Chapter 10

Taguchi, Fuzzy Logic and Grey Relational Analysis Based Optimization of ECSM Process during Micro Machining of E–Glass–Fibre–Epoxy Composite

Alakesh Manna

PEC University of Technology, India

ABSTRACT

In this chapter, the use of Taguchi method, Fuzzy logic, and Grey relational analysis based on an L_{16} (4^5) orthogonal array for optimizing the multi response process characteristics during electrochemical spark machining (ECSM) of electrically non-conductive e-glass-fibre-epoxy composite (e-glass-FEC) is reported. An electrochemical spark machining setup has been designed and fabricated for micro machining of e-glass-FEC and experimental results are utilized for optimizing the process parameter (DC supply voltage, Electrolyte concentration, and Gap between tool and auxiliary electrode) with considerations of the multiple responses such as material removal rate and over cut on hole radius effectively. From the analysis, it is found that at higher setting value of DC supply voltage (e.g. 70 volts) and at moderate setting value of electrolytic concentration (e.g. 80 g/l) and 180 mm gap between tool and auxiliary electrode the material removal rate (MRR) is maximum. Utilizing the test results, mathematical models for MRR and overcut on hole radius are developed to predict the setting value of ECSM parameters in advance.

1. INTRODUCTION

The development of composite materials and related advancement in design and manufacturing technologies are one of the most important achievements in the history of materials. Composites are multifunctional materials having unprecedented mechanical and physical properties that can be tailored to meet the requirements of a particular application. With the vast and rapid growth of engineering materials towards the direction from metal to non-metal and there after to ceramic and composites, the modern manufacturing industries have developed an increasing demand for machining of those advanced engineering materials irrespective of their hardness, toughness, configurational complexity, micro-structure, electrical conductivity or electrically non conductive properties etc. with the ultimate goal of developing highly sophisticated products for achieving greater precision, speed, temperature resistance, wear resistance and lower weight. In machining, the selection and optimization of machining process parameters is the key step to achieve high quality of product without cost inflation. The e-glass-fibre-epoxy composite is an electrically non-conductive material and conventional machining of fibre-epoxy composites leads to delaminating and fuzzing. Even non conventional machining processes like EDM, ECM, and WEDM etc are not suitable to machine because of its non conductivity of electricity property. To overcome this constraint a hybrid process has been conceived, in which the phenomenon of electro chemical spark is employed for material removal from electrically non-conducting materials. An electrochemical spark machining (ECSM) setup has been designed and fabricated based on combined technique of electrochemical machining (ECM) and electric discharge machining (EDM). The fabricated ECSM setup has been utilized to machine the electrically non-conductive e-glass-fibre-epoxy composite.

The basic principle of material removal in ECSM process is electrochemical dissolution of the work-piece in presence of electrical spark discharge action created by applying sufficient D.C. voltage to the electrolytic cell in proper polarity i.e. positive terminal connected to the anode (i.e. auxiliary electrode) and negative terminal connected to the cathode. When the applied voltage reaches beyond a certain level reduction of electrolyte take places and liberates hydrogen gas bubbles at the cathode, and generates electrolytic gas around the surface of the electrode. There is evolution of oxygen gas and formation of oxide films at the auxiliary electrode surface while machining of electrically non-conducting materials. When generated hydrogen bubbles become large in number and these bubbles grow in size, and ultimately detach from the electrode when a critical size is reached. When the number of hydrogen bubbles formed at the electrode becomes sufficiently large, the resistance at the tool-electrolyte interface becomes very high due to constriction caused by the insulating effect of the gas bubbles. This leads to an increase in the Joule heating around the tool electrode to temperature levels which cause formation of electrolyte in vapors. This leads to formation of a spark due to the inductance in the tool-electrolyte circuit similar to that in an electrical circuit. The ECSM process has been successfully applied for machining of electrically non-conducting materials and the effects of the various parameters on material removal rate (MRR), electrode wear, overcut etc were discussed by Jain, et al. (1999) and Bhattacharyya et al. (1999).

Material removal rate and overcut on hole radius are the two major machinability factors where more research has to be made during micro machining of electrically non-conductive e-glass-fibre-epoxy composite. During the research investigation, it has been understood that more attention should be put forward to search out optimal parametric combination for achieving better micro machined hole quality. Keeping in

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