Chapter 31

A Multiobjective Genetic–Algorithm–Based Optimization of Micro–Electrical Discharge Drilling: Enhanced Quality Micro–Hole Fabrication in Inconel 718

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ABSTRACT

Inconel 718 superalloy finds wide range of applications in various industries due to its superior mechanical properties including high strength, high hardness, resistance to corrosion, etc. Though poor machinability especially in micro-domain by conventional machining processes makes it one of the “difficult-to-cut” material. The micro-electrical discharge machining (μ-EDM) is appropriate process for machining any conductive material, although selection of machining parameters for higher machining rate and accuracy is difficult task. The present study attempts to optimize parameters in micro-electrical discharge drilling (μ-EDD) of Inconel 718. The material removal rate, electrode wear ratio, overcut, and taper angle have been selected as performance measures while gap voltage, capacitance, electrode rotational speed, and feed rate have been selected as process parameters. The optimum setting of process parameters has been obtained using Genetic Algorithm based multi-objective optimization and verified experimentally.

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INTRODUCTION

Background and Motivation

Inconel 718 superalloy owing to its superior mechanical properties under elevated temperature is widely used material for aviation, turbines and nuclear power plant applications (Dudzinski et al., 2004; Unune & Mali, 2016a). However, Inconel 718 is classified as a “difficult-to-cut” material because of its peculiar characteristics such as low thermal conductivity, high tendency to work hardening and high affinity for tool materials. The conventional drilling of Inconel 718 lead to the built-up edges formation at tool–chip interface as a result of micro-welding and chip braking becomes tougher as drilling proceeds. Even inferior machining may arise during drilling small and micro holes due to drill bit breaking, low rigidity and challenging evacuation (Dudzinski et al., 2004; Ezugwu & Machado, 1999; Zhu & Ding, 2013). However, nonconventional machining processes can be effectively used for machining of difficult-to-cut materials like Inconel 718 as in these processes there is no direct contact between the cutting tool and material. Electric discharge machining (EDM) is a nonconventional machining process which employs a series of sparks between the electrically-conductive workpiece and the electrode inside dielectric fluid relying on thermal energy for material removal purpose.

Micro electric discharge machining (µ-EDM) is a modified version of EDM for manufacturing of micro- and miniature parts and structures. In micro electric discharge machining (µ-EDM), the material removal takes as micro-sized craters due to accurately regulated sparks occurring between a rotating electrode and a workpiece and holes as small of 5-10 μm can be fabricated (Unune & Mali, 2014; Unune & Mali, 2016a). The micro electric discharge drilling (µ-EDD) utilized the rotating cylindrical electrode, unlike the stationary electrode in die-sinking µ-EDM, and rotating motion of electrode further enhances the performance of the process. µ-EDD has become popular process due to its ability to generate high-aspect-ratio (HAR) micro-holes in any conductive materials irrespective of hardness (D’Urso et al. 2015; Lee et al. 2015; Zhang et al. 2015). It is preferred especially for the difficult-to-cut materials owing to its high efficiency and precision. Although µ-EDD is a very efficient process in micro-hole machining and having many advantages, it also has some disadvantages. One of them is that it is a rather slow machining process; the other is that while the workpiece is being machined, the tool electrode also wears at a rather significant rate. This tool-wear leads to shape inaccuracies. Another drawback is the formation of a heat-affected layer on the machined surface. Since it is impossible to remove all the molten part of the workpiece, a thin layer of molten material remains on the workpiece surface, which resolidifies during cooling (Prakash et al. 2015; Zhenlonget al. 2014).

Careful selection of input parameters and their optimization plays a great role in the achievement of results. Various studies have been reported to investigate effects of process parameters in µ-EDD. Although, low MRR, high electrode wear ratio (EWR), overcut, circularity and taper angle of HAR micro-holes are still major research concerns in µ-EDD.

Related Work

Liu et al. (2005) explored outcomes of the discharge current on the quality of holes using Tungsten electrodes of 110 μm in high nickel alloy. They proposed the use of the second stage helically grooved