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Research on the surface quality of the Blasting Erosion Arc Machined Stainless Steel

Yingmou Zhu[a], Jipeng Chen[a], Hui Xu[a], Lin Gu[a]*, Wangsheng Zhao[a]

[a]*State Key Laboratory of Mechanical System and Vibration, School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai 200240,China*
* Corresponding author. Tel.: +86-021-34206954; fax: +86-021-34206954.*E-mail address:* lgu@sjtu.edu.cn

Abstract

The Blasting Erosion Arc Machining (BEAM) process is a novel process to efficiently remove the difficult-to-cut materials. Preliminary experiments show that the quality of the machined surface is influenced by the processing parameters including the discharge energy, flushing pressure and discharge polarity. In this paper, a 3-factor, 2-level full factorial experiment was conducted to investigate the influence of the processing parameters on surface roughness with BEAM of stainless steel. The experimental results show that the surface roughness increases with the raising peak current and pulse duration, and declines with the raising flushing pressure. Furthermore, a set of comparative experiment was designed to evaluate the integrity of the stainless steel surface machined with positive and negative polarity BEAM. The experimental results indicated that the negative BEAM results in a rough surface and the Ra was up to 55μm, the heat-affected zone was about 13μm and the recast layer was detected. On the contrast, positive BEAM could achieve a better surface and the Ra was less than 9.5μm, the heat-affected zone was less than 5μm and the recast layer was scarcely seen. In addition, comparing with negative BEAM, the positive BEAMed surface was smoother and brighter.

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1. Introduction

The Blasting Erosion Arc Machining (BEAM) is a process which is proposed to perform bulk removing of alloys especially the difficult-to-cut materials by electrical arc. Compared with conventional EDM process, the BEAM process erodes the workpiece materials with electrical arcing instead of sparking, and adding a strong multi-hole inner flushing. Due to arcing is capable of generating a plasma column with much higher energy density, and the high velocity flushing induces a strong hydrodynamic force into the gap to blow off the molten material explosively. Hence, it can achieve a higher efficiency, especially for difficult-to-cut materials [1]. However, the BEAMed surface is rough and requires additional post processing. How to improve the surface quality to it acceptable for subsequent processes is still a challenge to the arc discharge machining technology.

Zhao et al. [2] reported that the thickness of the heat affected zone caused by BEAM is less than 200μm when workpiece material was Inconel718 and the polarity of the workpiece was positive. And Wang et al. [3-4] studied compound machining of super high speed EDM milling and arc machining, the results demonstrate that the thickness of the heat-affected layer machined by super high speed arc machining is less than 100μm. Afterwards, in order to investigate how the polarity effect influence the machining process, Zhao et al. [1] studied the influence of polarity on the performance of Blasting Erosion Arc Machining, and experimental results show that the surface roughness of the BEAMed surface increases gradually with the increasing peak current, the maximum Ra reaches to 360μm and the minimum Ra is about 28μm. Meanwhile, Xu et al [5] discussed the machining characteristics of nickel-based alloy with positive polarity blasting erosion arc machining, and the results show that positive BEAM is capable of greatly improving the machined surface integrity. The surface roughness decreased from 274 μm (under negative polarity BEAM) down to 31 μm (under positive polarity BEAM). Additionally, fewer micro-cracks and a thinner heat-affected

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zone on the workpiece surface can be observed. However, although researches about arc machining are focused on how to achieve a high machining efficiency, the surface quality of the machined workpiece is also important because it has a dramatic influence on the subsequent machining process. Up to now, the influence of machining parameters on the surface quality of BEAM is not reported yet. Hence, this study focus on the influence of the machining parameters on the surface quality of the BEAMed stainless steel workpiece.

Nomenclature

Ra	arithmetical mean deviation of the profile
I_p	Peak current
T_{on}	Pulse duration
P	Flushing pressure

Stainless steel is a kind of widely used material which can be applied in the long-term high temperature, high pressure and high radiation circumstances. Presently, lots of researches have been reported in electrical discharge machining of 304 stainless steel. M. Dastagiri et al. [6] investigated the influence of EDM parameters on EDM of stainless steel&En41b, and the results show that Ra is affected significantly by the current, voltage, pulse on, and duty factor. The maximum Ra reaches to 8.1μm and the minimum Ra is about 3.1μm. Safian Sharif et al [7] investigated the influence of Electrical Discharge Machining (EDM) input parameters on characteristics of EDM process, the results show that the surfaces roughness is closely related to peak current and pulse on time, and the minimum value of surface roughness Ra can reach 3.363μm. Rajmohan.T et al [8] reported the optimization of parameters in Electrical Discharge Machining (EDM) of 304 Stainless Steel, the results show that the current and pulse off time are the most significant machining parameter for MRR in EDM of 304 stainless steel. In this paper, the machining characteristics of BEAM with different polarity were described and a 3-factor, 2-level full factorial experiment was conducted to investigate the relationship between the machined surface roughness and the processing parameters with Blasting Erosion Arc Machining of stainless steel. Afterwards, results were analyzed based on the experimental data and the metallographic photos of the recast layer and heat-affected zones.

2. Experimental Conditions and Procedure

2.1. Experiment Setup and Conditions

The experiments were conducted on a 5-axis BEAM machine. As shown in Fig.1, the electrode was fixed on a rotatable flushing device which can supply a strong internal flushing to the electrode. The working fluid was water based dielectric.

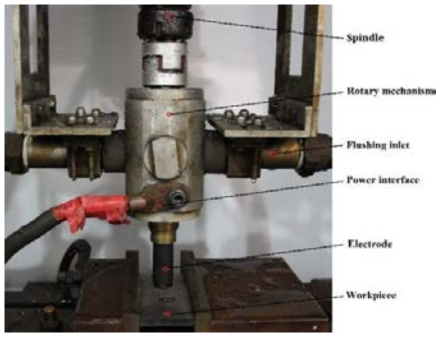

Fig. 1 Experimental Setup

The workpiece material used for the experiments was stainless steel. The mechanical properties of stainless steel are presented in Table 1. Meanwhile, a cylinder electrode with 2 flushing holes was used for the machining test, and the diameters of the electrode and its hole were 10mm and 2mm, respectively. During the experiments, the cylinder electrode fed in a layer milling mode, and a set of grooves with a depth of 2mm and a length of 50mm were machined on the workpiece.

Table 1 Mechanical properties of stainless steel

Density (Kg/m^3)	Elastic Modulus (GPa)	Thermal conductivity (W/m.k)	Hardness (HRC)	Specific heat (J/Kg.k)
8000	193	16.2	40	500

2.2. Experimental Procedure

Preliminary fractional experiments results show that the peak current, the pulse duration and the dielectric flushing pressure were significant for the machining surface quality. Hence, other factors were set to be constant for all experiments, such as the spindle speed was 1000 rpm, the open voltage was 90V and the pulse interval was 1ms. The indexes of the machining performance were surface roughness Ra. The surface roughness Ra was measured by a surface profiler (Type: Mitutoyo SJ210), and the profile length for the profiles is 5mm. The value of surface roughness Ra is the average of three measurements to assure the measuring accuracy. The surface integrity of the machined workpiece was detected by a metallographic microscope.

For a comprehensive analysis of the main effect and interaction effect of the factors, a 3-factor, 2-level full factorial experiment with 4 center points was designed. The experimental parameters are listed in Table 2.

Table 2. Experimental factors and levels

Factors	Levels (low, high)
Pulse duration, t_{on} (ms)	2 8
Peak current, I_p (A)	100 500
Flushing pressure, P (MPa)	1.2 2.0
Electrode polarity	- +