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# ON THE EVALUATION OF EXPLOITATION QUALITIES OF PRISTA SUPER 25W40 MOTOR OIL WITH DIA METHOD

# OCENA CECH EKSPLOATACYJNYCH OLEJU SILNIKOWEGO PRISTA SUPER 25W40 METODĄ DIA

*The paper considers one of the few studies of motor oil using Differential Impedance Analysis (DIA) method. The impedance data of Prista Super 25W40 motor oil are analyzed through this method, which is more advanced technique comparing to Electrochemical Impedance Spectroscopy. Structural changes in samples of long exploited oil are found. The analysis of samples of less used oil registers one important phenomenon, which is known from the practice. The possibilities for viscosity indices determination are discussed. General impedance data analysis is also conducted.*

**Keywords:** *Differential Impedance Analysis, Motor Oil, Oiliness, Quality Control.*

*Artykuł poświęcony jest badaniom oleju silnikowego przy pomocy Analizy Dyferencjalnej Impedancji (DIA). Zbadano tą metodę, która jest doskonalsza od Elektrochemicznej Spektroskopii Impedancyjnej, zmiany impedancji nowego oleju Prista Super 25W40 w okresie eksploatacji. Wyniki wykazują, że po pewnym krótkim okresie, używany olej ma lepsze właściwości smarne względem próbki oleju nieużywanego. Omówiono także możliwości oszacowania oleistości i przeprowadzono analizę wyników.*

**Słowa kluczowe:** *Analiza Dyferencjalnej Impedancji, olej silnikowy, oleistość, charakterystyki lepkości, analiza jakościowa oleju.*

## 1. Introduction

Recently a number of real-time motor oil condition systems have been developed. Usually the purpose of such systems is to determine the appropriate moment for the oil change. This is due to the fact that economical losses arise in both cases - if the oil has been changed before or after the useful life of the lubricant has been exhausted. The second case leads to a fast machine wear. The economical effect in the large commercial fleets is substantial. The most commonly used criterion for the oil change interval determination is the elapsed mileage. This doesn't ensure the optimal use of the lubricant, because of the various factors that affect its useful life. All the laboratory methods require a considerable amount of time and resources. For this reason the systems for **real-time analysis** find a wide application. Frequently as initial parameters for the analysis are used the specific resistivity and the dielectric permittivity. The high precision of the methods which use the *Electrochemical Impedance Spectroscopy* (EIS) is well known [2, 9]. During the past years an advanced technique for impedance data processing named *Differential Impedance Analysis* (DIA) was developed [9]. It does not require an initial working hypothesis and thus overcomes some principal disadvantages of the known systems.

The new capabilities of the DIA method permit to evaluate of viscosity indices of the motor oil. The present study is dedicated to the application of the DIA method to the analysis of the exploitation qualities of Prista Super 25W40 motor oil.

## 2. Basic equations and problem formulation

The impedance measurements are performed using high precision Frequency Response Analyzer - Solartron 1260 FRA at room temperature within a frequency range 1MHz - 0.1Hz with a density of 5 points per decade. The graphical representation of the results for different oil samples depending on the exploitation cycle are shown on figure 1.

The impedance of the cell $\dot{Z}(j\omega)$ typically has a resistance-capacitive character ($\omega$ - angular frequency).

There are two mechanisms which cause the total decreasing of the impedance by the exploitation period. The first is the oil oxidation which result in increasing the concentration of polar components, such as carboxylic acids, ketones and aldehydes et al. This leads to an increased dipolar and ionic nature of the solution [8]. The second is the presence of different contaminants - soot, antifreeze, water and metal particles from the machine wear causing the reduction of the specific resistivity. The spectral tale at the lowest frequency region is one of the reasons that obstruct modeling with simple equivalent circuit. This is due to the significant growth of the dielectric permittivity between the frequencies 0.1Hz - 10 Hz, possibly caused by the formation of micelles. General impedance data analysis

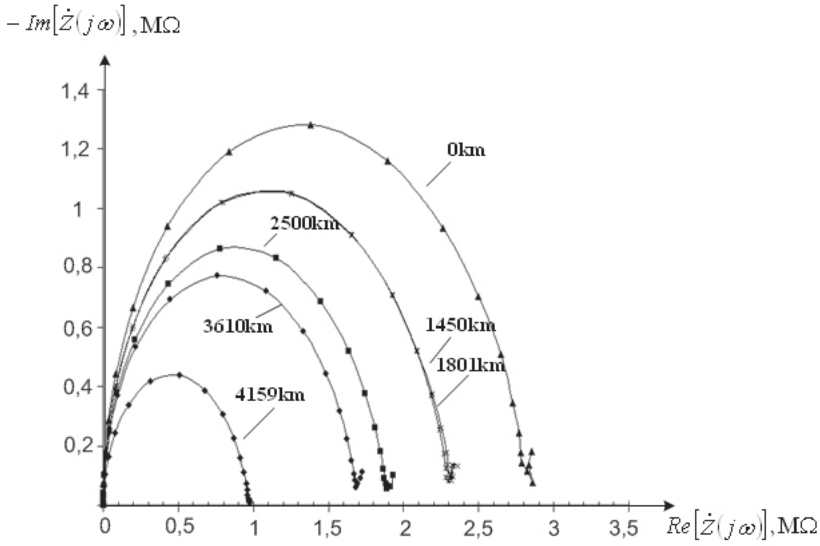


*Fig. 1. Nyquist plot the fresh and the exploited oils*

cannot investigate the non-linear character of the result and the identification of the motor oil exploitation qualities.

## 3. Solution of the problem

For the purposes of *Differential Impedance Analysis* in the time domain (Temporal Analysis) it is used the effective time constant distribution $lgT = F(lgf^{-1})$, where $f = \omega/2\pi$ is the frequency of the stimulus signal; $T$ – effective time-constant of the local scanning model according to DIA [1].

The calculation of the effective time-constant for specific frequency is based on:

$$T(\omega) = dL_{eff}(\omega)/dR_{eff}(\omega) \quad (1)$$

where: $dL_{eff}(\omega)$ - the effective inductance as a function of the angular frequency, $R_{eff}(\omega) = Re[\dot{Z}(j\omega)]$ - the real part of the impedance.

The basic property of the oil is the lubricating ability. It depends on the viscosity. The viscosity define the lubricating efficiency when the oil film is thin enough and then the viscosity doesn't effect the lubrication [3, 7]. If the viscosity is insufficient the friction and the machine wear is considerable, specially in the piston-cylinder group [4].

The viscosity is higher in case of an easier molecule polarization processes [10]. The time-constant distribution for the particular oil samples is shown on the figure 2. The diagrams display a frequency dependent and an approximately frequency invariant regions [10]. The decreasing of the $T$ with elapsed mileage when the shape of the distribution remains the same means an improved polarization ability. The specific negative peak (area **A** on figure 2.) is higher at the fresh oil comparing to the exploited oil. At the sample with longest exploitation cycle the representative time-constant has the shortest frequency

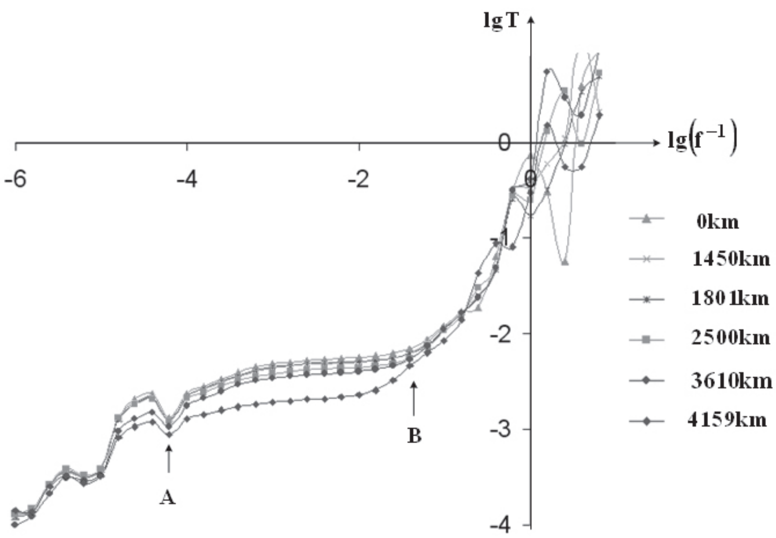


*Fig. 2. Temporal plot for the oil samples*

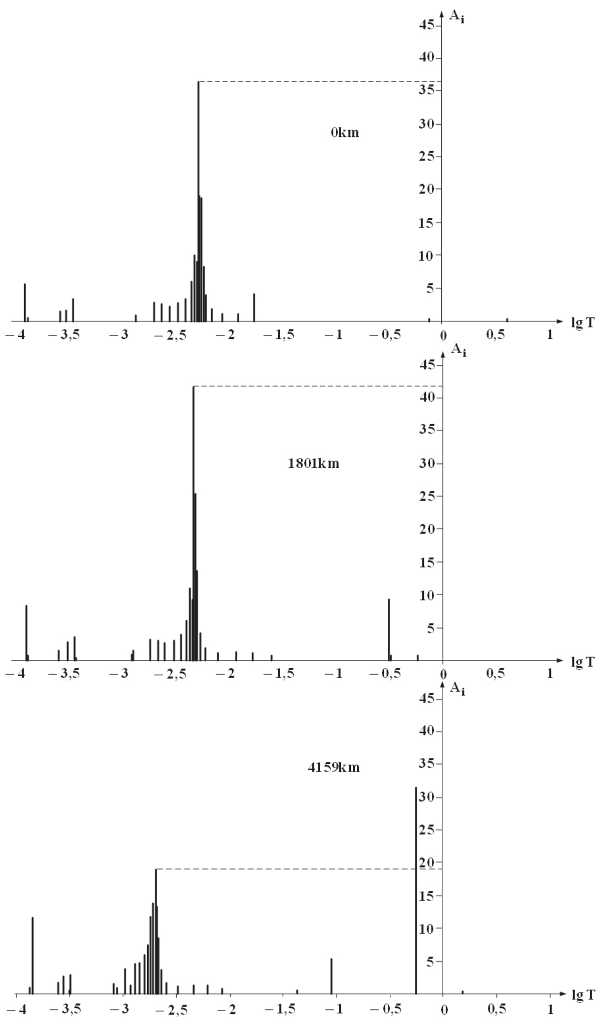


*Fig. 3. Spectral plot for the effective time-constant*

length (area **B**). This indicates structural changes which correspond to the destruction of the polymer macromolecules.

By means of a Spectral Analysis some additional information can be extracted. The spectral lines formation is conducted through a spectral transform procedure [9]. The amplitude $A_i$ of the line $i$ can be calculated through :

$$A_i = k_0 \left( \frac{dP}{dB} \right)^{-1} \tag{2}$$

where: $B = lg(f^{1})$, $P = lgT$, $k_0$ - coefficient of a proportionality (const).

The result is shown on the figure 3. This way of calculation is suitable only in case of a low noise and a high measurement precision. In general case the estimation of the amplitude of the spectral lines could be done by means of an accumulation of the calculated results with similar values. A high noise immunity is thus achieved [1, 5].

The figure 3 shows the time-constant spectrum for a three oil samples. The representative time-constant of fresh oil distinctly predominates and is concentrated in a narrow scope of values. For the longest exploited oil of the excerpt that parameter feebly prevails over the spectrum and is more distributed. This indicates an initial destruction of the polymer macromolecules, i. e. certain structural changes [10]. The Spectral Analysis confirms the result from the Temporal Analysis that the oil at 1000-2000 km has a better lubricating ability comparing to the fresh oil. Its representative time-constant is smaller and has a higher amplitude $A_i$ than the fresh oil sample. Such a result can hardly be recognized with other known methods of analysis.

The relaxation time within 10Hz-1MHz is approximately 1ms. According to some authors the relaxation processes at the frequency of several kilohertz is related to the inverse micelles, formed by hydrophilic core and hydrophobic hydrocarbon tails [8].

## 4. Conclusions

The impedance of the analyzed motor oils generally decreases with the exploitation cycle. The *Differential Impedance Analysis* can detect changes in the molecular structure of the lubricant. It registers an improved lubricating ability of the oil at nearly 2000 km, i.e. there is some activation period of the oil.

The DIA method displays a noise-immunity and a high potential for identification. It produces better results comparing to the Electrochemical Impedance Spectroscopy Technique [6], because of the absence of limitations from equivalent model.

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