Engine oil analyses of omnibuses in B100 operation

Publisher

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1 Introduction

The fast reduction of greenhouse gas emissions in the transport sector is one of the main goals of the EU climate and energy policy. One measure agreed by EU legislators in January 2024 was to reduce CO_2 emissions for heavy goods vehicles by 45% from 2030, 65% from 2035 and 90% from 2040 compared to 2019 [1]. This has also become necessary because heavy goods transport has increased across Europe in recent decades, with the result that heavy goods vehicles currently account for over 25% of European greenhouse gas emissions from road transport [2]. Heavy duty traffic therefore has a significant impact on prosperity, climate and health. The use of renewable fuels - such as biodiesel - presents an opportunity to radically reduce greenhouse gas emissions in this area as well and to realise the ambitious European climate targets.

Biodiesel is by far the most important biofuel in Europe achieving greenhouse gas savings of up to 90% [3]. In addition to the potential GHG reduction, the use of biodiesel can significantly reduce particle mass and unburnt hydrocarbons in the exhaust gas, is practically sulphur-free and easily biodegradable (water hazard class 1 – WGK 1). Because of its high flash point, biodiesel is not categorised as a hazardous material.

This report and its findings are based on the experience of operating modern buses and coaches (Euro 6) from various manufacturers with pure biodiesel (B100, fatty acid methyl ester – FAME). It is intended to provide stakeholders in the transport industry - including government representatives, consultants and fleet owners - with an insight into how buses can be operated with a higher proportion of renewable energy. It will highlight the potential of biofuels, and biodiesel in particular, for the energy transition within existing and future fleets and vehicles. By using biodiesel in these applications, it is already possible to make an active contribution to climate protection and significantly reduce GHG emissions.

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2 Project B100-Buses

This project focused on investigation the ageing of engine oil in omnibuses in B100 operation. It was conducted from October 2021 to April 2024 in cooperation with IOV Ilmenau GmbH. The aim was to examine the real stress on the engine oil after the specified engine oil change interval and to determine whether an extension of the change interval would be possible based on the data. Compared to the specified engine oil change interval of 30,000 km when using B100, the engine oil change intervals when using diesel fuel in accordance with EN 590 (B7) are significantly higher at 100,000 km.

2.1 Vehicles

At the time of the project the IOV Ilmenau ran a fleet of 38 omnibuses on B100. 30 vehicles of this fleet were examined at least once, some twice, and one vehicle three times. Buses from

Daimler (1 vehicle), IVECO (4 vehicles) and Volvo (25 vehicles) were used (Table **1**). All examined buses were approved for use with B100 and were operated in a similar driving cycle in mixed city, country and highway traffic.

Table 1: Overview of examined vehicles and the amount of engine oil.

Manufacturer	**Engine type**	**Quantity of engine oil in vehicle**
Volvo	B7	27 l
Volvo	B8	30 l
Volvo	B8R	24 l
Volvo	B8Re	30 l
Volvo	8900	26 l
IVECO	Not specified	21 l
Daimler	Not specified	30 l

2.2 Operating materials

The two different engine oils used are a 10W40 or a 5W30 depending on the vehicle. Table **2** shows selected parameters of the engine oils used. The amount of the engine oils used in the vehicles is shown in Table **1**. No additional additives were added to the engine oils in this project.

Table 2: Overview of selected parameters of the engine oils used.

Parameter	**Unit**	**Fresh oil 10W40**	**Fresh oil 5W30**
Iron	mg/kg	1	2
Aluminium	mg/kg	0	0
Copper	mg/kg	0	0
Sodium	mg/kg	0	0
Potassium	mg/kg	0	1
Diesel fuel content	% (m/m)	<0.30	<0.30
FAME content	% (m/m)	<0.30	<0.30
Viscosity at 40 °C	mm^2/s	97.98	70.53
Viscosity index	-	153	169
Base number BN	mgKOH/g	10.07	12.94

The biodiesel used was a pure rapeseed methyl ester (RME) that met the specifications of EN 14214 specifications and did not fulfil any other special requirements (appendix 1)

2.3 Sampling and analyses

Sampling of the engine oils used was carried out by the IOV Ilmenau GmbH workshop during the mandatory engine oil change after approximately 30,000 km. The engine oil was completely collected and a sample was then taken. This was to ensure that a representative sample was taken. The sample was subsequently analysed by OELCHECK. An example certificate of analysis is attached as appendix 2.

3 Results

All buses operated with B100 showed no abnormalities during the project and were always operational. Repeat measurements on the same vehicle show that the results obtained are reproducible and can therefore be directly compared with each other.

In the following sections, anomalies in the analysis of the engine oil are discussed. Alkali metal contents between 25 and 45 mg/kg are considered to be anomalies. Although this content is not classified as critical for the operation of the vehicles, it should nevertheless be emphasized as an increase. Alkali metal contents above 45 mg/kg are classified as critical and an engine oil change is then recommended. In addition to the metal content, engine oil dilution due to the entry of biodiesel, significant changes in viscosity and the base number are included in the discussion as critical parameters.

3.1 Engine oil dilution

One of the most important parameters when operating diesel vehicles with biodiesel is possible engine oil dilution. This occurs when diesel fuel is introduced through late post-injections, which are used to clean the diesel particulate filter. If the fuel does not subsequently evaporate, the lubricating effect of the engine oil continues to diminish. The engine oil dilution can be greater when using biodiesel than with fossil diesel fuel, as biodiesel only evaporates from the engine oil at much higher temperatures. In the past, this was known in particular from short-distance operation.

The tests on the buses, which were all operated in the city, country and highway cycle, show an average and uncritical biodiesel content of 1.0%, with a maximum content of 1.8%. The only exception is the B7 engine, which is susceptible to engine oil dilution with contents of 6.6% to 12.3% biodiesel. Due to the dilution with fuel, the viscosity of the lubricating oil fell significantly from 98 mm^2/s to an average of 71 mm^2/s. This does not lead to problems, but a shortened engine oil change interval is required to operate vehicles with this engine. All other engine types can be classified as uncritical regarding engine oil dilution, which is why operation with B100 beyond the shortened engine oil change interval of 30,000 km is possible.

3.2 Metal content

Alkali metal catalysts are usually used in the production of biodiesel. In addition, a water wash follows the production process. For these reasons, the specification standard EN 14214 currently limits the metals sodium and potassium as well as calcium and magnesium in biodiesel to a maximum of 5 mg/kg. Contact of B100 with the engine oil can lead to increased alkali metal contents. These could have a detrimental effect on the engine oil or engine technology due to the formation of salts or soaps. Components with calcium and magnesium are usually already used in the additives of the lubricating oil and therefore only play a subordinate role in the risk assessment of the analysis results. In addition to alkali metals, aluminium and iron contents are indicators of possible wear in the engine. This is not caused by the use of biodiesel and usually allows conclusions to be drawn about the age of the vehicle, among other things.

In the project, a slightly increased sodium content of 26 to 37 mg/kg was found in five cases, which was classified as uncritical for the operation of the vehicles. As vehicles with identical engines also had lower sodium contents and the biodiesel content in the engine oil of these vehicles fluctuated between 0.3% and a maximum of 1.8%. The metal contents found cannot be fully attributed to the biodiesel used. The vehicles with high biodiesel contents (see 3.1) showed no increased alkali metal contents. Increased sodium contents were usually accompanied by increased iron contents of at least 24 mg/kg.

Critical concentrations of aluminium (45 mg/kg and 64 mg/kg) were found in two cases. In both cases, the iron content was also increased at 31 mg/kg and 39 mg/kg. An iron content of 109 mg/kg was found in one vehicle. For all the abnormalities mentioned above, wear on the engine system is one explanation for the increased metal content.

In one vehicle, alkali metal contents of 108 mg/kg sodium and 45 mg/kg potassium were found, which are classified as critical. However, a biodiesel content of <0.3% was determined, meaning that contamination by biodiesel is not evident. Only sodium-containing catalysts were used to produce the biodiesel used in the project. An introduction pathway for any contamination with potassium, such as a coolant inlet or an accumulation in the engine oil sump, could not be determined in the project.

Four new buses were put into service and analysed as part of the project. An increased copper content was found in all cases. Copper is present in gear wheels, main bearings, connecting rod bearings, roller bearings and other components. At levels of 68 to 311 mg/kg, this is to be classified as quite critical, as copper ions can accelerate ageing reactions. In all cases with copper contamination, the viscosity fell from 98 mm^2/s to 72 mm^2/s and thus left the original viscosity class 10W-40. A direct correlation between the copper content level and the drop in viscosity could not be established. If copper is found together with potassium, sodium and glycol, it probably originates from the oil cooler. A combination of iron and tin indicates an entry from bearings or bushings. The current findings therefore tend to point to the cooling circuit, but this cannot be conclusively confirmed.[4] Elevated copper levels in new vehicles are also known to occur in diesel fuels without FAME content.[5] This leads to the conclusion that a shortened engine oil change interval is required when running in new vehicles and that the increased copper content is not a result of FAME operation.

Based on the results, operation with B100 over the shortened engine oil change interval of 30,000 km is possible regarding alkali and alkaline earth metals for all engines, except in new vehicles.

3.3 Base number

The base number is the so-called alkaline reserve of an engine oil, which serves to neutralise harmful acids produced during fuel combustion in the engine. It decreases over time. Starting from a base number of the fresh oil of at least 10.07 mgKOH/g, a base number below 5.00 mgKOH/g is categorised as critical. A lower base number could not be found in any case, but in six cases it fell significantly below 8.00 mgKOH/kg and was always accompanied by other abnormalities such as an increased FAME content, an increased copper concentration and once an increased iron content.

3.4 Unobtrusive parameters

Other parameters analysed, such as the tin, lead and manganese content, the PQ index, the water content, the oxidation and sulphation as well as the dirt carrying capacity, were found to be unremarkable in all tests.

4 Summary and Outlook

In the project, the engine oil of a total of 30 omnibuses was tested when running on pure biodiesel (B100). No operating problems occurred and the majority of the engine oils could have been operated well beyond the shortened engine oil change interval of 30,000 km. Three main reasons for a shortened engine oil change interval were identified:

1) Metal contents of sodium, iron or aluminium, the entry of which could not be attributed to B100.
2) The running-in of new engines and the resulting significantly increased copper content, which cannot be attributed to operation with B100.
3) Engine oil dilution due to the introduction of biodiesel in a special engine model, which led to low viscosities and base numbers.

Overall, changing the engine oil at the specified shortened change intervals of 30,000 km was recommended for 12 of the 35 samples. However, only four of these conspicuous samples were attributable to operation with B100 and related exclusively to a single engine model. Based on the data collected, all other engines can in principle be operated with a longer engine oil change interval even when using B100.

In the future, inconspicuous vehicles are to be tested under continuous control and monitoring at later engine oil change intervals (40,000 km, 50,000 km, 60,000 km and more). The aim is to check whether it is possible and sensible to extend the engine oil change intervals to avoid more frequent vehicle downtimes and unnecessary oil changes.

5 Acknowledgements

Special thanks go to IOV Ilmenau GmbH, without whom this work would not have been possible. We would also like to thank OELCHECK for carrying out the oil analyses and providing further information, as well as the members of the AGQM Technical Committee who supported the project.

6 References

[1] Agreement of the European Parliament and the Council of the European Union, press release 19 January. Adoption on 14 May 2024. Regulation not yet published.

[2] Statistisches Bundesamt (Destatis), as at 31 May 2023, source Eurostat database.

[3] Evaluation- and Progress Report2022, Federal Office for Agricultur and Food, January 2024
[4] C. A Palacio et al., Revista Facultad de Ingeniería, Universidad de Antioquia, 104, 9-19, 2022.
[5] Fitch, Jim; Practicing Oil Analysis; Copper and your diesel engine oils, 2-3, 2004.