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POSSIBILITIES OF DETECTING DIESEL LEAKING INTO ENGINE OIL WITH FUEL SNIFFER

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Abstract

The paper presents the possibilities of detecting diesel fuel without rapeseed methyl ester (RME) in the concentration range of 0–9.54 wt% leaking into engine oil of SAE 15W–40 viscosity specifications using Spectro FDM Q600 – Fuel Sniffer. The results are confronted with regard to the determination of the accuracy and precision of the repeatability of measuring diesel fuel in oil with this type of instrument. By expressing the linear dependence between the diesel concentration determined by Fuel Sniffer and the actual diesel concentration in engine oil of model samples, correlation R = 0.998 was obtained.

From the point of view of verifying the accuracy of the method, it was not proved that it would be burdened with systematic errors. Precision of measurement by this instrument, expressed as repeatability, reached RSD below 5% only for the concentration of diesel in the oil higher than 3.33 wt%.

Keywords: engine oil, diesel, lubricant quality, fuel, Fuel Sniffer, accuracy, precision

INTRODUCTION

The assessment of the engine oil status is significant given that lubrication is a critical factor affecting the life of combustion engines of means of transport and plays an important role in detecting engine running (Perić *et al.*, 2014; Siddaiah *et al.*, 2017).

There are many factors affecting the life of the oil filler, including engine design, fuel quality, engine load and operating conditions. Wei *et al.* (2019) monitored the influence of car driving parameters in urban traffic in China on engine oil properties that were taken approximately every thirty days. An improved grey relational analysis method resulted in the engine idle time, engine running time and number of starts being the three most important factors affecting the quality of engine oils used. Wei *et al.* (2018) also designed and verified a theoretical model of oil status monitoring using on board diagnostics data and gave reference values for end user. Gryazin *et al.* (2018) developed a universal lubricant quality sensor. Belogusev *et al.* (2018) developed a method for determining the dynamic viscosity of petroleum products in the pipeline. The causes of oil degradation also include (Sejkorová and Glos, 2017): a) oxidation and sedimentation of insoluble oxidation products within the lubrication

system; b) thermal degradation; c) corrosion; d) shear instability of shear viscosity modifiers; and e) contamination by mechanical impurities, water, glycol and fuel.

Engine oil contamination with unburned fuel is a relatively widespread and largely underestimated phenomenon compared to other causes of degradation (Macian, 2012). During engine operation, hot exhaust gases pass through the piston rings into the crankcase area where they come into contact with the oil. These hot exhaust gases always contain unburned fuel. The amount of fuel getting into oil because of its vapours condensing is affected by oil temperature in the crankcase area. The fuel vapour condensation into the oil is much higher in cold engines than that of engines at operating temperature. In this natural way, an average of 1–2% of petrol or diesel can get into the oil in cars during the change interval, and even greater quantities in the case of large-volume diesel engines with longer change intervals. According to Wolak *et al.* (2018), there is a problem of oil dilution with unburned fuel, especially in vehicles in urban driving conditions, where the regeneration cycle of a DPF filter is hindered. The amount of unburned fuel entering the engine crankcase due to the incomplete DPF regeneration cycle reaches up to 26.0–34.6%. The presence of fuel in engine oil also reduces its viscosity and lubrication abilities (Veselá *et al.*, 2014; Sejkorová *et al.*, 2018). The result is increased engine wear, which is proportional to the higher fuel content in oil and thus to the lower viscosity.

Fuel leakage into engine oil is mostly detected indirectly by determining the flash point. FTIR spectrometry is a method recently used for monitoring the fuel leaking into the oil (Glos and Svoboda, 2015). Sejkorová (2017) designed a process to detect the leakage of diesel fuel in a concentration range of 0% to 10% into the SAE 15W-40 mineral engine oil using the FTIR spectrometry in combination with the partial least squares (PLS) regression. Abdul-Munaim *et al.* (2018) sees a great potential in terahertz time-domain spectroscopy (Hz-TDS) for determining engine oil contamination by automotive petrol. A method of detecting the presence of unburned diesel in lubricating oil was developed by Capone *et al.* (2008). The principle of the method is the use of a variety of different metal oxide based microsensors which respond to the higher volatility of fuel hydrocarbons compared to the lower volatility of engine oil components. Spectro FDM Q600 Fuel Sniffer is available on the market for measuring fuel content in engine oil. This device uses a built-in acoustic wave surface sensor to measure the concentration of fuel vapour present in the atmosphere above the oil sample.

The paper presents the results of testing the accuracy and precision of the repeatability of determination of diesel oil concentration without the addition of RME in engine oil using Spectro FDM Q600 Fuel Sniffer. Diesel without RME is used as engine fuel by the Czech Army, Czech Railways and most transport companies in the Czech Republic.

MATERIALS AND METHODS

As part of the experimental work, the determination of diesel fuel (without RME) in the concentration range of about 0–10 wt% in the SAE 15W–40 engine oil was tested on model samples using Spectro FDM Q600 Fuel Sniffer (Spectro Inc., USA), including the assessment of the accuracy and precision of the determination.

Preparation of model samples and calibration sample

For model sample preparation, plastic 250 ml sample containers with a cap were used. For the correct and accurate measurement using Fuel Sniffer, the sample container has to be filled up to ¾ of its volume, i.e. up to 187.5 ml. Due to the difference in oil density (0.885 kg.m^{-3}) and diesel density (0.840 kg.m$^{-3)}$, weighing method was selected for the preparation of each model sample (see Tab. I). Oil and diesel weighing was performed with the accuracy of ±0.01 g on the Denver Instrument SI-2002 calibrated laboratory scale.

The mass concentration of diesel fuel in engine oil was determined according to the relationship (1),

$$c = \frac{c_f}{c_f + c_o} \cdot 100 \quad (1)$$

where: **c** is the diesel concentration in engine fuel (wt%); $\mathbf{c_f}$ is the diesel fuel weight (g); $\mathbf{c_o}$ is the engine oil weight (g).

The prepared model samples (see Tab. I) were mixed for 10 minutes and then let to stabilize for an hour with an open sample container so that the prepared model samples best fit the actual engine oil samples taken from the vehicle.

Fuel Sniffer is calibrated using an oil sample with 5 wt% diesel content; a calibration standard was prepared by mixing 7.98 g of diesel fuel and 152.02 g of engine oil.

I: *Model samples of engine oil and diesel fuel mixture (authors)*

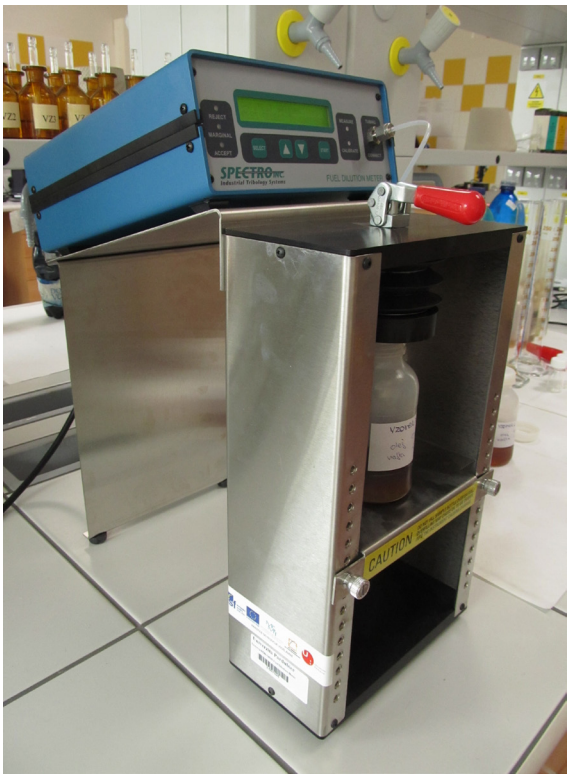
Sample Number	Concentration of Diesel in the Oil [wt%]	Diesel Fuel Weight [g]	Engine Oil Weight [g]
1	0.00	0.00	165.90
2	0.48	0.79	164.11
3	0.99	1.65	164.27
4	1.43	2.37	163.44
5	1.89	3.14	162.63
6	2.38	3.94	161.79
7	2.85	4.72	160.98
8	3.33	5.52	160.12
9	3.80	6.29	159.32
10	4.27	7.09	158.86
11	4.76	7.88	157.65
12	5.72	9.46	155.98
13	6.67	11.02	154.31
14	7.62	12.60	152.66
15	8.59	14.19	151.00
16	9.54	15.74	149.33

Determination of diesel in oil by Spectro FDM Q600 Fuel Sniffer

The concentration of diesel fuel without RME in engine oil was determined using Spectro FDM Q600 Fuel Sniffer. This type of instrument measures the concentration of fuel hydrocarbon vapours present above the sample, i.e. it is based on the Henry Law, assuming that the mass of gas dissolved at a given temperature and given pressure in the volume unit of the liquid is directly proportional to the gas pressure above the sample in the case of gas and liquid equilibrium. For measurements, Fuel Sniffer (see Fig. 1) uses a built-in surface acoustic wave (SAW) sensor which is coated with polymer to prevent contamination of the surface by fuel vapours.

The mechanism of detection is reversible vapour absorption in polymer.

The instrument should be kept warm and stabilized for 15 minutes before starting the measurement. During this time, a platform for sample placement was set so that the sample container stood in the middle, the platform was at the right height, and the sample container could be properly locked for measurement purposes. Since the SAW sensor has a linear response to the vapour



1: *Spectro FDM Q600 Fuel Sniffer*
authors

concentration above the sample, the instrument is calibrated with one standard before the start of the measurement, that is, a sample of oil with 5% diesel content, i.e. the midpoint of the dynamic range.

The measurement was repeated three times for each model sample and the arithmetic mean was calculated from these three measurements. Three or four blank measurements were performed between measurements of each model sample to clean the sensor from residual vapour, i.e. 0.0% fuel concentration was displayed on the instrument display.

The repeatability accuracy and precision of the concentration of diesel in the oil determination by Spectro FDM Q600 Fuel Sniffer was determined by repeated analysis of model samples covering the entire measured range at three levels: 0.48%; 3.33%; and 9.54%.

The accuracy of the result was calculated according to formula (2) below:

$$\left|\bar{X} - X_0\right| \leq 3 \cdot SD \tag{2}$$

where: $\bar{X}$ is the average concentration of diesel in the oil (wt%); X_0 is the actual concentration of diesel in the oil (wt%); SD is the standard deviation (%).

The precision of measurement is characterized by the variance of the results and was expressed as the standard deviation of repeated measurements. To clearly demonstrate the accuracy of repeatability, the relative standard deviation (RSD) in % was given by the formula (3):

$$RSD = \frac{SD}{\bar{X}} \cdot 100 \tag{3}$$

RESULTS AND DISCUSSION

The results of the determination of the concentration of diesel in the engine oil for each model sample prepared using Spectro FDM Q600 Fuel Sniffer are shown in Tab. II.

Tab. II shows that Fuel Sniffer gives the fuel in oil value expressed to one decimal place. Some inaccuracy is brought to the determination results by this type of instrument at the time of calibration, when the instrument can only be calibrated with a 5% solution of diesel in the oil; the actual value expressed to tenths of percent cannot be entered.

The following diagram shows the dependence between the values measured by Fuel Sniffer and the diesel mass concentration values in the engine oil of the model samples.

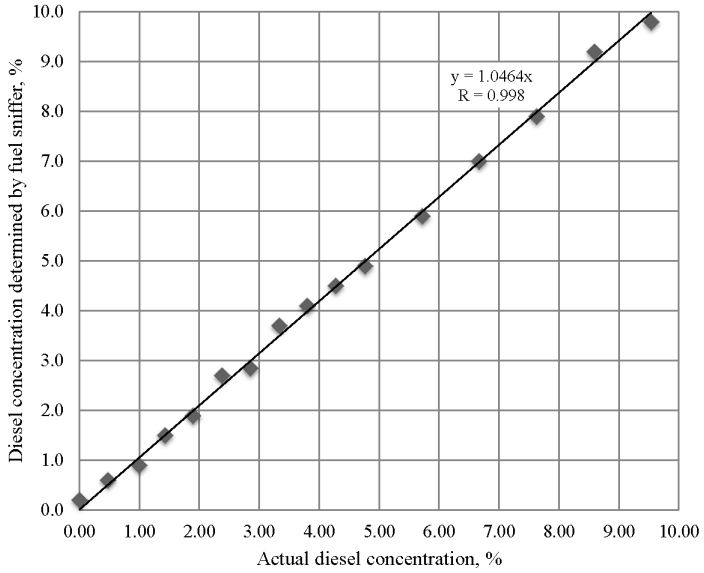
As can be seen from Fig. 2, there is an extremely close relationship between the diesel fuel concentration determined by Spectro FDM Q600 Fuel Sniffer and the actual diesel fuel concentration in the model samples of SAE 15W-40 engine oil as the correlation coefficient value is 0.998.

The accuracy of measurement is affected by systematic errors that may be caused by

II: *Results of diesel concentration determination by Fuel Sniffer*

current concentration of diesel in the oil [%]	diesel concentration determined by FUEL SNIFFER [%]
0.00	0.2
0.48	0.6
0.99	0.9
1.43	1.5
1.89	1.9
2.38	2.7
2.85	2.8
3.33	3.7
3.80	4.1
4.27	4.5
4.76	4.9
5.72	5.9
6.67	7.0
7.62	7.9
8.59	9.2
9.54	9.8

(authors)



2: *Regression dependence between the diesel concentration determined by Fuel Sniffer and the actual diesel concentration in engine oil of model samples*
(authors)

the method itself, by the use of the method or by the environment in which the measurement is performed. If the measurement is burdened by a systematic error, the causes must be removed and the correctness of the method repeatedly checked. The accuracy of the method means that if the measurement is repeated enough, the average will correspond to reality, although some of the individual measurements may be distant.

The accuracy of measurement on Spectro FDM Q600 Fuel Sniffer was calculated according to the formula (2) for standards with the concentration of diesel in the engine oil of 0.48; 3.33 and 9.54 with ten repetitions for each standard. The partial intermediate results required for the calculation are shown in Tab. III.

Calculation of measurement accuracy according to formula 2:

1. standard: $|0.56 - 0.48| \leq 3 \,.\, 0.27$
$0.08 \leq 0.81$
2. standard: $|3.65 - 3.33| \leq 3 \,.\, 0.19$
$0.32 \leq 0.57$
3. standard: $|9.72 - 9.54| \leq 3. \, 0.22$
$0.18 \leq 0.66$

The above calculation shows that the condition of accuracy is fulfilled, the method is this not burdened by a systematic error.

The accuracy of measurement is characterized by the variance of the results and, according to the determination conditions, is divided into repeatability and reproducibility. In the present case, the repeatability of the measurement was determined, i.e. The ability to provide repeatedly close values of the diesel concentration in engine oil determined by Fuel Sniffer by one worker in a short time. The repeatability was calculated as the standard deviation of the repeatability of ten

III: *Verification of accuracy and precision of repeatability of determination diesel oil concentration in the engine oil by Fuel Sniffer (authors)*

variable	1. standard	2. standard	3. standard
$\mathbf{x_0}$	0.48	3.33	9.54
$\bar{\mathbf{x}}$	0.56	3.65	9.72
SD	0.27	0,19	0.22
3.SD	0.81	0,57	0.66
RSD	48.20	5.33	2.26

Legend: $\bar{x}$ – average value of ten determinations (wt%), x_0 – verified value (wt%), SD – standard deviation (wt%); RSD – relative standard deviation of repeatability (%)

parallel determination of the diesel concentration in three samples (same as for the determination of the degree of accuracy) covering the entire concentration range. The repeatability of the method expressed as RSD is 48.20% for ten consecutive measurements at a concentration level of x_0 = 0.48 wt%, i.e. the instrument tested does not provide accurate results at the low concentrations of fuel in the engine oil. The relative determination error was 5.33% at the test concentration level x_0 = 3.33 wt% and RSD was 2.26% at the concentration level of x_0 = 9.54 wt%. Li Jingyan *et al.* (2012) indicate that if the RSD is higher than 5%, the method is not acceptable for accurate measurement.

CONCLUSION

Engine oil contamination by unburned fuel is a relatively widespread but often neglected cause of oil lubrication function failure. In common practice, this parameter is most often indirectly monitored by determining the flash point. FTIR spectrometry has been recently used to determine fuel leaking into engine oil but, with regard to the price of a spectrometer, it is not a commonly available method for transport company laboratories, rolling stock depots and repair shops. Therefore, Spectro FDM Q600 Fuel Sniffer appears to be a possible alternative, being suitable for the determination of diesel, petrol and other hydrocarbons in oils. It was verified by testing that this instrument is able to obtain the correct results of the concentration of diesel in the oil within a minute throughout the measuring range of the instrument, i.e. 0–10%. In the case of repeatability accuracy testing, it was necessary to check and clean residual vapours in the SAW sensor before each measurement. This type of instrument provides accurate results of detecting fuel without RME in engine oil for concentrations higher than 3.33 wt% by repeated measuring by one worker over a short period of time.

REFERENCES

BELOGUSEV, V., KOZLOV, K., EGOROV, A. *et al.* 2018. Method and instruments to measure dynamic viscosity of oil products in pipeline. *Engineering for rural development*, 17: 37–942.

CAPONE, S., ZUPPA, M., PRESICCE, D. S. *et al.* 2008. Metal oxide gas sensor array for the detection of diesel fuel in engine oil. *Sensors and Actuators B: Chemical*, 131(1): 125–133.

GLOS, J. and SVOBODA, M. 2015. Application infrared spectroscopy for monitoring the quality parameters of engine oils. In: *Transport Means - Proceedings of the International Conference 2015*. pp. 103–106.

GRYAZIN, V., BAGAUTDINOV, I., KOZLOV, K. *et al.* 2018. Tool for quality control of lubricants. *Engineering for rural development*, 17, 943–947.

JINGYAN, L., XIAOLI, CH., and SONGBAI, T. 2012. Research on determination of total acid number of petroleum using mid-infrared attenuated total reflection spectroscopy. *Energy Fuels*, 26(9): 5633–5637.

PERIĆ, S., NEDIĆ, B. and GRKIĆ, A. 2014. Applicative Monitoring of Vehicles Engine Oil. *Tribology in Industry*, 36(3): 308–315.

MACIAN, V., TORMOS, B, GOMEZ, Y. A. *et al.* 2012. Proposal of an FTIR Methodology to Monitor Oxidation Level in Used Engine Oils: Effects of Thermal Degradation and Fuel Dilution. *Tribology transactions*, 55(6): 872-882.

MUNAIM, A., MAZIN, A. A., MENDEZ, M. *et al.* 2018. Discriminating gasoline fuel contamination in engine oil by terahertz time-domain spectroscopy. *Tribology international*, 119: 123–130.

SIDDAIAH, A., KHAN, Z. A., RAMACHANDRAN, R. *et al.* 2017. Performance analysis of retrofitted tribo-corrosion test rig for monitoring in situ oil conditions. *Materials*, 10(10): 1145.

SEJKOROVÁ, M. 2017. Application of FTIR spectrometry using multivariate analysis for prediction fuel in engine oil. *Acta Univ. Mendelianae Brun.*, 65(3): 933–938.

SEJKOROVÁ and GLOS. 2017. Analysis of Degradation of Motor Oils Used in Zetor Tractors. 2017. *Acta Univ. Agric. Silvic. Mendelianae Brun.*, 65(1): 179–187.

SEJKOROVÁ, M., ŠARKAN, B., CABAN, J. *et al.* 2018. On relationship between infrared spactra of worn out engine oils and their kinematic viscosity [in Polish: O zależności widm w podczerwieni zużytych olejów silnikowych od ich lepkości kinematycznej]. *Przemysl chemiczny*, 97(1): 1000–1005.

WEI, L., DUAN, H., JIA, D. *et al.* 2019. Discussion on the influence of driving parameters of civilian cars on motor oil degradation. *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, 233(2): 281–288.

WEI, L., DUAN, H., JIA, D. *et al.* 2018. Motor oil condition evaluation based on on-board diagnostic system. *Friction.*

VESELÁ, K., PEXA, M. and MAŘÍK, J. 2014. The effect of biofuels on the quality and purity of engine oil. *Agronomy Research*, 12(2): 425–430.

WOLAK, A. , ZAJĄC, G. and ŻÓŁTY, M. 2018. Changes of properties of engine oils diluted with diesel oil under real operating conditions. *Combustion Engines*, 173(2), 34–40.

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