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FT-IR METHOD USED FOR EVALUATION OF MOTOR OIL CONDITION AND QUALITY

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Abstract

In this study there is an introduction to a concept of using FT-IR spectroscopic method for evaluation of motor oil condition and quality. The way of preparation of oil samples to laboratory analyses as well as methodology of research was presented.

Keywords*: spectroscopic methods, FT-IR method, FT-IR spectrophotometer, FT-IR spectrometry*

1. Introduction

The problem of motor oil quality diagnosing concerns the choice of strictly adjusted proper research methods. During recent years spectroscopic methods have grown in meaning in motor oil condition and quality. Because of growing interest in the above mentioned methods there is a need to develop motor oils and approach them in rational and optimal way in question of motor oil condition and operational properties evaluation.

Motor oils constitute a very complex medium both structurally as well as functionally, thus difficult to quality evaluation. As a result of thermo-chemical and physical and chemical transformations, during exploitation, changes of their chemical constitution occur. In practice it is not possible to characterize the detailed chemical composition of such a complicated mixture [4]. One of techniques applied to evaluate the above mentioned oil features is infrared spectral analysis (FT-IR), based on infrared radiation absorption by oscillating particles [2,3,4]. The equipment used in this type of marking are IR spectrometers with Fourier transformation (Fourier Transfer Infrared – FT-IR).

FT-IR spectrometers (Fig.1) are devices richly equipped with electronics and computers, which control the measurement process and help spectrum processing and analyzing. In this type of devices all optical parts as prisms and measurement corvettes must be transparent for IR radiation. The negative feature of these materials is low resistance to humidity and scratching so optical parts of the device need to be placed in special air-conditioned chambers with temperature slightly higher than ambient temperature. Liquid samples are examined in form of solutions in special corvettes which consist of two IR transparent windows, separated by pads of certain thickness. The thickness of solution absorption layer ranges from 0.01 mm to 2.0 mm. Properly adjusted solvent should dissolve the examined sample well and posses low absorptive within the sample absorption range. Frequently used solvents are carbon tetrachloride (within the range of 4000 – 1000 cm^{-1})

and carbon disulfide (within the range of 1300 – 600 cm^{-1}). This study presents the usage of FT-IR method for motor oil condition evaluation basing on experiments of other authors.

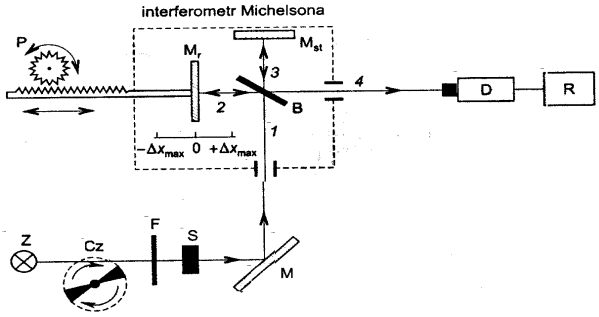

Fig.1.Schematic operation of Fourier spectrometer with Michelson interferometer [1,2]

2. Research methodology

In these article consideration are based on scientific material gathered in scientific work [1]. The results published refer to only one type of motor oil examined – synthetic oil TITAN CARGO 1040 MC. An important element for running such type of analyses is preparation of research station and control of performed marking. In this case the spectrometer used, was FT-IR Spectrum One by Perkin Elmer company (Fig.2). Before starting this type of instrumental apparatus, there are certain environmental conditions to be fulfilled, which among other are:

- in-door operation
- ambient air temperature of 5 ^{0}C to 40 ^{0}C,
- maximum relative humidity of 80% for temperature up to 31 ^{0}C,
- dust-free air,
- working desk free from shocks and vibrations,
- avoiding sunlit places,
- eliminating of strong magnetic fields in computer location.

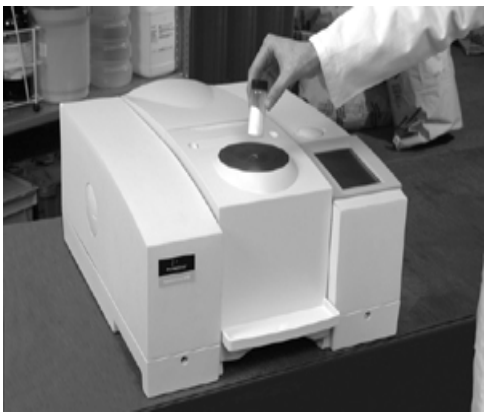

Fig.2. Spectrum One FT-IR spectrometer [1]

Spectrum software is used for Spectrum One operation which enables control and processing of spectra which were collected. It is important that a KBr measuring chamber window placed at front of Spectrum One, must display humidity level not exceeding 75%. Oil samples have to be collected from central part of a tank, always from the same depth in normal working conditions of the device (constant circulation, usual warmth). They should be collected by a hand pump or syringes to disposable tight-proof 500 ml containers made from plastic. The frequency of sample

collection should be adjusted to device work and should be increased when analysis results are worrying.

Samples for examinations were collected periodically, paying attention to well differentiated mileage, taking into account changes in motor oil condition. Examinations were performed in the range. Spectra of oil condition during exploitation were compared with spectra of fresh oil.

3. Interpretation of research results

In research result interpretation it is essential to analyze group composition, and consequently the quality analysis of motor oil composition. To achieve this goal we must know theoretical location of particular chemical compounds characterized in FT-IR spectrum, which indicates assignment of responsive functional groups to particular strictly defined areas [2], in which there are absorption bands, characteristic for fresh oils. Once we know locations of peaks which describe characteristic groups of chemical compounds in the spectrum, we can get information referring the most important physical and chemical features of the examined oil. On their basis we can evaluate oil condition and whether it is fit to further exploitation. For example peaks of bands of wave number about 3000 cm^{-1} and 1460, 1377 cm^{-1} are hydrocarbon bands and let determine the quality of base oil i.e. determine paraffin, naphthenic or aromatic hydrocarbons. In turn, by periodic recording of motor oil spectrum during motor exploitation we can watch changes occurring in oil i.e. oxidation, nitrating, sulfating, soot and water accumulation, exhausting of additives, fuel or coolant (glycol) pollution. This information can be used to motor oil quality control and to inform an operator about combustion conditions, wearing rate and pollutant penetration.

4. Research results and their analysis

In this part of the study there are presented examples of chosen spectra of motor oils [1]. Fig.3 shows a small decrease of peak 3640 cm^{-1}, testifying for antioxidant addition and peaks 1600 cm^{-1} for aromatic hydrocarbon quantity decrease. The ongoing processes of oxidation and nitrating can be detected when this narrow peak becomes wider and more circular. From decreasing of these peaks we read that viscosity of oil will grow. High depletion of D-D additive (peak 1230 cm^{-1}) and drastic drop of EP and AW (anti-wearing) additives point (peak 970 cm^{-1}) can suggest that basic number (TBN) is decreasing. This example shows a TBN drop readout a as well as kinematic viscosity rise without performing time-consuming and costly traditional analyses. Pollution, soot, dark color of base oil and water content cause vertical movement of a spectrum. The FT-IR spectrum of examined oil (Fig.4) shows a lack of peak 3640 cm^{-1} (antioxidant additive) and very low peaks 1500-1774 cm^{-1} – rate of oxidation, D-D, viscosator, lowering of aromatic hydrocarbons – these usually narrow peaks are widening and become more circular, which is result of oxidation and nitrating. Decrease of these peaks can, already without costly and time-consuming analyses of kinematic viscosity and viscosity indicator, suggest that these features will grow drastically. Lack of peaks 1000-1100 cm^{-1} suggests presence of glycol in motor oil. Figure 5 clearly indicates changes occurring in oil during exploitation, there are three different areas in which clear deviations from fresh oil are present.

The selected changes in motor oil during exploitation shown by the author in research study [1] cause disappearance of additive's absorption bands and increase of bands characteristic for oxidation products. It is also observed decreasing intensity of bands which are characteristic for dispersant and viscosator. Degradation of additives and increasing of content of oxidation products cause worsening of motor oil exploitation features

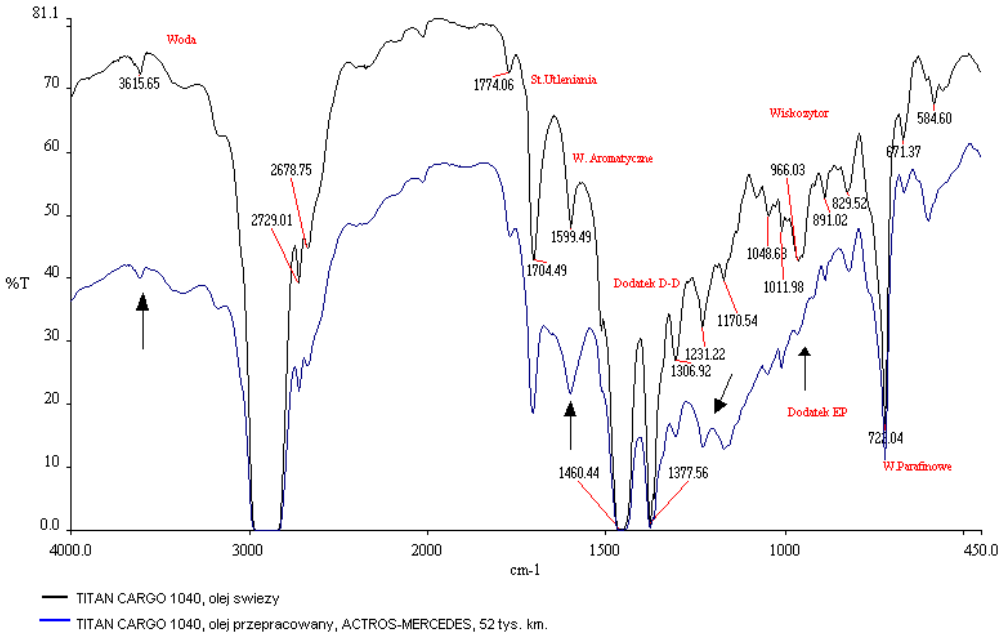

Fig.3. Example of fresh and overworked oil TITAN CARGO MC (wiskozator - viscosator; stopień utleniania - oxidation rate; w. aromatyczne - aromatic hydrocarbons; w. parafinowe - paraffin hydrocarbons; dodatek - additive; świeży olej - fresh oil; olej przepracowany - overworked oil)

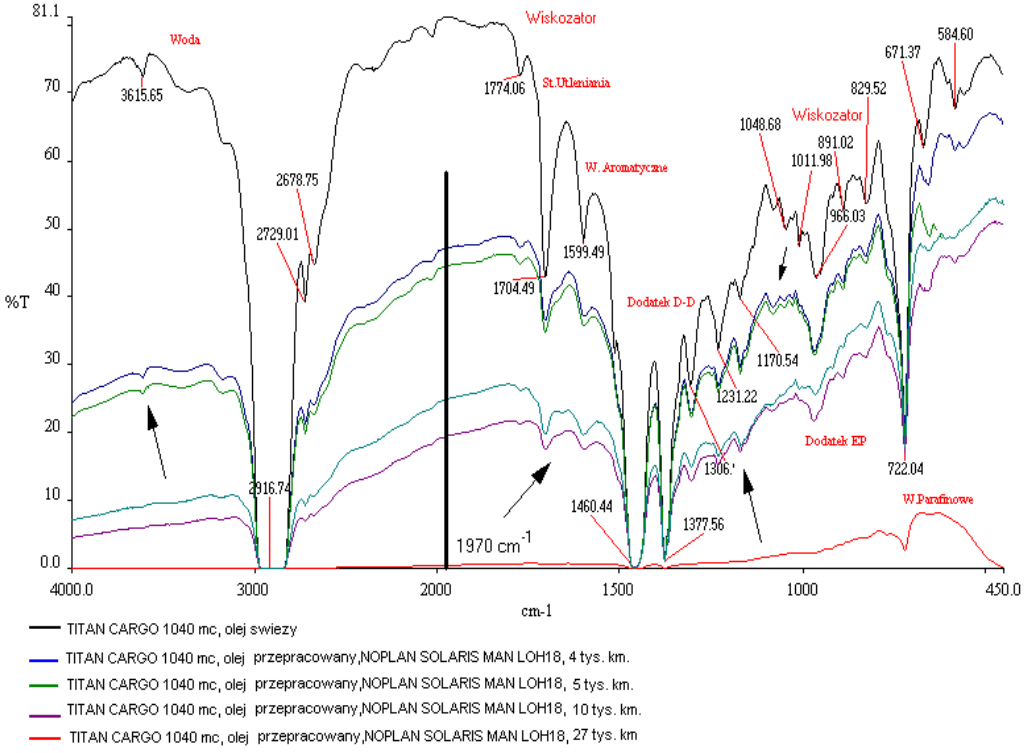

Fig.4. Example of fresh and overworked oil TITAN CARGO MC(wiskozator - viscosator; stopień utleniania - oxidation rate; w. aromatyczne - aromatic hydrocarbons; w. parafinowe - paraffin hydrocarbons; dodatek -additive; świeży olej - fresh oil; olej przepracowany - overworked oil)

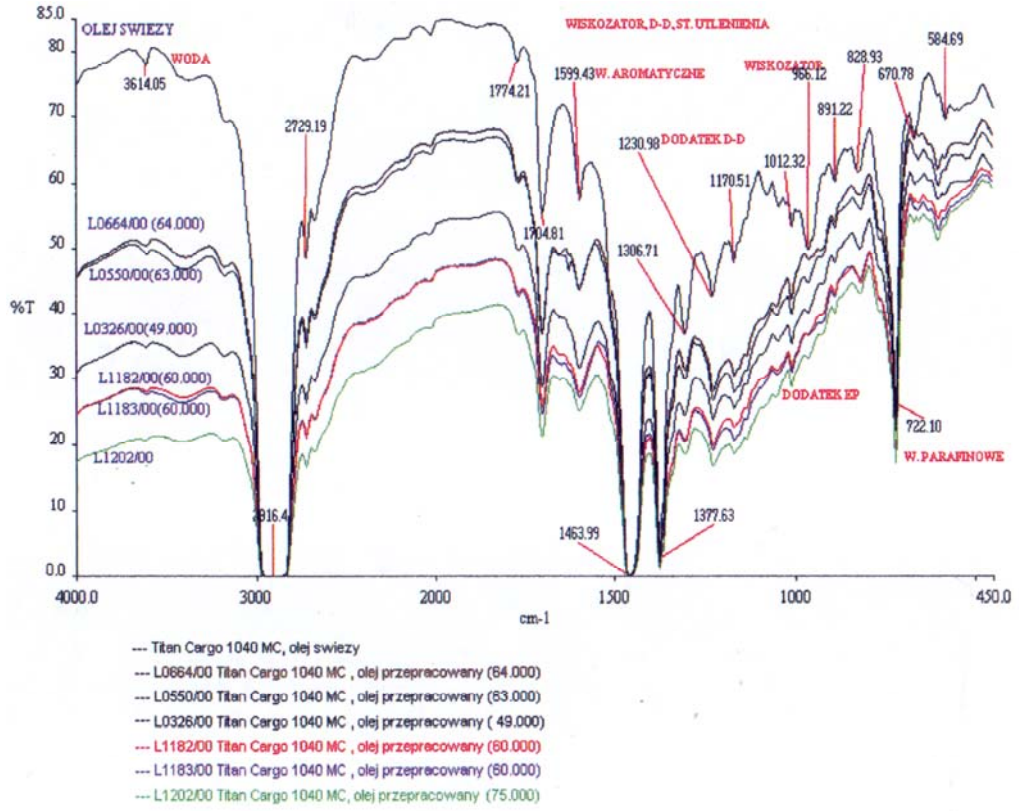

Fig.5. Example of fresh and overworked oil TITAN CARGO 10W40 MC (wiskozator - viscosator; stopień utleniania - oxidation rate; w. aromatyczne - aromatic hydrocarbons; w. parafinowe - paraffin hydrocarbons; dodatek - additive; świeży olej - fresh oil; olej przepracowany - overworked oil)

5. Final conclusions

In summary of this article considerations the following conclusions can be indicated:

1. The proposed way of implementation of spectroscopic methods for analysis and evaluation of motor oil condition during exploitation can successfully complement and finally replace traditional methods of motor oil monitoring, limit marking time and result interpretation, which can effectively protect against many defects of combustion engines.
2. FT-IR spectrum lets analyze oil composition and record changes which in turn makes it possible to differentiate oil conditions being basis for using this motor oil examination methodology.
3. Taking into account researches intending to more detailed analysis of typical groups of chemical compounds contained in motor oils depending on exploitation changes happening inside them – the FT-IR method can constitute an alternative direction for later development of scientific research.

References

[1] Wojciechowski, D., *Analiza i ocena stanu oleju silnikowego metodami spektroskopii*. Rozprawa doktorska, (The Analysis and Evaluation of Motor Oil Condition with Spectroscopic Methods. Ph.D. Thesis) Szczecin 2007.
[2] Silverstein, R. M., Webster, F. X., Kiemle, D. J., *Spektroskopowe metody identyfikacji związków organicznych*, (Spectroscopic Mehods of Organic Compound Identification) PWN, Warszawa 2007
[3] Woliński, J., *Chemia organiczna*, (Organic Chemistry) PZWL, Warszawa 1985.
[4] Grądkowski, M., *Problemy Eksploatacji*,(Exploitation Problems) 1, s. 93-5-125, 1995

[5] Mastalerz P., *Chemia organiczna*, (Organic Chemistry) Wydanie I, Wydawnictwo Chemiczne, Wrocław 2000.

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