Test report
HD4 Hendrik Petronella

Dex Premium Lubricants

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Preface:

At the end of 2017, Dex Oil was put in touch with Bais Beheer BV via Peter de Caluwé of ORM Advies. It was proposed that a test be conducted with a diesel generator set (Caterpillar 3306) aboard the fishing ship HD-30 Fortuna, owned by Bais Beheer BV in Den Helder. The engine oil that was used in this generator set had to be changed every 250 hours and the generator set consumed an average of 2.2 litres of engine oil per week. During this test, it was indisputably proven that the usage time of DEX lubricant is many times longer than that of other available oils and that its use results in a substantial decrease in oil consumption.

It was decided that follow-up tests would be conducted, the results of which are discussed below.

The ships:

The tests were performed on the fishing trawlers HD-4 Hendrik Petronella and HD-30 Fortuna in Den Helder.

HD-4 specifications:

- **Constructed in 1994**
- **Measurements: 42.9m x 8.5m**
- **IMO: 9115951**
- **Engine: 6SWD 280**
- **Fishing area: North Sea**

HD-30 specifications:

- **Constructed in 2003**
- **Measurements: 24m x 7m**
- **IMO: 9264295**
- **Engine: Mitsubishi 6 SRF**
- **Fishing area: North Sea**

Generator set:

DEX DP1 10W40 was used in the Caterpillar 3306 generator set on the HD-30. According to the crew, the generator set became audibly quieter almost immediately.

Based on the independent oil analyses, the oil lasted for 3000 hours (12x longer than normal) and the carter refill was done purely as a precautionary measure at the recommendation of ORM Advies. The reason for the replacement was the increasing ionized copper, which was later found not to be due to the DEX lubricant. Further analyses revealed that the oil was still in excellent condition. The oil consumption was cut back from 2.2 litres per week to 1 litre per week.

The new oil has since been in use for 5000 hours — 20x the normal usage time — and analyses indicate that it is still in good condition. See the attached ORM Advies report for more details.

As a result of the test conducted beforehand, DEX DP2 ISO VG100 gearbox oil was also applied to the reverse gear of the HD-4.

Reverse gear:

The reverse gear of the HD-4 had issues with resin accumulation and oil leakage. In order to resolve the varnishing issue and determine the lubricating properties of DEX lubricant, the decision was made to change the oil to DEX DP2 ISO VG100, due to its exceptional detergent properties. The resin-like impurities and varnishing in the reverse gear quickly disappeared, as did the hammering sound that was previously heard by the crew. The operating temperature of the reverse gear dropped by roughly 9° C, which was calculated to represent a decrease in diesel fuel consumption of approximately 6 litres per hour.
The oil leakage stopped as well, reducing lubricant consumption by 20 litres per week. However, since a reverse gear should not leak at all, this report does not qualify this reduction as actual savings.

As of the date of this report, the oil was still in excellent condition. See the attached ORM Advies report for more details.

Due to the decrease in diesel fuel consumption resulting from DEX Oil's gearbox lubricant, Bais decided to use DEX DP1 10W40 engine oil in the Wartsilla main engine on the HD-4 as well.

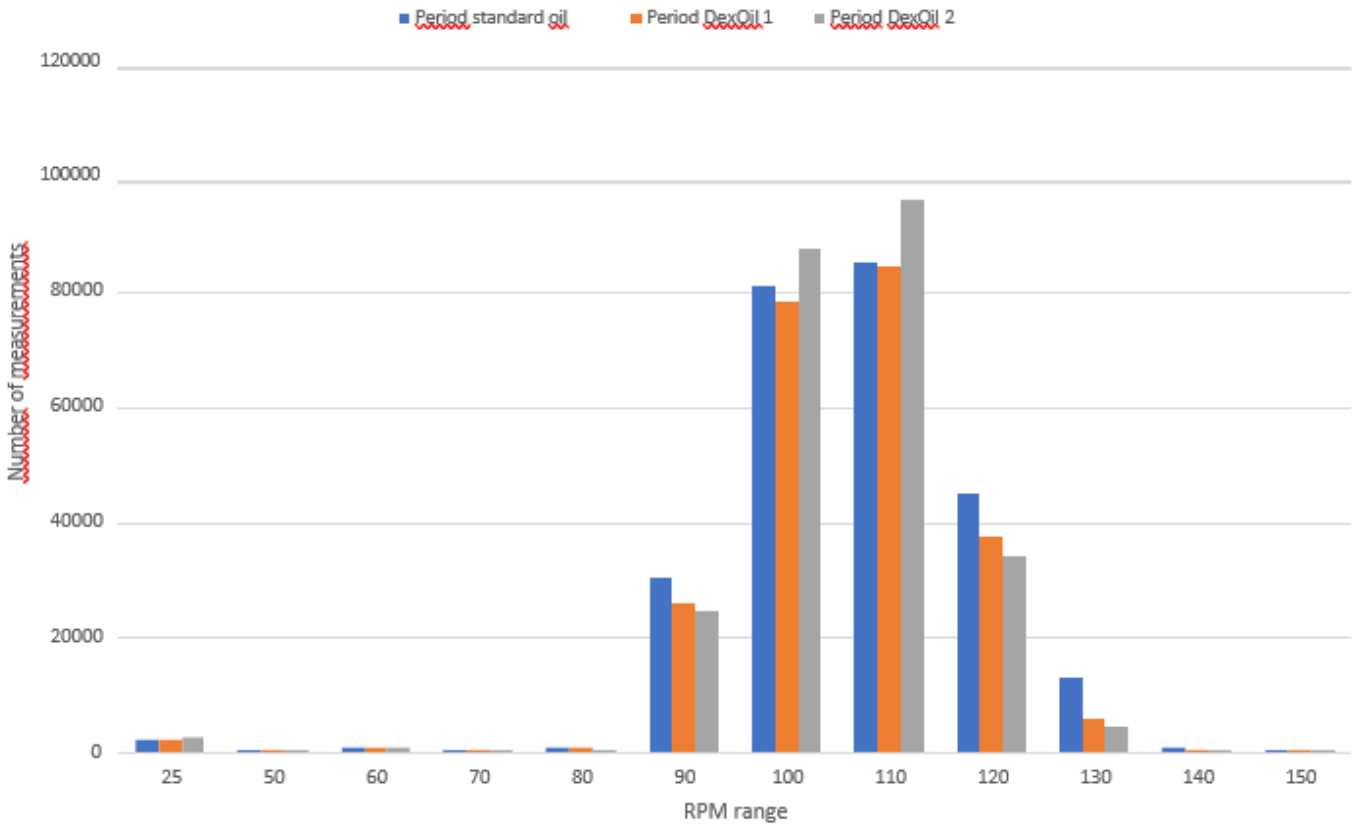
HD-4 main engine:

a. Description

In order to investigate the effect of the DEX DP1 10W40 on fuel use, continuous measurements were taken aboard the HD-4 Hendrik Petronella. These measurements were taken online using the following sensors and methods:

- Fuel consumption: Aqua Metro CONTOIL VZF II, accuracy 0.1%- 1%, for inflow and outflow
- Capacity measurement: HBM strain gauge with measurement amplifier
- Axle RPM: Measured using existing sensor on the propeller shaft
- Data logger: LLINQ Naptic® online data logger, log frequency of 5 seconds
- Measurement period: 3 September 2018 to 31 October 2018
- Lubricant change: To DEX DP1 10W40 on 20 September 2018

b. Sailing profile



Graph 1

- Three periods of sailing profiles
- Most observations were in the 80 and 120 RPM range
- This RPM range pertains to sailing to and from the fishing areas as well as the fishing itself
- Further research into the differences in diesel fuel consumption is based on this RPM range

c. Measurement data

In graphic 2 above, clear fuel savings can be seen across almost the entire RPM range.

d. Conclusion of fuel measurement

1. Part of the more than 1,000,000 measurements (especially in the 99 – 112 RPM range) turned out to be unusable, because of measured capacities that were theoretically impossible for the fuel consumption and/or RPM logged and vice versa. This was most likely caused because the circumstances at sea in conjunction with the measurements on the fishing ship varied too much. This is likely due to reactive forces from the fishing equipment while fishing.

2. The conclusions in this report, therefore, are based on consistent measurements only.

3. The sailing profiles with and without DEX DP1 10W40 were very similar. See graphic 1.

4. From graphic 2, it can be deduced that the consumption curve of the engine during the use of the DEX DP1 10W40 nearly always lies below the consumption curve for the engine without DEX DP1 10W40.

5. The available reliable measurements clearly show decreased fuel consumption.

6. Since the actual fuel savings were over 5%, it can be assumed that savings were achieved at nearly all RPMs.
   It should be noted that this does not include the savings of roughly 6 litres per hour (2%) for the gearbox described above. When these are included, the total savings for the entire engine system increase to over 7%.

*Note: Comparable fuel savings have since been achieved on other ships that use DEX lubricant. The same applies to the usage time of DEX lubricants.

Shiptech study:

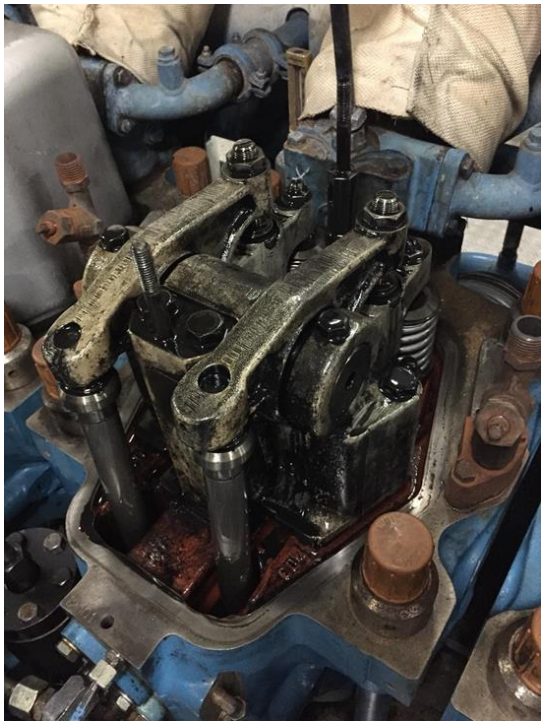
Commissioned by Bais, Shiptech conducted an endoscopic investigation into the Stork 6SWD 80 main engine.
During this investigation, the condition of the engine was observed before the oil was changed to DEX DP1 10W40 and then checked again after two months of sailing.

See the attachments for the complete reports and an excerpt.

One striking result was that, after only one week of sailing, the caps were already visibly cleaner, even though additional filtration (using a CJC filter HDU 27/108) had already been present before the oil change.

Before

After



CO2 reduction:

In order to determine the total CO2 savings, the following assumptions were used:

- 1 litre of lubricant has a CO2 footprint of 2.87 kg (well to carter)
- Fuel and CO2 savings are linearly proportional

1) The Caterpillar auxiliary engine
The oil was typically changed every 250 hours and 2.2 litres were added each week.

After 3000 hours, the oil was changed, which was later on determined to be unnecessary. The oil could have continued to be used for another 3000 hours. For our purposes, we are limiting the overall lifespan to 5000 hours, which at the time of writing is the current figure for the DEX lubricant now present in the engine (see ORM attachment).
The total savings on oil changes therefore amount to 20 x 36 litres of oil, which corresponds to 20 x 36 x 2.87 kg of CO2 (well to carter) or 2066 kg.
The fuel consumption savings for the generator set have not yet been measured and, as such, these CO2 savings have not been included.

2) The reverse gear
The reverse gear has not leaked oil since the oil was replaced with DEX. This was not taken into consideration for these calculations either. The fuel consumption savings that occurred as a result of the new lubrication of the gearbox were incorporated in the savings for the main engine.

3) The main engine

Despite the fact that DEX lubricants perform even better with the passage of time (the initial cleaning process being followed by the formation of a stable protective layer), substantial fuel savings already occurred in the first two weeks of sailing. Highly accurate measurements of specific consumption per kW taken during this period indicated a reduction of fuel consumption measured at >5% (>7% if the gearbox is included,). 6.5% was assumed for the CO2 calculation. At an average consumption of roughly 26,500 litres of diesel fuel per week, this translates to an annual decrease in fuel consumption of 6.5% of 1,325,000 litres, or 86,000 litres (rounded). These savings will increase until around 3000 sailing hours and will stabilize afterwards.

86,000 litres translates to a CO2 reduction of 86,000 x 3 kg of CO2 or 258,000 kg in total.

The total CO2 reduction aboard the HD-4 currently amounts to 260,000 kg per year, a figure comparable to the emissions from over 2,000,000 car kilometres (assuming 120 g per car kilometre).

Conclusion:

The tests conducted at Bais Beheer BV in Den Helder were monitored by independent advisers and clearly indicate that using DEX lubricant significantly extends usage time and provides substantial fuel savings. This has since been confirmed on other ships that use DEX lubricant.
Based on the Shiptech report, it can also be assumed that wear-causing impurities in the engine are reduced, which means less maintenance is likely needed.

The fuel savings of 7% for the HD-4 result in a CO2 reduction of 260 metric tonnes annually.
Based on the results of a study commissioned by the German government, which was conducted by the FSD (Fahrzeug System Daten), a reduction of NOx emissions of at least 15% (and most likely more in practice) can be assumed for the HD-4 as well, which will significantly reduce the costs of the Denox system required.