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Experimental Investigation and Optimization of Machining Parameters of Aerospace Material Using Taguchi's DOE Approach

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Abstract

Precision manufacturing of complicated geometries viz. micro-holes and micro-slits is a challenging task in the metal cutting industries, especially on difficult-to-machine materials viz. metal matrix composites and aerospace materials. WEDM is one of the most demanding machining technologies used currently for such productions using thin electrically conductive wires. In the present investigation, an efforts have been made to produce micro-slits finding applications in micro-diffraction gratings, micro electro mechanical system (MEMS) devices and defence components.
An experimentallayout has been conducted using Taguchi's L-9 Orthogonal array, experimental runs were conducted to predict the response viz. Overcut ona Ni-based super alloy (Inconel-600). In the present research article results have been discussed using Taguchi's Methodology and micro-structural studies (SEM). An experimental result reveals that overcut increases with peak current and pulse ON –time and decreased with increase of pulse OFF time (75-100μs).

Keywords: Taguchi's Method;MEMS;WEDM;SEM

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1. Introduction

Machining of complicated geometrical features viz. micro-holes and micro-slits is not possible using conventional single or multiple cutting tools. This may be due to its constraints and limitations such as small and precise tool fabrications, costs, and hardness of tool materials. EDM and its variant method (WEDM) have ability to machine harder-materials and complicated dies. Researchers have keen interest in attempting scientific and industrial research in producing micro-slits using rotary EDM, WEDM and Abrasive-mixed EDM processes [1-6]. Rotary EDM entails rotation of disk electrode, which increases the metal cutting productivity, with less changes of generation of recast layer with least thickness. This happens due to the effective flushing capability of debris and metallic particles due to the rotation of tool electrode but due to rotation of tool electrode, occurrence of overcut increased. Micro-EDM can produces precise thin slits, but cost of production increased. Wire-Electrical Discharge Machining (WEDM) can machine micro-slits easily using conductive wire electrode in the presence of the dielectric fluid. The electrical discharges of high frequency transpire in the micro-gap between the wire electrode and work piece material. Heat from the electrical discharges locally melts/vaporizes the work piece material in form of minute particles called debris. The debris is then washed away from the machining gap by the continuously flushing dielectric fluid [6-7].

2. Past Work

In the past, several researchers have experimentally proved to fabricate the micro-slits using variants methods of EDM Viz. conventional rotary EDM, revised rotary EDM, powder-Mixed EDM and Wire-EDM [3-6].Researchers enlighten those work-piece materials (Mild steel, Ti-6Al-4v, Nimonics were used to fabricate Micro-slits).Each of the method has their own advantages and some limitations, which includes fabrication of additional setup and tool electrode's, dimensional accuracy, surface finish and superior machinability. WEDM can produce controlled geometry but susceptibility of wire breakage is a problem. This problem has been reduced in the present investigation by treating brass wire cryogenically at low temperature for improving wear resistance capability. As per literature review, few attempts have been found in past to fabricate micro-slits on Inconel-600 using cryogenically treated brass wire using WEDM.

3. Experimentation Details

In the present investigation, maxi cut- Electronica CNC -wire electrical discharge machine (50 A) persisted to perform machining to study the response viz. overcut using Taguchi's Methodology and scanning electron microscope (SEM).

WEDM process variables at different setting of peak current (Ip), pulse-on time (Ton), pulse-off time (Toff), were used for the investigation analysis.

L9 Orthogonal array (three levels) with 3 input variables was selected for experimentation. Tables 1, show the various process parameters with their values at three levels and L9 orthogonal array (with three input variables and three level) respectively. Inconel-600 plate of thickness 1 mm was used as work material (Table.2). Inconel-600 finds wide applications in gas turbine blades, high temperature fasteners, and in aerospace components. Cryogenically treated brass wire electrode of diameter 250µm has been used to machine straight rectangular slits, required in MEMS components. Overcut after machining was measured using SEM.
The experimental set up of WEDM is shown in fig 1.

Table 1. Process parameters

Parameters designation	Process parameter	Level 1	Level 2	Level 3
A	peak current (A)	2	4	6
B	pulse ON time (µs)	50	75	100
C	pulse OFF time (µs)	50	75	100