



INFORMATION AND DEBATE PAGES
FOR MEMBERS OF SVEA, THE SWEDISH
VEHICULAR ENGINEERING ASSOCIATION

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The aim of SVEA is to:

- speak for vehicle engineers in the general debate, informing about advantages and disadvantages of various types of vehicles and means of transport, both nationally and globally.
- create a network for fast distribution of information on vehicle technology within the profession.
- attract talented youth to continue the heritage of today's vehicle engineers.

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Pursuit for Better Fuel Economy

Reducing Engine Friction Helps Maxing out Miles per Gallon

The continuing pursuit for better fuel efficiency stands behind many recent advancements in engine technology. The average fuel consumption, normalized to engine output, dropped from 10 L/100 km (23.5 mpg) in the 1980s to 5L/100 km (47 mpg) nowadays. "Downsize and charge" has become the major development trend alongside broad acceptance of fuel stratified injection (FSI) direct injection technology.

Even more significant progress occurred in the diesel engine development segment, following the introduction of high-pressure common-rail direct injection, variable geometry turbochargers and charge-air intercoolers during two past decades. As a result, modern diesel engine power output, acoustic comfort and emission behavior now approach the gasoline engine.

The valve train system, in particular, has seen a number of important technical innovations such as intake- and exhaust camshaft phasing, cylinder deactivation, mechanically variable valve train (MVVT) and electromechanical valve train (EMVT). These developments alone are claimed to improve fuel economy by as much as 20% compared to a legacy DOHC engine [1].

Apart from engine development, improving efficiency of power transmis-

sion is another way towards better fuel economy: continuously variable transmissions and automatic gearboxes with 6 to 8 speeds are getting increasingly common.

Reducing the weight of cars

As the use of new materials is concerned, the main focus is on reducing the weight of cars while increasing passenger safety and at the same time keeping manufacturing costs down. A 10% reduction in curb weight reduces fuel consumption by 3-6% [2].

As a reflection of this tendency, the use of advanced high strength steel (AHSS) and ultra-high-strength steel (A-UHSS) used in car construction is steadily increasing over past decades. Cast aluminum engine blocks have become the standard in passenger cars and light-duty vehicles. Increasingly common are getting billet aluminum blocks manufactured from a solid chunk of aluminum using computer numerically controlled (CNC)

machining. Billet blocks have significantly higher strength and are generally lighter than regular cast aluminum blocks. Compacted graphite iron (CGI) is another material of choice for engine builders which allows them to roughly double the strength of the casting without a weight penalty. CGI blocks are a preferred choice for heavy-duty engines, but are also quite common in performance engines for passenger cars, e.g. Audi V8 TDI diesel, BMW V8 TDI, Jaguar V6 TDI diesel to mention but a few examples [3].

More weight loss can be achieved

Many luxury cars such as Audi A8, Jaguar XJ, and BMW 7, have entire parts of their body made of aluminum in order to further reduce the weight and improve handling of the vehicles. If the price does not matter, even more weight loss can be achieved: super sport cars such as Zenvo, Koenigsegg, Bugatti and Lamborghini

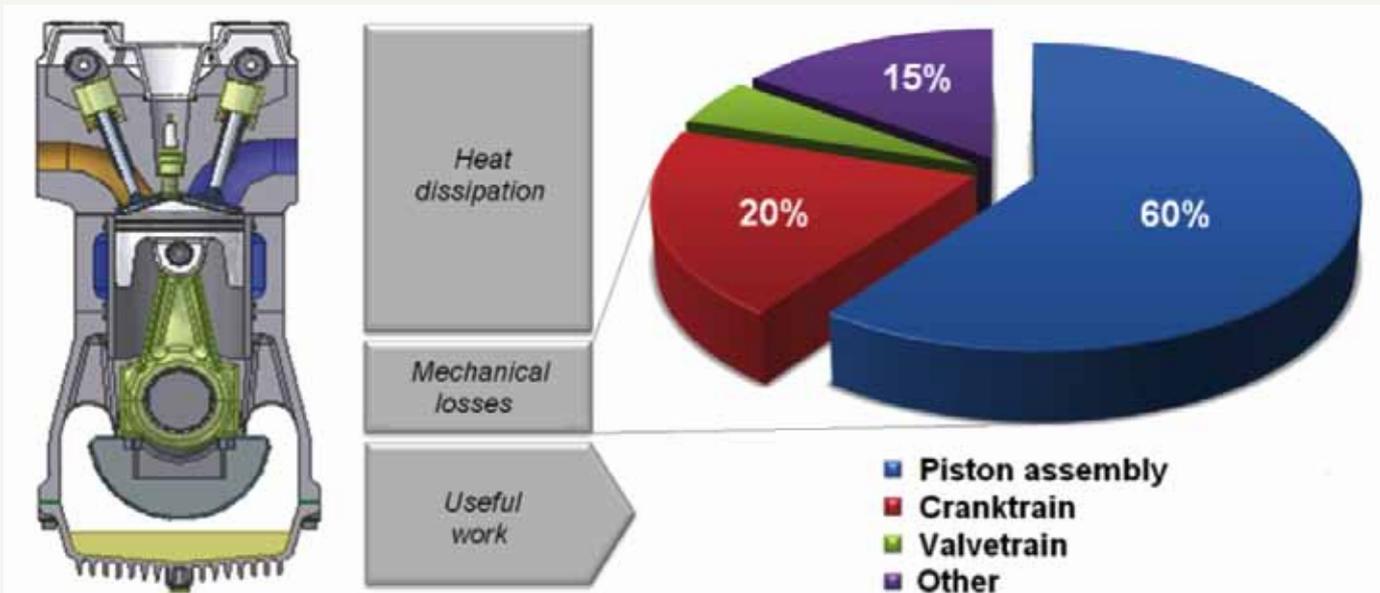


FIGURE 1: Estimated energy losses within the internal combustion engine.

This loss can be further subdivided, in a proportion 9:1, into a dissipative part (viscous dissipation due to lubricant flow) and a frictional part (mostly due to boundary friction in piston ring/cylinder bore, crank train and valve train systems) [4]. The dissipative losses can be reduced by

using lower-viscosity oils and smaller displacement volumes. The frictional part can be reduced by using antifriction coatings on performance-critical parts as well as by deploying special friction-reducing additives in engine oil. Unfortunately, use of additives in oil may cause exhaust catalyst poisoning and so must be constrained. This makes coatings an attractive alternative [8].

have certain parts of body construction made of carbon fiber or carbon-fiber reinforced plastics (CFRP). Another noteworthy advancement is the use of light-weight porous metals and composites as impact energy absorbers and sound-damping elements.

Antifriction coatings

In an internal combustion engine, estimated 10–20% energy is lost due to friction [4-7], see Fig. 1.

Nowadays, various coatings are used in automotive engineering to compensate deficiencies of bulk materials. Coatings can be used to improve wear resistance, corrosion resistance, appearance, adhesive properties, etc. Well-established methods for enhancing the tribological properties of various automotive components are chrome plating, ferritic nitrocarburization and phosphatation.

Nikasil, Alusil or wire-arc sprayed iron coatings represent more recent developments which have made their way to market during past two decades and are currently used in a number of production engines in order to improve oil film retention and to reinforce cylinder bore walls in aluminum engine blocks.

Alodine EC2 electroceramic coatings, are currently being evaluated for application in small displacement aluminum engines.

Fundamentally different philosophy

From an automotive engineering perspec-

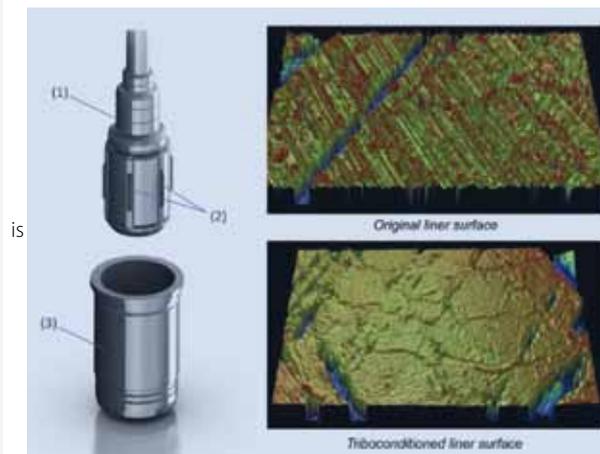


FIGURE 2: Triboconditioning of cylinder bores/liners in a honing machine. The only modification is that the honing head (1) carries a set of triboconditioning tools (2) installed in place of regular honing stones, and honing oil replaced by a special process fluid. On the right-hand side, the effect of triboconditioning on the surface roughness profile is shown.

ive, whenever advancements in coatings are discussed, one often tends to focus exclusively on hard antiwear coatings such as diamond-like carbon (DLC), silicon carbide (SiC), tungsten carbide (WC), titanium nitride (TiN), chromium nitride (CrN), etc., produced by chemical (CVD) or physical (PVD) vapor deposition. Hard antiwear coatings are used to protect fuel injection valves, tappets, piston pins, piston rings, ball joints and other wear-critical components. Antifriction coatings serve a different purpose: to reduce friction, thereby minimizing dependence on the additive package.

In an attempt to combine the mechanical toughness of hard coatings with high lubricity, composite PVD coatings such as Balinit C (WC/C, Balzers Ltd) and MoST (MoS₂/Ti, Teer Coatings Ltd) exhibiting self-lubricating properties have been developed.

Soft sacrificial coatings represent a fundamentally different philosophy in the development of antifriction and antiwear coatings: the coating can be sacrificed in action while protecting the coated parts.

Invented a new technology

As an example of such coatings, one can mention Molykote solid lubricant coatings developed and manufactured by Dow Corning. Molykote coatings are based on MoS₂ as the main friction-reducing component, but they may contain a number of other ingredients such as graphite, resin binder, corrosion inhibitor, etc. required to control consistency, adhesion, corrosion resistance, appearance and other properties. A similar concept has been used in the development of EcoTough coatings for piston skirt by Federal-Mogul Corporation [4].

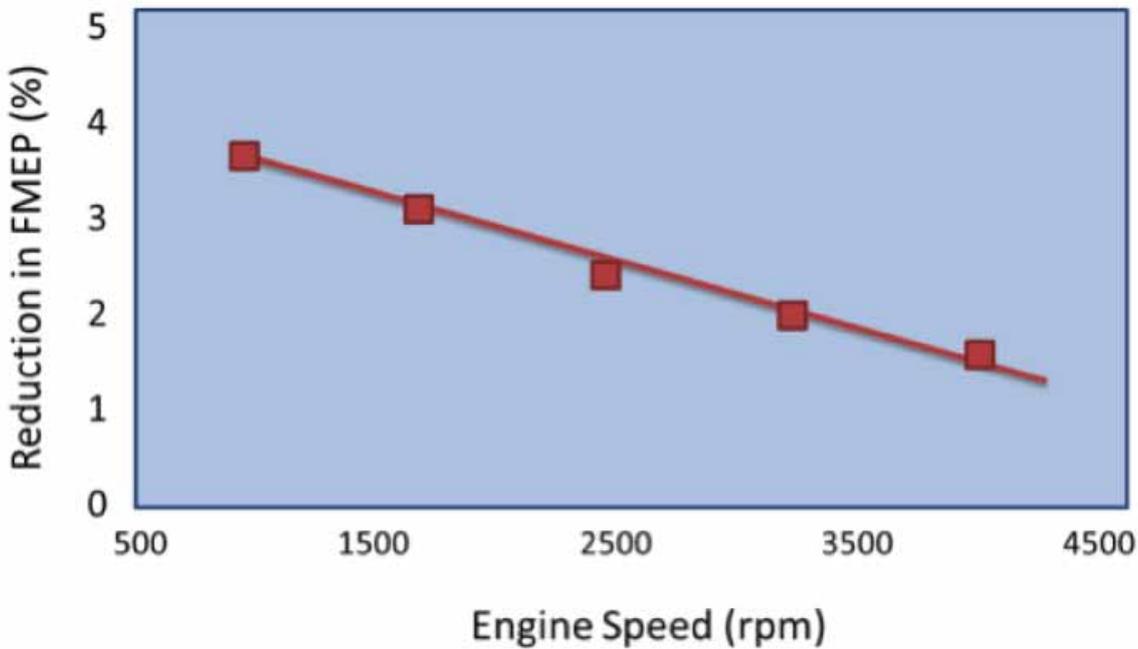


FIGURE 3: Reduction in engine friction mean effective pressure due to cylinder bore triboconditioning.

A Swedish company Applied Nano Surfaces (ANS) has invented and pioneered a new technology for friction and wear reduction by applying an in-manufacture running-in process.

Significant reduction in friction

The ANS process, known as Triboconditioning®, is a dedicated superfinishing process that combines elements of extreme-pressure mechanical burnishing of the component surface with a tribochemical, or mechanochemical, deposition of a low-friction antiwear film [9].

The mechanical treatment is essential

for improving the surface finish by leveling off asperities and building up compressive stresses within the underlying material, and for initiating the triboreaction that leads to the in-situ formation and interfacial nucleation of appropriate friction-modifying compounds, such as transition metal dichalcogenides, amorphous carbon, borates, phosphates, etc., onto the said surface.

The ANS process has been successfully applied to improve the tribological properties of cylinder bores and valve train components [10,11]. Triboconditioning of cylinder bores/liners can be carried out

using regular honing equipment as demonstrated in Fig. 2.

Triboconditioned engine blocks show a significant reduction in friction mean effective pressure (FMEP), see Fig.3, which is expected to translate into a higher power output and better fuel economy for the engine. Not less important is the fact that piston ring wear with triboconditioned blocks is significantly reduced, see Fig.4.

Broad range of operating conditions

The observed performance boost has a clear tribological rationale: Let us take a look at the Stribeck diagram, which plots the coeffi-

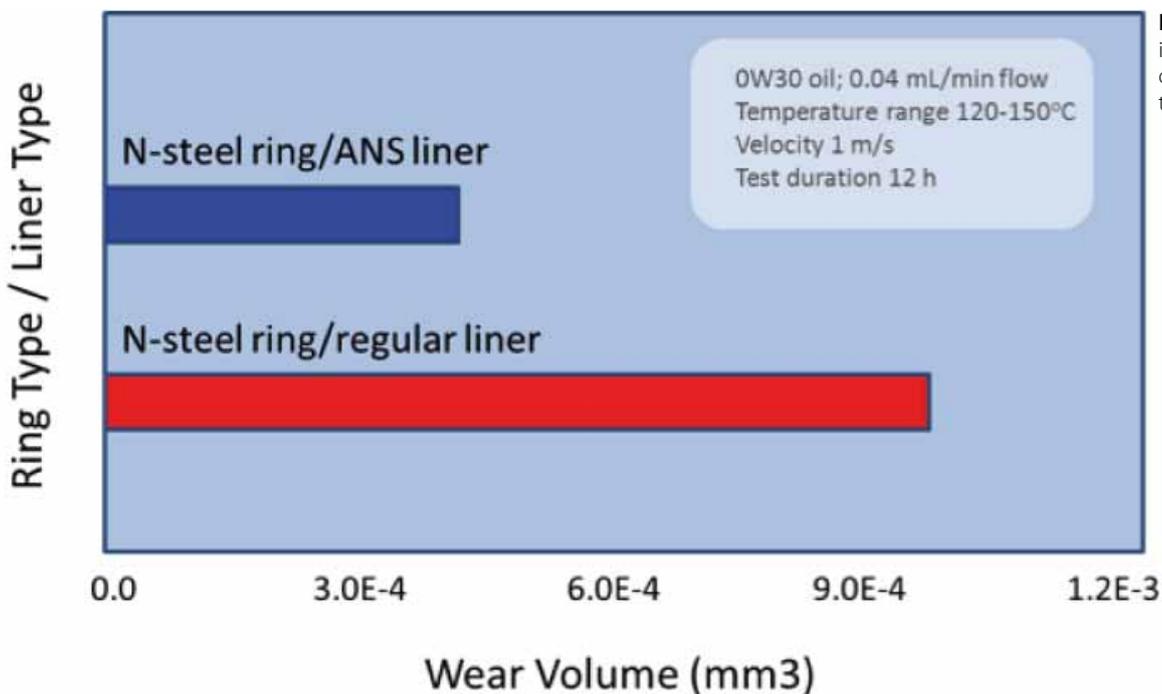


FIGURE 4: Reduction in piston ring wear due to cylinder bore triboconditioning.

cient of friction, μ , versus the so-called Hersey number, both in the logarithmic scale, see Fig. 5.

The Hersey number is defined as lube viscosity times sliding velocity divided by pressure in sliding frictional contact between the mated component surfaces.

The triboconditioning causes the Stribeck diagram to shift down (the friction modifier reduces boundary friction) and to the left (the removal of asperities extends full film lubrication towards higher loads). Therefore, friction is reduced over a broad range of operating conditions.

Other benefits of triboconditioning include improved surface finish and surface integrity, reduced tribomutation and fatigue accumulation during the running-in period, compressive stress build-up, and improved lubricant film strength.

Energy efficient lubricants

Since a significant part of energy losses in the internal combustion engine comes from viscous dissipation, there is an obvious trend towards low-viscosity oils, from SAE 40 and 50 viscosity grades common in the 1960-1980s to SAE 20 and 30 nowadays.

The transition has been facilitated by availability of high-quality hydroprocessed and synthetic base oils [12]. Due to their greatly reduced volatility and good low-temperature performance, modern base oils of API Group II-IV allow the formulation of thinner engine oils of 0W-30, 0W-20, or even lighter grades, to achieve better fuel economy.

Desire to capture every drop

There are already low viscosity products on the market claiming to meet SAE 0W-10 and 10W-10 grades that are not yet included in the existing SAE J300 engine oil viscosity classification system. Interest in these new grades is prompted by the auto-

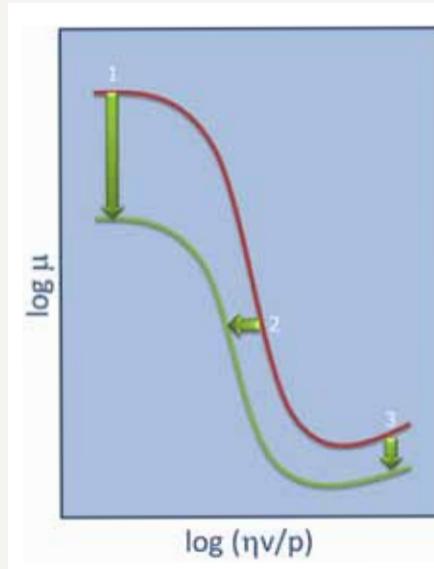


FIGURE 5: Changes in the Stribeck diagram due to triboconditioning:

- 1 – Boundary friction reduced due to the presence of a friction modifier
- 2 – Film lubrication extended towards higher loads due to removal of asperities and improved lubricant film strength
- 3 – Hydrodynamic friction can be reduced by using thinner lubricants

motive OEMs' desire to capture every drop of fuel economy by minimizing viscous dissipation.

One big issue, however, is to define safe high-temperature/high-shear (HTHS) viscosity limits for these new grades. The lowest HTHS viscosity allowed today is 2.6 mPa s at 150°C, and some proposals would take this much lower, down to 1.4 mPa s.

However, the use of thinner lubricants increases the risk of engine wear unless appropriate antiwear additives are simultaneously deployed in the formulations [13].

The ANS triboconditioning process allows one to enjoy the same fuel efficiency gain without having to use friction modifiers in engine oil. As a matter of fact, without the ANS process, rubbing parts in an engine would be “triboconditioned” – or run in – during the engine operation under conditions which are far from optimal. As a result, the engine may incur significant wear during the initial breaking-in stage.

The major difference that the ANS process brings is that breaking-in of engine components becomes a part of the component manufacturing process [9-11]. The outstanding wear-resistance of ANS-triboconditioned parts allows one to switch to lower viscosity lubricants for improved energy efficiency without accruing risk of wear-related failures and having to compromise between the level of antiwear protection and the lifetime of exhaust catalyst.

Conclusions

The major developments leading towards improved fuel efficiency of automobiles over past decades are:

- Powertrain optimization with focus on increasing power density and power transmission efficiency
- Curb weight reduction
- Change to lower-viscosity friction-modified energy-efficient lubricants
- Use of antifriction coatings

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