Experimental Investigation of Machining Characteristics for the WEDM of Al/ZrO$_2(\rho)$–PRMMC

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ABSTRACT

Presented is an experimental investigation of the machining characteristics and the effect of wire electrical discharge machine (WEDM) process parameters during machining of Al/ZrO$_2(\rho)$ particulate reinforced metal matrix composite (PRMMC). Experiments are carried out to investigate the effects of input parameters such as dielectric conductivity, pulse width, time between pulses, maximum feed rate, servo control mean reference voltage, short pulse time, wire feed rate, wire mechanical tension and dielectric injection pressure on performance measures like cutting velocity and surface roughness. Taguchi method based design of experiment and $L_{36}(2^{12} \times 3^8)$ mixed orthogonal array have been used for experimental investigation. Servo control mean reference voltage and wire feed rate have been identified as most significant and significant parameter for cutting velocity so called for material removal rate. Time between pulses and short pulse time have been identified as most significant and significant parameter for surface roughness height, $R_a\, (\mu m)$. Optimum response characteristics estimated and identified the range of predicted confidence interval at 95% confidence level is 7.459 to 9.995 mm/min. for cutting velocity and 0.602 to 1.261 (µm) for surface roughness height $R_a$, respectively.

Keywords: Cutting Velocity, Metal Matrix Composite, Surface Roughness, Taguchi Method, Wire Electrical Discharge Machine

INTRODUCTION

A composite is a multi-phase material in which the constituent phases must be chemically dissimilar and separated by a distinct interface. A composite exhibits a significant proportion of the properties of both constituent phases such that better combinations of properties are realized (Balasubramaniam, 2011). In particulate reinforced composites, discrete, uniformly dispersed particles of a hard brittle material are surrounded by a softer more ductile matrix. Small particles of uniform size with proper orientation exhibit more strengthening effects. Most of these materials have been developed for the aerospace industries, storage battery plates, satellite structures, antenna structure and high temperature structures (Kalpakjian
& Stevan, 2000). Al/ZrO$_{2p}$-PRMMC is a very good material recommended for applications where high strength to weight ratio is important for fuel economy e.g., aerospace, automotive and defense applications related components. Many researchers have tried modern machining methods to machine the MMC and out of which wire electrical discharge machining (WEDM) emerged as an effective machining method. WEDM is a machining process controlled by a large number of process parameters (Benedict, 1987; Boothroyd & Winston, 1989). The setting of the various process parameters required in the WEDM process, play a crucial role in producing an optimal machining performance. Parameters setting for advanced materials have to be optimized experimentally because parameters setting given by the manufacturers are only valid for the common steel grades. Hewidy et al. (2005) modeled the WEDM parameters for Inconel 601 using response surface methodology for the performance characteristics such as Metal Removal rate, Wear Ratio, Surface Roughness. Chiang and Chang (2006) presented an effective approach for the optimization of the WEDM process of Al$_2$O$_3$ particle reinforced in Al6061 alloy with multiple performance characteristics using pure copper as wire electrode. Surface removal rate and Surface roughness were investigated using grey relational analysis. Manna and Bhattacharyya (2006) used Taguchi L$_{18}$ orthogonal array and Gauss elimination method for the parametric optimization of aluminum reinforced silicon carbide metal matrix composite and used brass wire in WEDM. Effect of machining parameters on machining performance criteria such as metal removal rate, surface roughness, gap current, and spark gap were studied. Saha et al. (2008) analyzed the wire electrical discharge machining of tungsten carbide cobalt composite using uncoated brass wire and optimization method such as back propagation neural network (4-11-2) and Multivariable regression model were used. Patil and Brahmankar (2010) experimentally investigated the effect of electrical as well as non-electrical machining parameters on performance in WEDM of metal matrix composite (Al/Al$_2$O$_{3p}$). Reinforcement percentage, current and on-time was found to have significant effect on cutting rate, surface finish and kerf width separately. Garg et al. (2010) conducted a review of research work in sinking EDM and WEDM on metal matrix composite materials. Most of the published work belongs to SiC reinforced metal matrix composites. Not so much work is reported Al$_2$O$_3$ reinforced and other MMC types. Patil and Brahmankar (2010) determined the material removal rate in wire electro-discharge machining of silicon carbide particulate reinforced aluminium matrix composites and model was developed by using dimension analysis and non-linear estimation technique such as quasi-Newton and simplex. In addition, an empirical model, based on response surface was also developed. Jangra et al. (2011) studied a digraph and matrix method to evaluate the machinability of tungsten carbide composite with WEDM. A methodology based on digraph and matrix method was proposed to evaluate the machinability of tungsten carbide in terms of material removal rate. Shah et al. (2011) investigated the effect of all critical WEDM parameters for the machining of tungsten carbide cobalt composites using Taguchi L$_{27}$ orthogonal array. It was found that the material thickness has little effect on the material removal rate and kerf but was significant factor in terms of surface roughness. Taguchi L$_{18}$ orthogonal array was used by Kuriakose and Shunmugam (2005) for the WEDM of Titanium alloy (Ti$_6$Al$_4$V) and considered cutting velocity and surface finish as performance measures. Taguchi L$_{16}$ orthogonal array was used by Ramarishnan and Karunamoorthy (2006) for the WEDM of heat treated tool steel and considered material removal rate, surface roughness and wire wear ratio as performance measures. Taguchi L$_{27}$ orthogonal array was also used by Mahapatra and Patnaik (2006) for the WEDM of D2 tool Steel and considered material removal rate, surface finish and kerf as performance measures. Taguchi L$_{9}$ orthogonal array was used by Kansal et al. (2007) for the electric discharge machining of H-11 die steel. Kansal et al. (2007) analyzed the technology and research developments in
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