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Honing of grey cast iron with structured CVD-diamond-coated honing tools

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Abstract
Final machining of piston cylinder surfaces is carried out with the finishing process honing. The cylinder bore characteristics, influenced by the surface characteristics such as shape accuracy and roughness, are achieved with conventional grains by at least three or more consecutive honing operations. The stochastic distribution of the conventional grains in the bond leads to an nonreproducible material removal rate and thus to a varying surface topography, which is also influenced by the progressive wear of the honing stones in the form of grain splintering and grain breaking. Thus, a honing tool with geometrically defined cutting edges was developed.
Previously performed investigations have shown that structured CVD-diamond-coated honing stones with different pyramid shapes (tip angle of the pyramids, pyramid width) can be machined reproducibly by grinding. First analyses concerning the cutting behaviour of the structured honing stones in relation to conventional honing stones revealed very uniform surface textures in grey cast iron in which very good and, above all, comparable roughness and material removal rates are achieved.
This paper presents in more detail the application behavior of the structured and coated honing tools during external cylindrical honing of grey cast iron, in particular with regard to the surface textures of the workpiece and the wear of the honing stones over a long processing time. In addition, the paper shows the functional correlation between material removal rate and tool wear in comparison to conventional honing stones.

Honing; structured CVD-diamond honing tool; precision engineering

1. Introduction

The application of structured CVD-diamond-coated honing stones has already shown in first investigations that despite the completely new composition of the honing stones, comparable and reproducible material removal rates and roughness could be achieved in relation to conventional honing stones. This paper briefly describes the composition of the structured CVD-diamond-coated honing stones as well as the fundamental results on the application behavior in external cylindrical honing. An important point regarding the functionality is also the cutting behavior of the structured honing stones with increasing cutting time. In particular, the wear behavior and the material removal rate over time are of interest and will be examined in more detail in chapter 3.

2. Structured CVD-diamond-coated honing stones

The composition of the structured honing stones was selected according to the respective honing steps. Different "grains" were chosen by the design of pyramidal structures on the choice of heights, angles and distances and the form of the pyramidal tips (pointed, flat), so that different surface roughness and material removal rates can be examined. The structuring of the base bodies of the honing stones takes place on a precision grinding machine (Primacon PFM 24) in a profile grinding process [1]. Figure 1 shows the variations of the structures .

Shape	Pyramid width V	Angle δ	Height h
h δ	480 µm	60°	415 µm
h	480 µm	60°	235 µm
h V	480 µm	120°	138 µm
	480 µm	120°	120 µm
	346 µm	120°	100 µm
	173 µm	60°	150 µm

Figure 1. Overview of the machined structures of the pyramids.

In addition, defined pyramid structures with differently shaped tips were fabricated (Figure 2). The investigated structured honing stones were coated with CVD-diamond at the Fraunhofer Institute for Surface Engineering and Thin Films.

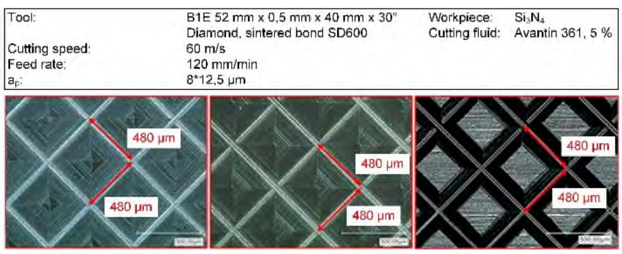

Figure 2. Comparison of different pyramid tips: point-shaped (left), linear (middle) and flat tips (right).

3. Cutting behavior in external cylindrical honing

3.1. Fundamental investigations

The fundamental investigations of the cutting behavior of the structured CVD-diamond-coated honing stones took place at the test rig for external cylindrical honing. The rotating workpiece is located on a hydraulically movable spindle unit and is pressed in feed motion against the oscillating honing stone, in this study with a comparatively low contact pressure of p = 1 N/mm².

Ring-shaped workpieces of grey cast iron EN-GJL-250 with a diameter of 39 mm and a width of 25 mm were machined. Before honing, all rings were prepared by turning them to a similar initial roughness of about R_z = 8-12 µm (Hommel-Taster T1000, T1E (Hommelwerke GmbH). It could be shown that the macrostructure of the structured CVD-diamond-coated honing stones has a significant influence on the resulting roughness and material removal rate (Figure 3). As the density of the pyramids per mm² increases, the force distribution becomes more uniform and the depth of cut per pyramid decreases. The material removal rate and the roughness are lower analogous to conventional grains. Figure 3 also shows the results for unstructured honing stones and flat-shaped pyramids.

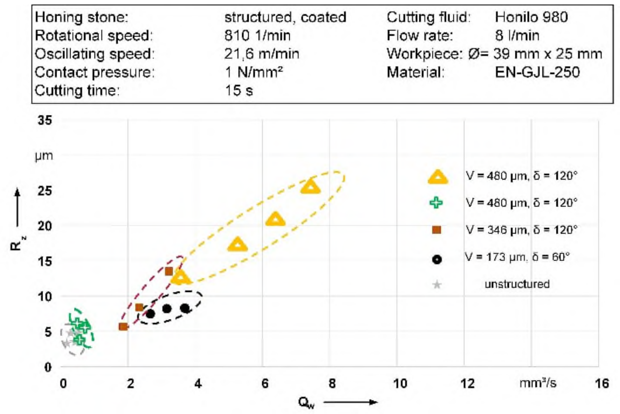

Figure 3. Comparison of the cutting behavior of differently structured honing stones.

3.2. Cutting behavior with increasing tool life

In a further series of investigations, the wear behavior of a structured CVD-diamond-coated honing stone was examined with a significantly longer cutting time. With the honing stone (tip angle δ = 120 °, V = 480 µm) a total time of 17.5 h was honed. After a certain time, the honing process was interrupted and the honed workpiece was weighed so that the honed volume per hour could be detected. In addition, an image of the surface of the honing stone was made with precision molding material in order to avoid removing the honing stone and still be able to detect tool wear. As the cutting time increases, the material removal rate decreases to a quasi-stationary range, just as tool wear changes to a linear progression (Figure 4).

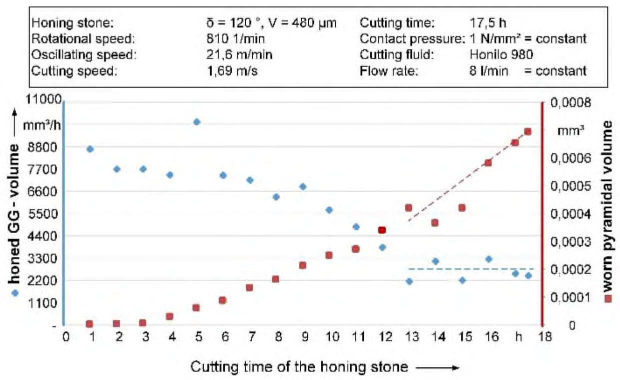

Figure 4. Honed volume of grey cast iron per hour (left axis) and worn tool volume (right axis) plotted over the cutting time of the structured honing stone.

With the structured CVD-diamond-coated honing stone, a gray cast iron volume of V_{GG} = 97865.880 mm³ was honed within 17.5 hours. This corresponds to approximately 85 bores of standard cylinder crankcases with a bore diameter of d = 84 mm, a cylinder bore length of l = 145 mm and a honing oversize of 60 µm in diameter for rough honing. The most noteworthy feature is the very low wear height of the pyramid tips, after 17.5 hours it is only 52 µm. The end of tool life of the honing stone was not reached. With increasing cutting time the pyramid tips become flatter and the honed surfaces become smoother. Based on the observed wear behavior in form of advancing flattening of the pyramid tips at approx. 3 µm/h (Figure 5), the honing stone is still expected to work for further 29 hours.

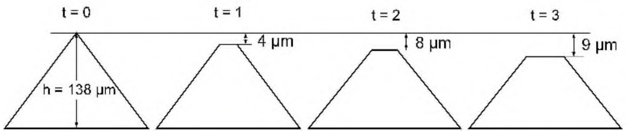

Figure 5. Schematic progress of the wear behavior of the pyramid tips.

Reference investigations with a conventional honing stone D151 over 11.5 h under the same process parameters have shown that around 54 % of the honing stone were already worn. This corresponds approximately to a wear height of 2.15 mm and a wear volume of V_{Wear} = 138 mm³ with a honed grey cast iron volume of V_{GG} = 168173.4 mm³. This results in a G-factor for the conventional stone D151 of G = 1218. Based on the thickness of the honing stone of b_H = 4 mm, it is possible to work with this honing stone for another 11.5 h. The volume machined in external cylindrical honing with the conventional D151 stone corresponds to approximately 147 bores of standard cylinder crankcases.

4. Summary

In this paper, the cutting behavior of structured CVD-diamond-coated honing stones was presented. Therefore, structured and subsequently CVD-coated base bodies were examined during external cylindrical honing. It was shown that for each structure a specific material removal rate and resulting surface roughness was achieved due to the form and shape and thus the number of pyramids per mm². Furthermore, the cutting behavior with increasing tool life has shown promising results in comparison with conventional honing stones. Especially in view of the very low wear of the pyramids a higher tool life of the innovative honing stones is expected. It was also shown that with lower contact pressure higher material removal rates in combination with lower workpiece roughness can be archieved. Thus, in addition to a reproducible honing process a more economical honing process can be accomplished.

5. Acknowledgements

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