Comparison of Conventional, Powder Mixed, and Ultrasonic Assisted EDM by Phenomenological Reasoning

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ABSTRACT

Electro-discharge machining (EDM) is widely used in industries for machining complex shapes and difficult-to-machine materials that are conductive. In the present work, performance of conventional die-sinking EDM process is compared with powder mixed and ultrasonic assisted processes in machining of D3 steel. Using different sets of parameters for rough and finish ED machining, material removal rate and surface roughness are obtained experimentally. The influences of the parameters on material removal rate and surface roughness are presented on the basis of phenomenological reasoning. The results are discussed and suitable recommendations for the practitioners are included.

KEYWORDS

Conventional, D3 Steel, Die-Sinking, Electrical Discharge Machining, Material Removal Rate, Phenomenological Reasoning, Powder Mixed, Surface Roughness, Ultrasonic Assisted

1. INTRODUCTION

Electro-discharge machining (EDM) process is based on spark erosion phenomenon under controlled condition. The process is used for machining of conducting materials that are difficult to machine by cutting with hard tools. Die-sinking EDM is widely used in industries as it has the capability to machine complex 3D shapes such as die and mould cavities in hardened steels (Kiyak and Cakir, 2007; Bose and Pain, 2016; Kharola, 2016). Apart from metals, different types of metal matrix composites have also been machined by EDM successfully (Bhuyan et al., 2014; Dixit and Awasthi, 2015). In certain applications, sinking of holes with sizes going down to micro level is also carried out (Jahan et al., 2009; Porwal et al., 2014; Kibria et al., 2014). The die-sinking EDM process has been investigated for its performance with different materials for tool and work, different types of dielectric media, different powders mixed in dielectric media and ultrasonic assistance. In many research attempts, a set of operating parameters is selected on the basis of settings available in the machine. The setting parameters are voltage (V), current (I), pulse on time (T_{on}), pulse off time (T_{off}) and dielectric pressure (P). Puertas and Luis (2003) have studied surface finish in EDM and attempted to optimize the process from surface finish point of view. Numerical simulation of surface roughness formation has been attempted by Suryavanshi et al., (2014). Klocke et al., 2013 have analyzed the process for material removal rate (MRR). Usually, one set of experiment is planned according to design of experiment (DoE) covering the operating range, and setting parameters are identified for MRR and surface finish (Lin et al., 2006; Barenji et al., 2016). During interaction with practitioners...
in the industry, it has come to our knowledge that the practitioners use different strategies for rough and finish machining in EDM. It seems logical as maximum amount of material is removed in rough EDM, while improvement of surface finish becomes the objective in the finish EDM.

It is seen from the literature that investigations have been carried out on the effect of powder-mixed dielectric on EDM performance, taking conducting powders like as graphite, copper, aluminum, tungsten, titanium, chromium, etc. and non-conducting powders like as alumina, silicon carbide, titanium carbide, tungsten carbide, molybdenium disulphide, etc. (Kozak, et al., 2003; Rehbein, et al., 2004; Çoğun et al. 2006; Marashi et al., 2016). Under certain combination of powder-mix, the surface finish is also found to improve (Wong et al., 1998; Peças and Henriques, 2008). While conducting powders are found to assist in the sparking phenomenon and enhance material removal rate, surface modification is done using appropriate powders that get deposited on the workpiece surface. It is also seen that graphite powder is used widely for different steels to enhance process performance (Jeswani, 1981; Fong and Chen, 2005; Lin et al., 2006). In an earlier work by Jeswani (1981), concentration of graphite in dielectric is varied from 0.25 to 6.0 gm/l and the material removal rate is found to improve with the concentration. From a practical point of view, a fixed concentration of graphite is preferred in the industry.

This research work also focuses on ultrasonic assisted EDM. From the literature survey, it is seen that ultrasonic vibration is imparted to the tool electrode (Kremer et al., 1989; Goiogana, et al. 2016) or workpiece immersed in the dielectric medium (Shabgard, et al., 2011). Numerical studies have also been carried out by Shervani-Tabar and Mobadersany (2013) on the effect of ultrasonic vibration on dielectric medium in the electrode gap. In the experiments reported in the literature, the frequency is taken as 20 or 40 kHz, while the amplitude varies from 6 to 15 μm.

Literature also reveals that researchers have attempted to study material removal rate and surface finish in EDM using statistical and Artificial Intelligence (AI) techniques, though there are few attempts to develop analytical models (Abbas, et al., 2007; Balraj, et al., 2014). While statistical methods use empirical relations, AI techniques use artificial neural network (ANN), fuzzy logic and hybrid methods. The empirical relations do not bring out the phenomenon associated with spark erosion. The fuzzy and network methods develop models whose parameters do not reflect the real process mechanics. By phenomenological reasoning, it can be inferred that erosion occurs due to electrical energy discharged through pulses and the process is controlled by certain multiplicative association of voltage, current and pulse on time.

It is seen from the literature that the researchers have attempted to enhance the performance using powder mixed and ultrasonic assisted conditions. However, comparison is difficult, as EDM is performed at different conditions using different machines. Also attempt is made to recommend a single set of parameters to maximize material removal and minimize surface roughness, while practitioners employ different conditions for rough and finish machining. There is also a need for a different approach based on phenomenological reasoning to understand the process behavior.

The specific objectives of this study were (a) to explore the performance of the die sinking EDM process in rough and finish machining separately; (b) to evaluate the material removal rate and surface roughness in conventional, powder mixed and ultrasonic assisted conditions; and (c) to establish and test the phenomenological models of the processes. In order to meet these objectives, the experiments are carried out separately for rough and finish EDM. A fixed concentration of graphite powder is used in powder mixed EDM, and fixed vibration frequency and amplitude is used in ultrasonic assisted EDM. The performances of EDM under different conditions have been reported and discussed comprehensively based on phenomenological reasoning in this paper. From the results presented, the practitioners can select suitable conditions and range of setting parameters depending on their requirements.
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