

Dielectric Impedance Spectroscopy - an Insight into Motor Oils Behaviour

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Dielectric Impedance Spectroscopy (DIS) – Why?

1. The quality of the motor oils evaluation is essential both for the transport and the economy sectors, and the quantity of polluting products in the environment, too
2. Viscosity and oiliness are of leading importance for all types of oils
3. Motor oils are used for lubrication of the moving parts of various internal combustion engines
4. The classical methods used for characterisation of the quality of motor oils are slow and time-consuming.
5. The obtained results confirm the high selectivity of the technique as a method for non-destructive estimation of motor oils



DIS – What is it?

1. Modification of Electrochemical Impedance Spectroscopy
2. Specially tuned for measurements and analyses of dielectrics permittivity properties
3. Avoids the problems arising from the measuring electrodes
4. Ensures contactless measurements of a wide variety of objects with respect to their physical behaviour and conductivity without the need of any reference electrode



Dielectrics as Objects under Investigation

DC conductivity: Low (Very Low)

Classification:

- Non-polarisable – are composed of molecules which do not have dipole moment – e.g. molecules of H_2 , N_2 , O_2
- Polarisable – their molecules have permanent dipole moment – e.g. Motor oils molecules, H_2O molecules
- Ionic Crystals – hetero polar crystals. Without external electrical field they do not have own dipole moment



DIS - Dielectrics permittivity properties

- With DIS we study the permittivity properties of polarisable and non-polarisable dielectrics which are under the influence of variable current electrical field
- Permittivity is the ability of the Dielectrics to conduct Alternative Current



DIS – Application

Classical Approach:

- Study of dipoles re-orientation
- Fr. Range: 1 to 100 MHz
- Special Instrumentation
- Large frequency range
- Objects: gases and liquids



DIS - Electrochemical Approach

Our Approach:

- Middle Frequency range
- 1 MHz down to 1 Hz
- Ordinary Electrochemical Instrumentation
- Observation of Phenomenon in real objects
motor oils, small and large batteries, pharmaceuticals
and bio-samples



OUR AIM – Investigation of Motor oils behaviour

- Investigation of the frequency dependence of the effective capacitance of different motor oils sample having different nature
- Studies motor oils lubricating properties changing during exploitation; emerges as an important direction in motor oils studies



DIS – working conditions

- Equipment: Solartron 1260 FRA
- Frequency range: 1 MHz – 0.1 Hz
- AC: 300 mV
- Density of 5 points / decade
- Samples of natural, semi-synthetic and synthetic motor oils



$$Z(j\omega) = -j(\omega C)^{-1} \quad (1)$$

$$C = \varepsilon_0 \varepsilon_r S / d \quad (2)$$

$$\varepsilon = \varepsilon' - j\varepsilon'' \quad (3)$$

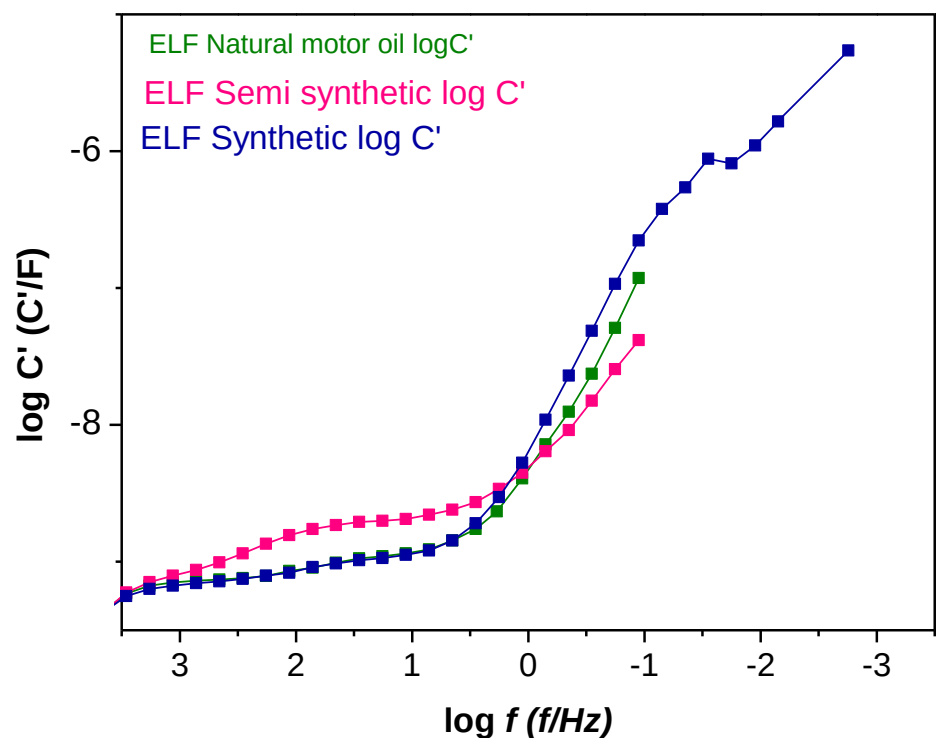
$$C = C' - jC'' \quad (4)$$

$$Y(j\omega) = 1/Z(j\omega) \quad (5)$$

$$Y(j\omega) = j\omega C = j\omega(C' - jC'') = \omega C'' + j\omega C' \quad (6)$$

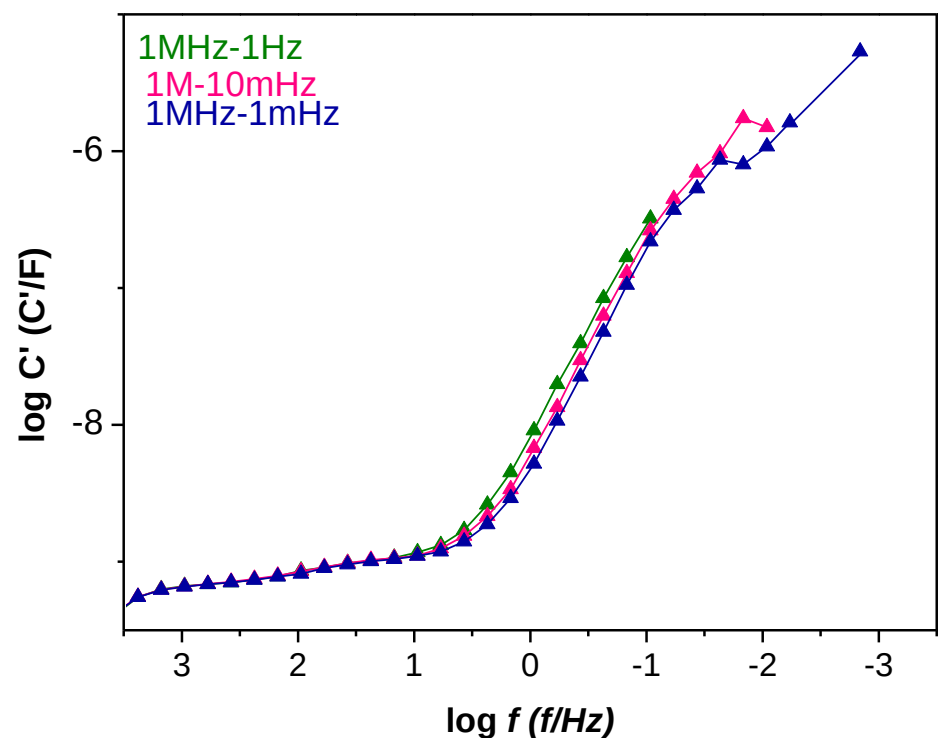


Effective capacity of 3 different samples of motor oils





Measurement of a synthetic motor oil sample at different frequencies





Lubricating oils

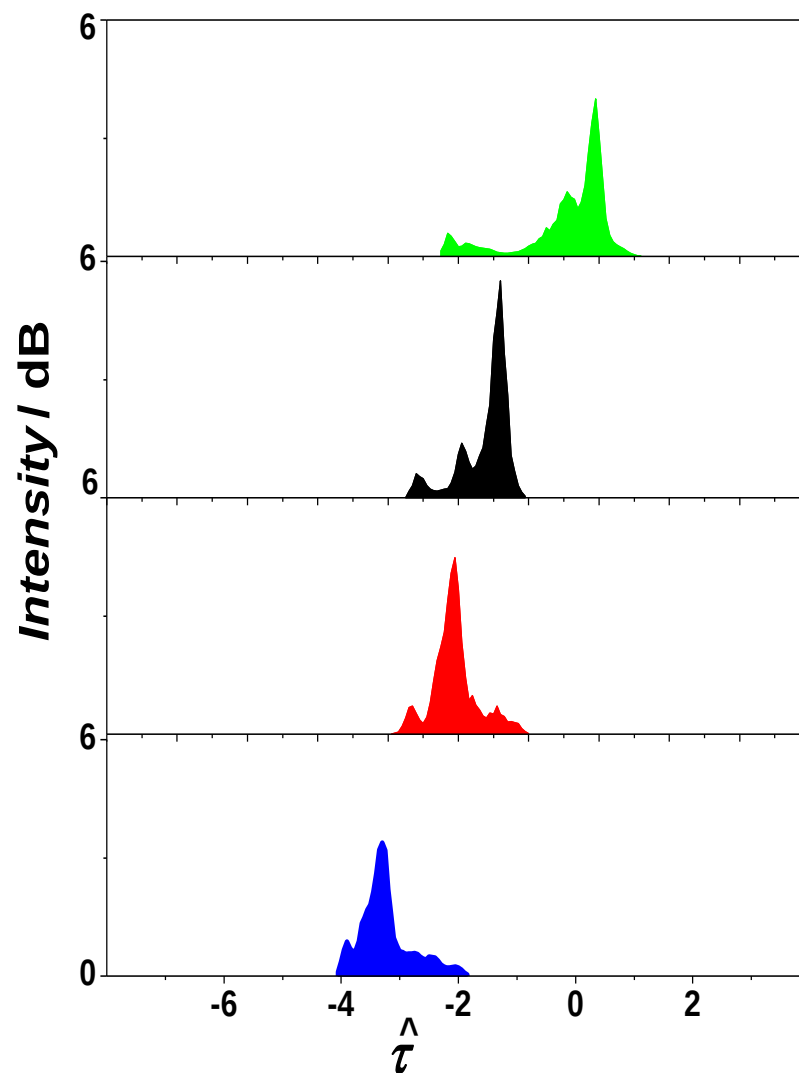
Time-constant Spectra

natural -20 y. old

natural

semi-synthetic

synthetic

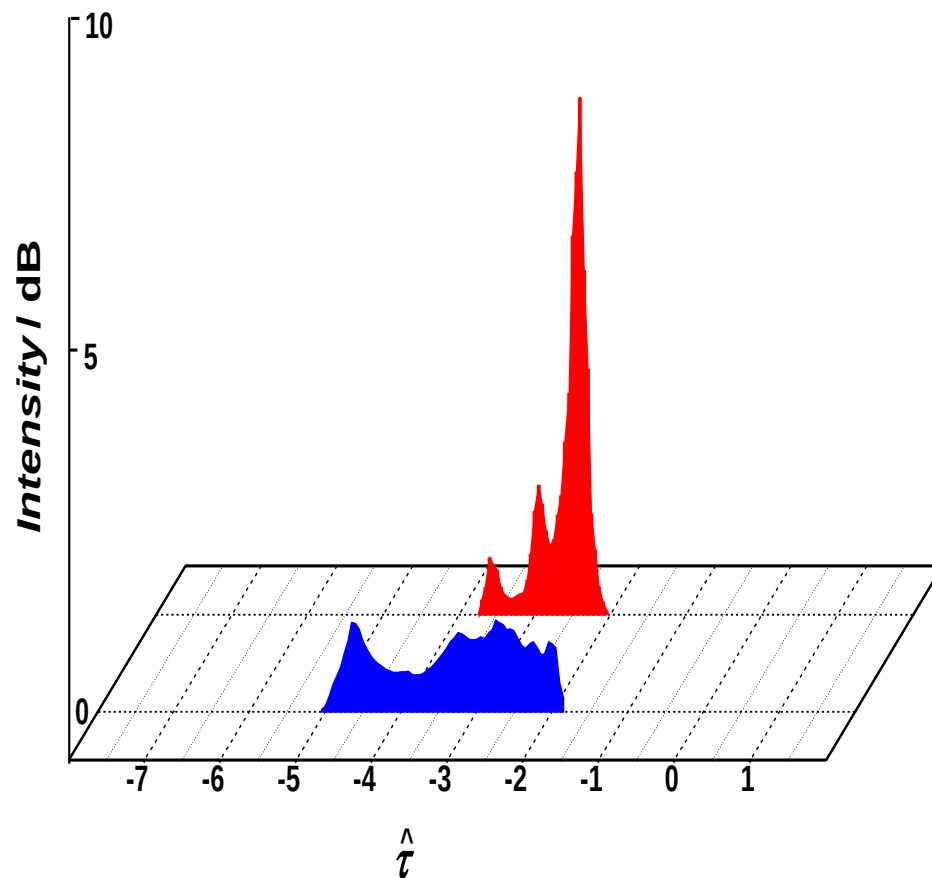




Lubricating oils

Natural new

Natural after 10000 km





Conclusions

- Phenomenon of Gigantic Enhancement of the effective capacitance was observed
- Time-constant Spectrum Position depends on the Oil Nature & Viscosity
- Time-constant Spectrum Sharpness corresponds to oil quality (degradation)
- This approach is used for fast assessment of oils quality and degradation



Conclusions

- The careful measurements of synthetic oils from different companies show identical behaviour
- The most interesting frequency range is below 0.1 Hz
- The obtained results confirm the high selectivity of the technique which will be further developed as a method for non-destructive estimation of motor oils lubricating properties, including the influence of specialised additives.



Thank you



Daniela Levi