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Experimental Study of Laser Etching on Al_2O_3-SiC Composite Ceramics

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Abstract

Analyze the composition of micro area of the laser etched surface via X-Ray Energy Dispersive Spectrometer, and by analyzing the elemental change rule of Al_2O_3-SiC composite ceramics, study the removal mechanism of laser direct etching on Al_2O_3-SiC composite ceramics, and compare with composite etching of water jet and laser. The results show that: In the process of laser direct etching, Al_2O_3 mainly happens the molten removal, a large number of tiny molten particles concentrate the etched surface, so the content of aluminum is increased, but for SiC, because of the decomposition needs a more laser energy, so the SiC has a little decomposition. In the process of composite etching of water jet and laser, water jet with certain pressure can wash a lot of molten particles of Al_2O_3, reducing the accumulation of molten particles of Al_2O_3, the content of aluminum is decrease, the content of silicon is increased relatively.

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Keywords: Composite ceramics, Laser etching, Composition, Mechanism, Water jet

1. Introduction

Owing to SiC particles are added in the Al_2O_3 substrate, Al_2O_3-SiC composite ceramics can significantly improve the strength and fracture toughness and wearability[1-3], but as a difficult-to-process material, Al_2O_3-SiC composite ceramics have the same defects like the Al_2O_3 ceramics, which often appears serious tool wear, material fracture, rough surface in the conventional machining methods. Laser ablation processing is a kind of special processing method which is non-contact, no-cutting force, the small area of heat influence, clean[4-5], so it is widely used in various engineering fields. Ji L[6] adopted the CO_2 laser whose biggest power is15kw to cut 10mm thickness of Al_2O_3 ceramics, the surface roughness of the machined material can reach to 16-23um, Cheng MF[7] investigates the influence of the factors such as frequency of CO_2 laser pulses, laser average power and the pressure of assistant air on the quality of cutting. However, laser processing also has some defects, when laser ablates material directly, the range of laser ablation is larger, thus the melting volume of material is larger, however in the process of laser direct ablation, existing some problems such as poor ablation morphologies and microcracks, which affects the processing quality seriously. In order to solve this problem, water jet is introduced, on the one hand, making full use of the flushing action of water jet, which can can take away a lot of slag in the groove, on the other hand, making full use of the cooling effect of water jet, which can avoid thermal stress to form microcracks, so water jet improves the processing quality of groove effectively. The speed of water jet is an very important factor, suitable speed is necessary, the speed is too big or too small, both have a bad effect on the cooling and impact effect of the water jet.

In order to compare the morphology differences of laser direct etching and the water jet assisted laser hybrid etching on Al_2O_3-SiC composite ceramics, analyze the composition of micro area of direct etching and water jet assisted laser hybrid etching via X-Ray Energy Dispersive Spectrometer, discuss the elemental change rule in the process of etching, study the removal mechanism of Al_2O_3-SiC composite ceramic.

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2. Experimental materials and Device

This experiment uses the Al_2O_3–SiC composite ceramics, the size of the material is 20x20x3mm, the mass fraction of SiC in the Al_2O_3–SiC composite ceramics is about 60%,the specific composition and physical parameters are shown in table 1.

Table 1.The composition and physical parameters of Al_2O_3–SiC composite ceramics

Composition	SiC	Al	Al_2O_3
Mass fraction（%）	60~65	20~25	10~15
Density（g.cm-3）	3.215	2.70	3.95~4.1
Mohs hardness	9.5~9.75	2.5~3	9.0
Melting point（℃）	\	660	2050
Boiling point（℃）	2830	2327	2980
Thermal conductivity（w.m-1.k-1）	25.5~40	237	36

The experimental device was mainly composed of the laser system and the water jet system, schematic diagram of experimental apparatus is shown in figure 1.The laser systems uses Nd^{3+}:YAG solid laser cutting machine, the model is HGL-LMY500, the range of out-put power is 0~500w,the pulse width is 0.2~10ms, the pulse repetition frequency is 0~ 100Hz, oxygen is the assisted gas and the pressure is 0~0.5MPa. the workbench can move by the linkage of three axis, workbench is controlled by CNC system, The main function of the water jet system is shooting water jet, the velocity of water jet is adjusted through the pump's rotary switch, the water jet's velocity increases when rotating the switch anticlockwise and the water jet's velocity decreases when rotating switch clockwise, the speed of water jet is 0~32m/s.

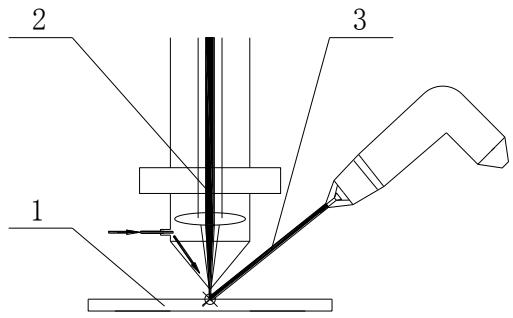

Fig.1.Schematic diagram of experimental apparatus
1—workbench; 2— laser beam; 3—water jet beam

3. Results and analysis

3.1 .The morphology comparative study of laser direct etching and water jet assisted laser hybrid etching on Al_2O_3-SiC composite ceramics

In the experiments, laser energy is 19.5mj, the pulse width is 0.8ms, the pulse repetition frequency is 35Hz, the scanning speed of laser is 0.8 mm/s, the pressure of the assisted gas is 0.5MPa, the defocus distance is 1.5mm, The scanning length of laser is 10mm. the speed of water jet is 16m/s which is measured through several times. Compare the surface and cross-sectional morphologies of laser direct etching and the water jet assisted laser hybrid etching on Al_2O_3-SiC composite ceramics, as shown in figure 2 and figure 3 respectively.

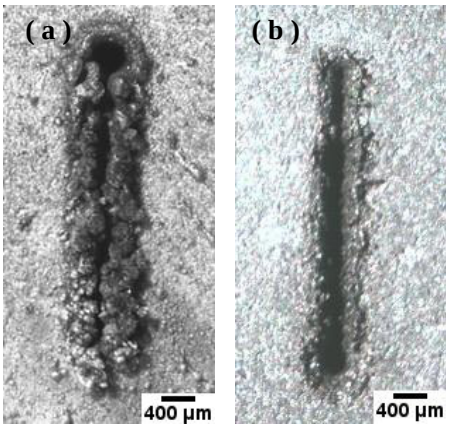

Fig.2 .The surface morphology compare of laser direct etching and water jet assisted laser hybrid etching on Al_2O_3-SiC composite ceramics

Figure 2 (a) is the surface morphology of laser direct etching on Al_2O_3-SiC composite ceramics by magnifying 20 times, Figure 2 (b) is the surface morphology of water jet assisted laser hybrid etching on Al_2O_3-SiC composite ceramics by magnifying 20 times, From the contrast of figure 2 (a) and 2 (b), it can be obviously seen that the surface morphology of water jet assisted laser hybrid etching is better than direct etching in the condition of the same process parameters, this main shows that the surface of the water jet assisted laser hybrid etching has no the accumulation of slag, the thickness of recast layer is low, and the heat affected zone is small. This is mainly due to the water jet in the process of laser etching, laser energy transfers into water jet partly, the bubble created from constant impact of water jet is help for the discharge of slag, the water jet can also play a role in washing a lot of slag, reduce the thickness of recast layer, and also can use the cooling action of water jet, lessen the heat affected zone, as shown in figure 2 (b). when it has no water jet in the process of laser etching, the main material removal is light heat effect, a large number of the melt was splashed into the two sides of the groove, as the melt cannot discharge, it can solidify again and form slag, then adsorbed on the surface of groove, the new formed slag also can be adsorbed on the formed surface