euspen's 17th International Conference & Exhibition, Hannover, DE, May 2017
www.euspen.eu

Honing with a new tooling concept – defined cutting edges coated with CVD-Diamond

K. Dröder[1], H.-W. Hoffmeister[1], S. Baron[1]

[1]Institute of Machine Tools and Production Technology, Technische Universität Braunschweig, Germany

k.droeder@tu-braunschweig.de; h.hoffmeister@tu-braunschweig.de; s.baron@tu-braunschweig.de

Abstract
The production of optimum surfaces for piston cylinder surfaces of combustion engines is an important requirement for influencing the engine properties, such as the oil consumption. Final machining of piston cylinder surfaces is carried out with the finishing process honing. In the industrial production process, various honing steps are necessary in order to achieve the required surface quality. Usually honing stones with grains, e.g. silicon carbide or diamond are used, whose grain size is adapted to the respective honing step. The topography of the honing stones changes during processing by the wear of the grains and the bond. For this reason, tool life is limited. Furthermore, the honing process demands a high amount of cooling lubricant, which is required in order to remove the chips from the contact zone between the honing stone and the cylinder wall. This paper presents a new honing tool that has geometrically defined cutting edges. This results in defined chip spaces, which can be adjusted in such a way that their size is adapted to the occurring specific material removal rate of the respective honing step. Thus, an improved chip removal with a simultaneous lower cooling lubricant use is enabled. By means of a homogeneously designed cutting geometry of the honing tool, reproducible workpiece surfaces can be achieved. A coating with CVD diamond applied to the defined cutting edges lead to low wear due to the high hardness of diamond. In this case, the crystallite tips of the diamond coating take over an additional machining task as so-called secondary cutting edges. In the following, both the machining of the defined structures on the base body and the first research results in the external cylindrical honing of grey cast iron (EN-GJL-250) are presented.

Honing; geometrically defined cutting edge; tooling concept

1. Introduction

The finishing process honing is one of the machining methods with geometrically undefined cutting edges and is characterized by a continuous contact of the honing tool with the workpiece surface [1]. The composition of the honing stones has a decisive influence on the processing result in honing. The topography of the honing stones is characterized by the size, shape, position and number of the cutting grains [2]. It changes during processing by wear. For this reason, the lifetime of the honing stones is limited.

Due to the required shape deviation and surface topography, several successive honing steps are generally necessary since not all quality requirements can be achieved with one honing step. Gray cast iron cylinder crankcases can be honed with a minimum of three honing steps; some car manufacturers also use five honing steps. In the present paper, a novel tool concept with defined cutting edges is presented which, depending on the honing step, has structures which allow adapted removal rates and surface characteristics.

2. Tooling concept with defined cutting edges

The basic idea for the production of defined honing stones is to grind structures into the basic body according to the respective honing steps. In this case, honed surfaces are to be produced, with honing grooves whose shape, depth and distance from each other is defined. Through the process-adapted design of the macroscopic surface structure, the "grain size" and thus the resulting roughness of the surface can be defined.

The variations in the heights and angles of the structures are chosen in such a way that different cutting behaviors can be investigated. Thus, for example, sharp pyramids should have good cutting abilities, whereas flat pyramids are planned for finishing with low roughness depths and high carrying behavior of the honed surface (Fig. 1).

Figure 1. Possible explanations of macro geometry

2.1. Machining of the defined structures on the base body

Silicon nitride (SN-GP from the producer FCT Ingenieurskeramik) is used as the material for the honing stone base bodies to be structured. This high-performance ceramic is characterized in particular by its high strength, damage tolerance and corrosion resistance. The structuring of the honing stone base bodies is carried out with abrasive wheels in an external round grinding process on a precision grinding machine (Primacon PFM 24) using the contouring control. Diamond grains in metallic bonding are used as cutting tools. The grinding wheels lead to corresponding flank heights and angles of the structures by their profile shape and their profile angle Θ as well as by their width b_S.

2.2. New machined and structured honing stones

Structures were machined in the form of pyramids. In this case, the tip angle δ of the pyramids as well as the pyramid width (grinding wheel offset V) were varied so that honing stones with different tip densities and tip heights h were produced (Fig. 2).

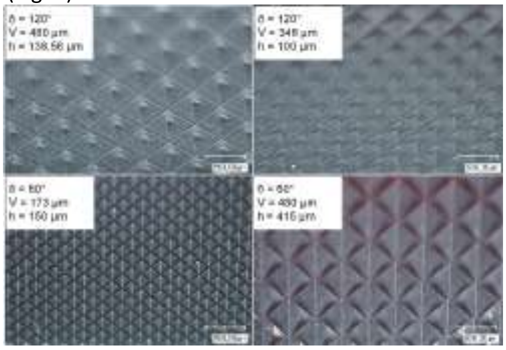

Figure 2. Structural variations of the honing stones

In addition, pyramids with point-shaped (Fig. 3, left), linear and flat tips (Fig. 3, right) were produced by adjusting the infeed depth and the grinding wheel offset.

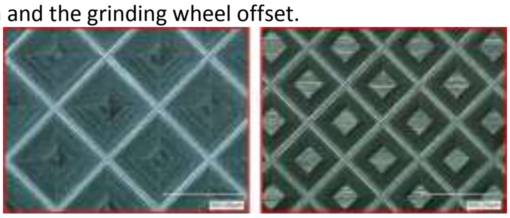

Figure 3. Depictions of the pyramid tips

The structured honing stones were subsequently coated with CVD diamond at the Fraunhofer Institute for Surface Engineering and Thin Films. In this case, the crystallite tips of the polycrystalline diamond coating take on an additional machining task as secondary cutting edges [3] and are intended to lead to a longer lifetime due to the high hardness of diamond.

3. External cylindrical honing of grey cast iron

Ring-shaped workpieces of grey-cast iron (EN-GJL-250) were machined for the research studies. The rings were 39 mm in diameter and 25 mm in length. Before honing they were prepared by turning to a similar initial roughness of about R_z = 8 µm to 10 µm.

The experiments were carried out on a test rig for external cylindrical honing. The workpiece rotates and is pressed in feed motion against the oscillating honing stone. With the machine pressure the contact pressure is adjusted.

At first grey-cast iron rings were machined with conventional honing stones. Tab. 1 shows the process parameters.

Table 1. Process parameters of the honing experiments with conventional honing stones

Grain size	D151-D76-D54-D15
Cutting time [s]	15
Rotational speed [1/min]	810
Oscillating speed [m/min]	4,8 to 21,6
Contact pressure [N/mm²]	1 to 2
Cutting fluid	Honilo 980
Cutting fluid flow rate [l/min]	8

Subsequently, the structured and coated honing stones were tested under a contact pressure of 1 N / mm^2 and the maximum oscillation speed v_a = 21.6 m / min. It could be shown that comparable workpiece roughness is achieved (Fig. 4).

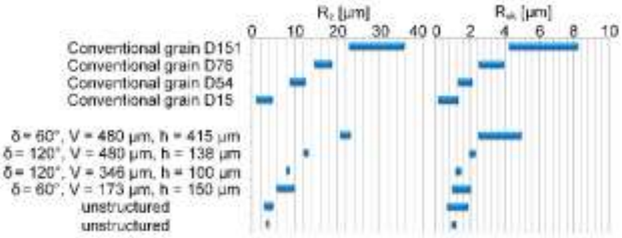

Figure 4. Comparison of the achieved workpiece roughness between conventional honing stones (D151 - D15) and the novel CVD diamond honing stones

The novel honing stones thus enable results comparable to conventional grains. This also applies for the material removal rates Q_W. Some cases are even characterized by the fact that a lower roughness can be achieved at comparable material removal rates. Only minimal wear on the diamond layer could be detected in the form of flattening of the crystallite tips as well as negligibly small adhesions. The resulting honing grooves, on the other hand, were defined and regular and lead to very uniform surface textures.

4. Summary

In the present paper, a new tool concept for honing with defined cutting edges was presented. For this purpose, base bodies made of silicon nitride were structured by grinding and defined pyramids were produced. After coating with CVD diamond, the honing stones were tested in relation to conventional honing stones. It could be shown that with the novel, defined honing stones, very uniform and reproducible surface textures are honed in grey cast iron. An other advantage is the great chip removal rate by a low workpiece roughness. It is assumed therefore that in conjunction with the low wear this innovative honing stones lead to a reduction of the machining time and the number of honing steps, and also to a longer lifetime of the honing stones.

5. Acknowledgements

The IGF project 18682 N of the German Research Association for Galvano- und Oberflächentechnik eV was funded by the AiF within the framework of the program for the promotion of industrial joint research (IGF) by the Federal Ministry of Economics and Energy on the basis of a decision of the German Bundestag.

References

[1] DIN 8589-14:2003-09, Manufacturing processes chip removal - Part 14: Honing and superfinishing; Classification, subdivision, terms and definitions, *Beuth.de*

[2] Flores, G.: Grundlagen und Anwendungen des Honens, 2. Auflage 2017, Vulkan-Verlag GmbH.

[3] Gäbler, J., Schäfer, L., Pleger, S.: Neue Diamantschleifbeläge für Präzisions- und Mikro-Schleifwerkzeuge, Industrie Diamanten Rundschau, Band 39, Heft 3, S.260-268, 2005