Abstract

An inexpensive in-situ micro-tool fabrication technique, sheet electrical discharge grinding (sheet-EDG) has been developed to fabricate high aspect ratio cylindrical WC micro-tools using a 100 μm thick brass sheet as the cathode. The process has been investigated thoroughly, and the effects of all possible process parameters, such as optimal tool path, radial infeed positions, sheet thickness, sheet-EDG parameter, radial infeed per pass, radial infeed rate, and traverse feed rate have been discussed. Also, various tool paths have been employed for fabricating different shaped microtools. However, optimizing the process parameters during sheet-EDG becomes challenging due to the varying nature of initial tool eccentricity. Slit-cut process, an alternative experimental investigation, has been conducted to overcome these challenges by halting tool rotation. A face-centered central composite design has been employed to perform 20 slit-cuts on tungsten carbide sheet-electrodes with varying process parameters like voltage, sheet-EDG parameter, and radial infeed. Later the effect of these parameters on responses like volume removal rate (VRR) and electrode wear rate (EWR) has been studied. After statistical validation through analysis of variance (ANOVA), regression equations for both VRR and EWR have been developed and simultaneously optimized using various nature-inspired algorithms. Multi-Objective Bonobo Optimizer (MOBO) outperformed other techniques based on the quality of the Pareto front. Ethylene glycol (EG) based pure and mixed electrolytes have been used for fabricating blind microholes on Ti6Al4V. The performance of these electrolytes has been compared considering factors, such as surface irregularities (pitting corrosion, stray corrosion, and sludge deposition) and radial overcut (ROC). Also, different potentiodynamic polarization tests have been conducted to understand the anodic dissolution behaviour of Ti6Al4V in these electrolytes. Finally, EG-based 1:3 mix of NaBr and NaCl has been considered as the most suitable electrolyte. Later, a set of 20 through microholes has been performed on 1.2 mm thick Ti6Al4V by altering voltage, feed rate, and electrolyte concentration using central composite design, to observe their effects on the output parameters, such as volume removal rate (VRR), radial overcut (ROC), and taper. MOBO has reported the best Pareto-surface in terms of both uniformity and spread measures, and suggested fixing the feed rate at 0.3 μm/s for optimal electrochemical micro-drilling operations.

Keywords: Micro electrical discharge machining; In situ micro-tool fabrication; Sheet electrical discharge grinding; Ti6Al4V; Electrochemical micro-drilling; Ethylene glycol; Potentiodynamic polarization test; Multi-objective optimization; Nature-inspired algorithms.