NEW MECHANICAL PRETREATMENT PROCESS FOR THERMALLY SPRAYED ALUMINUM CRANKCASES

Hans-Werner Hoffmeister¹, Christian Schnell¹
¹Institute of Machine Tools and Production Technology
TU Braunschweig
Braunschweig, Germany

INTRODUCTION
The increasing demand for vehicles with reduced fuel consumption and emission is the reason why the material aluminum is frequently used for crankcases in the automotive industry. A method to increase the wear resistance of the cylinder bore surface is to use hyper-eutectic cylinder liners, which are cast-in or are assembled by force fitting. Another possibility to improve the tribological behaviour is to coat the surface with a wear-resistant coating by thermal spraying. To guarantee functional and heavy duty coatings, it is necessary that there is a strong bond between the coating and the aluminum body. To achieve this aim, the surface of the cylinder bore has to be pretreated. State-of-the-art are blast processes as well as employing chemical bond coats. These processes have some disadvantages like high investment and process costs, environmental pollution with chemical remainder or expensive grit reconditioning. Therefore, a new pretreatment process has been developed. This new machining process is a kind of modified fine boring process. During machining a defined profile is cut into the surface by using a PCD-tool with a special geometry. The tool rotates and moves axially with a defined feed rate through the cylinder bore. The resulting profile is a reproducible and defined structure which — regarded in a cross-section — reminds of a dovetail. The undercuts in the cylinder surface secure a strong bonding between the aluminum substrate and the coating. Adhesion tensile strengths up to 60 MPa were measured, which clearly exceed the values which can be achieved by high-pressure water-jet roughing. Another advantage of the mechanical pretreatment method lies in the fact that the machining can be accomplished on the fine boring machine. The fine boring process is a step in the process chain which cannot be substituted up to now. Therefore, there is no necessity for an extra pretreatment machine. This also means that additional time and therefore costs for the transport and a readjustment in the fixture of the crankcase can be avoided. Another advantage of this new machining process is the short cutting time with about 10s per cylinder bore, depending on material and cylinder length. Therefore, the process can be excellently integrated into the process chain.

The significant advantages of this new pretreatment process seem to offer an interesting alternative to the state-of-the-art pretreatment processes for thermally sprayed light-metal crankcases.

STATE-OF-THE-ART
Thermal spraying is an excellent method to provide cylinder bores of aluminum crankcases with a wear resistant coating. This coating has a thickness of one or two hundred microns after the concluding honing process. To assure the functionality of the coating on a real engine it is necessary that there is a strong bond between the aluminum alloy and the spraying material. The main reason why the coating adheres to the substrate is mechanical interlocking. Besides, the adhesive tensile strength is influenced by adhesive forces and diffusion processes between the different material components [1]. State-of-the-art are blast processes like high-pressure water-jet roughing or grit blasting, as well as employing chemical bond coats like the NiAl/Flux procedure. These processes show profound disadvantages like high investment and process costs or the laborious diposal of the chemical remainders.

These disadvantages were the reason to look for an alternative pretreatment method. This process should be a cutting process with a defined cutting edge. Furthermore, it has to meet the following demands:

• High adhesive tensile strength between aluminum and coat (> 30 MPa)
• Machining time < 30 s / cylinder bore
• Defined and repeatable surface topography
Applicable to the fine-boring process of the cylinder bore

The mentioned machining time and the adhesion tensile strength of more than 30 MPa are values which are known for the high-pressure water-jet roughing.

**MECHANICAL ROUGHING OF CYLINDER BORES**

After casting the crankcases, a lot of machining operations (drilling, milling) have to be carried out before the spraying of the cylinder bore is possible. One of these processes is the fine-boring process which is normally accomplished on a machining centre. Therefore, the mechanical roughing process should be applicable to the fine-boring process. This implies that there is no need to change the clamping device and no blasting plant is needed so that investment and prime costs can be reduced.

The used tool body is a fine-boring tool. Only the cutting insert is replaced by a special insert for mechanical roughing.

During the cutting process the tool rotates and moves axially with a defined feed rate through the cylinder bore. The result is a helix with the cutting profile. During preliminary inspections it was shown that a mechanically roughed surface has to feature numerous undercuts, so that the coating adheres to the aluminum [2]. A lot of surface profiles have been tested and best results were gained with a profile which reminds of a dove tail (fig. 1). The two undercuts which are arranged symmetrically inhibit the removal of the coating by occurring shear forces.

Figure 2 shows a schematic diagram of a roughed cylinder bore. Different cutting materials (carbide tools, coated carbide tools, CBN) were examined, at which polycrystalline diamond (PCD) proved to be the best choice for roughing aluminum-alloy crankcases.

As a result of the adhesive tensile strength test, values up to 57 MPa were measured. Best results were reached when the cutting depth amounted from 100 to 120 µm. When the cutting depth is too low (<75 µm), the undercut area is not sufficient and the bond between the coat and cylinder bore is weak (fig. 3). A further increasing of the cutting depth is not advisable because the strain to the tool increases. Furthermore, more spraying material is needed to pour in the undercuts. This causes higher spraying times and increasing material costs.
The tool geometry was developed at the Institute of Machine Tools and Production Technology in Braunschweig, Germany. The tool consists of two parts: a carbide base body and a soldered PCD cutting insert. The insert shows two edges each with a corner radius amounting to 20 µm. The geometry is produced by wire electro discharge machining and the chosen edge and entering angle affect the shape of the undercuts.

To understand the cutting process figure 5 shows a schematic diagram. During machining the first edge produces the first undercut which looks like a sawtooth. Then, the second cutting edge generates the opposite undercut so that the dovetail profile is completed (fig. 5).

Summary
This new mechanical pretreatment method uses a special PCD insert which is clamped to a fine-boring tool. This insert consists of two cutting edges which are arranged symmetrically. The cutting profile reminds of a dovetail. The roughing process shows some strong advantages in comparison to conventional pretreatment methods like high-pressure water-jet roughing or chemical bond coats. The adhesive tensile strength is high (up to 57 MPa) and the cutting time is short (~10 s / cylinder bore). The biggest advantage is that the fine boring machine can be used so that there is no need for an additional pretreatment machine and for changing the clamping of the workpiece. This means that process- and investment costs can be reduced.

Therefore, the mechanical pretreatment method seems to be an interesting alternative to conventional pretreatment methods. Currently, different modifications of the cutting tool and the influence of coolant are tested to improve tool lifetime.
REFERENCES