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Effect of Cryogenic Treatment of Tool Electrode on the Machining Performance and Surface Finish during Electrical Discharge Machining of Hastelloy C-4

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Abstract

Advancements in machining science provided a wider scope for the development of composites and advance materials. As the researches are going on into this field newer materials are coming into existence, having complex meteorological structure and high mechanical-resistance ability. Due to the extreme strength, toughness and hardness of these materials advance machining processes are taking over the conventional machining processes in this field. Electrical discharge machining (EDM) is one of its own kind of advance machining process, which has been used during this research work. This study investigates the performance and surface finish of cryogenic treated and non-treated copper tool electrode during electrical discharge machining of Hastelloy C-4. Effect of cryogenic treatment, current, Pulse on time, Pulse off time was investigated on surface roughness. The comparative study reveals that pulse on time, tool electrode and current are the most influential parameters that affect Performance and surface finish during EDM. The study shows that cryogenic treated copper tool generates better surface finish than the conventional copper tool electrode. Microstructural studies show that thick recast layer was observed in case of cryogenic treated copper electrode and also deep shallow craters were found at higher value of current.

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*Keywords:*Hastelloy C-4; Electric discharge machining; Cryogenic treatment; Taguchi L18 OA; Surface integrity; Surface roughness

1. Introduction

The developments in the field of advanced alloys having new characteristics, causes the growth of advanced machining processes.

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Nomenclature

OA	Orthogonal Array
SR	Surface Roughness
MRR	Material removal rate
T_{on}	Pulse on time
T_{off}	Pulse off time
ANNOVA	Analysis of variance
Seq. SS	Sum of squares
Adj. SS	Adjusted mean of squares
DOF	Degree of freedom
S	Standard deviation
SEM	Scanning electron microscope
EDS	Energy dispersive spectroscopy

Electrical discharge machining (EDM) is a non-conventional machining process and is found to be more economical during the machining of advanced alloys and composite materials. It works on the principle of erosion of material from the work piece with controlled and repetitive sparks produced by the DC pulse generator. It hasvarious input parameters such as Tool polarity, Pulse on time, Pulse off time, current, voltage, Duty factor, flushing pressure, dielectric, Tool type, etc.Selection of EDM parameters for better output characteristics requires a lot of experimental work which is time consuming and costly. A lot of research work has been carried out by the researchers to study the effect of EDM parameters on its response characteristics such as MRR, TWR and SR. It is pertinent to select optimum input machining parameters for the best response parameters.Choudhary et al.have investigated the performance of Nimonic75 on die sinking EDM using Taguchi's L18 orthogonal array.Tool polarity,current,pulse on time and voltage were used as input parameters in this study. In case of positive tool polarity, MRR is found to be more for Nimonic75 and hence produce more surface roughness than negative tool polarity.It was also found that there is maximum deposition of carbon in the case of positive tool electrode. Out of the four input parameters, Tool polarity, current and Pulse on time was found to be more influential that affect surface roughness and MRR [1]. Kong et al.Investigated the EDM characteristics of Hastelloy. The primary parameter which was varied in his study was pulse on time. Since the pulse on time is one of the main factors that determines the intensity of electric discharge energy. It was observed thatthe combination of longer pulse on time and short pulse off time corresponds to relatively poorer surface integrity as compared to shorter pulse on time. Pulse on time also has a great influence on a number of micro cracks [2]. Choudhary et al.have conducted investigations on the machining of EN-31 die steel with different tool electrodes (copper, brass, graphite). The study concluded that copper as a tool electrode shows good response towards MRR whereas brass gives a superior finish as compared to other tool electrodes [3]. Taweel investigated the relationship of process parameters in electro-discharge of CK45 steel with novel tool electrode material such as Al–Cu–Si–TiC composite produced using powder metallurgy (P/M) technique. Al–Cu–Si–TiC P/M electrodes are found to be more sensitive to peak current and pulse on time than conventional electrodes [4]. Kumar et al.Developed a special experiment setup of (Electric discharge surface grinding) EDSG using EDM and surface grinding machine to investigate the effect of seven input parameters, namely tool polarity, peak current, pulse on-time, pulse off-time, rotational speed, abrasive particle size, and abrasive particle concentration on the material removal rate (MRR) as a performance measure during machining of 6061Al/Al_2O_3p 10% metal matrix composites (MMC) by a composite tool electrode. The studies revealed that tool polarity, peak current and rotational speed are the most influential parameters that affect MRR in EDSG process. It was also concluded that the abrasive particles substantially improve the MRR after removing the re-solidified layer from the machined surface [5]. Kumar et al. Attempted to study the performance of Hastelloy during EDM with P/M tool electrode using positive polarity. In this study, current and voltage is taken as input parameters. It was found that MRR increases with the increase in gap current up to a certain limit and start decreasing due to deposition of tool material on the work piece[6]. Swaraj et al.investigatedtheelectrical discharge machining with parameters like tool polarity, peak current, rotational speed and pulse on time using the Taguchi methodology toobserve the machining characteristics of HASTELLOY C-276 with