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Materials Today: Proceedings 4 (2017) 7252–7261

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ICAAMM-2016

Multiple Quality Optimizations in Electrical Discharge Drilling of Mild Steel Sheet

[a]Ankit Jain, [b] Arun Kumar Pandey*

[a,b]Mechanical Engineering Department

[a,b]Jaypee University of Engineering & Technology, A.B. Road, Raghogarh-473226, Guna (M.P.)India

Abstract

The small diameter holes in different materials by using conventional drilling methods are challenging tasks. But such types of holes may be done by using advanced machining processes. Among the different advanced machining processes, the electrical discharge drilling may be applied with certain advantages over other processes. But electrical discharge drilling has certain defects or disadvantage at the drill specimen due to sparking such as hole circularity and hole taper. These may be optimized by selecting the optimum process parameter levels. In this study, the experiments have been conducted by well-planned orthogonal array L_{27} in the electrical discharge drilling of mild steel sheet. For the experimentation, discharge current, pulse on time, pulse off time and dielectric pressure have been selected as input process parameters and hole circularity & hole taper as output parameters. The multi regression models for hole circularity and hole taper have been developed by using the experimental data. The statistical analysis for the developed models shows that the models are reliable and adequate and may be used for predicting these quality characteristics satisfactorily. These quality characteristics have been optimized by using genetic algorithm MATLAB tool. In the genetic algorithm optimization, the regression models for circularity and taper have been considered as objective function. The multi-objective optimization result obtained by genetic algorithm, show improvements in both of the quality characteristics.

Keywords: Electrical Discharge Drilling; Hole Circularity; Hole Taper; Multi-objective Optimization; Genetic Algorithm

* Corresponding author. Tel.: +91-9575272128; fax: +91-7544-267011.
*E-mail address:*arunpandey76@gmail.com

1. Introduction

In the present scenario non-traditional machining processes are widely used in industries for many applications due to their significant advantages which are proving beneficial to a greater extent [1].In recent years, the applications of micro-holes are rapidly increased for several purposes in a lot of products, such as inkjet printer nozzles, spinner holes, turbine blades cooling channels etc. Electrical Discharge Drilling (EDD) is a controlled metal-removal process that is used to remove metal by means of electric spark erosion. Electric sparks are generated between two electrodes when the electrodes are held at a small distance from each other in a dielectric medium and a high potential difference is applied across them. The metal-removal process is performed by applying a pulsating (ON/OFF) electrical charge of high-frequency current through the electrode to the work piece. This removes (erodes) very tiny pieces of metal from the work piece at a controlled rate. Localized regions of very high temperatures are formed. Work piece material in this localized zone melts and vaporizes [2]. Most of the molten and vaporized material is carried away from the inter-electrode gap by the dielectric flowing, in the form of debris particles. Drilling is a process used to produce holes inside solid parts. The tool is rotated and also moved in the axial direction. Drilling is used to create tiny round holes in different advanced materials such as super alloys, ceramics and composites.

Many studies have been conducted to analyze the process details and find optimal conditions in this machining process. Khannaet al. used brass electrode for Al 7075 on electro discharge drilling and optimize material removal rate and tool wear rate using L_{27} array based Taguchi grey relation theory[2]. The optimization results showed that the combination of maximum pulse on time and minimum pulse off time gives maximum MRR. Jahan etal. used pure tungsten electrode having diameter of 200μm for WC-Co cemented carbide and SUS 304 austenitic stainless steel on electro discharge drilling and optimize MRR and electrode consumption rate[3]. The optimization results showed the better machinability during the deep-hole micro-EDM drilling, providing relatively higher MRR and stable machining[3].Yilmazet al. has developed a system for an interactive and visual interface for IN718 and Ti64 alloys on electrical discharge Drilling and optimize total drilling time, minimum required electrode length, and roughness of the produced surface[4]. Shuet al. Used Cu/SiC*p* composite electrode for P20 WC and HPM 50 mirror mild steel on Electrical discharge abrasive drilling and optimize material removal rate and surface roughness[5]. The optimization result showed that EDAD machining efficiency was three to seven times that of normal EDM operation [5].Yildizet al. has developed a second order mathematical stochastic model for the White Layer Thickness for Be–Cu alloy on electro discharge drilling [6]. Kuppanet al. used copper tube for Inconel 718 on electro discharge drilling and optimize material removal rate (MRR) and depth averaged surface roughness (DASR)[7].

In the present research work,L_{27} orthogonal array is used for electrical discharge drilling of mild steel sheet by using brass electrode. Discharge current, pulse on time, pulse off time and dielectric pressure have been selected as machining parameters and hole circularity & hole taper as output parameters. The multi regression models for hole circularity and hole taper have been developed by using the experimental data and quality characteristics have been optimized by using genetic algorithm MATLAB tool.

2. Experimental Methodology and setup

This experimental work was carried out on EDM, model innovative Automation Product(IAP) 3X-spark DRO (EDM-Drill) with a DC stepper motor which continuously maintaining the constant gap voltage between electrode and work material. The work piece material for EDD is a 1 mm thick sheet of mild steel and its chemical compositions is shown in Table 1.Single hole brass tubular electrode of diameter of 1mm and length 400mm tool was used for experiment. Based on literature survey, four machining parameters such as discharge current (I), pulse on time (μs), pulse off time (μs) and dielectric pressure (kg/cm^2)are selected for experiments and a series of pilot