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An approach for increasing the micro-hardness in electrical discharge machining by adding conductive powder to the dielectric

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Abstract

The present study deals with investigations on the effect of process variables on micro-hardness during electro-discharge machining (EDM) and powder mixed electro-discharge machining (PMEDM) of H-11 die steel. Taguchi's L_{27} orthogonal array has been used to conduct the experiments using chromium powder mixed dielectric fluid with varying "powder concentration (C_p), peak current (I_p), pulse on time (T_{on}), duty cycle (DC) and gap voltage (V_g)." Analysis of variance (ANOVA) has been used to establish the optimal setting. Empirical model has been developed to predict micro-hardness. The optimum set of parameters for maximum micro-hardness was identified as C_p of 6 gm/l, I_p of 9Amp, T_{on} of 150µs, DC of 80% and V_g of 50 V. Confirmatory test reveals a relative error of 1.95% between predicted and experimental values of micro-hardness. Material migration from tool to the machined surface, conductive powder and dielectric fluid has been analysed using "Scanning Electron Microscope" (SEM) and "Energy Dispersive Spectroscopy" (EDS).

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Keywords: EDM;PMEDM;Taguchi; micro-hardness; surface-characterization;SEM;EDS.

1. Introduction:

Electrical discharge machining (EDM), a non-traditional machining method, is now a well recognized machining operation in many manufacturing industries all over the world. H-11 die steel possesses excellent mechanical properties and is more often put to precise applications where conventional machining becomes difficult due to extensive hardness and toughness.

PMEDM enhances the processing capabilities of EDM. Studies on surface modification resulting from material migration in electrical discharge machining (EDM) process have gained enormous research interest in the last decade. Machining without powder particles gives rise to cracks, holes, pores and surface pits with more non-

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uniform surfaces. Addition of powder to the dielectric fluid improves the surface topography with less defects and cracks.

The process parameters play an important role for the material removal mechanism. Performance of the PMEDM process depends upon characteristics like powder type, concentration, particle size, electrode area, work-piece constituents and properties [1]. Powder particles when added to the dielectric fluid get deposited on the machined surface by forming carbides or in combination with the carbon atoms resulting from the breakdown of the hydrocarbon dielectric [2]. Addition of titanium powder to the dielectric leads to the formation of titanium carbide layer with micro-hardness of 1600 HVN on carbon steel when machined with copper tool [3]. Formation of a larger plasma channel occurred due to the mixing of aluminium powder to the dielectric as the discharge channel dispersed on a greater workpiece surface which was observed using a High Speed Framing Camera (HSFC) technique [4]. Surface roughness values of around 0.2microns were achieved on addition of a surfactant together with aluminium powder to the dielectric [5]. With the addition of different kind of powders to the dielectric, a considerable change in surface quality occurred for the same set of input parameters [6]. The mixing of different powders and additives to the dielectric fluid leads to the surface modification of the tool and workpiece material. Transfer of material occurs from Cu, Cu-Cr and Cu-W electrodes to AISI H13 die steel in presence of tungsten powder suspended in the dielectric [7-8]. The response of three die steel materials to surface modifications when machined using tungsten powder mixed dielectric show more than 100% increase in micro-hardness due to the formation of WC and W_2C in the plasma channel [9]. Parametric optimization of MRR and TWR during PMEDM for EN-8 steel using chromium powder mixed dielectric fluid enhances the surface properties by improving the rate of material removal [10-11]. The effect of process parameters and mechanism of surface deposition during PMEDM of H-11, EN-31 and HCHCr using different powders mixed to the dielectric increased the micro-hardness of the machined surface. Current, powder and interaction between workpiece and electrode are the significant parameters influencing the micro-hardness and graphite powder was found to be the most suitable type of powder to increase the micro-hardness when mixed with the dielectric fluid [12]. Addition of tungsten, silicon and graphite powders to the dielectric fluid improved the surface properties of different die steels resulting in a higher micro-hardness [13-14].

From literature it is evident that the surface modification occurring on the work materials due to PMEDM is still at an experimental stage. Though several studies have been reported using different powders mixed to the dielectric fluid but much work has not been done on the performance characteristics of the PMEDM process on H-11 die-steel with and without the addition of powder to the dielectric fluid. The surface modifications and material transfer mechanism on H-11 die steel using chromium powder mixed in varying concentrations to the dielectric fluid has not been investigated. The present work is a step in this direction. An effort has been made to find an optimal set of process variables for maximum micro-hardness. A comparison between EDM and PMEDM has been made by conducting experiments without adding powder at one level. The empirical model has been developed to predict micro-hardness. The material transfer mechanism from the suspended powder or electrode during the process has been investigated through microstructural analysis using scanning electron microscope (SEM) and Energy Dispersive Spectroscopy (EDS).

2. Materials and Methods:

2.1 Set-up:

Experiments for the investigation of surface modifications were conducted on EDM, model Electronica Smart ZNC EDM (Die sinking type) with positive polarity and servo-head. Dielectric fluid used was commercial grade EDM oil. Workpiece material selected for the experiment was H-11die steel having a composition of “0.39%C, 1%Si, 0.5%Mn, 0.03%P, 0.02%S, 4.75%Cr, 1.1%Mo, 0.01%Co, 0.01%Cu, 0.5%V and rest Fe”. The dimension of the workpiece was 120x60x25mm obtained in proper annealed condition. The machine set up used for the experiment is shown in Figure.1.SEM studies for selected samples polished using Nital as etchant were carried out using an optical metallurgical microscope.