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Fuel economy drives change for passenger car oil formulations

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Legislation and consumer demand are driving vehicle manufacturers to find ways to improve fuel economy and reduce CO_2 emissions across their vehicle fleet. In the passenger car market OEMs have responded by looking for energy savings from a variety of technologies including advanced transmissions, turbocharging, engine control systems and advanced materials. Many of the easy options for efficiency gains have already been implemented and OEMs now have to look much harder at each vehicle component, which of course includes the engine oil. The passenger car lubricant development scientists at Infineum have been working on a variety of projects to support this quest for fuel economy, two of which are outlined here. The first area of focus is a phenomenon called low speed pre-ignition (LSPI) that has arisen from the downsizing of gasoline engines. The second is our research into the ways low viscosity formulations can be tailored to ensure fuel efficient lubricants continue deliver sufficient hardware protection.

Understanding low-speed pre-ignition

Engine downsizing is one simple yet effective method OEMs are using to improve fuel economy. The reduced engine displacement results in less pumping and frictional losses and lower gases-to-wall heat transfer, which means the engine is more efficient. Although engine downsizing can clearly improve fuel economy, it unfortunately comes with a sacrifice of performance. This means the engine boost pressure must be increased by adding turbochargers or superchargers to compensate for lost power output.

Some auto manufacturers are already offering downsized and boosted gasoline engines in their vehicle portfolio. However they have been known to exhibit disruptive abnormal combustion, such as knocking and LSPI.

LSPI occurs early in the combustion cycle and always prior to spark-triggered ignition. Its initial combustion is relatively slow and similar to normal spark initiated combustion, but then there is significantly advanced combustion timing. This can lead to very heavy knock, which can in turn cause catastrophic damage in only a few engine cycles. LSPI is especially important for pistons and connecting rods because they are rising when the aberrant combustion event occurs. In the most severe cases, LSPI can lead to broken piston rings, damaged pistons and bent connecting rods.

An example of piston damage due to LSPI observed during testing at Southwest Research Institute®. Photo courtesy of Southwest Research Institute®.

To enable these smaller boosted engines to be used as part of OEMs' fuel economy and CO_2 emission reduction strategies it is clearly essential to fully understand the mechanisms and causes of LSPI. And, because these combustion events are widespread and lubricant design can have an impact on LSPI, Infineum began its own research in this area.

The causes of LSPI

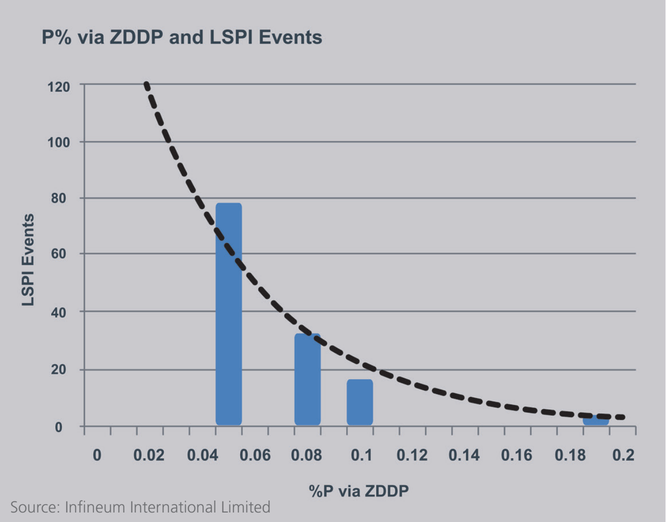
Initially it was thought that pre-ignition sources were located at hot spots in the cylinder, or were from soot accumulation. However, further optical investigation revealed that pre-ignition occurred randomly throughout the combustion chamber, which means surface ignition is not the only source of LSPI. Our current thinking is that the auto-ignition of oil droplets or deposit particles is probably the major cause of LSPI.

When the fuel is injected directly into the combustion chamber, it dilutes the oil film lining the cylinder. This fuel dilution reduces the surface tension and viscosity of the oil, causing an oil-fuel mixture to accumulate in the upper reaches of the piston top land crevice. The mechanical energy of the upstroke during compression pushes droplets into the combustion chamber, where they vaporise and can auto-ignite prior to spark ignition.

Lubricant formulation

In addition to investigating the causes of LSPI, Infineum is studying the effects of lubricant composition to better understand how it might contribute to the suppression of LSPI events. Work has already been undertaken to investigate the effects of using different types and levels of base stocks and additives.

The initial focus of the research has been to evaluate the effect of using different detergent chemistries, Zinc dialkyl dithiophosphate (ZDDP) types as well as varying the levels of other additives. Some chemistries have been found to have major credits while others have significant debits on LSPI events.



Infineum found that ZDDP type can impact LSPI events.

This research has been very challenging. The destructive nature and random occurrence of LSPI has necessitated the development of sophisticated testing and simulation methods in an attempt to fully investigate the phenomenon. Despite the challenge, the initial findings from this research have identified a number of lubricant and fuel chemistries and hardware and operational conditions that can suppress or increase LSPI activity.

Test developments

Work to date has stimulated discussions about the possibility of new chemical limits for future OEM and industry lubricant specifications. Infineum's position here is clear: achieving performance in an engine test that correlates to the field is the preferred method because arbitrary chemical limits do not always result in relevance in the field. Introducing a new test rather than new chemical limits will allow formulators to use their full expertise to find the best solutions to overcome the LSPI challenge. For example, the deleterious effects of one component may be mitigated by other additive chemistries and combinations, which can be optimised to deliver the required engine protection. Tightening chemical limits has the potential to stifle creativity and technical innovation.

Controlling LSPI will have a very significant impact on the composition of next generation lubricants, required to meet OEM and industry specifications. Our collaborative efforts with other stakeholders to develop a meaningful engine test to measure the effects of lubricant composition on the occurrence of LSPI will continue.

Low-viscosity formulations

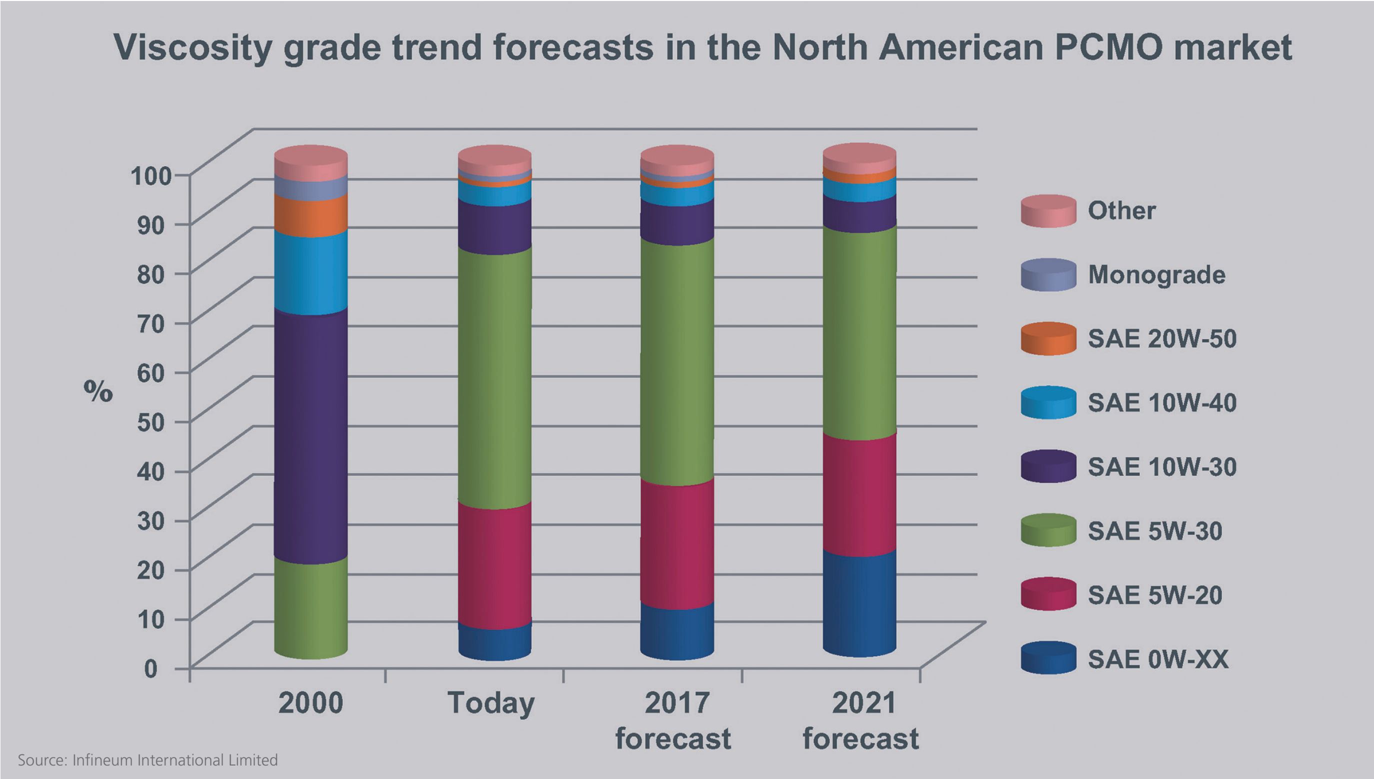
A second area of focus for Infineum research and development is on the formulation of lubricants that help to meet the latest fuel economy legislation without compromising engine durability.

Fuel economy derived from advanced lubricant technology is an attractive option for OEMs because it comes at a smaller cost than redesigning hardware. Reducing viscosity, which in turn reduces engine friction, is clearly an effective way for lubricants to contribute to vehicle fuel economy performance. We already see SAE 0W-16 in the market, and some OEMs are beginning to look at viscosities as low as SAE 0W-8, or even 0W-4. In this low viscosity era it is becoming increasingly important to understand the implications this has on the formulation envelope and on hardware protection.

Moving to ultra-low viscosity

Lowering a lubricant's high temperature high shear (HTHS) viscosity might result in fairly small improvements in fuel consumption. But, the potentially significant fines for non-compliance to emissions and fuel economy legislation mean OEMs value every contribution to help them meet their fleet-wide efficiency targets. This means the trend to ultra low viscosities is extremely likely to continue.

However, because vehicle population age and OEM market share both impact viscosity grade trends, it will take some years before these new viscosity grades make up a significant portion of the market. Take North America as an example, here SAE 5W-30 is currently the most common viscosity grade, but it took



from the late '80s until 2006 for it to reach this position. And, even though SAE 5W-20 and 0W-20 are now the most widely recommended grades for new cars, it will take a long time for SAE 5W-30 to exit the market.

Even as far out as 2020, SAE 0W-16 and below will account for a just small percentage of oil sold in North America – a picture likely to reflect global viscosity grade trends.

Low viscosity and durability

The first formulation challenge presented by moving to lower viscosity lubricants is how to balance the desire for fuel economy with the need to protect the engine and all its components. The thinner oil films associated with low viscosity fluids mean it is harder for the oil to keep the loaded contact surfaces in the engine sufficiently apart from each other. This can lead to accelerated wear rates, and even locally increased friction. In our view, it makes little commercial sense to trade engine durability for fuel economy gains.

Infineum studies indicate that, in some engines, reducing lubricant viscosities to 2.3 HTHS presents little risk of engine component wear. Below this level, specific engine components, for example the top ring and bearings, observe higher wear rates. To ensure ultra low viscosity lubricants deliver fuel economy and wear protection it is becoming increasingly important to co-engineer the vehicle hardware and lubricant system.

Tailored lubricants

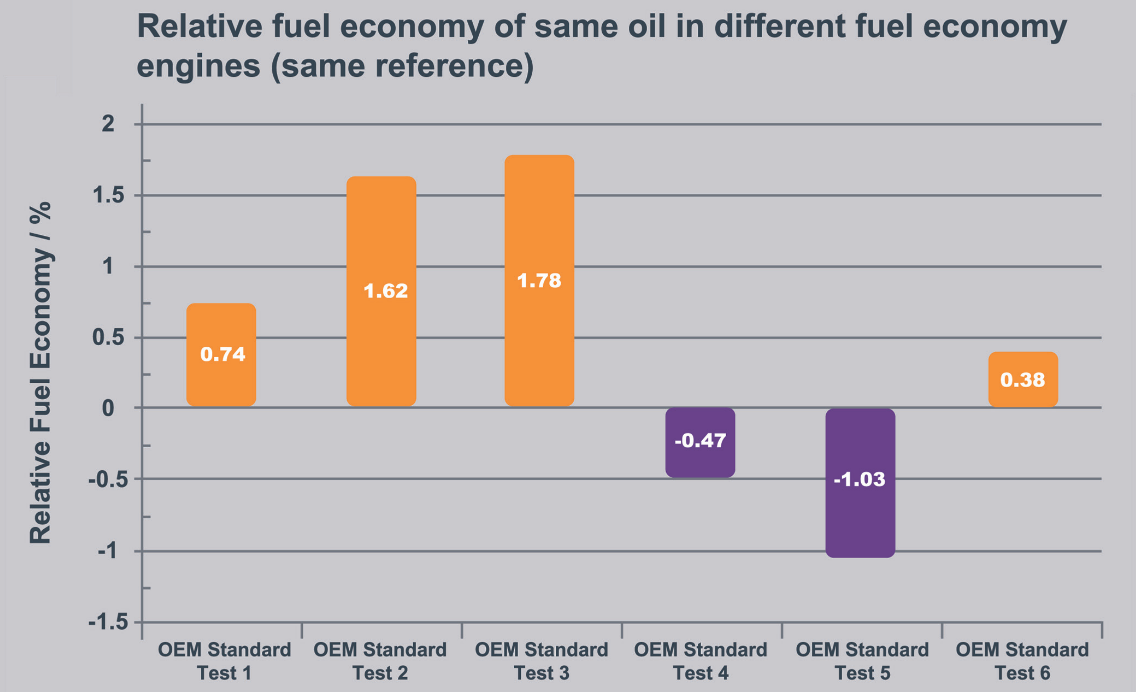
This collaborative development approach becomes even more important when you consider that not all engines deliver the same fuel economy performance with low viscosity formulations. In recent testing Infineum examined a variety of engines using the New European Drive Cycle. The engines were run on the same SAE 0W-30 oils and measured against the same reference oil. The chart above shows the different fuel economy performance seen across the range of engines.

What is clear from our research is that fuel economy lubricants must be individually tailored to suit each vehicle type, something that will add significant complexity to their development, or compromises must be made to balance fuel economy across a range of engine types.

Viscosity and volatility

Increased wear is not the only consequence of lowering lubricant viscosity because as viscosity goes down volatility also increases. In the high operating temperatures of modern engines the lighter ends of the hydrocarbons in a lubricant can evaporate. This pushes the viscosity of the lubricant up and, as a result, any fuel economy improvement gained from the low viscosity of the oil may be lost due to an increase in friction.

There is a minimum HTHS level before volatility increases above limits specified in lubricant specifications. And while using less of the additive package can improve this situation it could also compromise performance. Clearly the fine balance between viscosity and volatility is an important consideration that must be addressed in the design of innovative additive technologies, which must offer sufficient performance at lower viscosity levels.



Source: Infineum International Limited

The base stock mix

To produce effective low viscosity lubricants, base stocks with lower viscosity, higher viscosity index (VI) and lower volatility are needed. This means the pace at which we move to ultra low viscosity will be heavily influenced by the availability and cost of high quality base stocks. Currently sufficient volumes of Group III should be available to meet the demand for SAE 0W-16 and 0W-20 viscosity grades. But it is not clear if there will be sufficient very high VI or PAO base stocks to meet demand for ultra low viscosity oils - something that could increase investment challenges for all stakeholders.

This is a very complex area, where decisions are often driven by OEM specifications. And, because these are not all the same, the Group III, high VI Group III, PAO, and ester base oils mix can vary depending on which characteristics in the specification are the most challenging to meet. Part of our job is to provide the most cost effective and supply reliable formulation solution to the market.

Getting the balance right

Fuel economy is undoubtedly one of the biggest drivers for change in the automotive industry, which means moving to ultra low viscosity engine oils is a trend that is bound to continue. Thorough formulation development and careful base stock selection is essential to ensure we strike the right balance between fuel economy and hardware protection and between lubricant viscosity and volatility.

Right now, we believe the technical wear protection challenges presented by SAE 0W-16 oils can be handled by lubricant and engine design advances, but some OEMs are already looking at lower viscosity grades. Now that the definition of SAE 0W-8 and 0W-12 has been approved the move to low viscosity grades may accelerate. In our view, because lubricant derived fuel economy is engine specific, it is increasingly important to create tailored formulations. This approach will ensure the most benefit is derived without needing to compromise on performance across a myriad of different engine designs with different needs. Infineum is continuing to assess the impact of a number of variables including the effects of using different combinations of viscosity modifier polymers and high quality base stocks.

Collaboration is essential

As engines get smaller, more powerful and more fuel efficient, passenger car engine oils are expected to meet three key performance requirements, which are potentially conflicting.

They must:

- Keep engines cleaner for longer
- Contribute to OEMs' fuel economy aspirations
- Protect engine hardware

Developing a deep understanding of issues including LSPI and the impacts of lubricants with ultra low viscosity is essential as we design next generation lubricant technologies to deliver against these requirements.

In our view the close collaboration of OEMs with lubricant and additive suppliers is essential to ensure that changes in the design of both hardware and lubricant systems continue to work in harmony.

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