Lead-free bearings

An optimized production process enables the removal of lead from heavy-duty application bearings, and can improve the overall fatigue life while lessening environmental impact

The use of lead in bearings poses an array of health and safety issues. Lead is also a contaminant that inhibits the recycling of other metals. Until recently virtually all modern three-layer engine and transmission bearings (consisting of a steel back, softer metal substrate and sliding layer) had a high proportion of lead in the substrate and sliding layer.

Growing restrictions from legislators on the use of lead in passenger cars and light commercial vehicles led Federal-Mogul to anticipate the industry's move toward more environmentally friendly bearing products for those applications. Now the company has introduced lead-free bearing materials for engines in the heavy-duty sector.

Federal-Mogul provides a comprehensive range of lead-free bearings. These products have a reduced impact on the environment, without compromising on the effectiveness of the component in demanding, heavy-duty engine applications

Lead is an extremely effective material for the brutal operating conditions encountered in automotive and commercial engines. To replace lead as an alloying element in sliding bearings, Federal-Mogul scientists had to develop materials with quite different tribological and physical mechanisms. Moreover, these materials needed to be effective in a variety of operating environments (gasoline and diesel engines), applications (main and connecting rod bearings) and under a broad range of load cycles (speed, temperature, force relationship). As a result, manufacturing lead-free bearings required re-optimization of the complete production process chain, including production of the semi-finished material, shaping and mechanical surface processing.

Federal-Mogul's approach to these challenges was unique, according to Joachim Häring, the company's European manager of application engineering for bearings. "By considering the substrate and the sliding layers, we identified an array of complementary material combinations that enabled us to provide a complete range of solutions for the entire global engine and transmission market," he explains. "Concentrating only on the sliding layers would have produced less capable solutions suitable only for specific applications."

More than 100 copper-based materials with various chemical compositions and microstructures (cast and sintered) were characterized by their physical, mechanical and tribological properties. The optimum combination was identified as a copper/nickel alloy substrate, cast onto a steel backing, with a range of five alternative sliding layers to suit particular applications.

The creation of such a variety of material solutions was made possible by having the required manufacturing and process technologies in-house to develop and manufacture the new products. For example, cast, sinter and roll-bond processes were used to produce the lead-free strip material, and electroplating, physical vapor disposition (PVD) and spray coatings played a key role in applying the sliding layers. Each of these coating technologies has individual characteristics that offer the optimum solution for a specific application.

Introducing lead-free bearings into the heavy-duty sector brought additional challenges. Vehicle lifetime mileages are much higher, reaching up to 1.5 million kilometers, requiring greater wear resistance and improved durability. The crucial design step that made lead-free formulations realistic for heavy-duty applications was to individually optimize the materials for the upper and lower halves of a bearing pair.

Compared with a high-revving, light-duty engine, in which large inertia loads act both upward and downward, the loads in a heavy-duty diesel are dominated by the firing event, so act predominantly downward through the connecting rod. This creates the greatest loads in the lower halves of the main bearings and the upper halves of the big ends. By selecting a coated bearing material with high fatigue resistance for the bearing shell that carries the higher loads, and an aluminum substrate with good embeddability for the counter shell, which is highly tolerant of particles in the engine oil, Federal-Mogul was able to provide both long life and high load capacity.

This approach has been so successful that Federal-Mogul claims its lead-free products are not only environmentally superior but can provide longer bearing fatigue life, or create the potential for more cost-effective solutions in some cases. "Our lead-free bearings use a superior substrate made either from cast or sintered material," explains Häring. "To provide a

robust solution for rod bearing loads up to 95MPa previously necessitated a sputtered coating, but with lead-free materials we can satisfy such requirements while using better value alternatives such as our Irox polymer coating."

There is a clear market trend for high-strength aluminum to replace electroplated bearing materials for the lower main bearing, once unthinkable in a heavy-duty application. "If needed, Irox can be used as an upgrade to the high-strength aluminum, optimizing the load capacity and the wear resistance," Häring adds.

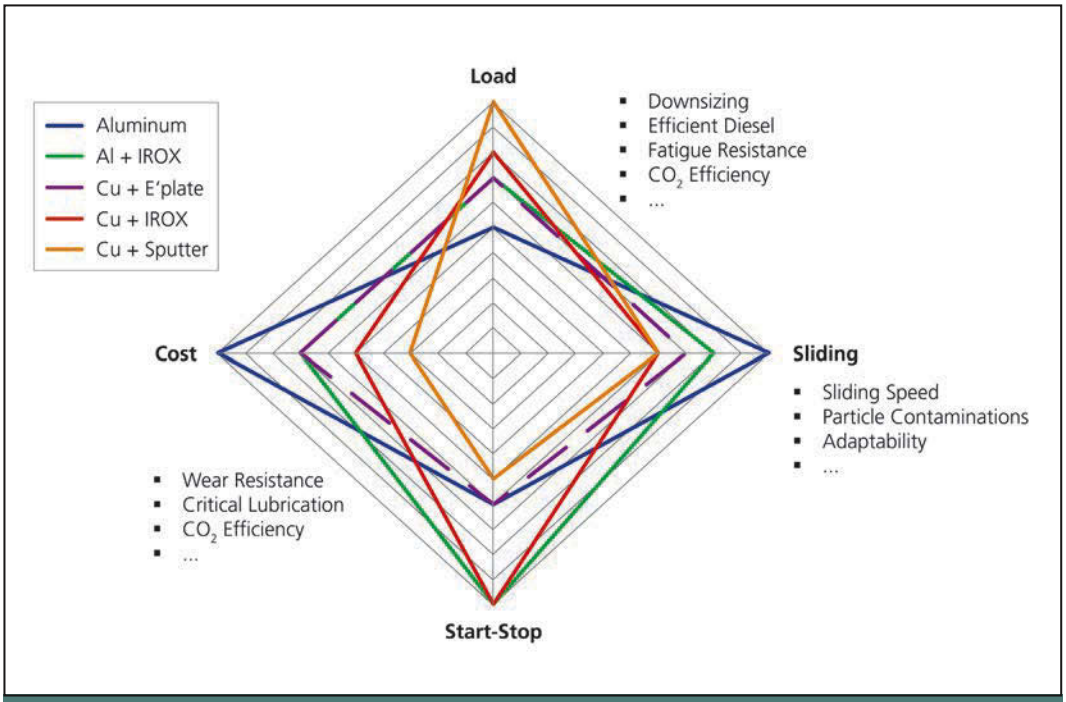
Heavy-duty engines contain a much greater variety of bearing parts than passenger car engines, extending beyond the crank train to rocker gear, cam drives and cam bushings. Satisfying an OEM's preference to work with a single supplier requires a comprehensive system understanding and full bearing material portfolio.

Successfully applying the new bearing materials required sophisticated processes in design, validation and manufacture. At the design stage, elastohydrodynamic studies and finite element methods were used to optimize bearing specifications and performance within the engine structure.

Federal-Mogul has invested US$50m in production technology for its range of lead-free bearings

Evaluation and validation testing, including wear-resistance and embeddability tests, made use of state-of-the-art techniques such as energy dispersive x-ray spectroscopy and scanning electron microscopy. As the products were validated in a growing number of applications, they effectively became an industry benchmark, which in turn enabled customers to shorten their own product development times.

Lead-free bearing materials are developed at Federal-Mogul's Wiesbaden technology center in Germany. The facility has nearly 120 years of experience in bearing design and development. Though stimulated initially by European demand, Federal-Mogul recently completed an extension to its Korean manufacturing plant to meet growing requirements in the Asian market, and also recently announced the acquisition of Russian bearing manufacturer DZV, intended to provide a growth platform for increased presence in the commercial vehicle and industrial engine market in eastern Europe.



A performance comparison of the different bearing materials in Federal-Mogul's advanced lead-free bearings product portfolio