# SPECIFIC ASPECTS OF FUEL ASSESSMENT

Assoc.Prof. M.Sc. Čorňák Š. Dr.[1], M.Sc. Ulman J.[1]
Faculty of Military Technology, University of Defence in Brno, Czech Republic[1]

stefan.cornak@unob.cz

***Abstract:*** *We have tested typical samples of fuel (diesel, gasoline, technical gasoline and a mixture of unknown fuel). For fuel analysis we have used an analyzer IROX DIESE with an in-built infrared interferometer of Michelson's type. The results proved that within a wavemeter from 650 up to 1800 cm-1 for each fuel there is a typical infrared spectrum. This spectrum can be compared with human fingerprints. It is possible to positively identify the majority of fuels with the usage of these spectra. Moreover in case of unknown mixture, it is possible to use these spectra for determination of their mutual ratio.*

**Keywords**: OPERATING FLUIDS OF VEHICLE, DIESEL FUEL, FTIR, IROX DIESEL

## *1. Introduction*

Basic fuel of diesel engines is diesel or kerosene. These fuels are mixtures of structurally different hydrocarbons – standard alkenes, isoalkenes, alkenes, naphthenics and aromatics with 12 up to 22 atoms of carbon in a molecule. Their boiling point is from 180° to 370°C and their mutual proportional representation arises from the quality of oil/petrol used and also from the applied technological processes. Fuel for diesel engines has to meet a number of qualitative criteria.

These criteria can be divided into several groups of physio-chemical characteristics, low-temperature characteristics, chemical composition, detonation behaviour, lubricity, parameters characterizing purity and other parameters [1].

For improving utility properties (depressants, detergents, lubricants, corrosion inhibitors, anti-foaming additives, bio-components in the form of methyl esters of fatty acids, etc.) there are other additives added into diesel.

Diesel qualitative parameter values and methods of their valuation are strictly defined by the standard ČSN EN 590 and is provided in the table 1 [2].

Strict refinery fuel quality checking nearly eliminates the possibility of selling of low-quality fuel which does not meet appropriate qualitative requirements. Fuel is stored in various storage places and transport tanks, which may be a source of undesirable contamination during distribution. This contamination can have a serious impact on engines.

Mechanical pollution by dust, abrasion and corrosive elements usually does not represent any serious problems because fuel is filtered before distribution to consumers, and fuel filtration is carried out at petrol stations. If the blow down system works well, even "usual" pollution by water should not represent any serious risk.

Pollution of fuel by heterogeneous carbide or organic fraction respectively could have an impact on the physical-chemical characteristics of fuels. Most frequently fuel is contaminated during transport in transport tanks where fluids are changed. This is usually minor mutual contamination of diesel fuel and motor petrol caused by technological negligence of a transporter. In the real life, it is possible to experience fuel pollution by completely different organic fraction than motor petrol or diesel fuel.

It is necessary to take into account the intentional admix of heterogeneous or "tax free" fraction in order to generate illegal profit or attempts to "improve" fuel by consumers [3].

Practical evaluation of physical-chemical characteristics of diesel by using classical methods is financially as well as operationally very demanding. Therefore there was an effort to develop an easier and faster method. One of them is a modern instrumental method, which is based on the assessment of fuel infrared spectrum with the application of the Fourier's transformation (FTIR).

***Table 1:*** *General requirements and methods of assessment according to the ČSN EN 590 [2]*

| Quality | Limit values | | Units | Method of testing |
|---|---|---|---|---|
| | min | max | | |
| Cetane number | 51 | | - | EN 15195 |
| Cetane index | 46 | | - | EN ISO 4264 |
| Density (15 °C) | 820 | 845 | kg/m$^3$ | EN ISO 12185 |
| Polycyclic aromatic hydrocarbons | - | 8 | % (m/m) | EN 12916 |
| Content of sulfur | | 10 | mg/kg | EN ISO 20884 |
| Content of oily acids methylesters | - | 7 | % (V/V) | EN 140078 |
| Point of outburst | 55 | | | EN ISO 10370 |
| Oxidative stability | | 25 | g/m$^3$ | EN ISO 12205 |
| | 20 | | h | EN 15751 |
| Lubricity (60 °C) (wsd 1,4) | - | 460 | µm | EN ISO 12156 |
| Viscosity (40 °C) | 2 | 4,5 | mm$^2$/s | EN ISO 3104 |
| Content of ash | | | | EN ISO 6245 |
| Content of water | - | < 65 | % (V/V) | EN ISO 12937 |
| Total content of impurities | 85 | - | % (V/V) | EN 12662 |
| Corrosive operation of copper | - | 360 | °C | EN ISO 2160 |
| **Distillation test** | | | | - |
| at 250° C it is distilled | - | < 65 | % (V/V) | EN ISO 3405 |
| at 350° C it is distilled | 85 | - | % (V/V) | |
| 95 %(V/V) | - | 360 | °C | |

## *2. Theoretical base of solution*

The principle of infrared spectrometry is based on the Lambert-Beer law:

$$I = I_0 . e^{-\varepsilon . c . l} \quad (1)$$

where: $I_0$ - incident radiation intensity; I - passing radiation intensity; $\varepsilon_0$ - molar absorb coefficient; l - absorb medium thickness; c - concentration of monitored substance.

The principle of infrared spectrometry is based on the infrared radiation absorption measurement in the range from 2.7 μm to 15.4 μm with the use of a spectrometer with Fourier's transformation. The result is spectral record [4]:

$$I(d) = \int_{-\infty}^{\infty} I(\tilde{\nu}) cos(2\pi d\tilde{\nu})\, d\tilde{\nu} \qquad (2)$$

where: I –radiation intensity; d – trajectory difference of folded rays; $\tilde{\nu}$ - wave number (1/λ).

The interferometer principle, most frequently of Michelson's type, is shown in the Fig. 1.

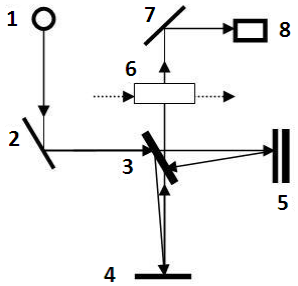


***Fig. 1*** *Michelson type interferometer principle diagram [5]*

*where: 1 - infrared source; 2, 7 - mirror; 3 - ray divider (semi-permeable mirror); 4 - fixed mirror; 5 - moveable mirror; 6 - measuring cuvette; 8 - infrared detector*

The light from infrared Source 1 is divided by Mirror 2 and Ray divider 3 into two equivalent rays. The first ray is reflected by a fixed Mirror 4 and the second ray is reflected by a Moveable mirror 5. Both rays are put together in a divider of ray 3 and then they are routed to Measuring cuvette 6, which is filled up by an unknown sample. Because a Moveable 5 mirror moves along a definite track, in each moment of a spectrometer activity other wave lengths are magnified and reduced. If the distances of mirrors 4 and 5 are identical, rays on the semi-permeable ray divider are added. If the distances are not identical, there is interference between both parts of ray. This variable light passes through cuvette 6, which is filled by an unknown sample and turns out over the Mirror 7 on the Infrared detector 8. The interference diagram (dependence incident radiation intensity in time) is consequently recalculated on spectrum with the use of Fourier's transformation.

## *3. Materials and methods*

A lot of operating fluid samples were analysed at the Department of Combat and Special Vehicles. An extensive database was created from these analyses. Only for demonstration purpose in this paper there are presented results of 2 fuel samples. These are diesel (civilian diesel fuel and military diesel fuel F54). We have used IROX DIESEL analyser with an in-built infrared interferometer of Michelson's type for quality evaluation. Basic specification of IROX DIESEL you can see in the table 2.

***Table 2:*** *Technical data of IROX DIESEL [5]*

| Measuring Parameters | Range |
|---|---|
| Overall content of aromatic compounds [% v/v.] | 0 – 60 |
| Multi-kernel (PN) aromatic compounds [% vol.] | 0 – 40 |
| Cetane number | 25 – 75 |
| Cetane index | 30 – 70 |
| Additive for cetane number improve [ppm] | 0 – 5000 |
| Distillation characters [$^{o}$C] (T85, T90, T95) | 300 – 450 |
| Bio-components content [% obj.] (ethyl-ester, methyl-ester) | 0 – 40 |
| Consistence [g.cm$^{-3}$] ± 0,001 g.cm$^{-3}$ | 0,5 – 1,999 |
| Sample content for complex measuring [ml] | 7,5 |

We have accomplished calibration of equipment with calibration fluid 99+ % n-hexane before the main measurement. The calibration library included 180 samples. The recorded evaluation of measured values was accomplished with the use of program MINIWIN 2.2.4.

## *4. Results and conclusion*

The general measuring results are presented in the next graph (Figure 2).

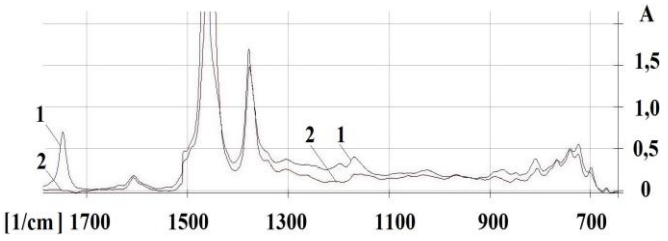


***Fig. 2*** *Infrared spectrum (finger printer) of diesel fuel*

*1 – civilian diesel fuel, 2 – military diesel fuel (F54)*

This spectrum in the extent of 650 to 1800 cm$^{-1}$ is called "**an area of fingerprint**" in which a position (wavemeter) of lines represents characteristic groups contained in fuel. By these lines it is possible to identify positively and unmistakably the majority of mixtures. It becomes clear from Figures in this paper that for diesel there are typical wavemeter peaks 1377 cm$^{-1}$ and 1377 cm$^{-1}$. Moreover, wavemeter 1747 cm$^{-1}$ is typical for the contents of FAME, which is added into diesel.

## *5. Conclusion*

In this paper the author deals with the evaluation of fuels. Samples of civilian diesel fuel and a military diesel fuel were analyzed and evaluated. For the evaluation an analyzer of Michelson's type was used with an in-built infrared interferometer. The results obtained proved that in the range of wavemeter 650 to 1800 cm$^{-1}$, there is a unique typical unmistakable infrared spectrum, which can be compared with human fingerprints. By the use of these spectra it is possible to identify unmistakably the majority of fuels. Moreover in case of unknown mixtures, it is possible by the use of these spectra fingerprints to analyse and state their mutual ratio.

## *6. References*

[1] Matějovský, V.: Vehicle fuels. Grada 2004, ISBN 80-247-0350-5. [In Czech]

[2] Motorová paliva-Technické požadavky a metody zkoušení ČSN EN 590, ÚNMZ2010

[3] Čorňák, Š.: Assessments of diesel fuel quality . Transport means: proceedings of the International Conference**,** 2011, no. 1, p. 30-33. ISSN 1822-296X.

[4] Kreidl, M., Šmíd, R. Technická diagnostika. BEN, Praha 2006. ISBN 80-7300-158-6

[5] IROX DIESEL. Portable FTIR fuel analysis. Grabner instruments$^{TM}$, Vienna 2006.

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