

SUMEBore - The Coating Solution to Protect Cylinder Liner Surfaces

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ABSTRACT

Rising fuel prices and more stringent requirements in the field of the vehicle emissions such as nitrogen oxides, particulate matter and carbon dioxide will increase the pressure on the engine manufacturers to utilise technologies which contribute to a reduction in these emissions. As a result, interest in cylinder surface coatings has increased considerably in the last few years, also in the SUMEBore® coating solution from Sulzer Metco.

SUMEBore coatings are applied by a powder-based air plasma spraying (APS) process. Such an APS process is very flexible and can also process materials to which wire-based methods do not have any access, particularly metal matrix composites and pure ceramics. The compositions can be tailored to the specific challenges in an engine, e.g. excessive abrasive wear, scuffing, corrosion caused by adulterated fuel or high exhaust gas recirculation (EGR) rates, etc. Over the past several years cylinder liner running surfaces from trucks, diesel locomotives, marine and gas engines, for power generation and gas compression have been coated with such APS materials and engines have been tested successfully. Most of the tested engines achieved significant reductions in lubricant oil consumption (LOC), sometimes in excess of 70%, reduced fuel consumption, very low wear rates and good corrosion resistance on the liner surfaces. Results are presented from a full size test on an EMD-710G3A locomotive engine, which was performed in collaboration with GE Transportation at the Southwest Research Institute (SwRI) in San Antonio, TX.

This APS coating solution has already been commercialized in various markets; it has proven to be suitable for mass production on both new engine blocks and liners, and for repair of worn-out parts. Such coatings will continue to play an important role when it comes to reductions of emissions from internal combustion engines.

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INTRODUCTION

This paper describes the APS cylinder liner surface coating process from its development through a number of industrial applications realized over the past years to the latest testing work with such coatings applied to a full-size EMD-710G3A engine. In this test engine eight out of the 16 cylinder liner inner surfaces were coated with an APS thermal spray coating. The target was to reduce the LOC by at least 50%, when compared to a defined baseline, which is today's standard configuration. LOC test results will be shown, the main elements of the coating process and some of the coating materials will be introduced.

SUMEBORE - THE COATING SOLUTION

In the early 1990s, Sulzer Metco began to develop coating equipment with rotating Air APS torches in order to put

coatings on cylinder inner diameter (ID) surfaces in both aluminum and cast iron engine blocks. Today, this so-called RotaPlasma® equipment is utilized by various original equipment manufacturers (OEM) to coat cylinder bores in engine blocks and liners.

For lined engines the same plasma torches can be used for the coating application but typically with the liner rotating, instead of a rotating plasma torch. [Figure 1](#) shows both an aluminum 4-cylinder block ready to be coated (with two plasma torches working simultaneously) and coated truck liners.

Over many years the APS technology was refined and new materials which are tailored to the various cylinder surfaces to achieve low friction, high wear and corrosion resistance and low oil consumption (to name just a few) were developed. The honing process of such coatings was optimized in order to bring out the advantages of the coating porosity. The progress with regard to development of the

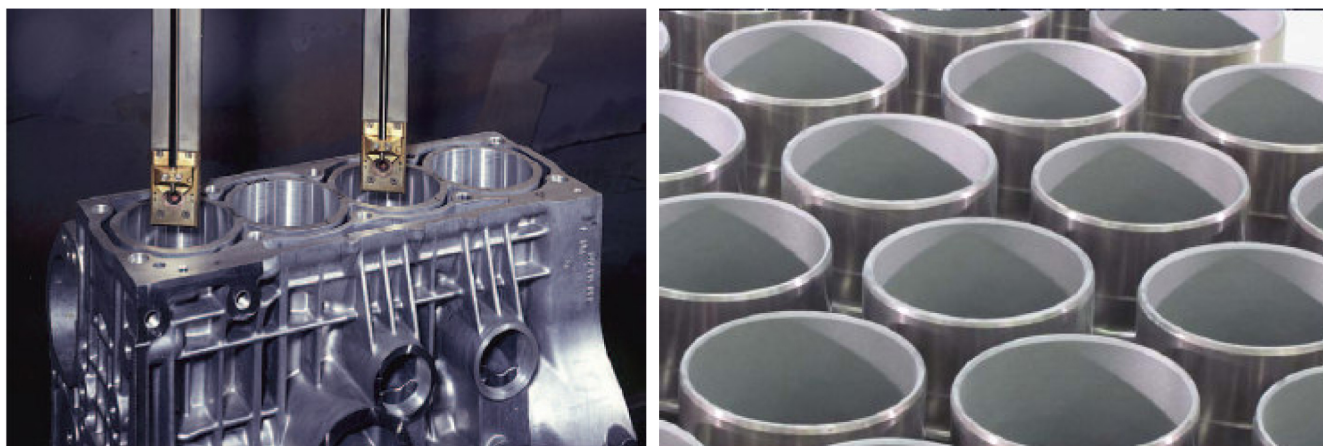


Figure 1. Aluminum engine block with rotating SM F210 APS torches (left) and truck liners coated with rotating liner (right)



Figure 2. Schematic representation of the SUMEBore coating process (from left to right, including honing)

process and the materials has been documented in a number of publications over time [1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27]. Today, the APS cylinder surface coating is offered on the market as a complete solution under the name of SUMEBore.

PROCESS OVERVIEW

The main elements of the APS cylinder surface coating process is portrayed schematically in Figure 2 on an aluminum engine block (without washing/cleaning step). The process flow is identical for coating of liners that are typically made of cast iron or steel.

PREPARATION AND SURFACE ACTIVATION

Before the application of the coating the bore diameter has to be oversized to accommodate the coating. The oversize is determined by the target coating thickness after the final machining (honing). This pre-machining can be carried out by means of line boring, single point drilling, honing, etc. A roughness $R_a < 4\mu\text{m}$ is required after pre-machining. Thereafter the part has to be thoroughly cleaned / washed, to remove any oil and residues from the machining process from the surface. This is typically done in a dedicated washing machine. The minimum surface tension after cleaning and drying is ca. 38mN/m, in the area where the coating will be applied. The cleanliness can easily be checked on the part with a test fluid of defined surface tension [28]. A clean surface is necessary to guarantee the adhesion of the coating.



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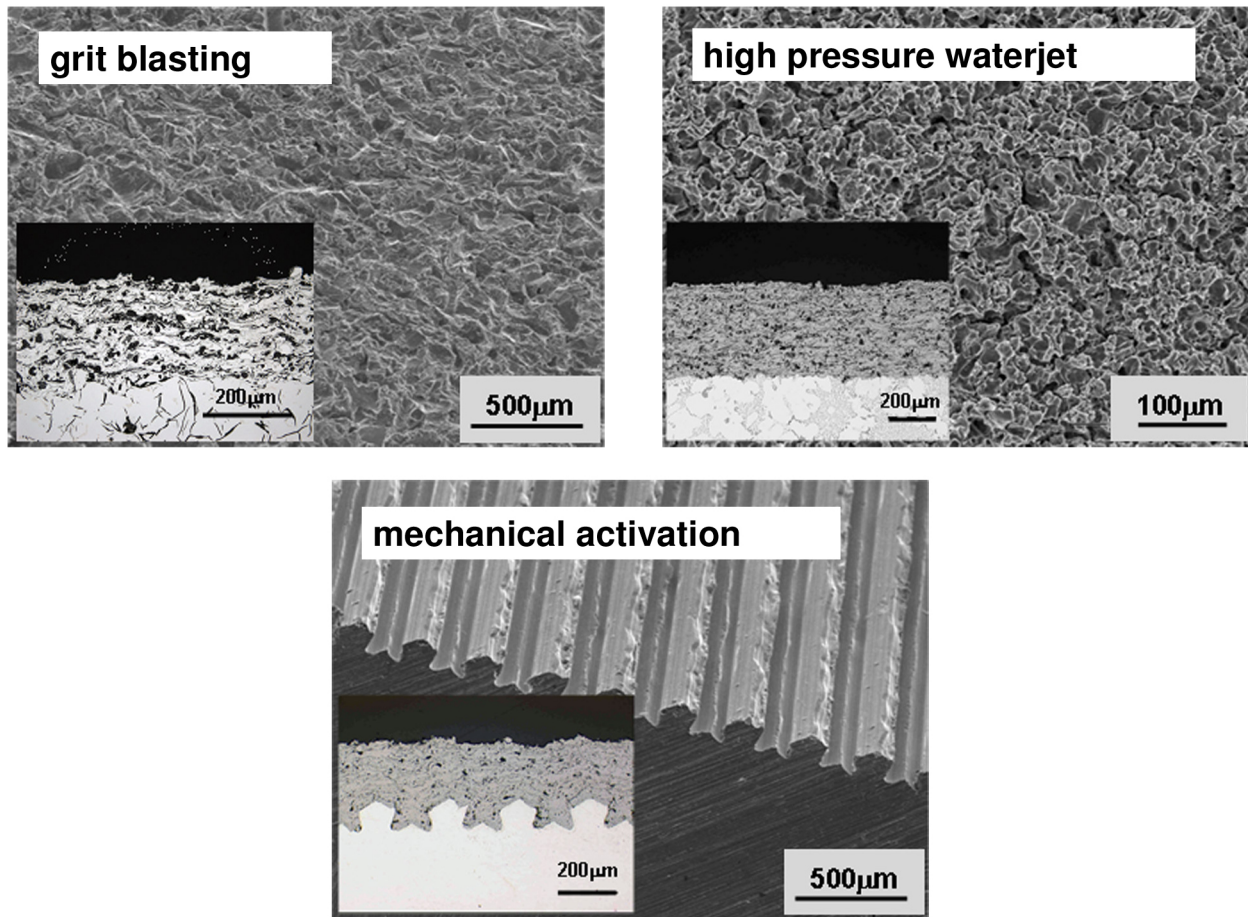


Figure 3. activated surfaces from three different processes. Small pictures: transverse profile of plasma coatings on activated surfaces ("as sprayed"). top left: grit blasting (with Al_2O_3), top right: high pressure water jet activated, bottom: mechanical activation (machining) with the profile of the Braunschweig University of Technology [29]

The next step in the coating process is the so-called surface activation. In principle it consists of a roughening of the substrate surface to increase the surface area and produce a structure which facilitates the mechanical interlocking of the coating with the substrate. This is necessary, because the adhesion is not due to a metallurgical bonding (as known from a weld overlay coating) and this roughening will guarantee the adhesion of the coating. There are a number of processes available for the activation (roughening) of the surface. Activated surfaces generated with the most commonly-used activation processes are shown in Figure 3.

Grit blasting with Al_2O_3 is suitable for the activation of all metal based materials and is most flexible with regard to geometrical constraints, e.g. at the bottom of the bores in engine blocks (pulsation holes, honing allowance, bearing block, etc). Grit blasting is the most frequently used activation process for thermal spray coatings. It is utilized in all the large-scale series production installations in place today for the application of APS thermally sprayed cylinder surfaces, both in engine blocks and cylinder liners. After grit blasting the activated surface is cleaned with pressurized, oilfree and dry air, before the coating is applied. Such a grit

blasted surface is shown in Figure 4 on an 2-stroke diesel EMD 16-710G3A liner which was coated for the engine test in San Antonio.

High pressure water jet activation (without abrasive particles in the water) works well on aluminium but not on cast iron. In principle the mechanical activation (machining a profile) works on both aluminium and cast iron, however, the tool wear during the activation of cast iron is excessively high, which does not allow an economic process [29].

APS COATING PROCESS AND MATERIALS

As indicated above, the APS coatings are applied either with a rotating plasma torch (engine blocks) or if the parts are rotationally symmetrical (liners) they can easily be rotated and the plasma torch will only move up and down in Z-axis during the coating application. Different torches are used depending on the size of the bores. Below a diameter of $\text{Ø}150\text{mm}$, this would generally be the SM F210 gun, while for larger bores which are typically used in both 2-stroke and 4-stroke medium speed diesel engines and gas compressors