Process control of thermally sprayed coatings

A new measuring device enables rapid and non-destructive coating thickness measurement in thermally sprayed coatings. Process deviations can be detected and corrected early on.

Prof. Dr. Nils Reinke

If the usual grey cast iron insert in the aluminium crankcase is replaced by a thermally sprayed iron-base coating, very high requirements must be specified regarding porosity and mechanical properties of the aluminium casting in the area of the cylinder bores. The actual coating process essentially consists of four steps: fine boring, roughening, coating and post-processing. Between the individual process steps, tests are conducted for quality assurance. The tests must be conducted up to 100% depending on the number of units, application and critical quality parameters. The purpose of the fine boring is to align the bore to the crankshaft axis as well as to enlarge the bore, in accordance with the desired layer thickness after the final processing. Both the shape and position tolerances are determined here, and the cylindricity is also produced. Only very limited positional tolerances can be corrected later regarding the thickness of the coat, which amounts to a few hundred micrometres. The bore is thus set in position before the roughening and coating process.

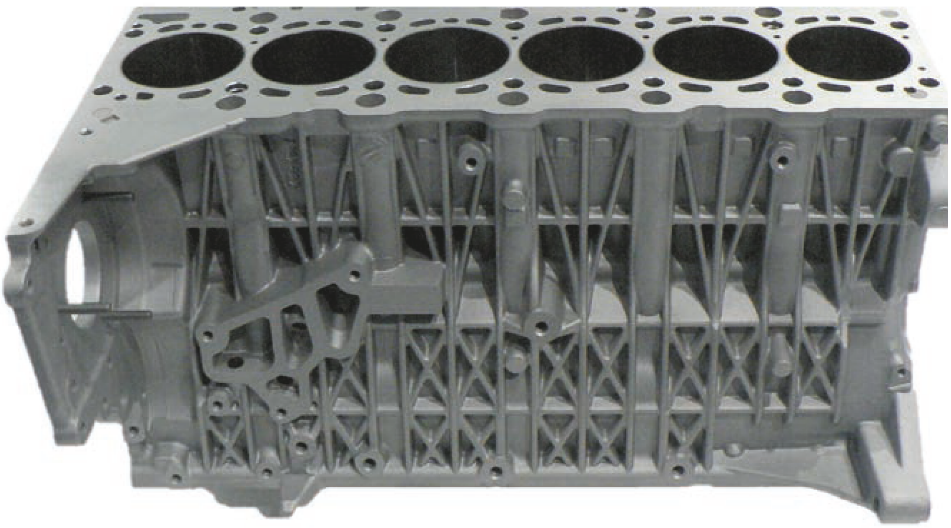


Figure 1 > If the conventional grey cast iron insert in the crankcase of an eight-cylinder engine is replaced with a thermally sprayed iron-based coating, it results in very high requirements regarding the porosity and mechanical properties of the aluminium casting in the area of the cylinder bores.

The roughening of the cylinder surface serves to produce the required coating adhesion. This step is accomplished either by blasting corundum, high pressure or pulsed low pressure fluid jets or by a purely mechanical processing. The corundum blasting and the fluid jet processes for roughening the surfaces to be coated are conducted in a separate plant.

The mechanical roughening of the crankcase can typically be performed after fine boring in the same clamping. Thus, the roughening profile can be introduced without offset. Next, an optical image recognition is used to detect possible surface defects and to sort for reworking. In the case of corundum blasting, such surface defects can be embedded corundum particles; in the case of fluid jet, it is mainly stripped phases and dilated pores.

Figure 2 > For coating thickness measurement, the measuring optics are inserted into the cylinder bore (upper bore cut open). Thus, the coating thickness can be reliably measured at any position in the circumference and in the depth of the cylinder bore.

In the case of mechanical roughening, a groove profile is cut into the aluminium. The shape of this profile, which also has indentations, and its metallic glossy surface make it unsuitable for inspection by a camera system.

Increased service life of the engine

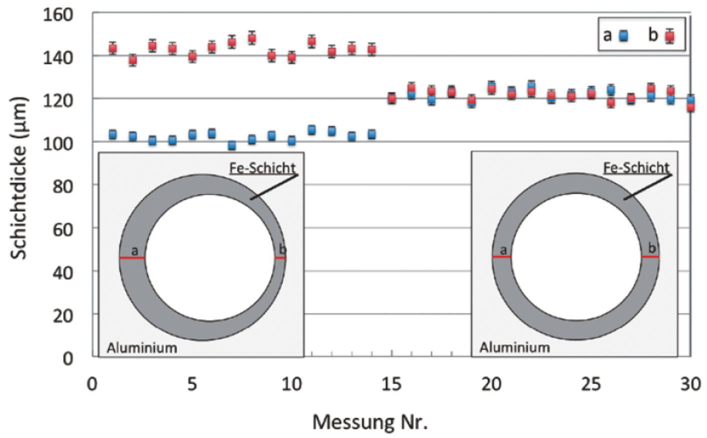
The thermal spraying process is distinguished in that the coating material is fused by a thermal source, for example a plasma flame, and spin-coated onto a component by a gas flow. The liquid particles solidify abruptly upon contact with the surface and produce a coating in layers. By means of the powder-based atmospheric thermal spraying, almost all materials can be processed. The layer spectrum ranges from thermoplastics and metals and carbides to ceramic layers. The iron-based coatings provide the required tribological properties and are available as wire or powder. Wire arc spray coating, the plasma transferred wire arc (PTWA) and the rotating single wire (RSW) are examples of the wire coating process.

The powder-based atmospheric plasma spray coating also offers the option of spraying ceramic materials in addition to metals. Low alloy carbon steels are mainly used for the coatings of the running surfaces of both gas and diesel engines. The coatings are heterogeneous and consist not only of fused and solidified particles. Within the coatings, oxides and carbides build up, as well as pores, the frequency of which being between 1 to 4%, depending on the choice of process parameters and process. These pores are used as a lubricant reservoir after the honing and bind the lubricant to a fixed location. Frictional forces between the piston ring / piston and the cylinder wall are thereby reduced to a minimum, the fuel consumption is reduced and the service life of the engine is increased.

Coating thickness measurement under one second

The thickness of the still unprocessed thermal spray coat must follow narrow tolerance bands. Any deviation from the specified tolerances can lead to subsequent re-processing and destruction of the honing tool in the subsequent processing step. Using early coating thickness measurement, any subsequent processing steps in the value-addition chain can be spared, for example, if the coating thickness is too small. Traditional coating thickness measuring instruments feature a low accuracy of repetition due to the rough sprayed surface and therefore are not suitable for quality assurance. Random checks via photomicrographs are very time consuming and do not allow a seamless and non-destructive inspection of the coating process. In turn, the new device (CoatMaster) from Winterthur measures the average coating thickness via a widening of the measuring surface to a diameter of 1 to 3 mm. As a result, even at high roughnesses, high repetition accuracies of 1 to 2% are achieved. A measurement takes less than a second and thus the testing of several measurement points for each bore is also possible in the series production.

The measuring instrument is based on the procedure of the thermal coating test. The light source of the device heats the sprayed coating surface by a few degrees Celsius for a period of a few milliseconds. It determines the chronological sequence of the surface temperature via optical elements and an infrared sensor.



Measurement no.

Figure 3 > The coating thickness measurement inside the cylinder working surface from bottom to top at opposite points (a, b). Measurements 1-15 Crankcase 1, Measurements 16-30 Crankcase 2.

The technical data of the used light source are comparable with photographic flash tubes and do not pose any hazard to humans or the environment. More than 100,000 temperature readings are analysed for each measurement process, which then determines the coating thickness. The measurement can be conducted with an adjustable measuring surface of 2 to 50 mm from a distance of up to one meter. The error of single measurement is typically under 1%. Coating thicknesses can be recorded with a frequency of up to 2 Hz. Through an optical measuring probe *(Figure 22),* which is screwed onto the device, measuring positions are automatically recorded in a fixed grid over the entire cylinder working surface. "The CoatMaster makes it possible to produce accurate and fast coating thickness measurement of the thermally sprayed coating in a non-destructive manner directly in the process. Process deviations that influence the coating thickness can be detected and corrected quickly," explained Dr. Peter Ernst, Head of SumeBore running surface coating technology at Oerlikon Metco.

Reduction in surface roughness

In the final honing process, the structures on the rough sprayed surface are removed and thus the roughness of the surface is reduced to an average roughness rate in the range of <5 microns.

A final layer thickness measurement at defined positions of the cylinder working surface allows inspection of the concentricity of the honed coating and the fine boring. Due to the higher reflectance of honed surface, the standard deviation of the coating thickness measurement increases by 2 to 4% with the measuring instrument. A determined asymmetry *(Figure 3)* can be easily corrected by adjusting the honing tool when honing with a rigid axis. //

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