Optimization of Electrochemical Grinding Parameters for Effective Finishing of Hybrid Al/(Al$_2$O$_3$+ZrO$_2$) MMC

K.Z. Molla, Department of Mechanical Engineering, Punjab Campus, Chitkara University, Rajpura, Punjab, India

Alakesh Manna, Department of Mechanical Engineering, PEC University of Technology, Chandigarh, Punjab, India

ABSTRACT

In this study, the Taguchi method, a powerful tool in the design of experiment is used to optimize electrochemical grinding (ECG) parameters for effective finishing of hybrid Al/(Al$_2$O$_3$+ZrO$_2$) MMC using a resin bonded copper impregnated diamond grinding wheel. An orthogonal L$_{13}$($3^{13}$) array is used for 3$^4$ factorial design and analysis of variance (ANOVA) is employed to investigate the influence of grinding wheel speed, electrolyte concentration, D.C. supply voltage, current density and work-piece speed on the surface finish, $R_a$ and $R_t$ respectively. Test results reveal that the $R_a$ and $R_t$ both are lesser at moderate grinding wheel speed i.e. 9000 rpm with current density 0.25A/mm$^2$ and 30% electrolyte concentration. Taking all five parameters considered for experimentation and using multivariable higher order regression, mathematical models for surface finish, $R_a$ and $R_t$ are established to investigate the influence of Electrochemical Grinding (ECG) parameters during finishing of hybrid Al/(Al$_2$O$_3$+ZrO$_2$) MMC. Confirmation test results established that the developed mathematical models are appropriate for effective representing the surface finish criteria, $R_a$ and $R_t$ (μm).

Keywords: Analysis of Variance (ANOVA), Electrochemical Grinding (ECG), Hybrid-MMC, Mathematical Models, Surface Finish

1. INTRODUCTION

Particulate reinforced hybrid metal matrix composites are gaining widespread applications due to their inherent better unidirectional strength to weight ratio, higher strength and better wear resistance properties at adverse operating condition. The aluminium alloy reinforced with discontinuous ceramic reinforcement is rapidly replacing conventional materials in various automotive, aerospace and automobile industries as stated by Allison and Cole (1993); Manna and Bhattacharyya (2003). But ceramic reinforced metal matrix composite machining is one of the
major problems, which resist its wide spread engineering applications as stated by Manna and Bhattacharyya (2003; Cronjager and Meister (1992). The hard reinforced particles of MMC, which intermittently come into contact with the hard surface and act as small cutting edges like those of grinding wheel on the cutting tool edge, which in due course becomes worn out by abrasion, resulting in the formation of a poor surface during conventional machining of MMC as stated by Manna and Bhattacharyya (2004). Various non-conventional machining processes such as, ECM, EDM, WEDM, etc. are also not effectively used for the machining of particulate reinforced metal matrix composites. Machining of Al/SiC-MMC by EDM requires a huge amount of current and discharge of SiC/Al is more irregular as stated by Hocheng et al (1997). Thus machining problems like low material removal rate, high surface roughness, heat affected zone and poor dimensional accuracy etc on finished parts remains unresolved. Manna and Bhattacharyya (2006) stated that the advance non-traditional machining techniques such as abrasive jet machining, water jet machining, laser beam machining etc can be applied for the machining of Al/SiC-MMC. Cost effective manufacturing of mini and micro dimensional part of slurry casted hybrid Al/(Al$_2$O$_3$+ZrO$_2$) MMC with satisfactory tolerance by any well known machining processes is still very difficult. Hence, an applied research investigation is highly important to identify the optimum machining process condition to produce cost effective parts from Al/(Al$_2$O$_3$+ZrO$_2$) MMC.

2. PLANNING AND DESIGN FOR EXPERIMENTAL STUDY

An electrochemical grinding setup has been designed, fabricated and utilized for experimental investigation. Figure 1 shows schematic block diagram of the designed and fabricated electrochemical grinding (ECG) setup, which has four different units. Figures 2, 3(a), 3(b) and 4 show the details of the schematic diagram of each unit of fabricated ECG setup i.e. main power supply unit, tool rotational and feed motion unit, work-piece rotational and x-y movement unit, and electrolyte flow control unit respectively.

The different sets of experiments have been performed on developed fabricated electrochemical grinding setup. According to the Taguchi method based robust design as explained by Ross, P.J. (1989), an orthogonal L$_{27}$($3^{13}$) array is used for 3$^5$ factorial design for finishing of hybrid Al/(Al$_2$O$_3$+ZrO$_2$) MMC. A total of five ECG parameters with three levels for each parameters such as factor A (grinding wheel speed), factor B (electrolyte concentration), factor C (D.C. supply voltage), factor D (current density) and factor E (work-piece speed) are considered as the controllable parameters for optimality analysis during finishing of hybrid Al/(Al$_2$O$_3$+ZrO$_2$) MMC (Table 1). The sodium
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