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Fuel economy in focus: advances in development of energy-efficient lubricants and low-friction coatings for automotive applications

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Meeting the challenge

New fuel economy standards for automobiles erected by governments in the G20 major economies and change in customer preferences driven by high fuel prices put increased pressure on car makers. Thus, the U.S. Environmental Protection Agency is preparing to look at standards for 2017 and beyond - setting at the top of its potential range a standard of 62 mpg by 2025. In one or another way, those political and economical incentives intensify research and development efforts taken by major OEMs in order to achieve new ambitious fuel economy targets. Apart from engineering efforts on use of alternative energy sources to reduce green house gas emissions, use of new materials to reduce vehicle weight, development of hybrid cars, and continuing powertrain optimisation, a big emphasis is made on understanding tribological aspects of energy losses in powertrain and utilising current advancements in lubrication engineering and coatings to fight those losses. Indeed, friction and wear are inherent in operation of any machines and mechanisms. The majority of machines and mechanisms can be viewed as complex tribosystems containing mechanical parts and lubricant. Correspondingly, friction and wear can conceptually be controlled in three different ways:

- On the material side - by choosing lighter and durable materials with appropriate mechanical and tribological properties in manufacturing of mechanical parts;
- On the coating side - by improving tribological behavior of existing materials by means of surface coatings;
- On the lubricant side - by developing lubricants to obtain desired tribological behavior for a given material.

Development costs, material costs and production costs are always important factors when market potential of one or another approach is to be assessed.

Smarter engines, lighter cars

Engineering advancements in car construction over the past decades did not come unnoticed: the average fuel consumption, normalised to engine output, dropped from 10L / 100 km in the 1980s to 5L / 100 km nowadays. Most noticeable developments are broad acceptance of fuel stratified injection (FSI) direct injection technology. Though FSI technology has been around for at least half a century, its advantages could not be fully realized until electronic engine control modules become available. FSI technology increases the torque and power of spark-ignition engines, makes them as much as 15 percent more economical at a given power output. The motor industry in Europe and North America has now switched completely to direct fuelling for the new petrol engines it is introducing. The majority of modern FSI engines are actually turbo-FSI (TFSI or TSI) as they combine direct injection with twincharging - a turbocharger and a supercharger working together.

In a FSI engine, the fuel is injected into the cylinder just before ignition. This allows for higher compression ratios without knocking, and leaner air/fuel mixtures than in conventional Otto-cycle internal combustion engines. By regulating injection pressure and valve timing and lift, constant electronically-aided engine efficiency tuning is possible based on the actual load, fuel type, exhaust parameters, and ambient conditions.

An alternative to FSI is homogeneous charge compression ignition (HCCI) technology which can be viewed as a hybrid of homogeneous charge spark ignition (in gasoline engines) and stratified charge compression ignition (in diesel engines). In theory, HCCI allows one to achieve gasoline engine-like emissions along with diesel engine-like efficiency. Analogously to diesel engines, in an HCCI engine, the air/fuel mixture is ignited due to compression without using an electric discharge. Stratified charge compression ignition in diesel engines also relies on temperature and density increase resulting from compression, but combustion occurs at the boundary of fuel-air mixing, caused by an injection event, to initiate combustion. Inherently, HCCI engines are more difficult to control than other modern combustion engines, and to date, there have only been a few prototype engines running in the HCCI mode. Recently, a vehicle powered by 25 cc 1.3 hp HCCI engine deploying WS^2 antifriction coating was constructed by Royal Institute of Technology KTH, Stockholm, Sweden (Figure 1)