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EVALUATION OF ENGINE OIL DEGRADATION (MO) SHELL HELIX HX-8, SAE 5W-30 ON BMW 330D XDRIVE

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Abstract: Work deals with the description of the used technology and motor oil used in my work. The next section describes the engine oils and the monitored degradation parameters of engine oils. In the practical were performed tribodiagnostic measurements of oil level during downtime of the BMW 330d Xdrive in order to determine the current quality status of engine oil and the degree of its degradation.

Keywords: Oil; Degradation; Kinematic viscosity; TAN; TBN; Soot; Nitritation.

1 INTRODUCTION

Oils are technologically very complex products with a number of parameters that must meet performance requirements under various load conditions. Despite the time and mileage declaration of the service life interval from the manufacturer, there may be cases where there is an accelerated degradation action and the associated risk of premature wear or engine failure. In my work, I focused on measuring the quality indicators of engine oil during operation and to determine the degree of degradation. Sampling was performed from a BMW 330d Xdrive. We performed measurements of the reference sample and 2 measurements of the oil filling. Sampling took place in the workshop premises of the Department of Mechanical Engineering and measurements were performed in the tribodiagnostics laboratory also belonging to the Department of Mechanical Engineering. The work consists of theoretical and practical part.

2 VEAHICLE BMW 330d Xdrive

The BMW 330d Xdrive, equipped with the M-package and the F30 generation, is a vehicle equipped with an in-line diesel 6-cylinder, which has an output of 190 kW at 4000 rpm and a torque of 560 Nm at 1500-3000 rpm At the beginning of the measurements, the vehicle had a mileage of 193 256 kilometers and at the last measurement it had 200 396 kilometers. [1,4]

3 N57 ENGINE

In 2008, the in-line 6-cylinder turbo diesel N57 was launched, which was to replace the popular BMW M57 engine. The new engine consists of a closed aluminum cylinder block with cast iron inserts and a forged crankshaft. Engine capacity is 2997 cm^3. The block is covered by an aluminum cylinder head, which is slightly lower than the M57 predecessor. To increase the distance between the engine and the hood, the wiring has moved to the rear of the engine. The timing chain on the N57 is single-row and will last longer than on the 4-cylinder sibling N47. The service life of the timing chain exceeds 200,000 km. The N57 uses the 3rd version of the Common Rail injection system. [6]

4 MOTOR OIL SHELL HELIX HX-8 SAE 5W-30

It is a fully synthetic motor oil, providing high performance, cleaning and protection.

Table 1 Parameters of used motor oil Shell HX-8 5W-30

Viscosity grade SAE	**5W-30**
ACEA	**C3**
API	**SN**
VW	**504.00/507.00**
Viscosity index	**171**
Viscosity at -30°C (mPa.s)	**4640**
Kinematic viscosity at 40° C (mm^2/s)	**67,8**
Freezing point	**-48° C**

Source: authors.

The sampling shown below in the images was carried out after the engine had warmed up to operating temperature. After opening the front hood, we took an undefined small amount of engine oil through the channel of the oil dipstick of the lubrication system. Samples were collected using a syringe with an infusion set. [11]

5 USED TRIBODIAGNOSTIC DEVICES

From the point of view of maintaining competitiveness on the market, very high demands are placed on today's high-performance motor oils. They are technologically very complex products with a number of parameters that must fulfill performance parameters in various load conditions. Despite the time and kilometer declaration of the service life interval by the manufacturer, there may be cases where accelerated degradation occurs and the associated risk of premature wear or engine failure.

A set of operating factors (e.g. cold starts and their frequency, the operator's approach to gradually warming the engine up to operating temperature, technical condition of the engine, operating load of the vehicle, length of operating distances, operation in difficult terrain, operation in a dusty environment) has a decisive influence on the service life of the engine oil. etc.). It is precisely the operation of technology in the Slovak Armed Forces that is significantly characterized by the above-mentioned factors. In order to maintain the combat capability and reliability of military equipment, it is therefore necessary to pay increased attention to the monitoring and evaluation of engine oil degradation.

The service life of the lubricating oil is negatively affected mainly by various unsuitable and unforeseen operating conditions. We check the lubricating oil according to three criteria, which also determine the time to change the oil filling. This is mainly the deterioration of the base oil, the decrease in the content of additives in the engine oil and various impurities. Degradation of engine oil is mainly accelerated by thermal degradation and oxidation processes in engine oil. [3]

Additives are added to base oils to reduce destructive processes and improve beneficial properties. For example, antioxidant additives help slow the rate of oxidation. Detergent additives help prevent deposits and sludge. Anti-wear additives are added to some motor oils to form a coating on metal components to prevent wear. Exhaustion of additives is one of the main reasons why engine oil loses its effectiveness and needs to be changed. Although all motor oils deteriorate over time, synthetic oils last longer than conventional oils and provide improved protection against wear and deposits. [3]

6 USED TRIBODIAGNOSTIC DEVICES

6.1 SpectroVisc Q3000

It is a portable viscosimeter which is used to measure the kinematic viscosity at 40 ° C and then calculates the kinematic viscosity at 100 ° C on the basis of the viscosity index of the engine oil. [12]

Fig. 1 SpectroVisc Q3000
Source: authors.

Before the actual measurement, we turn on the SpectroVisc Q3050 device and pull out the metal sampler at the instruction of the imaging unit. The internal surfaces of the device must be thoroughly cleaned.

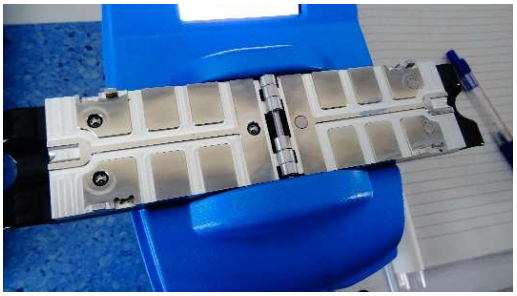


Fig. 2 Sampler with prismatic slot
Source: authors.

Subsequently, the sampler with the prismatic slot is inserted into the device and the device is allowed to heat up to an operating temperature of 40 °C.

Fig. 3 Warming up the SpectroVisc Q3000
Source: authors.

After heating, the device will give us an instruction to insert the sample: „Load the sample".

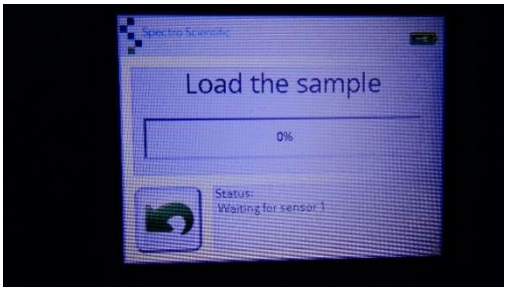


Fig. 4 Device prompt to insert oil sample
Source: authors.

Using a special applicator, we insert a sample of 60 microliters into the device.

Fig. 5 Inserting a sample
Source: authors.

6.2 Fluidscan 1000

This instrument analyzes the qualitative properties of motor oils on the basis of infrared spectrometry. The device provides comprehensive information on the status of engine oils through individual monitored parameters. After inserting the sample, the device analyzes it, provides us with the required data via the user interface and saves the measurement results in its memory, where it is able to store up to 5000 measurement results. [7, 10]

Fig. 6 Fluidscan 1000
Source: author.

Before measuring, it is necessary to clean the measuring surfaces when prompted by the device.

Subsequently, in the system, we select the vehicle from which the engine oil sample is to be evaluated by the device. The vehicle is predefined in the device by the user of the device in the form of a directory. Individual measurements are stored in the directory in the form of files. The system includes the new measurement in the database of previous measurements for the given vehicle. Subsequently, we apply an unspecified volume (drop) of engine oil through a sampling syringe with a connected tube. The volume of the sample must be sufficient to cover the surface of the slide. When inserting the sample, we ensure that bubbles do not form, which could negatively affect the accuracy of the measurement. The images show the actual application of the sample to the slide.

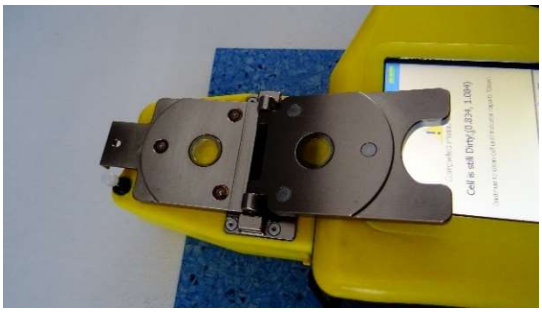


Fig. 7 Cell
Source: authors.

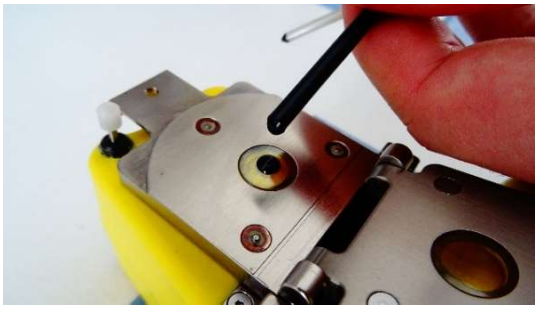


Fig. 8 Inserting the sample on the sample slide 1
Source: authors.

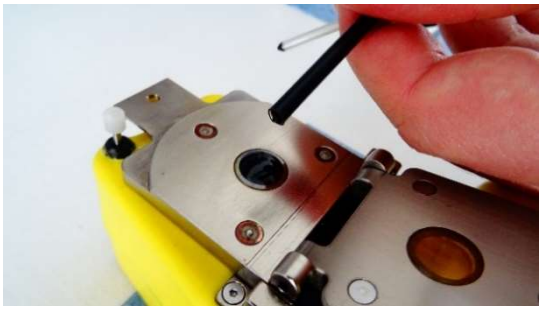


Fig. 9 Inserting the sample on the sample slide 2
Source: authors.

The output of the device is the measured parameters in numerical form and a graphic display, which compares the state of the new oil (reference sample) and the current state of the oil filling in the engine. In the graphic display, the red curve represents the new oil (reference sample). The black curve represents the worn (current) sample of engine oil. A large distance between the curves indicates a high degree of oil degradation. In this case, it is a relatively large degree of degradation in the monitored chemical parameters.

7 CRITERIA FOR USABILITY AND EVALUATION OF ENGINE OIPARAMETERS

- **Appearance.** Do not allow turbidity - matt surface with light reflection.
- **Kinematic viscosity.** Engine oil may only be operated within a viscosity range of ± 20% of the reference sample and diesel engine oil manufacturer's data.
- **Viscosity index**. Temperature dependence of oil fluidity.
- **Sulfation products**. Sulfates are products containing sulfuric acid salts, sulfates. They cause the breakdown of the base oil components and additives in the engine oil.
- **The glycol content.** (Ethylene Glycol-C2H6O2, or Propylene Glycol-C3H8O2) in engine oil is not permitted.
- **TBN - alkalinity number.** Do not allow the operation of engine oil when the TBN value is reduced by more than 50% of the value of the reference sample and the engine oil manufacturer's data.
- **Total engine oil additive.** Do not allow the operation of engine oil when the value of the total additive is reduced by more than 50 %.
- **Water content**. The limit value of the water content in motor oil is 0.5% w / w / 5,000 ppm (concentrations of 0.1 - 0.3% w / w / 1,000-3,000 ppm are already a risk factor). [4] [12]

Table 2 Parameters of used motor oil Shell HX-8 5W-30

Measured samples	**4.12.2021 (reference sample)**	23.02.2022 (first used sample)	**27.4.2022 (second used sample)**
Kilometres worked	**0**	3940	**7140**
Veahicle approach	**193256**	197196	**200396**
Aditives [%]	**100**	80	**69,3**
Glycols [%]	**0**	0	**0**
Nitritation [abs/cm]	**6,3**	7,3	**12,2**
Oxidation [abs/0,1]	**14,6**	20,5	**22,8**
Soot [% wt]	**0**	0,05	**0,14**
Sulfatation [abs/0,1]	**17,8**	34	**33,5**
TBN [mg/KOH]	**7,75**	4,4	**2,8**
Water content [ppm]	**37,5**	207	**264**
Kinematic viscosity at 40° C [cSt]	**+20% 81,4 67,7 -20% 54,16**	**66,9 -0,8/-1,18%**	**67,2 -0,6/-0,88%**

Source: authors.

8 MEASURMENT RESULTS

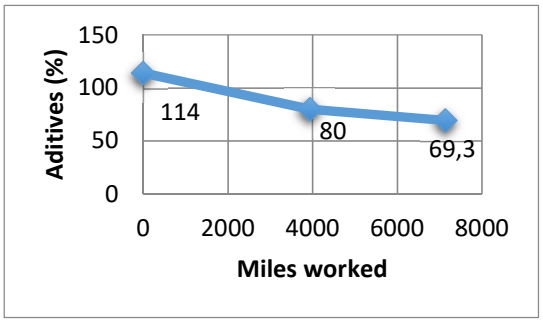
- **SUITABLE** kinematic viscosity / 40 ° C: 67.2 [cSt], MO viscosity reduction is 0.5 [cSt] - Mo viscosity reduction by -0.88 [%]. The allowable tolerance is derived from a reference sample of 67.7 [cSt], ± 20% (+ 20% = 81.4; -20% = 54.16cSt), cf. Table.

Other parameters of the monitored properties, measured in the Laboratory of Tribodiagnostics AFA are within the tolerances of the usability of the MoD, valid for the used MoD No. 1 (see table).

- **Alkalinity number (TBN)** [mg KOH / g] - 2.8 - if the TBN value decreases by more than 50% of the value of the reference sample, MO operation is not permitted - **NOT SUITABLE.**
- **Carbon black [% w / t]** - 0,14 - increase compared to the reference sample by 0,14 [% w / t], maximum value is up to 2% w / t – **SUITABLE.**
- **Oxidation [abs / 0,1]** - 22,8- increase compared to the reference sample by 7,4 abs / 0,1 - do not allow MO operation if the value of antioxidant content decreases by more than 50% of the value of the reference sample – **SUITABLE.**
- **Nitration - Nitritation [abs / cm]** - 12.2 - increase compared to the reference sample by 5.9 abs / cm.
- **Sulfation [abs / 01]** - 33.5 - process in MO causing decomposition of base oil components and additive by starter water is present in MO in proportion to the presence of water - **SUITABLE.**
- **Water content [ppm]** - 264 - reference sample was not contaminated with water - monitored and limit values of water content in MO are 0.1-0.3% w / w / 1000-3000ppm – **SUITABLE.**

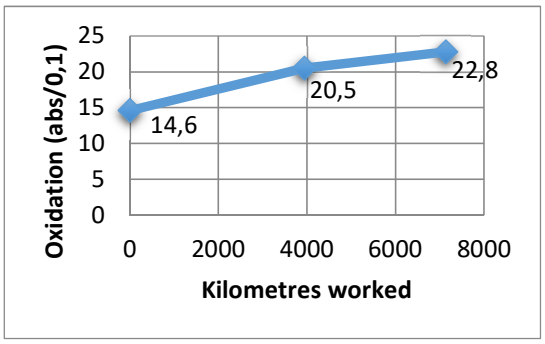
- **Glycols [%]** -0,0- value the same as in the reference sample / the presence of glycols in the MO is not allowed - **SUITABLE.**
- **Addivation [%]** - 69.3 - decrease compared to the reference sample by 39,2 [%] - do not allow MO operation if the value of the total additive is reduced by more than 50% - **SUITABLE**

Appearance (comparison of clarity, gloss, odor and turbidity) Determine whether or not it satisfies according to its own methodology (practical and professional experience). Do not allow turbidity - matt surface with light reflection



Graph 1 The level of motor oil addition depending on the mileage of the oil level
Source: authors.

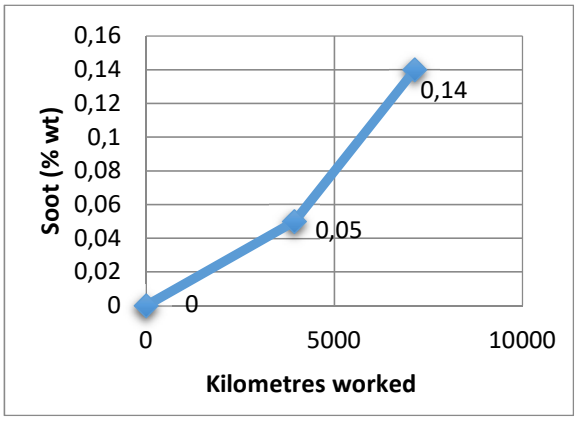
As the mileage of the oil fill increases, the concentration of the additives in the engine oil decreases due to chemical reactions during operation.



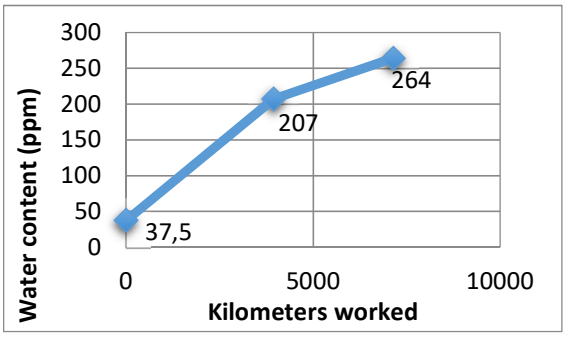
Graph 2 The level of oxidation of the engine oil depending on the kilometers of oil filled
Source: authors.

The measurements showed a gradual slight increase in the oxidation of the engine oil. However, the increase in oxidation was minimal. We can say that the oil is characterized by good oxidative stability.

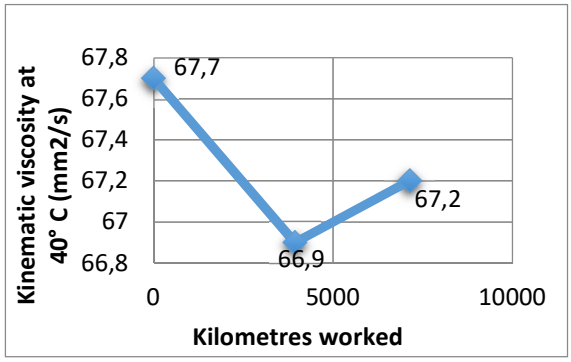
The carbon black content was expected to increase during the period under review. This increase is due to the penetration of combustion products into the oil charge.



Graph 3 Soot content in the engine oil depending on the mileage of the oil level
Source: authors.



Graph 4 Water content of engine oil depending on the mileage of the oil
Source: authors.



Graph 5 Change in kinematic viscosity of the engine oil at 40 ° C depending on the kilometers of oil filled
Source: authors.

During the monitored period of operation, the water content of the engine oil increased, but it was within the permitted values. Water causes additives to fall out because it triggers the sulfation process. Water also has a corrosive effect on steel surfaces.

Kinematic viscosity values remained stable during the observed period. Viscosity values were within the allowable range. Kinematic viscosity is the primary physical parameter monitored for engine oil.

9 CONCLUSION

This work consisted of tribodiagnostic measurements and their evaluation. The measured values show that the new oil filling during the first ones showed a significant decrease in the TBN parameter. Measurements showed unsatisfactory TBN parameter. We recommend to measure sample of the motor oil after driving next 2 000 km and then is possible to decice about the further operation of the MO.

References

[1] *Bmw 3*. (Online). Available at: https://edukr.ru/en/avtoyurist---free-consultation/bmv-dvigatel-3-litra-dizel-osobennosti-ekspluatacii-dizelnye-dvigateli-bmv/

[2] *Classification SAE*. (Online). [cit. 2021-5-5]. Available at: https://www.motorove-oleje.sk/dokumenty/klasifikacia-sae/

[3] LUKÁŠIK P. and MARKO, M. *Deterioration dependability diagnostics. Monitoring of motor oils degradation by the operation of the vechiles 155mm ShKH Zuzana type 2000, 2017.* ISBN 978-80-7582-009-9.

[4] *Engine cooling and lubrication systems.* (Online). Available at: https://www.cedengineering.com/userfiles

[5] *Engine lubrication system, diagnostics and distribution of oils.* (Online). Available at: http://www.autorubik.sk/clanky/ mazaci-system-motora-diagnostika-a-rozdelenie-olejov/

[6] *Engine N57.* (Online). Available at: http://australiancar.reviews/bmw_N57.php

[7] FluidScan 1000 User´s Guide: Spectro Scientific. One Executive Drive Chelmsford, 2014.

[8] *Principles of lubrication.* (Online). Available at: https://blog.emersonbearing.com/blog/ principles-of-lubrication

[9] MARKO, M. a kol. BULL-12-6, *Properties and tribodiagnosis of lubricants in the operation of motor vehicles.* Trenčín.

[10] ČERNÝ, J. *Properties of motor oils-Oxidation stability, nitration of oils.* (Online). Available at: https://www.oleje.cz/clanek/Vlastnosti-motorovych-oleju---Oxidacni-stabilita--nitrace-oleje/ [cit: 2021-05-05].

[11] *Shell Helix HX-8 5W-30.* Available at: https://www.shell.co.id/in_id/motorists/oil-and-lubricant/helix/helix-hx8/_jcr_content/par/contentblock/link.stream/1587444518076/71a934067d799f774bcbd632722a86fc3ae5fd24/hx8-x-5w30.pdf

[12] SpectroVisc Q3000 Series User´s guide: Spectro Scientific. One Executive Drive Chelmsford, 2014

[13] STOPKA, J. *Technical information č. 4/2011.* Undesirable impurities in engine oil for diesel engines, 2011. [online]. Available at: http://www.tribex.sk/info/info.pdf/

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