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Measurements of surface texture parameters after ultrasonic assisted and conventional grinding of ZrO_2 based ceramic material characterized by different states of sintering

Roman Wdowik[a]*, Janusz Porzycki[a], Marek Magdziak[a]

[a]*Rzeszów University of Technology, Department of Manufacturing Techniques and Automation, al. Powstańców Warszawy 12, 35-959 Rzeszów, Poland*

* Corresponding author. Tel.: +48 17 865 11 32; fax: +48 17 854 25 95; *E-mail address:* rwdowik@prz.edu.pl

Abstract

The article presents the results of measurements of surface texture parameters after ultrasonic assisted grinding (UAG) and conventional grinding (CG) of ZrO_2 based ceramic material. The machined samples are characterized by different states of sintering. Ultrasonic 20 linear machine tool and two different diamond grinding pins were applied to machine ceramic samples. Surface roughness measurements were performed and the values of parameters were computed using Infinite Focus Real 3D microscope (optical focus-variation technique) and 3D scanner Talyscan (contact measurement). The results of measurements were analyzed in order to state the influence of machining conditions on surface texture parameters.

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Keywords: grinding, ultrasonic, roughness, ceramic

1. Introduction

Ultrasonic assisted grinding (UAG) is a hybrid machining process. There are different variants of ultrasonic assisted grinding. Usually, ultrasonics are applied by the use of vibrations of a grinding pin (a tool) or a workpiece. It is also possible to use ultrasonic vibrations of a tool and a workpiece at the same time. There are lots of scientific investigations which prove the usefulness of ultrasonic assisted grinding of hard and brittle materials (e.g. ceramics) [4, 7, 13 – 15, 17] and ductile materials (e.g. steel [12], nickel based superalloys [1], titanium alloys [8]). Usually, the influence of ultrasonic vibrations on selected quality indicators such as process forces, surface roughness, tool wear and accuracy of parts is investigated by researchers. The quality of surface plays the important role among quality indicators. Denkena et al. [2] stated that, after micromachining of ceramic samples with ultrasonic assistance, values of Ra can be obtained between 20 and 30 nm. Liang et al. [6] stated that there are two components of vibrations in elliptical ultrasonic assisted grinding – radial and axial. They also conclude that axial vibrations have the positive impact on surface roughness, while radial vibrations lead to lower process forces. The similar investigations were performed by Yanyan et al. [16]. They describe the results of ultrasonic assisted grinding of ZrO_2 based ceramic material. The results of experiments, regarding surface roughness, indicate the better surface quality after ultrasonic assisted grinding. Ra parameter was measured in these experiments [16]. The significant investigations were also carried out by the performers of CORNET project which concerned ultrasonic assisted grinding of different hard and brittle materials. Their work is presented in report [13]. In the case of ZrO_2 based ceramic material, the authors of report stated the influence of feed rate and mounting torque of a tool on surface roughness of machined slots. The similar results to the report are also presented in papers [4, 5, 14] of the contractors of this CORNET project. The tool wear and the method of cooling also play the important role in shaping of the surface roughness [5, 9]. Gao et al. [3] stated that the critical depth of cut, when the ductile material removal mechanism is the dominant one, was increased in ultrasonic assisted grinding of nano-ZrO_2, comparing to the

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conventional grinding. In paper [18] the influence of depth of cut, feed rate, and the cutting speed was investigated in the case of Al_2O_3 based ceramic material.

This article presents the investigations of ultrasonic assisted grinding process with vibrations of a tool. The influence of machining conditions on surface texture parameters was investigated.

2. The need for measurements of surface texture

There are several reasons for the measurements and analysis of surface texture parameters after ultrasonic assisted grinding process. The first of these reasons is a lack of sufficient data, regarding surface texture parameters measurements after UAG in existing publications. The results presented in the introduction and the results of other work are usually based on the measurements of parameters of a profile (e.g. Ra).

The next reason is associated with the results of microscopic investigations of different surfaces machined in ultrasonic assisted and conventional grinding. Ultrasonic assistance leads to the visible change of surface texture but material properties have an influence on the material removal mechanisms. The investigations, regarding alumina and zirconia ceramics, performed at Rzeszów University of Technology indicate the differences in material removal mechanisms for these two materials. Grinding of alumina based ceramic material reveals rather brittle fracture while grinding of zirconia based ceramic material leads to clearly visible plastic deformations [15]. Grinding of Al_2O_3 based ceramic material leads also to the removal of directional traces of grains after UAG (Fig. 1). Because of more plastic deformations, the differences between the surfaces machined in conventional and ultrasonic assisted grinding are visible in microscopic images in the case of zirconia based ceramic material (Fig. 2).

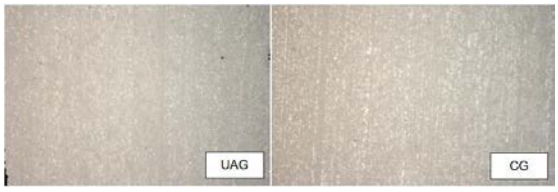

Fig. 1. Example of machined surfaces of Al2O3 based ceramic material (CG – conventional grinding, UAG – ultrasonic assisted grinding) [15]

The presented results are identical to these which were obtained by other researchers and are presented in selected publications, e.g. [4, 7].

This work is also motivated by the previous research. Investigations in the area of surface roughness were focused on the measurements of parameters of profile (Ra, Rz, Rt) in two directions - parallel and perpendicularly to the direction of feed [15]. The machining process was performed with the use of the lateral surface of grinding pins. The results of investigations usually illustrate the worse surface roughness in the case of hybrid machining of ZrO_2 based ceramic material – mainly for the measurements in the direction of feed. Figure 3 illustrates the differences in Ra values after ultrasonic assisted grinding and conventional grinding. It can be, inter alia, stated that the values of Ra for the measurement performed perpendicularly to the direction of feed compared to the measurements parallel to the direction of feed are higher. It is a typical observation for conventional grinding but ultrasonic assistance, for specific machining conditions, did not change the results of this observation [15].

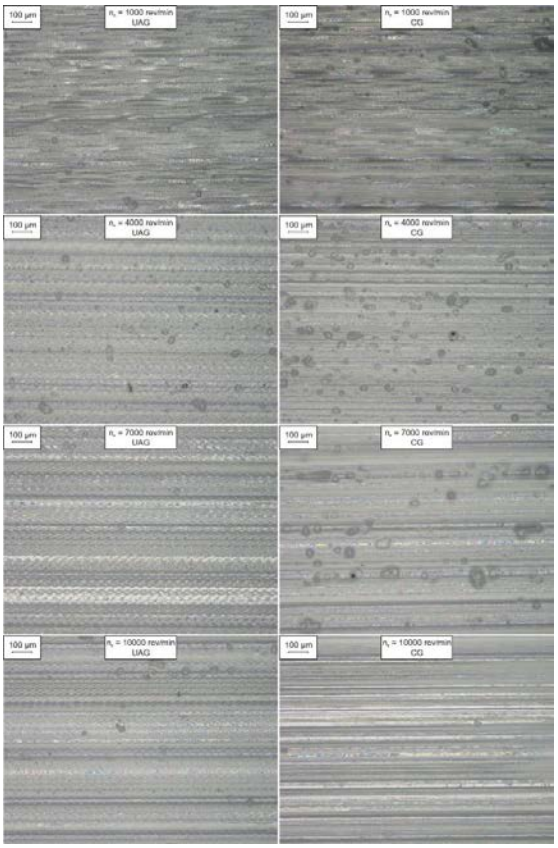

Fig. 2. Comparison of machined surfaces of ZrO2 based ceramic material (CG – conventional grinding, UAG – ultrasonic assisted grinding)

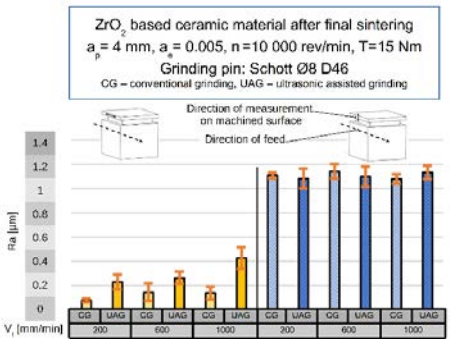

Fig. 3. Comparison of the results of measurements of Ra parameter [15]