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TRENDS IN DIESEL ENGINES

ANTON VASKOVICH, VLADIMIR IVANOV
PolotskStateTechnical University, Belarus

Soaring oil prices and challenging emission regulations in the near future demand significant efforts on the part of engine builders to bring down emission levels. Both developments have attracted the notice of the Sulzer Metco cylinder bore coatings specialists in various markets.

More than 15 years ago, Sulzer Metco started developing materials and application processes to coat the cylinder walls of combustion engines. The goal was to decrease friction, increase fuel economy, and reduce oil consumption. However, with the low oil prices during the nineties and at beginning of the new century, the interest in the market to adopt the technology was low. Only one car manufacturer began applying an iron- based cylinder coating.

Diesel engines have long been popular in bigger cars and this popularity is now spreading to smaller cars. The diesel engine has undergone a technical revolution over the last twenty years. With the benefit of modern technology, today's diesel engine with a rating of 150 horsepower (hp) delivers basically the same performance, in terms of acceleration and actual top speed, as a turbocharged gasoline engine of up to 200 hp, but with significantly lower fuel consumptionand carbon dioxide emissions. Diesel engines have a high thermal efficiency,which leads to low carbon dioxide emissions. The main problem of diesel engines is the emission of nitrogen oxides (NO_x) and particulate matter (PM). These two pollutants are traded against each other in many aspects of engine design. Very high temperatures in the combustion chamber reduce PM emissions but, on the other hand, produce higher levels of nitric oxide (NO). By lowering the peak temperatures in the combustion chamber, the amount of NO produced is reduced, but the likelihood of PM formation increases[1].

An additional challenge facing the diesel car is the quality of diesel fuel. Sulfur in the fuel causes the exhaust to smell, is incompatible with the necessary exhaust aftertreatment technology, and can cause corrosion on the cylinder liner and the piston. The use of low-grade fuels can lead to serious maintenance problems because of their high sulfur content. The challenge is more pronounced in marine diesel engines, as the allowed sulfur content in the fuel is much higher than in fuel for on-highway applications.

Legislation forces the pace. In recent years, legislation concerning the emissions of diesel passenger cars has become increasingly restrictive, especially for NO_x and PM. This trend is predicted to continue in all different engine sectors as shown in [fig. 1]. One way the car industry is reacting to these requirements is by pushing the use of lightweight components, replacing steel or cast iron. The substitution of cast-iron engine blocks is an important part of this development. Even diesel engines— which continue to gain a substantial increase in market share in Europe—are now being cast in aluminum, although diesel engines run at up to three times the pressure of gasoline engines. Progress in aluminum alloy development and new casting techniques lead to improved material properties that enable aluminum to meet the requirements. The ability to produce high-quality aluminum engine blocks opens a large window of possibilities, especially bearing in mind that nearly 50% of all new cars in Europe have diesel engines. Apart from reduced emissions, this growth is accompanied by requirements such as lower fuel consumption, larger power output and torque, and, especially in passenger cars, more compact engines due to space limitations.

Weight reduction. The highest weight reduction on a crank case of a passenger car can be achieved by completely replacing the cast iron through aluminum, also omitting any cast-in cast-iron liners. This task can be solved by applying a hypereutectic high- silicon-containing aluminum alloy, which is expensive, is difficult to cast, and requires special honing techniques or by using a cheaper aluminum alloy with good castability and putting a thermally sprayed, protective coating directly on the aluminum cylinder wall. This will minimize the necessary bore-to-bore distance and will lead to a very compact, lightweight design of the crank case. Here, the Sulzer MetcoSUMEBore coating solution comes into play and offers a low-cost, mature technology that has proven its reliability and its effectiveness. More than three million cylinder bores have been coated over the past five to six years, mainly in diesel engines of passenger cars but also gasoline engines of high- performance streetcars and a variety of race engines from F1, GP2, NASCAR, and DTM to LeMans LMP1 diesel, MotoGP, and so on [2].

Fig. 1. Tested sample made from steel St3

Fig. 2. Coating of a cylinder bore of a diesel

Wear in the cylinder. A thermally sprayed coating on the cylinder wall is exposed to a variety of different wear mechanisms at work in a diesel engine, such as scuffing and scoring, corrosion, carbon deposits on piston and combustion chamber, abrasion by soot and high ash content, and so on. Diesel fuel contains sulfur. Even low-sulfur diesel fuel contains 300 to 400 ppm of sulfur. When the fuel is burned in the engine, this sulfur is converted to sulfur oxide (SOx). In addition, one of the major products of the combustion of hydrocarbon fuels is water vapor. Therefore, the exhaust stream contains NOx, SOx, and water vapor. In the past, the presence of these substances was not problematic because the exhaust gases remained extremely hot, and these components were exhausted in a gaseous state. However, when the engine is equipped with an exhaust gas recirculation (EGR) system to reduce NOx, the exhaust gas is mixed with cooler intake air and recirculated through the engine. The water vapor condenses and reacts with the NOx and SOx components to form a mist of nitric and sulfuric acids. This phenomenon is further intensified when the EGR stream is cooled before it is returned to the engine—cooled EGR.

The SUMEBore coating solution. Sulzer Metco offers a complete solution package to address such challenges in the cylinder liners. The package consists of a production system, which is highly standardized for this specific market segment, tailored coating materials, and extensive know-how for the industrialization based on more than ten years of experience with the SUMEBore technology in different markets. The market segments covered range from small engine blocks (passenger cars), to high-speed diesel engines/liners (trucks), up to medium- and low-speed diesel engine liners with bore diameters exceeding 500 mm. An example of SUMEBore equipment designed to address the market for the remanufacturing of medium-speed diesel engine. Sulzer Metco has developed a full range of thermal-spray coating materials that can be applied on cylinder walls, all of them exhibiting low friction and offering protection of the surface against scuffing, corrosion attack, and abrasive wear. The materials toolbox. The materials can be applied to steel, cast iron, aluminum, or magnesium surfaces. These coating materials are used as powders, offering the highest flexibility of customizing the compositions to customer needs at the lowest cost. The powders are alloyed metal powders or metal matrix composites (MMC) blended from metal and ceramic powders or pure ceramic compositions. The most promising compositions—currently widely applied in the heavy-duty diesel market—are MMCs with a ceramic content of more than 30% by weight.

Materials and equipment. The materials are applied using an air plasma spray process (APS). There are a number of different plasma guns to best cope with the full range of the cylinder bore sizes. They ensure fast deposition of the coatings, high deposition rates, and a very stable process. The guns with the highest performance can spray powder in excess of 500g/min. The F210 plasma gun for the coating of small cylinder bores is shown in [fig. 2]. A typical metallography cross section of a corrosion-resistant and highly abrasion-resistant MMC coating on a cast-iron liner of a heavy- duty diesel engine. Shows a large liner of a diesel locomotive with a 317.5mm diameter bore after coating application using a high performance plasma gun and a feed rete of 500g/min.

Sulzer Metco has the knowledge of the complete process from premachining, through washing, surface activation, plasma coating, and smooth-surface finishing by diamond honing (mirror finishing). In order to be able to offer the complete process, Sulzer Metco has entered into partnerships with suppliers of all necessary equipment that Sulzer Metco does not produce in house.

Sulzer Metco, with its global presence, is able to supply a customized, industrial- scale SUMEBore solution package to almost any part of the world, including the necessary process support and maintenance on site[3].

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MODERN GEAR OILS AND SPECIAL ASPECTS OF THEIR PRODUCTION

NIKITA LEBEDEV, SERAFIMA POKROVSKAYA
Polotsk State University, Belarus

In this article tendencies to improvement of gear oils quality for machines experiencing high loads are described. Gear oils are obtained by mixing of high viscosity index base with a package of additives.

Technological progress has made modern cars more complex and more perfect, so the performance requirements of oils increase. Gear oils were created for machines experiencing high loads.

Wherever the torque is transmitted to gear pairs (gearboxes, drive axles, transfer boxes, steering units) gear oils are used.

Today, there are two standard classifications which divide all gear oils into viscosity classes:

1. The Russian classification GOST 17479.1-85;
2. International Classification SAE.

The main purpose of gear oil is to transfer engine power, to lubricate and to cool down high speed and heavy-loaded gears in the transmission units.

Modern gear oils must possess the following properties [1]:

– Good anti-wear and antiscoring properties;
– Good viscosity-temperature characteristics;
– Low corrosiveness;
– High thermal stability that ensures constant viscosity during work cycle;
– High protective properties against rust;
– Small influence on the sealing material;
– Low toxicity.

The main physical and mechanical properties of gear oils include [2]:

– Kinematic viscosity;
– Dynamic viscosity;
– Pour point;
– Viscosity index.

The basic tribological properties of gear oils include:

– Scuffing load - the mode, when sliding of friction surfaces becomes difficult;
– Weld point - the force when the friction surfaces are not able to slip relative to each other;
– Load wear Index - an index indicating the efficiency of antiscoring properties in the range between the weld point and the scuffing load. The higher load wear index is, the better.

For the production of modern gear oils high viscosity index base and a package of additives are required.