

IMPEDANCE CHARACTERIZATION OF TIME-DEPENDENT DEGRADATION OF INDUSTRIAL LUBRICANTS

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Crankcase lubricants provide a fluid film to separate the moving parts of an engine, suspend contaminants, neutralize corrosive acids from the combustion process, protect wear surfaces, and provide other performance improving features (1). Ultimately, lubricants reach the end of their useful-life due to any one of a wide variety of degradation modes, such as oxidation, nitration, base depletion, acid build up (TAN), soot contamination, water, fuel and air containment and viscosity reduction and increases. The degradation mechanisms are as complex and varied as the global engine platforms the lubricants service (2, 3). Historically, vehicle fluid condition has been monitored by measuring miles driven or hours operated. However, it has been extremely difficult to anticipate all possible environmental and engineering variables leading to lubricant and engine failure (4). True failure protection can only be provided by detailed real-time measurements and interpretation of a lubricant's physical and chemical properties (5, 6).

This paper examines the use of sensors based on multi-frequency / multi-electrochemical potential Electrochemical Impedance Spectroscopy (EIS) (7, 8) to determine an engine oil condition and focuses on the relationship between lubricant chemical composition and interpretation of the EIS results. Data is presented which demonstrate a necessity to rely on several EIS output parameters collected over a broad frequency and potential range in order to correctly investigate complex decomposition pathways occurring both at the interface and in the bulk solution and relate them to chemical and physical condition of a lubricant. The paper offers an attempt to model electrochemical structure of a lubricant degradation through use of equivalent R-C circuits (Voigt model) that represent bulk, charge transfer, adsorption and diffusion processes. EIS analysis of an additive component matrix shows that properties of dispersants, detergents, other lubricant components and their complexes can be modeled to provide reasonable correlation with the total electrochemical output of the finished lubricant. The model also demonstrated a good correlation between the experimental data and chemical and physical parameters of fully formulated industrial lubricant throughout its lifetime determined by traditional off-line analytical methods. The modeling and analysis of the time-dependent data, for example a combination of changes of solution, bulk, and charge transfer resistances, capacitances and CPE parameters (Fig. 1), and their correlation with off-line analytical methods, allows to accurately determine useful life of a lubricant in industrial equipment. Remaining ambiguities in interpretation of the impedance outputs and their correlation to a chemical composition of the lubricant can be resolved by complimenting EIS by other analytical techniques suitable for in situ applications, such as QCM and IR.

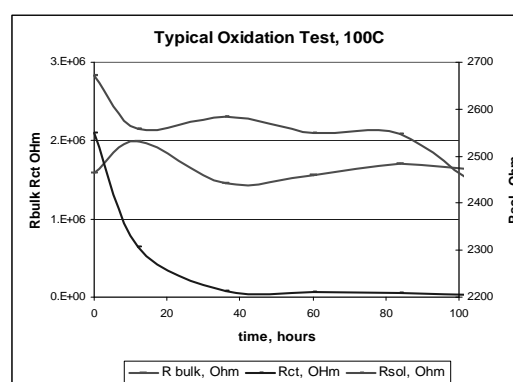


Fig.1

1. R. M. Mortier and S. T. Orszulik, "Chemistry and Technology of Lubricants", Blackie Academic & Professional, 1992.
2. M. Johnson, S. Korcek, R. Djensen, A. Gangopadhyay, E. Soltis, "Laboratory Assessment of the Oxidation and Wear Performance Capabilities of Low Phosphorus Engine Oils", SAE Technical Paper 013541, 2001.
3. T. Smith, V. Kersey, T. Bidwell, "The Effect of Engine Age, Engine Oil Age and Drain Interval on Vehicle Tailpipe Emissions and Fuel Efficiency", SAE Technical Paper 013545, 2001.
4. M. Batko, D. Florkowski, V. Ebeling, R. Geibach, L. Williams, "Lubricant Requirements of an Advanced Designed High Performance, Fuel Efficient low Emissions V-6 Engine", SAE Technical Paper 011899, 2001.
5. M. Smiechowski, V. Lvovich, "Electrochemical Monitoring of Water-Surfactant Interactions in Industrial Lubricants", J. Electroanal. Chem., 534 (2), pp.171-180, 2002.
6. V. Lvovich, F. Boyle, "Method and apparatus for on-line monitoring of quality and/or condition of highly-resistive fluids", US Patent, allowed.
7. J. R. MacDonald, "Impedance Spectroscopy", John Wiley and Sons, New York, 1987.
8. S. Grimmes, O. G. Martinsen, "Bioimpedance & Bioelectricity Basics", Academic Press, London, 2000.