential parameter during the process. In another study, Nikam et al. [6] fabricated arrayed feature tool for EDM process by using REDM process. Surface roughness, MRR and TWR during REDM process were analyzed and observed that I_p affects them severely.

Since, the processes characterized by various responses which are of conflicting nature, optimization of the process parameters become an essential part of the process. So far various MADM methods are used for that purpose and all of these techniques are having different assumptions and procedure to get the optimized set of the parameter from the finite alternatives so there will be a possibility that this set may be varied from technique to technique [7].

Though the EDM processes are utilized to generate complex parts from hard to cut materials, there is a need to manufacture textured type features and arrayed structures on the part surfaces at macro level which could be useful for surface texturing, heat dissipation i.e. fin-like structures, component assembly and packaging. Researchers have tried to reproduce micro arrayed feature using EDM process by changing its sequence. However for the manufacture

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