Experimentation and Analysis into Micro-Hole Machining of Ti-6Al-4V by Micro-EDM Using Boron Carbide Powder Mixed De-Ionized Water

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ABSTRACT

In micro-electrical discharge machining (micro-EDM), dielectric plays a significant role during the machining process as different types of dielectrics encounter different chemical compositions, cooling rates and dielectric strengths. Therefore, while employing these different dielectrics, dissimilar process responses are accounted when machining in EDM at micron level. The present paper investigates micro-EDM characteristics such as material removal rate (MRR), tool wear rate (TWR), overcut (OC), taperness and machining time (MT) during micro-machining of through holes on Ti-6Al-4V superalloy employing de-ionized water based dielectric other than conventional hydro-carbon oil i.e. kerosene. The paper also includes the comparative study of the micro-EDM machining characteristics employing boron carbide (B\textsubscript{4}C) powder as additive in de-ionized water dielectric at different discharge energies. The results show that MRR and taper of micro-hole are better and TWR is less employing B\textsubscript{4}C additive in the dielectric than pure one, i.e. the productivity is improved and same micro-tool can be used for machining an array of micro-holes. Surface topography and recast layer formed during micro-hole machining by micro-EDM has also been investigated based on optical and SEM micrographs. Energy dispersive spectroscopy (EDS) analysis of machined surface as well as tool electrode surface has been done and the results show that there is significant amount of infusion of tungsten element onto the machined surface. A significant amount of carbon element is found onto the tool electrode surface.

Keywords: B\textsubscript{4}C Powder Suspended Dielectric, Boron Carbine, De-Ionized Water, Material Removal Rate, Micro-EDM, Micro-Hole, Scanning Electron Microscopy, Ti-6Al-4V

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1. INTRODUCTION

With the trend of rapid development of micro-machining technology, the demand of precision miniaturized products has grown tremendously. Again, the innovation of hard-to-machine materials has thrown a challenging task to the manufacturing engineers to fabricate micro-components by micro-machining of these materials. Micro-EDM is one of the established and emerging advanced micro-fabrication processes, which are being utilized to manufacture micro-sized features in products made of hard materials like titanium superalloys, etc. Micro-EDM utilizes the spark erosion phenomenon for removing material from electrically conductive workpiece through a dielectric medium. As the material removal process is non-contact type between the micro-tool and workpiece, it produces no mechanical stresses in workpiece, thereby reducing chatter or vibration problems during machining.

Since micro-EDM process is performed into a dielectric fluid, the types of dielectric fluids influence the machining performances criteria. Typically, in EDM, generally hydrocarbon oil kerosene is used as the dielectric fluid. However, in micro-EDM, the use of kerosene dielectric creates several problems such as (1) deposition of carbide layer on workpiece surface that reduces material removal rate, (2) adhesion of carbon particles on micro-tool surface that makes the discharge inefficient and (3) formation of harmful vapours such as CO and CH₄ that create toxic environment around the machining area, etc. (Zhang et al., 2006; Chung et al., 2007). To promote better micro-machining performances and safe machining environment, experimental investigations are going on employing different non-hydrocarbon based dielectric oils. The oxygen-based fluid, i.e. de-ionized water is one of them that can be applied as dielectric liquid during micro-machining in EDM. The oxygen-based dielectrics improve the electrical discharge phenomena in the machining gap and further results in better machining efficiency in EDM (Kunieda et al., 1991; Chen et al., 1999).

Several experimental studies on powder-mixed EDM process have been performed by researchers across the globe to investigate their influences on electrical discharge machining performances (Kansal et al., 2007). The researches include powders of Al, Cr, Cu, graphite, silicon, silicon carbide etc in some of the dielectrics such as kerosene and de-ionized water (Kansal et al., 2007; Erden & Bilgin, 1980; Tzeng & Lee, 2001; Jeswani, 1981). Influence of electrically conductive additives such as Al, Cu, graphite etc. and non-conductive additives such as SiC, Al₂O₃ etc. have been investigated. These electrically conductive additives are soft in nature and cannot withstand at high temperature and SiC, Al₂O₃ which are hard but electrically non-conductive. P. Peças et al. studied EDM technology for the effect of the electrode area on the surface quality measured by the surface roughness and craters morphology while using conventional EDM process. A comparative study of different type of dielectric fluid i.e. conventional as well as powder mixed dielectric has also been done. A significant improvement in the performance is achieved with a linear relationship of electrode area with surface quality measurements (Peças & Henriques, 2008). G. S. Prihandana et al. carried out research investigation during micro-EDM process suspending micro-MoS₂ powder in dielectric fluid and using ultrasonic vibration. The authors adopted Taguchi method (L18 orthogonal array) to ascertain the optimization of material removal rate. Four process parameters i.e. ultrasonic vibration of the dielectric fluid, concentration of micro-powder, tool electrode materials, and workpiece materials were studied and a significant improvement of material removal rate and surface quality has been found using MoS₂ micro-powder in dielectric fluid and using ultrasonic vibration (Prihandana et al., 2009). Y.F. Chen et al. investigated the combined process EDM and USM to explore and study the machining performance and surface modification on Al–Zn–Mg alloy using TiC particles mixed dielectric. Material removal rate, relative electrode wear rate, surface roughness and expansion of machined
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