Optics and Laser Technology 109 (2019) 418–428

Contents lists available at ScienceDirect

Optics and Laser Technology

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

Full length article

Precision grinding of silicon nitride ceramic with laser macro-structured diamond wheels

Xiaohong Zhang[a,b,*], Zhicheng Zhang[a], Zhaohui Deng[c], Si Li[a], Qiaoping Wu[b,c], Zhongxiong Kang[a]

[a] *College of Mechanical Engineering, Hunan Institute of Science and Technology, Yueyang 414006, PR China*
[b] *Advanced Manufacturing Technology Research Center, Liverpool John Moores University, Liverpool 999020, UK*
[c] *Hunan Provincial Key Laboratory of High Efficiency and Precision Machining of Difficult-to-cut Material, Intelligent Manufacturing Institute, Hunan University of Science and Technology, Xiangtan 411201, PR China*

HIGHLIGHTS

- Precision grinding of silicon nitride ceramic was effective under LMSG conditions.
- The grinding forces and grinding temperature decreased significantly.
- Probability of ductile removal increased under LMSG conditions.
- Structured pattern geometry produced great impact on the surface generation.

ARTICLE INFO

Keywords:
Laser macro-structured
Grinding force
Grinding temperature
Subsurface damage

ABSTRACT

Silicon nitride ceramics are extremely difficult and time-consuming to machine with conventional methods due to high strength and hardness. Laser-assisted machining has been a field of extensive research during the past decade, as it is a promising solution to enhance the machinability of many difficult-to-cut materials, including silicon nitride ceramics. To enhance the processing precision of silicon nitride ceramic grinding, in this work a laser macro-structured method using pulsed laser is proposed and applied to produce certain macro patterns on the surface of diamond grinding wheel. Grinding performance of the macro-structured grinding wheel is tested and compared with a non-structured grinding wheel. It is found that the laser structured pattern has a strong influence on the grinding characteristics. The normal and tangential grinding forces for laser macro-structured grinding (LMSG) condition are 16.3% (15.1%) lower than that in the conventional grinding (CG) condition. The grinding temperature and subsurface damage decrease significantly for LMSG condition. However, due to the influence of pattern geometry, the improvement for surface roughness is not obvious. The groove wear does not reveal a significant increase in wear of the structured grinding wheel.

1. Introduction

Difficult-to-machine materials, such as ceramics and high temperature alloy, have attractive applications in the field of high technology because of their good mechanical properties. It is known that silicon nitride ceramic have good functional properties such as high temperature wear resistance, high hardness, high tensile strength, high thermal resistance, excellent chemical inertness, low thermal conductivity and high fracture toughness value [1,2]. However, the great hardness and brittleness associated with engineering ceramics lead to high grinding forces, inherent material removal difficulties, high wheel wear, as well as surface and subsurface damage. Therefore, investigating effective machining techniques for improving the machinability of engineering ceramics has become a new and fascinating area research topic.

Many researchers have made tremendous effort in the grinding mechanism of silicon nitride ceramics over the past decades. Kumar et al. [3] investigated the grinding mechanism of silicon nitride ceramics by utilizing nanofluids. The results indicated that the nanofluids considerably improve the process performance in terms of grinding forces, surface finish and subsurface damage. Liu et al. [4,5] reported the effect of process parameters on the ground surface quality and grinding forces during diamond grinding of silicon nitride. It was demonstrated that low depth of cut leads to smooth surface with enhanced

* Corresponding author at: College of Mechanical Engineering, Hunan Institute of Science and Technology, Yueyang 414006, PR China.
E-mail address: jansbomb@126.com (X. Zhang).

https://doi.org/10.1016/j.optlastec.2018.08.021
Received 5 June 2018; Received in revised form 17 July 2018; Accepted 12 August 2018
Available online 23 August 2018
0030-3992/ © 2018 Elsevier Ltd. All rights reserved.

strength and vice-versa. Wan et al. [6] build a prediction model for the subsurface damage depth of silicon nitride ceramics and analyzed the influence of different grinding parameters on subsurface damage depth. As a fact, the wear of diamond wheel frequently lead to thermal damage and large residual stress on workpiece surface and subsurface. Therefore, wear mechanism of grinding wheel in machining ceramics was widely studied. Yu et al. [7] investigated the wear mechanism and life expectancy of electroplated CBN grinding wheels. This paper provided a framework for the electroplated CBN grinding wheels' life cycle assessment and the detailed topological evolution of the wheel surface. Zhang et al. [8] studied the diamond wheel wear mechanism and its impact on the surface generation of RB-SiC/Si carbide under parallel grinding. The inherent complexity of the grinding process leads to difficulties in its analysis, leading to the limitations of the accuracy and efficiency of the super-abrasive wheel during grinding.

To improve the grinding performance of super-abrasive grinding wheel, some researchers have put forward a series of structured methods. For instance, Jin et al. [9,10] presented a construction and manufacturing method of discontinuous grinding wheel with multi-porous grooves. Daneshi et al. [11] investigated the performance of twist free surfaces grinding by structured grinding wheels. The experimental result indicated that the structured methods have great advantages in grinding in terms of grinding force and temperature reduction. Denkena et al. [12] presented an innovative method for the machining of patterns into the grinding wheel topography in a flexible and productive way by using fly-cutting kinematics. The patterned grinding wheels showed great potential to enhance the overall grinding performance by significantly decreasing process forces and grinding burn. Nakayama et al. [13] studied the influence of helical grooves on the grinding performance of a conventional vitrified bonded wheel. Mohamed et al. [14,15] studied the influence of circumferential grooves on the creep feed grinding performance of vitrified alumina wheels at different wheel surface areas. Guo et al. [16,17] presented a series of micro-structured coarse-grained diamond wheels for optical glass surface grinding aiming to improve the grinding performance. Compared with conventional coarse-grained diamond wheel, the subsurface damage depth was reduced effectually. However, the better surface roughness was not obtained by the micro-structured coarse-grained diamond wheel. Silva et al. [18] presented the possibilities and limitations of structured surfaces using special grinding wheels. Walter et al. [19,20] proposed a laser structuring method employing picosecond lasers and applied to produce various micro patterns on the surface of hybrid bonded (metal-vitrified) CBN grinding wheels. The grinding force was significantly reduced because of the microscopic and patterning of the grinding wheel. From the literature review above, it can be seen that many scholars made a lot of researches on the microcosm and mesoscopic structure of the grinding wheel and acquired significant contributions. However, the advantages including the enhanced coolant transportation ability and the improved chip disposal of the microscopic or mesoscopic-structured grinding is not obvious.

In this paper, we study the characteristics of macroscopic structured diamond grinding wheel by laser ablation and silicon nitride ceramic grinding. Laser macro-structured grinding force model is established. Meantime, the grinding forces are compared and the influence of the workpiece speed, the wheel speed and the depth of cut on the grinding force are discussed. The difference of grinding temperature, surface roughness, surface morphology, subsurface damage and grinding wheel wear are compared and investigated under LMSG and CG conditions.

2. Experimental procedure

2.1. Experimental apparatus

Laser ablation experiments are conducted by a compact pulsed ytterbium-doped fiber laser (Model: YCP-1-120-50-50-HC-RG). The laser energy output has an approximately Gaussian distribution. The laser beam is transmitted to the inducing head with a standard isolator fixed on a vertical motorized translation stage (Model: 7STA01A) by a single-mode fiber. The laser processing is conducted on a 4-axis laser machining workstation (X-Y-Z linear, B rotary). The diamond wheel are clamped to the rotary axis and located in the center of the focal plane of the scan head lens. A segmental structured process is realized by step-wise rotation of the B-axis, whereat for each step, a pattern segment is processed on a defined section of the wheel surface through beam deflection by the scan head. The laser apparatus is displayed in Fig. 1.

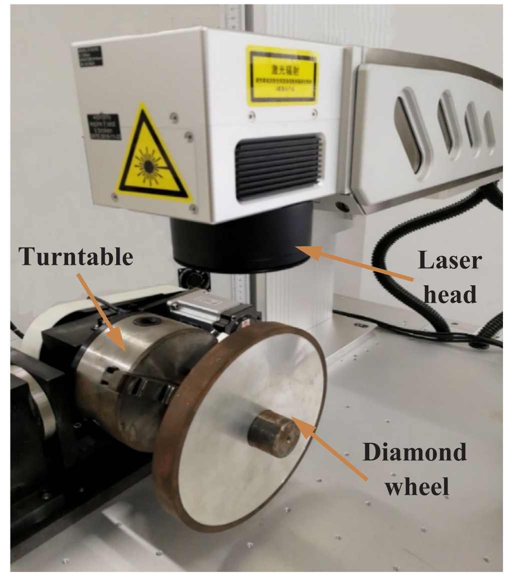

Fig. 1. Experimental apparatus for laser structured.

Grinding experiments are carried out in the down grinding mode on a MGK7120 type grinder. All experiments are conducted under wet condition that a 3% solution of water-based coolant (Type W20) is applied. The flow rate of cooling fluid is 18 L/min in all experiment. Normal and tangential grinding forces are measured by means of a dynamometer (Kistler Instrument Corporation, type Kistler 9257B) immobilized on the machine table, and force signals are recorded by a personal computer via a data acquisition system. The temperature measurement technique used in our experiments is the foil/workpiece thermocouple method. The grinding facilities is shown in Fig. 2. Relevant grinding parameters used in all tests are listed in Table 1.

2.2. Experimental materials

The grinding material used in this study are silicon nitride ceramic. Its relative molecular mass is 140.28 g/mol, the density is 3.44 kg/m^2,

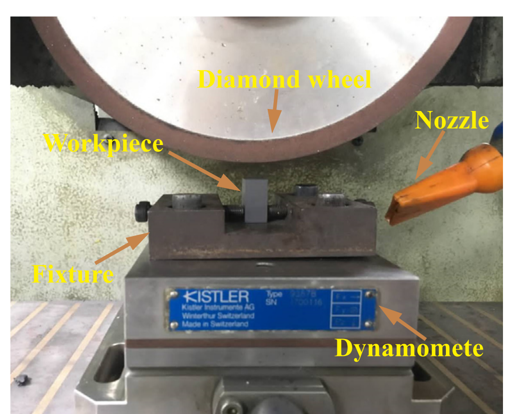

Fig. 2. Experimental apparatus for grinding silicon nitride ceramics.

Download English Version:

https://daneshyari.com/en/article/11003655

Download Persian Version:

https://daneshyari.com/article/11003655

Daneshyari.com