The VLSFO Challenge: Looking Deeper for Lubricant Performance

Lubrizol

1. Introduction

The International Maritime Organization's (IMO) global sulfur cap will dramatically alter the marine fuel market from 1 January 2020 – and with it the often overlooked but critical role of cylinder lubrication for 2-Stroke marine engines.

The new 0.5% limit on fuel sulfur will drive a market previously dominated by high-sulfur heavy fuel oil (HFO) towards new blends of very low-sulfur fuel oil (VLSFO)[1]. That change in sulfur content alone will demand a shift in the cylinder oil used on many ships operating with a 2-Stroke engine for propulsion. But concerns about the expected properties of the new blends – including stability, viscosity and combustion characteristics – mean that existing lubricants may not be robust enough to protect engines.

In the new, low-sulfur era, the traditional lubricant indicator of base number (BN) – used to quantify acid neutralisation capability – will be only part of the equation. New refinery processes and fuel blend stocks used to produce VLSFOs, as well as the expected incompatibility between VLSFO products, could lead to engine condition challenges that can only be tackled effectively with new lubricant additive chemistries.

As a leading supplier of marine lubricant additives, The Lubrizol Corp has invested heavily in understanding the fuel characteristics of potential VLSFO blends. Based on this research Lubrizol has developed and rigorously tested its own robust, low-BN additive package for cylinder oils to be used with VLSFOs. The resulting formulation deploys dispersant chemistry that is new to the marine lubricant sector and is specifically designed to help engines perform reliably while burning 0.5% sulfur fuels with a wide range of fuel properties.

"Shipping faces an unprecedented fuel switch in 2020," says Ian Bown, technical manager, marine diesel engine oils, Lubrizol. "The majority of ship owners and operators that are planning to comply with VLSFO should understand that legacy lubricant products used with low-sulfur fuels will not necessarily protect their engines as required. Lubrizol's robust BN40 additive package has been formulated specially to handle the wide range of fuel characteristics anticipated in VLSFO blends."

2. The Role of Lubricants and Additives

The main function of marine engine cylinder lubricants is to provide lubricity that prevents damage to pistons and cylinder liners. Neutralisation is another important role, preventing excessive corrosion which can reduce the life of cylinder liners.

A particular type of corrosion, known as cold corrosion[2], can be found on large modern engines running on high-sulfur fuel. Cold corrosion is the result of lower temperatures in ultra-long-stroke, large bore engines that cause acidic sulfur gases to condense on liner walls. To protect against this, lubricant additive packages for use with high-sulfur fuels in modern engines traditionally contain highly alkaline detergents. These provide greater acid neutralisation (a higher BN) to protect from corrosion while also cleaning any deposits or cylinder wear residues – another crucial job for the lubricant.

Cylinder oils also need to have strong thermal management properties in order not to degrade at high temperatures within the combustion chamber. To meet these various roles and demands cylinder lubricants need the right combination of additives.

3. Selecting the Right Lubricant

Choosing the right cylinder oil depends on several factors. As mentioned above, sulfur content can have an impact. Traditionally, high-sulfur fuels have required high-BN lubricants – of BN70 or more – to counter the corrosive effect of the sulfuric acid produced when the fuel is combusted. Lower sulfur fuels require much less corrosion protection, so a lower level of basicity is appropriate.

Operating conditions also make a difference to how engines are lubricated. For example, engines running at a higher load will use more fuel and will require proportionally more cylinder oil. As well as BN, ship operators also need to keep an eye on the rate at which the cylinder oil is injected onto the liner (known as the feed rate). Analysis of cylinder oil not burned off in the combustion process (sometimes called scrapedown or piston underside) enables operators to check that their engines are correctly lubricated, without excessive levels of corrosion. As too much BN can also be disadvantageous, leading to ash deposits, used oil analysis also indicates whether there is sufficient level of residual base to protect the engine.

These factors have influenced the current standard practice for lubricating 2-Stroke engines. The majority of vessels today run on high-sulfur HFO, and therefore require a high level of alkaline detergency to manage both the risk of deposits and corrosion. As a result, additive packages with high BN and strong detergency have been a mainstay in marine lubricants designed for HFO.

For the few vessels that have used low-sulfur fuels – including those operating in 0.1% sulfur emission control areas since 2015 – the demands have been different. Lower sulfur content means lower BN requirements, whilst a good level of deposit control is always important.

"High BN detergents have dominated cylinder lubricant formulations as they deliver the acid neutralisation needed for HFO and help to keep the high temperature surfaces of the engine clean of deposits" explains Harriet Brice, technology manager, marine diesel engine oils, Lubrizol. "Reducing these high BN detergents for the lower neutralisation needs of 0.5%S fuels without rebalancing the formulation with extra deposit control additives would severely impact on the lubricant cleanliness performance."

[1] Energy consultant Wood Mackenzie expects marine demand for HFO of 600,000 barrels per day (bpd) in 2020, down from 3.5 million bpd in 2019. VLSFO supply is anticipated at 1.4 million bpd in early 2020, with marine gas oil expected to meet the remaining low-sulfur fuel demand; https://www.reuters.com/article/shipping-bunker-imo-gasoil/imo-2020-to-boost-gasoil-demand-by-12-mln-bpd-woodmac-idUSL3N26H2CQ

[2] International Council on Combustion Engines (CIMAC) Guideline, Two-Stroke Engine Cold Corrosion, November 2017; https://www.cimac.com/cms/upload/Publication_Press/WG_Publications/CIMAC_WG8_Guideline_2017_Two_Stroke_Engine_Cold_Corrosion.pdf

4. The Impact of 2020 Fuels

Concerns have arisen in the industry about the variation in constituents of new VLSFOs and the effects they could have on fuel stability, compatibility and combustibility. For lubricant additive manufacturers, the main concern is the potential impact on combustion zone deposit formation. Excessive deposits can affect engine efficiency and durability. Lubricants and the additive packages within them need to be designed to keep components free of these deposits.

To understand the characteristics of VLSFOs, their effect on engine deposits and how lubricants perform when used with these fuels, Lubrizol closely examined five such fuels available in China (one of the only markets where they were available before late 2019) alongside five VLSFOs blended by its in-house laboratory. The results demonstrate how appropriate additives can effectively reduce the impact of fuel variability, with enhanced deposit control improving engine durability. This goes beyond conventional cylinder oil formulating and demonstrates that BN alone is not the solution for 0.5% sulfur fuels.

Wide variability

The fuels sourced in China provide a good example of VLSFOs that meet the ISO 8217:2017 marine fuel standard. During use, however Lubrizol observed measurable differences in deposit formation. These blends are manufactured from normal refinery components that meet the specifications for residual fuels set out in the ISO standard. But even using these well known fuel streams, the formation of deposits can vary considerably between blends.

To study this, piston groove cleanliness was tested using three different batches of VLSFO and a reference cylinder lubricant. One of the three engine tests showed increased deposit formation (see figure 1). As the engine operating conditions were similar, the difference can be attributed to a variation in fuel properties.

“Even within the same small sourcing area, variation can be seen to affect the amount of deposit formed in the engine,” explains Harriet Brice. “With the almost overnight global expansion of 0.5% sulfur fuels from 2020, the variation could be even greater as more atypical blend constituents are used to meet demand. Using a more robust lubricant will help to reduce the impact to the engine of this variability.”

Compatibility and stability

Compatibility concerns around VLSFOs relate to the co-mingling of incompatible bunkers and can be managed through tank segregation until compatibility can be confirmed through testing. Stability refers to each individual fuel blend being a stable product. A contributing factor underlying both is asphaltene stability. Asphaltenes are present in all crude petroleum residues but vary in content and characteristics depending on the crude’s origin. Asphaltenes are sensitive to changes in the aromaticity of the total fuel matrix, which changes when fuels are blended. Combining a residual stream with a paraffinic refinery stream (such as a low-sulfur distillate) to reach the 0.5% sulfur limit would therefore increase the risk of the final blend being unstable.

One way of characterising fuel composition is by determining the quantity of saturate, aromatic, resin and asphaltene (SARA) fractions. These components are each associated with asphaltene stability and so this technique can be useful in identifying fuels with the potential for stability issues.

As well as establishing the SARA measurements, Lubrizol also probed the stability of the commercial VLSFOs using a proprietary bench test. Fuel B showed higher instability than Fuel A which indicated this could be a contributing factor to the deposit differences in Figure 1. By mixing a portion of the fuel in to the marine diesel cylinder lubricants (MDCLs) tested in the engine, it was found the instability test directionally aligned with the piston cleanliness. This provided a screening tool to evaluate different cylinder lubricant additives. Figure 2 shows the instability results for the three most unstable fuels tested B,D and E when mixed with two different MDCL formulations. One contains a detergent known to be effective in deposit control and asphaltene stabilisation (additive 1) and the second contains a novel dispersant known to be effective in deposit and varnish control and asphaltene stabilisation (additive 2). The lubricant containing the novel dispersant was shown to be the most effective in the engine by controlling deposit formation on piston lands and in piston ring grooves with these fuels.

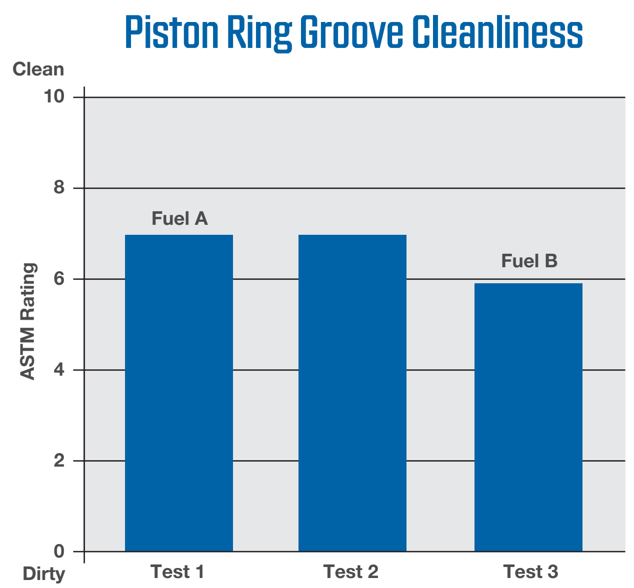

Figure 1: Lubrizol testing showed a measurable difference in piston ring groove cleanliness for a reference oil tested with different <0.5%S fuels

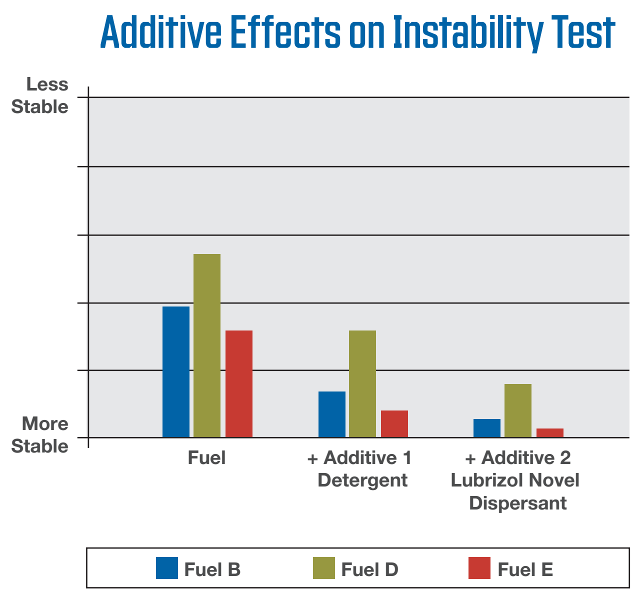

Figure 2: Lubrizol novel dispersant significantly increased fuel stabilisation in each of the three most unstable VLSFOs tested

5. Lubricating for VLSFOs

"Detergents are not the only additives in the formulator's tool kit," explains Harriet Brice. "Dispersants are very good at piston cleanliness. They have been used in automotive applications for many years but are not commonplace in marine cylinder oils for deposit control."

In order to determine the appropriate BN and deposit control requirements of cylinder lubricants for use with 0.5% sulfur fuels, Lubrizol formulated a series of BN25 and BN40 oils and tested these with commercially available VLSFO blends in a stationary 2-Stroke marine diesel engine. Scrapedown samples were used to tell if the lubricant was delivering enough protection from corrosive wear.

To maintain corrosion protection, residual BN of scrapedown oil should be maintained at around 15 or higher, according to OEM guidance at the time of development. The average residual BN for the BN25 oils across all tests was 12.5 compared to an average of 24.2 for the BN40 oils (see figure 3). Lubrizol therefore concluded that BN40 was the most appropriate level for oils used with VLSFOs, providing enough base reserve to meet OEM guidance while allowing some margin for more corrosive engine types and operating conditions.

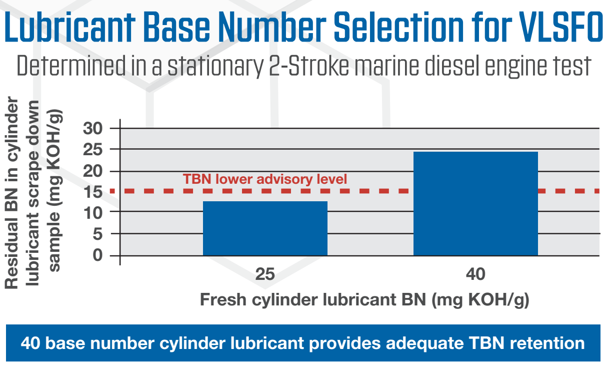

Figure 3: Lubrizol testing concludes that 40 BN is more appropriate than 25 BN cylinder lubricant for VLSFOs

A Lubrizol advanced dispersant known to be effective at addressing piston groove deposits and varnish was used to formulate one of the BN25 oils for comparison with a conventionally formulated oil. The lubricant with advanced dispersant had superior piston cleanliness with lower deposit formation in the piston ring grooves and on the piston lands. The BN25 oil with advanced dispersant also offered improved performance than a conventionally formulated BN40 oil, demonstrating that performance can be delivered independently of BN.

The testing demonstrated that BN40 oils previously developed for use with fuels with a sulfur content of up to 1.5% may not provide the performance required to handle VLSFOs. It also demonstrated the effectiveness of dispersants to bring additional performance in the area of piston cleanliness compared to conventionally formulated oils when using these fuel blends.

These findings have fed into the development of Lubrizol's newly developed additive package for cylinder lubricants to be used with VLSFOs. In line with engine designer recommendations, the additive package provides basicity at BN40. It also offers deposit handling performance through the novel dispersant additive technology. This technology, deployed for the first time in marine lubricants, has been balanced with detergents to offer robust protection from the expected wide variability in VLSFO fuel characteristics.

The new robust BN40 package has been verified through Lubrizol's four-step product development cycle: formulation, bench testing, fired engine testing, and field trial assessments. Product managers define the performance targets while considering feedback from customers, engine manufacturers and users in the field. Marine lubricant formulators then draw on extensive knowledge of additive performance characteristics to design a lubricant that meets those requirements. In addition to existing additive technologies, new and innovative additives are developed in conjunction with Lubrizol's world-class research scientists.

"It is clear that some features of VLSFOs introduce variability that will require lubricants with improved deposit handling performance," says Harriet Brice. "We have been able to identify and address these issues."

6. Conclusion

After extensive research into new fuels and a rigorous development process, Lubrizol's findings are clear: the additive chemistries found in traditional marine diesel cylinder lubricants may not suffice for the challenges of handling VLSFO blends. More advanced solutions are needed to tackle deposit formation without relying on the high base detergents that were a mainstay of cylinder oils used with high-sulfur fuels. Lubrizol's new BN40 additive package, deploying novel dispersant technology to marine cylinder oils, is specifically formulated for handling low-sulfur fuels.

But development of additive chemistries for marine lubricants will not stop there. As shipping looks beyond IMO's sulfur limits to its long-range carbon-cutting initiatives, notably its commitment to reduce total greenhouse gas emissions by at least 50% on 2008 levels by 2050, more new fuels will enter the market. These may include hydrogen, ammonia and other gas and liquid fuels generated by using biomass or renewable energy. Each new fuel will bring its own challenges to engine conditions, requiring new, sophisticated chemistries to counter them. Advanced lubricants themselves could also contribute to reducing greenhouse gas emissions by, for example, reducing friction in engines to cut fuel consumption.

Simon Tarrant, global business manager, large engines, Lubrizol, concludes: "As a global company spanning multiple sectors – including automotive, industrial and agricultural – Lubrizol already has experience of deploying many of the additives that will be the basis of marine solutions tomorrow. By harnessing that cross-sector experience and applying its marine-focused research and product development processes, our customers – and ship owners and operators worldwide – can be confident that we will be able to deliver the right additive packages to treat these emerging challenges."

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The Lubrizol Corporation
www.lubrizol.com