marine lubricants information bulletin 17

scuffing & red deposits after fuel transition: causes and solutions

In a multi-fuel environment, operators face a range of options to ensure that their vessels are compliant with legislation, and continue to deliver reliable performance. The transition to Very Low Sulphur Fuels (VLSFOs) was successful in the vast majority of cases, but created a problem with red deposits for some vessels.

An investigation by Chevron Marine Lubricants demonstrates the need for a flexible but measured approach to evaluating and solving issues with marine main engines.

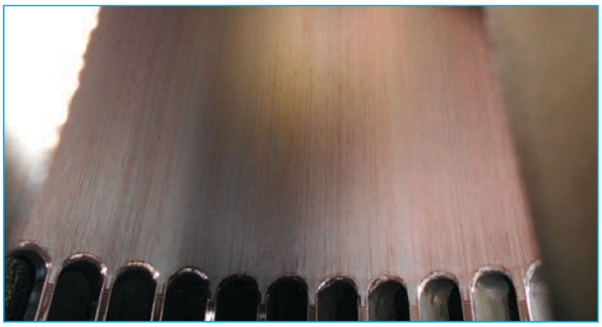
A number of vessels that have switched to VLSFOs reported abnormal main engine liner wear, identified through routine DOT.FAST® onboard testing. In these cases, evidence of liner scuffing and red deposits formed locally on piston crowns or top edges was recorded, with red colored iron burrs in the scavenge port discovered in a few instances.

In order to prevent further damage from occurring, Chevron Marine Lubricants worked with customers to carry out a comprehensive program of field monitoring. Alongside in-depth drip oil analysis with the DOT.FAST onboard and onshore service, a range of additional tests were conducted which we will review at length here.

Figure 1: Photographs (A–C) of damaged liners. Courtesy of Chevron Marine Lubricants, 2020

A) Piston with scuffing and deposits.

B) Iron burrs in scavenge port.



C) Cylinder liner with deep red layer with scoring marks.

These tests were chosen specifically by the technical team in order to identify and help treat the cause of the problems experienced by these engines.

Chevron field investigation overview

Following the identification of issues with piston rings, the Chevron Marine Lubricants Field Technical Specialist team identified seventeen vessels requiring further investigation. The age of the ships varied between four and twenty years, across a wide range of ship types including bulker, oil tanker and container vessels. All engines were two-stroke marine main engines from the major OEMs. It should be noted that in the majority of cases the piston rings fitted in these engines were not of the latest design — hard coated and gas sealing rings.

Cylinder condition observations

The issue of red deposits did not impact all of the cylinders, but it was found in some cylinders with pre-existing poor cylinder liner or piston ring pack condition.

In most cases the scuffing appeared only on individual liners. Some scuffed units showed red deposits on piston crowns with other units showing no signs of either scuffing or deposits.

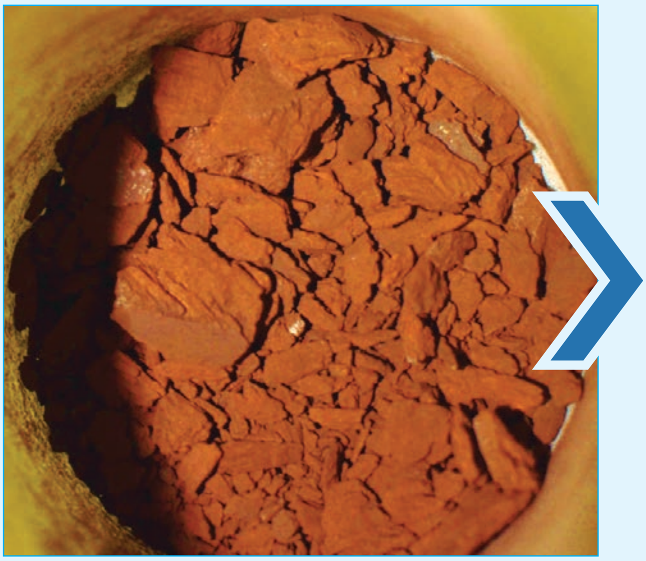
Cylinder lubrication

It became clear that this issue wasn't limited to a single lubricant supplier or linked to the BN level of the lubricant used in the application. In fact, it was found in vessels using 40BN to 100BN lubricant grades. Therefore, the problem was unlikely to be the result of cylinder lubricant performance or engine brand.

Analysis of red deposits in the samples

To establish the cause of the deposit formation and to be able to advise on how to deal with the issue, identification of the chemical composition of the samples, as well as a detailed analysis of the used oil, was carried out. Details on the analytical methods employed can be found in Figure 2.

Figure 2: An example of the red deposits analysed at Chevron laboratories



Analytical methods

1. **CHN: Combustion Analysis with Thermal Conductivity Detection**
   Measures organic carbon, hydrogen and nitrogen content.
2. **XRD: X-Ray Diffraction**
   Detects crystalline compounds comparing with standard spectrum.
3. **SEM/EDX: Scanning Electron Microscopy/Energy Dispersive X-Ray Spectroscopy**
   Visual screening and point at specific particles to determine the elemental composition of the particles.
4. **XPS: X-Ray Photoelectron Spectroscopy**
   Oxidation state of the element identification based on binding energy.

Results from analysis of red deposits

1. **CHN: Organic Carbon, Hydrogen, and Nitrogen**

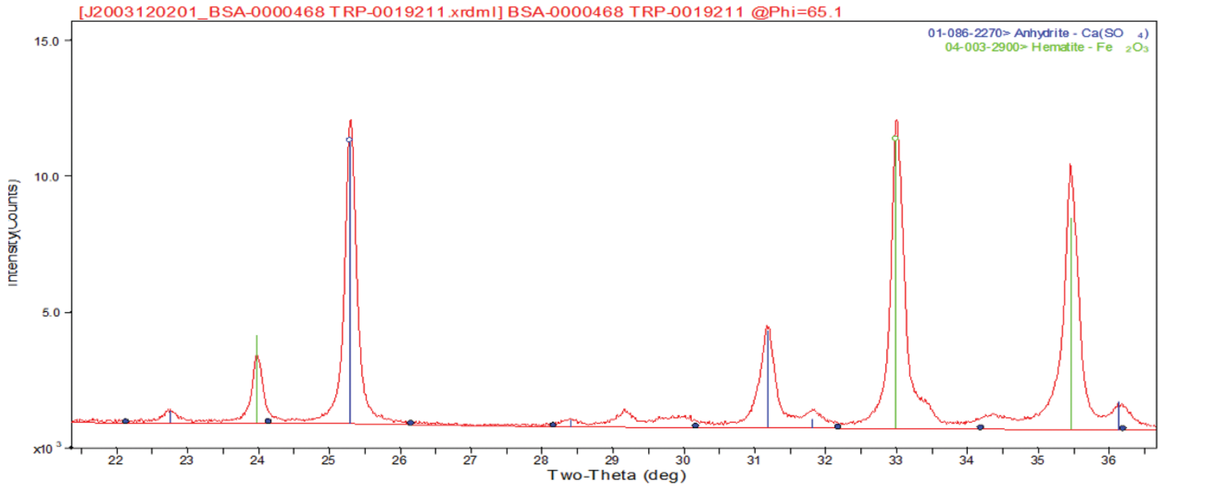
Figure 3: Measurement of Total Carbon, Hydrogen and Nitrogen

Test Method	Elements	Wt %
Test Method 31319 = ASTM D5291 and D5373	C	<1
	H	<1
	N	<1

Conclusion: There are very few carbon, hydrogen and nitrogen compounds in the deposit. This may indicate that all organic compounds have been burned off due to the very high combustion temperature.

2. XRD: X Ray Diffraction Analysis

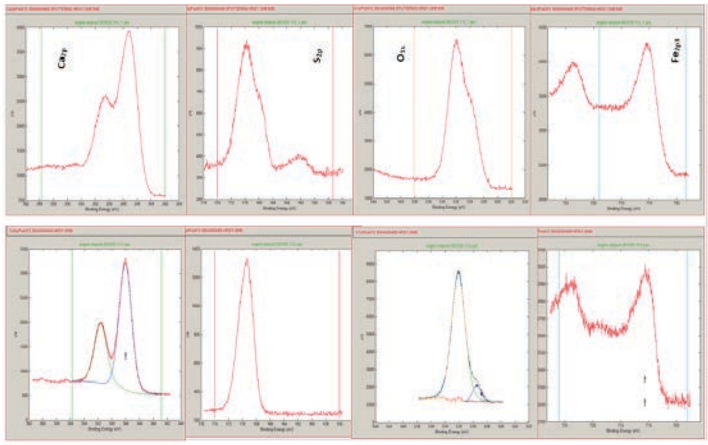
Figure 4: X-Ray Diffraction Analysis

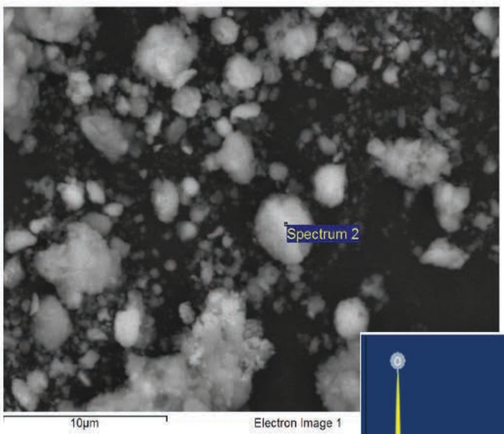


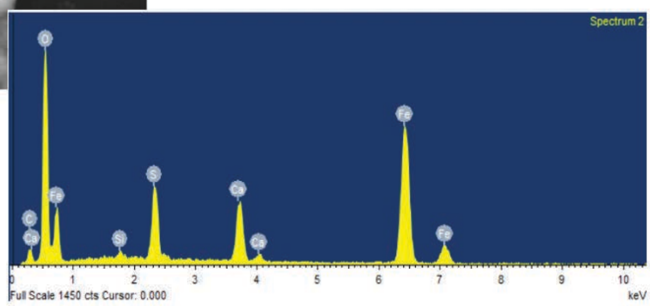
Conclusion: The XRD analysis indicates that the red deposit consists of mostly crystalline materials as Anhydrite $CaSO_4$ and Fe_2O_3 (Hematite). Hematite is even harder than ferrous metal.

3. SEM/EDX + XPS

Figure 5: SEM/EDX + XPS Visual screening and point at specific particles to determine the elemental composition of the particles







Conclusions:

- The major phase(s) in this sample (>95%) consists of Ca, S, Fe and O which are calcium sulfate and iron oxide.
- Trace amounts (<5%) of Ni, Cu, P, Si were also detected.
- Interestingly, the morphology of some of the iron particles are in the form of spheres (~10µm in size). While the most obvious inference is that the iron oxide is rust, please note that welding spatter also tends to form such spheres.
- The morphology of other types of particles are random and they too contain iron.
- The iron oxide spheres seem to have been bound by the calcium sulfate material.

Summary of findings

Following this program of analysis, the results indicate that the deposits contain very little organic material. This suggests that the source of the calcium sulphate — not a cause for concern in itself — is probably as a result of harmless detergent additives from the lubricants. The iron oxide, however, is the result of harmful abrasive wear of the piston and liner.

VLSFO Fuels

The key element that changed prior to the observation of red deposits is the introduction of lower sulphur fuel due to IMO 2020 implementation. Therefore, it is important to look in detail at the characteristics of the fuels in use.

We have calculated the CCAI (Calculated Carbon Aromaticity Index) and determined the combustion characteristics ECN (Estimated Cetane Number) via Fuel Combustion Analysis (FIA/FCA-IP 541) for the various fuel types most commonly bunkered post IMO-2020 enforcement, and compared them with HSFO, which would have been the predominant fuel used in these engines pre-2020.

Key characteristics of VLSFOs

- VLSFOs analysed showed excellent combustion properties — typically faster burning, higher energy release than traditional HFSO.
- The time between injection and reaching maximum pressure is shorter, hence peak combustion is reached earlier in the combustion cycle.
- Overall, more energy released — typically higher max ROHR level.

VLSFO from liner scuffing cases showed typically low CCAI and high ECN. The key observation is that most VLSFOs typically have a lower CCAI in comparison with compared to HSFOs.

Figure 6A: ROHR = Rate of Heat Release

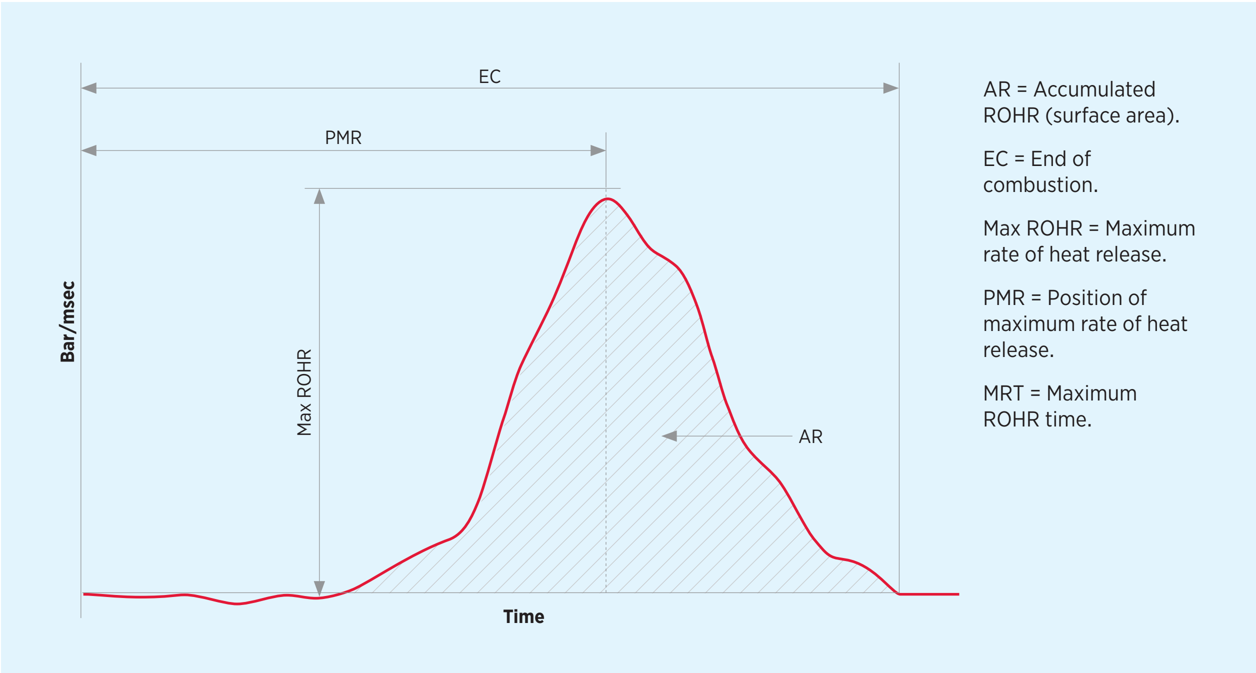


Figure 6B: Comparison of ROHR from different batches of VLSFO

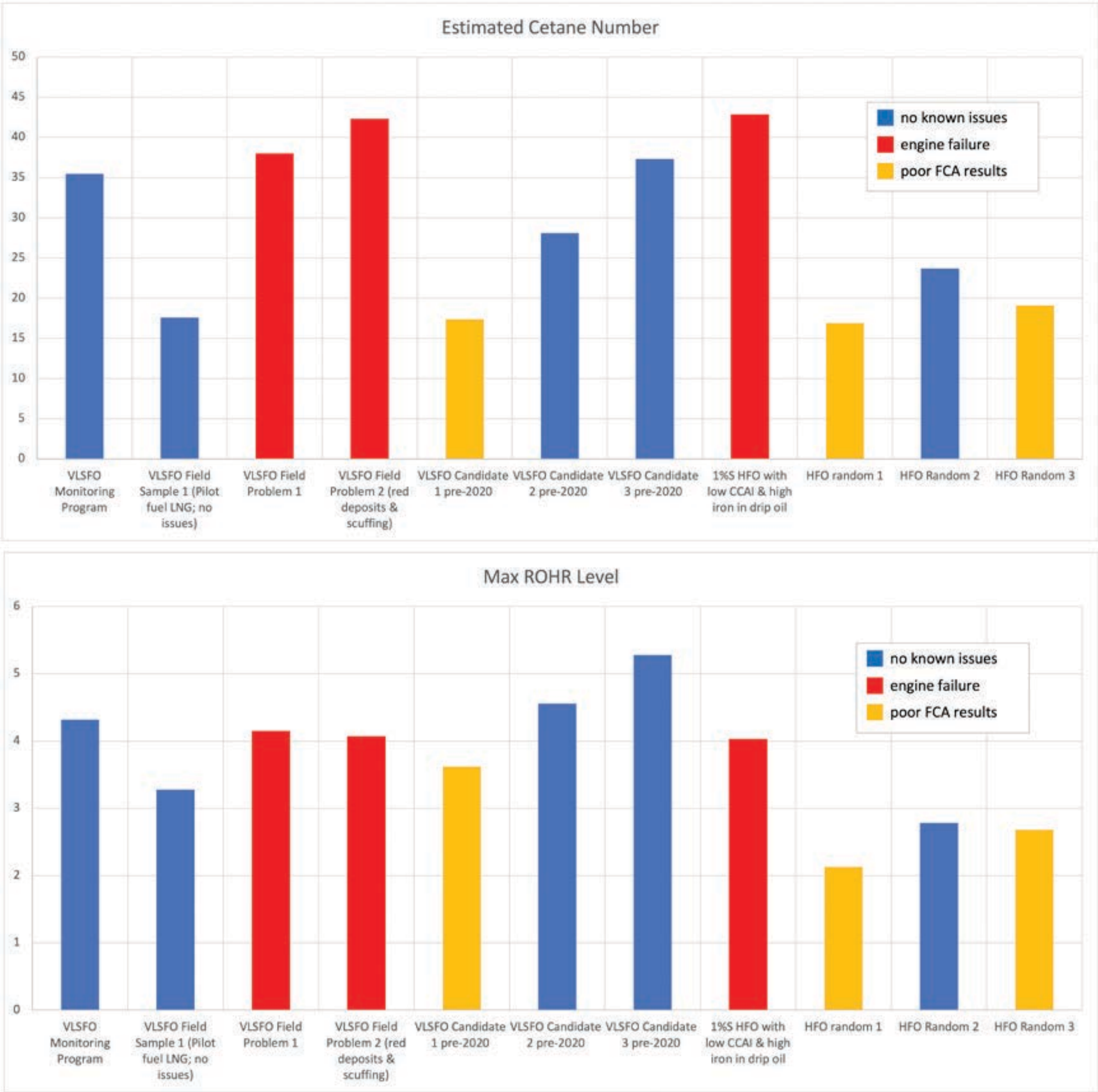


Figure 7A: Difference in FCA Test — Comparison of the combustion process in VSLFO and HSFO

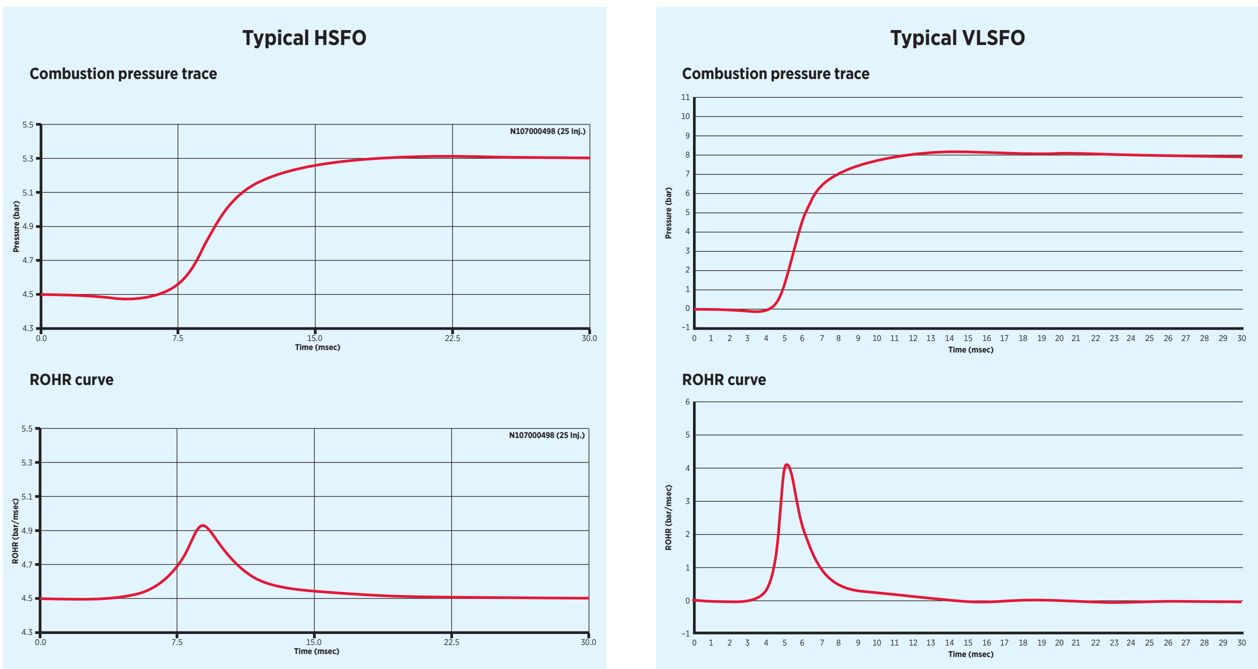
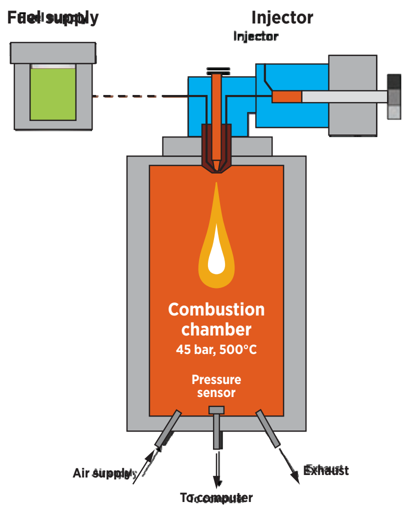


Figure 7B: Fuel Combustion Analyzer



Conclusion

Vessels experiencing issues with red deposits tend to have been in operation for a few years. Analysis of the deposits indicates that they are mostly composed of inorganic compounds, formed as a result of piston and liner wear. The issues are not related to the base number or the lubricant brand used, as typically the engine experienced the problem in only one or a few of the cylinders.

Fuel analysis indicates that VSLFO typically has higher combustion engine density properties, resulting in more harsh operating conditions and more stress on the engine components. According to Luc Verbeeke, Senior Engineer, Chevron Marine Lubricants, the vast majority of customers transitioned well to VLSFO and the typical higher energy content of the fuels means more value for money.

"While newer ships do not have a problem using these fuels, engines already closer to an overhaul did struggle sometimes," said Luc Verbeeke. "Cylinder units that could have run for another six months or a year on HSFO did not survive the tougher conditions with the new fuels."

Combined with incorrect fuel handling when transitioning to VLSFO, these challenges with older engines and the impact of flushing waste material from tank cleaning through engines account for most of the scuffing incidents observed. The fact that reports of scuffing have since declined to usual levels suggests that the industry has now come to terms with the procedures it needs to operate safely and reliably with VLSFO, and that the engine maintenance program recommended by Chevron Marine Lubricants helps provide vital protection against liner wear and damage. ■

Figure 8: Chevron's DOT.FAST® Onboard Testing Kit

Routine testing with Chevron's DOT.FAST® onboard testing kit can help identify abnormal main engine liner wear which may lead to liner scuffing and red deposits.