

New Polymeric Coating on Sputtered Bearings for Heavy Duty Diesel Engines

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ABSTRACT

Worldwide emissions standards are becoming increasingly rigorous, and this leads to more complex engine demands. Several new PCU (Power Cell Unit) technologies are being applied to cope with these demands. This means engine parameters are changing, e.g. higher EGR (Exhaust Gas Recirculation) rates, higher PCP (Peak Cylinder Pressure), lower viscosity oils, higher oil contamination and soot. Therefore the operating conditions for the bearings have drastically changed, leading to an environment prone to seizure occurrences.

There is a clear demand for seizure resistant bearings motivated mainly by the increased engine complexity described above. Therefore for HDD (Heavy Duty Diesel) applications the PCU robustness should not be compromised also in terms of wear and fatigue resistance. The polymeric coating developed by MAHLE was applied over a sputtered layer and has demonstrated to be a suitable solution to attend to the application demands. The seizure and wear resistance were strongly reinforced with the use of a polymeric coating when compared to a typical Al-Sn sputtered layer. The functional polymeric layer remains in place after long durability tests in a demanding HDD engine.

This paper shows detailed bench and engine test results achieved with this new product to support the conclusions.

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INTRODUCTION

The operating conditions under new emission targets of HDD engines require a more robust bearing system. The LCC (Load Carrying Capacity), wear and seizure resistance are the main parameters to guarantee high performance and durability for the current and future HDD engines.

Due to the high mileage requirement for HDD applications, a sputter bearing is often the only suitable solution. Although sputtered bearings present the highest LCC and wear resistance they are not the most adequate in terms of soft properties, mainly for scuff-seizure resistance.

Global environmental concerns are driving internal combustion engine design to higher efficiency. New legislations are setting up milestones to reach HDD emission limits e.g. NOx and particulate levels. Considering that, the technological trend for the HDD engines indicates that bearings specific loads are increasing which translates into lower oil film thickness and increased operating temperatures. Bearing system under such conditions potentially could increase the occurrences of metal to metal

contact generating a more aggressive bearing operating environment, susceptible to wear and scuff-seizure events [1].

In some cases the option is to introduce a sacrificial or "running in" polymer coating to enhance surface properties to improve compatibility and in consequence increase seizure resistance. The disadvantage of a sacrificial layer is that after a short period of time the layer will wear, increasing operating clearances, noise, oil flow and the risk of premature seizure failure. It was desired to develop a functional coating layer to maintain the soft properties of a polymer coating not just for the running in period.

The proposed solution for the bearing system consists of steel back lead free bronze based materials combined with a functional polymer coating on top of a conventional Al-Sn sputter overlay.

ENGINE BEARINGS

A bearing is a component used to reduce friction and to maintain clearance between stationary and rotating components of the engine. Bearings, or bearing surfaces, are

located on the crankshaft, connecting rod, camshaft, and also in the cylinder block [2].

Most engine bearings have a layered structure, which provides an optimum combination of the bearing material properties, fatigue strength (load carrying capacity), seizure resistance (compatibility), wear resistance, conformability, embeddability, corrosion and cavitation resistance [2].

When developing a material and selecting the appropriate product for each engine application, it is essential to ensure there is a correct balance of hard properties (fatigue and wear resistance) and soft properties (seizure, embeddability and conformability).

According to the number of the main functional layers the bearings may be mono-metal (solid), bi-metal, tri-metal or multi-layer. Most engine bearings are either bi-metal or tri-metal. A typical structure of a tri-metallic bearing is shown in Figure 1.

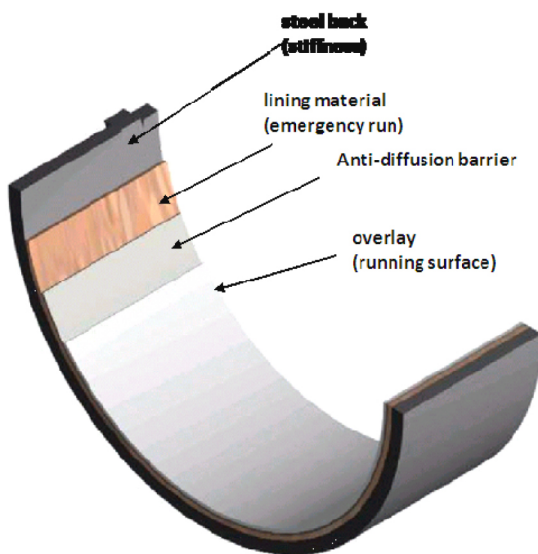


Figure 1. Typical Tri-metallic Bearing Structure

Each one of the layers that composes a bearing has specific function:

- **Steel back** supports the bearing structure, provides its rigidity and press fit under severe conditions of increased temperature and cycling loads.
- **Lining** is a layer located between the steel back and the overlay. This intermediate layer is made of a material with moderate or low anti-friction properties (conformability, compatibility) but high fatigue strength providing durability of the bearing working under alternating loads generated by the internal combustion engine.
- **Anti diffusion barrier** is deposited between the lining and the overlay in order to prevent migration of tin from the overlay into the intermediate material (copper).
- **Overlay** is a thin surface layer made of a soft material with good surface properties e.g. seizure resistance and embeddability.

Bearings for HDD Engines

In HDD applications normally the most important parameter to be considered in the engine bearing design is LCC. This, associated with reasonable wear resistance gives long durability performance demanded by the current heavy duty diesel engines [3].

The graph presented in Figure 2 illustrates the MSL (Maximum Specific Load) that a bearing material can support. This is one of the parameters used to select the bearing material for a certain application. The material ranking was originated from experimental fatigue testing, combined with other design criteria. It can be noticed that Cu based bearings can support higher loads than Al based bearings.

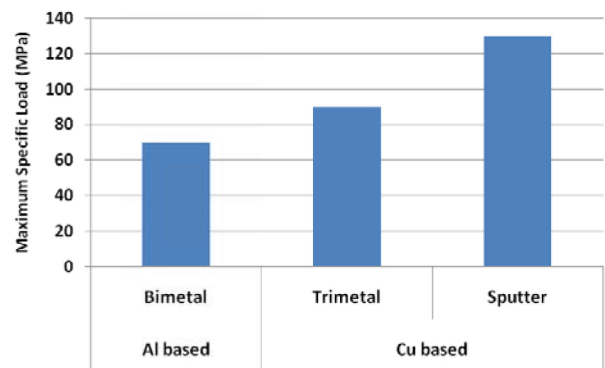


Figure 2. Maximum Specific Load of Typical Bearings as Function of Their Material Composition (MPa)

Commercial vehicles are expected to run over 1.6 million kilometers. These applications require a higher fatigue resistance alloy substrate to enable them to withstand the imposed loads. In this case a copper based alloy is bonded on the steel support backing. Unfortunately, these alloys do not have sufficient conformability and compatibility properties; therefore they are not suitable to be used as functional layers. Copper based substrates have been used for many years, however originally they contained lead and although they were not used as a functional layer, they had improved conformability and compatibility properties. Due to environmental legislation bearings now use lead free materials. [4]

To improve the conformability and compatibility properties a third, thin antifriction layer is applied to the substrate, known as an overlay. Examples of overlays include aluminum tin sputtered and electroplated tin based layers. The addition of an overlay provides the product with the correct balance of properties, however due to the complexity of the layered structures and the number of production steps these are premium products. [4]

Sputtered Overlay plus Polymeric Coating

To meet the new requirements of modern HDD engines, the proposed bearing solution uses a functional polymeric