Proceedings of the 14th eu**spen** International Conference – Dubrovnik – June 2014

Binderless-cBN for micro machining

E. Uhlmann[1,2], D. Oberschmidt[1], J. Polte[2], D. Lorenz[2], M. Polte[2]
1 Fraunhofer Institute for Production Systems and Design Technology, Germany
2 Institute for Machine Tools and Factory Management, Technische Universität Berlin, Germany
Julian.Polte@iwf.tu-berlin.de

Abstract

A new generation of binderless-cBN for micro machining of ferrous materials has been investigated. In this paper, detailed information about cBN-tools for turning operations, cutting edge preparation by grinding and polishing as well as the first results of cutting tests are given.

1. Motivation

There is a strong need for ultra-precision cutting of ferrous materials in industry. Especially hardened steel mould with optical surface finish and high accuracy in shape are required. The use of diamond tools is well known for machining aluminium and other non-ferrous materials. Cutting of ferrous materials leads to an excessive tool wear on the diamond. PAUL ET AL. [PAU96] have described a relation between a chemically influenced wear of the diamond tool and different workpiece materials that feature unpaired d-electrons in their atoms. The excessive wear of the diamond tool led to another strategy to avoid the direct cutting of ferrous materials. Currently, steel moulds are coated with nickel-phosphorus-layers, the hardest known material which can be treated by diamond machining without an excessive wear [BRI00]. In spite of the hardness of the nickel-phosphorus-layer the lifetime of the coated steel mould is not as long as the uncoated and hardened steel mould [GLA04]. Additionally the coating process leads to an increase of the product costs and development time. In this content many investigations have been done, one approach was the ultrasonic vibration cutting by MORIWAKI and SHAMOTO [MOR91].

2. Cutting edge preparaption for binderless-cBN-tools

Consequently a new specific of binderless-cubic-boron-nitride-(cBN)-tools has been developed. The binderless-cBN is a new cutting material in the field of micro machining and has not been investigated widely. The cBN has been sintered without any binder phase by Sumitomo Corporation, Itami, Japan. The Cutting edge preparation for the recent generation of binderless-cBN has been done by grinding and polishing. The cBN-material was machined by Mössner GmbH, Pforzheim, Germany and equipped with a corner radius $r_\varepsilon = 50$ µm. Figure 2.1 shows two stages of cutting edge preparation. At first the soldered cBN-tip was machined with a grinding wheel and in the second step the rake face was machined by polishing. Based on machine kinematics a polishing process of the flank face is possible from a corner radius $r_\varepsilon = 200$ µm. For the visualization of the cBN-tools a scanning electron microscope LEO 1455 VP of the company Leica Electron Optics was used.

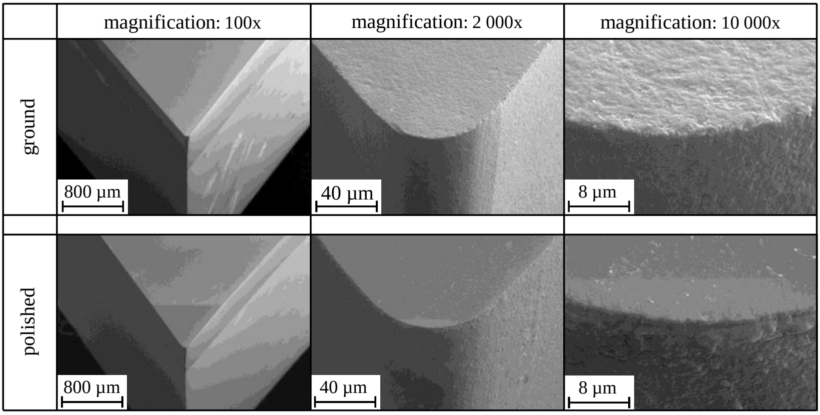

Figure 2.1: Comparision between ground and polished cutting edges

Cutting edge preparation by grinding and polishing influenced the surface topography of the rake face as well as the flank face and is illustrated in figure 2.1 and figure 2.2. The ground cBN-tool shows an arithmetical mean deviation Ra = 32 nm and an average surface roughness Rz = 245 nm on the rake face. The cutting edge which was prepared by polishing shows a smoother rake face and an improved cutting edge quality. The rake surface of the polished cBN-tool shows an arithmetical mean deviation Ra = 11 nm and an average surface roughness Rz = 70 nm. The measured arithmetical mean deviation Ra was decreased by 65.6 %, the average surface roughness was decreased by 71.4 %. The surface characterization was carried out by using a Hommel-Etamic nanoscan 855, Jenoptik industrial metrology Germany GmbH, Schwenningen, Germany and an atomic force microscope (AFM) Bruker N8 from the company Bruker Corporation, Billerica, USA.

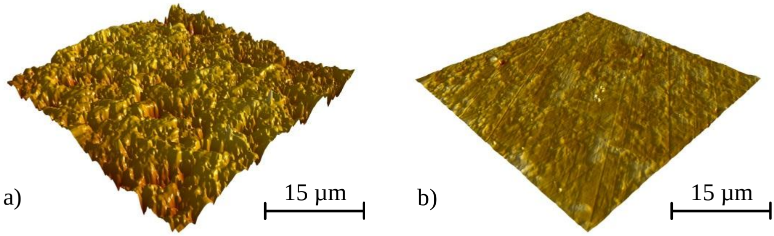

Figure 2.2: AFM-Image of the investigated cBN-material a) ground b) polished

The cutting edge radius r_β was measured with the mentioned AFM. The cutting edge radius r_β of the ground cBN-tool shows a volatile progression along the corner radius r_ε. The measured cutting edge radius was $r_\beta = 1.87$ µm with a standard deviation of $s_n = 0.83$ µm; number of measurements n = 10. The polished cBN-tool shows a smooth progression along the corner radius r_ε which could contribute the chip removal. The measured cutting edge radius was $r_\beta = 1.43$ µm with a standard deviation of $s_n = 0.25$ µm; number of measurements n = 10.

3. Cutting tests

Preliminary face turning cutting tests with polished binderless-cBN-tools were carried out on an ultra-precision machine tool NANOTECH ® 350 FG of the company MOORE NANOTECHNOLOGY SYSTEMS, LLC, Swanzey, USA, which is usually used for diamond machining. STAVAX ESR with a hardness of 52 HRC and a grain size $d_{gs} = 16$ µm was used as workpiece material. The arithmetical mean deviation Ra and the average surface roughness Rz were measured with a white light interferometer NewView 5010 of the company ZYGO CORPORATION, Middlefield, USA. A piezoelectric dynamometer KISTLER MiniDyn 9256C2 was used for the cutting force acquisition. Figure 3.1 shows the arithmetical mean deviation Ra as well as cutting force F_c in dependence of the cutting speed v_c. An arithmetical mean deviation Ra = 14 nm was achieved by using a cutting speed $v_c = 3$ m/min. In addition the cutting speed $v_c = 3$ m/min led to the lowest cutting force $F_c = 0.1$ N. In the further progression the arithmetical mean deviation Ra and the cutting force F_c show a varying distribution in dependence of the cutting speed v_c.

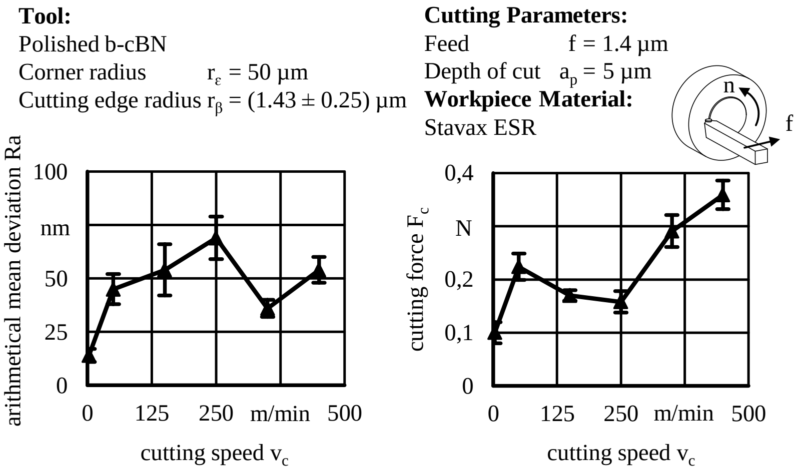

Figure 3.1: Results of the cutting test

4. Conclusion and outlook

As a result of this work, a new approach for micro manufacturing of steel mould is shown. An arithmetical mean deviation of Ra = 14 nm and an average surface roughness of Rz = 38 nm could be achieved. In the next step a tool with a corner radius r_ε = 200 µm with polished rake face and flank face will developed and tested. Further research activities address cutting edge preparation by ion beam etching and laser machining. This work is funded by the German Research Foundation (DFG) within the project “Ultra-precision machining with binderless-cBN”.

References:

[BRI00] Brinksmeier, E.; Riemer, O.: Wirkmechanismen bei der Mikrozerspanung. Materialwissenschaft und Werkstofftechnik, Vol. 31 (2000) Issue 8, P. 754 – 759.

[GLA04] Gläbe, R.: Prozess- und Schneidstoffentwicklungen zur ultrapräzisen Drehbearbeitung von Stahl. Forschungsberichte aus der Stiftung Institut für Werkstoffe Bremen. Aachen: Shaker, 2004.

[MOR91] Moriwaki T., Shamoto E.: Ultraprecision diamond turning of stainless steel by applying ultrasonic vibration. Ann CIRP, Vol. 40 (1991), P. 559 – 562.

[PAU96] Paul, E.; Evans. C.J.; Mangamelli, A.; McGlaufin, M.L.: Chemical aspects of tool wear in single point diamond turning. Precision Engineering, Vol. 14 (1996) 1, P. 4 – 19.