Precision Engineering 45 (2016) 143–152

Contents lists available at ScienceDirect

Precision Engineering

journal homepage: www.elsevier.com/locate/precision

Study on methods of enhancing the quality, efficiency, and accuracy of pulsed laser profiling

Cong Zhou[a], Hui Deng[b,c,*,1], Genyu Chen[a]

[a] State Key Laboratory of Advanced Design and Manufacturing for Vehicle Body, Hunan University, Changsha 410082, China
[b] Hunan Provincial Key Laboratory of High Efficiency and Precision Machining of Difficult-to-Cut Material, Hunan University of Science and Technology, Xiangtan 411201, China
[c] College of Mechanical and Electrical Engineering, Hunan University of Science and Technology, Xiangtan 411201, China

ARTICLE INFO

Article history:
Received 16 October 2015
Received in revised form
30 December 2015
Accepted 12 February 2016
Available online 20 February 2016

Keywords:
Tangential laser profiling
Bronze-bond diamond grinding wheel
Quality
Efficiency
Accuracy

ABSTRACT

A pulsed fiber laser was employed in a systematic study on the tangential profiling of a coarse-grained bronze-bond diamond grinding wheel. The goal of the present study was to improve the profile quality and enhance the efficiency and accuracy of the profiling process. Our results demonstrate that when using a long laser pulse, graphitization of the grain after profiling is unavoidable. However, by blowing argon from the side onto the surface during laser profiling, the degree of graphitization can be reduced, thereby improving the profiling quality. Higher laser peak power resulted in higher profiling efficiency. Only when the laser depth of cut was equal to the initial surface profile error of the grinding wheel, i.e., the "deep single layer cut, stepwise feeding tangential laser profiling method" was used, could the highest profiling efficiency be attained. Increasing the peak power of the laser or the overlapped rate of the laser scanning paths enhanced the profiling accuracy with no appreciable effect on the quality. After laser profiling, the initial circular runout and parallelism error of the surface of the grinding wheel were reduced from 83.1 and 324.6 μm to 6.8 and 3.8 μm, respectively. Because the peak power of the pulsed fiber laser was not sufficiently high, the surface profile accuracy of the grinding wheel was slightly lower than the profile accuracy using the diamond wheel.

1. Introduction

Laser profiling can be used to obtain high profile accuracy and good surface quality for grinding wheels that must be dressed (Fig. 1). The effects of ideal laser profiling can be summarized in three aspects: (1) high accuracy – high surface profile accuracy of the grinding wheel; (2) high quality – low damage to the grains and binding agents; and (3) high efficiency – high removal efficiency of the grain and binding agent.

When profiling a grinding wheel, the incident laser beam is normally either in the radial or tangential direction. In the radial direction, the laser beam can sharpen but cannot accurately shape the grinding wheel. To address this issue, Walter et al. [1–3] conducted experiments on tangential laser profiling of a hybrid-bonded (metal-vitrified) cubic boron nitride (CBN) grinding wheel and demonstrated the feasibility of tangential laser profiling. However, conclusions were not reached concerning the degree of surface profile accuracy that could be achieved. Recently, our research team [4–6] has employed a tangential laser profiling method on a bronze-bond diamond grinding wheel, and a circular runout of approximately 10 μm was attained. Although the surface profile accuracy of the grinding wheel was significantly improved, the profiling efficiency was low. In addition, although laser profiling could achieve higher accuracy, during ultra-high precision grinding, a surface circular runout of approximately 2 μm is normally required. For example, Zhao et al. [7–9] of the Harbin Institute of Technology used a cup-shaped diamond wheel combined with in-process electrolytic sharpening to dress 91-μm diameter grains of an electroplated diamond wheel. The circular error was reduced to within 2.5 μm, and the surface roughness of the workpiece ground by the wheel was 20 nm. Thus, laser profiling has yet to meet the accuracy requirements of ultra-high precision grinding.

In view of this, we conducted systematic studies to determine methods of improving profile quality and enhancing profiling efficiency and accuracy. The parameters that determine the effects of laser profiling were summarized, and experiments on the laser profiling of a coarse-grained bronze-bond diamond wheel were

* Corresponding author at: Hunan Provincial Key Laboratory of High Efficiency and Precision Machining of Difficult-to-Cut Material, Hunan University of Science and Technology, Xiangtan 411201, China. Tel.: +86 15173238527.
E-mail address: denghnu@163.com (H. Deng).
[1] Joint first author.

http://dx.doi.org/10.1016/j.precisioneng.2016.02.005

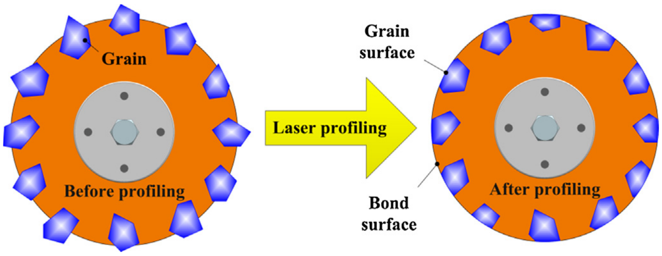

Fig. 1. Laser profiling of a grinding wheel.

conducted. The effects of the process parameters on profiling were studied. Profiling experiments using a pulsed fiber laser with optimal parameters were conducted, and the surface accuracies were compared with that of profiling using a diamond grinding wheel.

2. Experiments

2.1. Experimental materials

The experiments were conducted using a $100D \times 10T \times 5X \times 31.75H$ coarse-grained bronze-bond diamond grinding wheel (as shown in Fig. 2(a)) with a diameter (D) = 100 mm (radius (R) = 0.5 × D) and width (W) = 10 mm. The grains were irregular polyhedrons with diameter (d_0) = 126 μm (as shown in Fig. 2(b)).

2.2. Experimental setup

Fig. 3(a) depicts a schematic diagram of the pulsed fiber laser (model YLP-1/120/50/50-HC) profiling setup. The average power of the laser was P_{avg} = 20–50 W; the pulse repetition frequency was f = 50 kHz, and the pulse width was τ = 210 ns. After collimation, the Gaussian laser beam was focused (laser focal spot diameter of d = 35 μm and r = 0.5 × d) tangentially on the surface of the grinding wheel mounted on the spindle of a MGS-250AH surface grinder.

During profiling, the ablation head of the laser was moved down a distance a (i.e., the depth of cut was a, as shown in Fig. 3(b)) by the electronically controlled translation stage (model 7STA01A). The ablation head then scanned back and forth along the axial direction of the grinding wheel, directly removing excess grains and binding agents from the surface. Real-time measurements of the grinding wheel surface circular runouts were performed using a charge-coupled device (CCD) laser displacement sensor (model LK-G80) synchronized to the motion of the ablation head. Argon gas was blown from the side onto the surface or grinding fluid (model SY-1HSG) was injected from the side. The diameter of the nozzle was 4 mm, and the pressure of the argon jet was 0.1 MPa.

After the experiment, the surface topography, surface roughness, and graphitization degree of the grains of the grinding wheel were measured by a VHX-S1000 large depth of field three-dimensional microscope, a JB-4V surface roughness tester, and a LabRAM-010 Raman spectrometer, respectively.

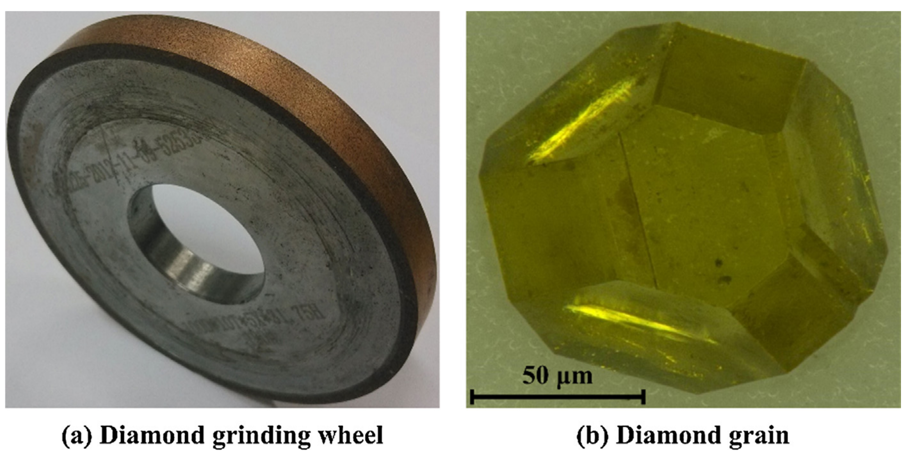

Fig. 2. Bronze-bond diamond grinding wheel.

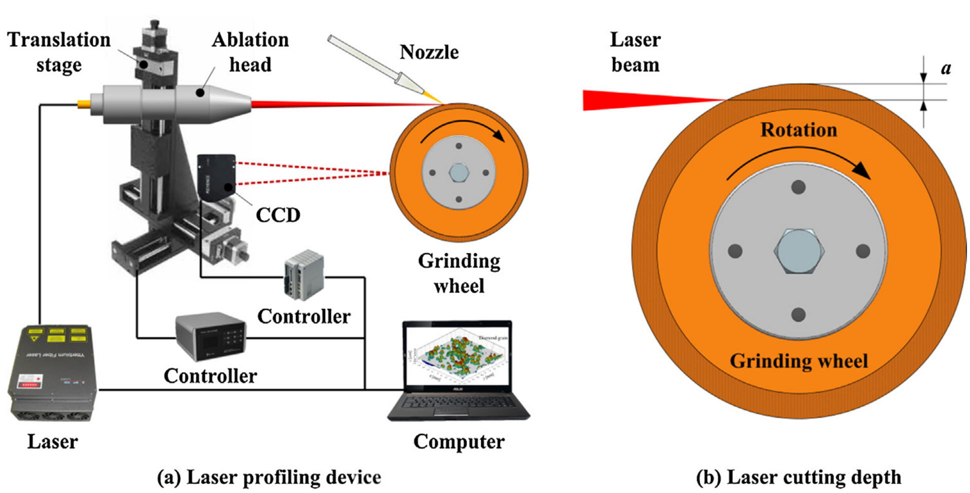

Fig. 3. Schematic diagram of the experimental setup.