Real-Time Prediction of Incipient Failure in Working Fluids

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INTRODUCTION: Working fluids (engine oil, transmission fluid, hydraulic fluid, coolants, etc.) become contaminated in use. To ensure that the equipment is not damaged by the contaminated fluid, the fluid is typically removed and replaced periodically. For large groups of machines, the used fluid is then shipped to an analysis laboratory and a complicated analysis is performed to ensure that the fluid replacement period is correct for each machine and that each machine is not in need of immediate repair. This procedure is costly, time consuming, and does not always work in a timely manner to prevent machine failure.

This paper presents a new approach to working fluid analysis. The model presented herein demonstrates the value of real-time analysis of the differential electrical admittance of the working fluid in-situ to detect the incipient failure of the working fluid. .

COMPUTATIONAL METHODS: The model presented in this paper employs COMSOL Multiphysics® and the AC/DC Module. This model is derived from the Frequency Domain Modeling of a Capacitor model (12693). In this case, the model is developed to show how the differential electrical admittance changes in the Frequency Domain, as a function of the shift in the parametric value of the electrical conductivity and/or the relative permittivity.

1. $Y=1/Z$

Where: Y is the admittance, measured in siemens
Z is the impedance, measured in ohms

2. Z = R + jX

Where: R is the resistance (real part), measured in ohms
X is the reactance (imaginary part), measured in ohms
j is the square root of minus one (-1)

The geometry chosen is that of a four (4) part capacitor, with a dielectric material (engine oil) located between the two (2) horizontal plates. See Figure 1

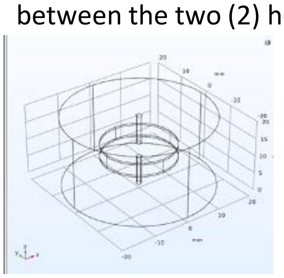

Figure 1. Capacitor Structure

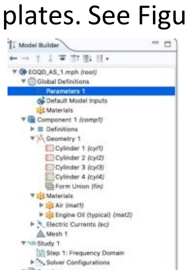

Figure 2. Model Details

Figure 2 shows the capacitor build and material specification details.

Figure 3 shows the parametric variables that were added to the original model to allow for the electrical property changes caused by the contamination of the engine oil.

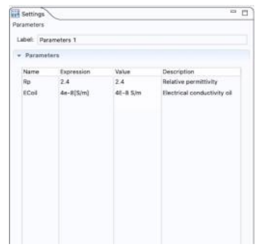

Figure 3. Parameters

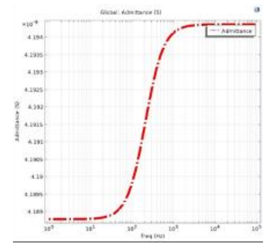

Figure 4. Pure Engine Oil

RESULTS: Figure 4 shows the admittance values vs. Frequency for pure engine oil. Figure 5 shows how the shape and location of the admittance vs frequency curve changes after a small amount of water is added as contamination to the engine oil. Figure 6 shows how the shape and location of the admittance vs frequency curve changes after a small amount of water and metal or carbon particles are added as contamination to the original engine oil.

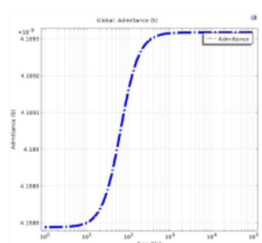

Figure 5. Engine Oil + H2O

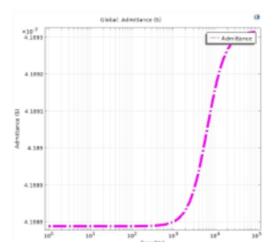

Figure 6. Engine Oil + H2O + Particles

CONCLUSIONS: The use of a real-time prediction methodology for the detection of the incipient failure of each working fluid, in situ, will allow each fluid to be used in a particular machine for an optimum period of time in that machine. The particular fluid will then be replaced, at a convenient time, with new fluid before reaching the catastrophic failure point in that machine.

REFERENCES:

1. https://en.wikipedia.org/wiki/Admittance
2. https://en.wikipedia.org/wiki/Electrical_impedance