Editorial

Thoughts on the Degradation of Oil

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1. Introduction

The author has been involved in a joint research project with KYB Corporation for several years. The project is intended to develop a sensor that can detect changes in the properties of oil caused by its degradation by using a low-cost simple device. Oil is used in mechanical equipment for various purposes including lubrication, cooling, electrical insulation, and rust prevention. It is also widely used as a working fluid in hydraulic systems virtually everywhere in the world. However, oil gradually changes in property with time as the systems are operated as seen in the familiar example where the engine oil used in automobiles gets black little by little as the mileage increases. Such changes generally progress unfavorably. Therefore, this is called "degradation".

Oil degradation is mainly caused by oxidation and contamination. The degradation appears as changes in various physical parameters.[1)-6)] The degree of oxidation can be evaluated by total acid value but we are focused on "permittivity", which is an electrical parameter that may be relatively highly correlated with total oxidation.

The permittivity of a material can be determined as the capacitance (a parameter indicating how easily the material can charge electricity) between two electrodes filled with the material. Capacitance measurement itself is one of the basic electrical measurement techniques and may be carried out using various methods. In fact, there is sufficient space for exploring an appropriate method for detecting changes in oil properties from various angles. This paper briefly introduces our related efforts and describes my various thoughts about the word "degradation" of oil.

2. What is Permittivity?

The “permittivity” of a material can be plainly described as how easily the material can be electrically drawn. Electricity borne by an object is called "electric charge". Electric charge can be positive (+) or negative (-). It is well known that like charges (positive charges or negative charges) repel each other and unlike charges (positive and negative charges) attract each other. All matter consists of elements that are combinations of atoms as a basic unit. Each atom includes a positively charged nucleus surrounded by negatively charged electrons. In other words, matter contains countless positive and negative charges. Normally, matter has the same amount of positive and negative charges. The center of gravity of positive charges is aligned with that of negative charges. These two types of charges are evenly distributed in the matter as a whole.

When matter is filled between two electrodes and applied with a voltage, the positive charges in the matter are repelled by the positive electrode and attracted by the negative electrode. The negative charges are applied with a force in the opposite direction. As a result, the center of gravity of the positive charges in the matter is misaligned with that of the negative charges. This is called "polarization". Thus, permittivity is a parameter indicating how easily this polarization takes place.

There are several possible causes of polarization. One is that the electron cloud surrounding the nucleus of each atom is attracted by the positive side to cause displacement. This is called electron polarization, which is a phenomenon that always takes place in all matter as long as matter consists of atoms. Some kinds of matter consist of atoms that are divided into positive and negative ions and are bound together by attractive forces between the positive and negative ions. In this case, if a force is applied to the positive and negative ions in opposite directions to each other, the ions each move from a position of equilibrium in the opposite direction, resulting in a positional difference in the center of gravity between the positive and negative charges. This is called ionic or atomic polarization.

Some other kinds of matter originally consist of molecules in which the center of gravity of their positive charges is dislocated from that of their negative charges. Molecules that have originally been polarized are called "permanent dipoles". Matter consisting of permanent dipoles, when viewed as a whole, are not particularly biased in terms of polarity, because the dipoles are usually oriented at random. However, when the positive/negative poles are applied with a force in the opposite direction,

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the dipoles are aligned in a direction parallel with the force. As a result, the matter as a whole is polarized. This is called orientation polarization.

It can be said that the majority of molecules constituting matter consist of permanent dipoles. One typical and familiar example is water molecules. A water molecule consists of two hydrogen (H) atoms and one oxygen (O) atom. Hydrogen is assigned the atomic number 1, which means that it has only one electron. This electron is used to bond to the oxygen atom. This uncovers the positive charge of the nucleus (proton) of the hydrogen atoms to make them positive and the oxygen atom negative. The two hydrogen atoms and the oxygen atom are not aligned in a line but bonded together at an angle of 104.5°. This means that the center of gravity of the positive charge is dislocated from that of the negative one. Therefore, water shows a notably high permittivity among liquids.

3. Detecting Minute Changes in Permittivity

The capacitance between two electrodes is proportional to the permittivity of the insulation between the electrodes. Any change (increase) in permittivity due to oil degradation is as small as several percent at most, although it depends on the extent of the degradation. Furthermore, the electrodes of the sensor only show a small capacitance themselves because the sensor cannot be so large. So, it is necessary to detect tiny changes in such a small value. These minute changes in permittivity may be detected in several ways.

In general, when you try to measure a physical quantity using an electronic technique, you always end up measuring the magnitude of the target quantity in units of voltage or time. A challenge you must eventually overcome is how you can practically convert the magnitude of capacitance into a voltage or time.

For example, it is useful to remember that the voltage between two electrodes can be determined by dividing the amount of charges accumulated between the electrodes by the capacitance between the electrodes. Measuring the voltage between the electrodes when a certain amount of charges is present there will give the capacitance. To accumulate a certain amount of charges between the electrodes, you can just supply a certain amount of current for a certain time. If the current has a known fixed value, you may either supply the current for a certain time to measure the voltage of the charged electrodes or measure the time you need to complete the charging. Anyway, the rate of change in capacitance is very small and is similar to the rate of change of the measurement indicator. When trying to detect any minute change, the measurement performance directly depends on how you can suppress unavoidable noise to ensure an appropriate signal-to-noise (S/N) ratio.

To resolve this challenge, a device should be prepared that can convert minute changes in capacitance into much larger changes in another physical quantity. One of the means to implement this is to make use of “resonance”. Resonance refers to a phenomenon in which a system with a natural frequency (a resonance frequency) is excited at a frequency close to its natural frequency to vibrate with a large amplitude even with weak excitation. In an electric circuit, resonance may occur with a combination of capacitance and “inductance”, which constitute the two major parameters of electromagnetism. Inductance is normally implemented by a coil. A coil is a spiral conductor wrapped around any core. Since capacitance is represented by the letter C and inductance by the letter L, resonance with capacitance and inductance is generally called "LC resonance".

When resonance occurs, the phase relationship between the signal exciting the resonance and the vibration caused by the excitation substantially changes around the resonance frequency. The phase is a quantity indicating the timing at which the vibration swings in whichever direction. Therefore, when phase differences are plotted with the horizontal-axis showing frequency and the vertical-axis showing the phase difference between the exciting signal and the vibration caused by the signal, the curves (representing the phase characteristics) show a steep slope around the resonance frequency. On the other hand, the resonance frequency changes as the capacitance changes. With the frequency of the exciting signal kept at a fixed value close to the resonance frequency, any minute change in resonance frequency can be expanded and

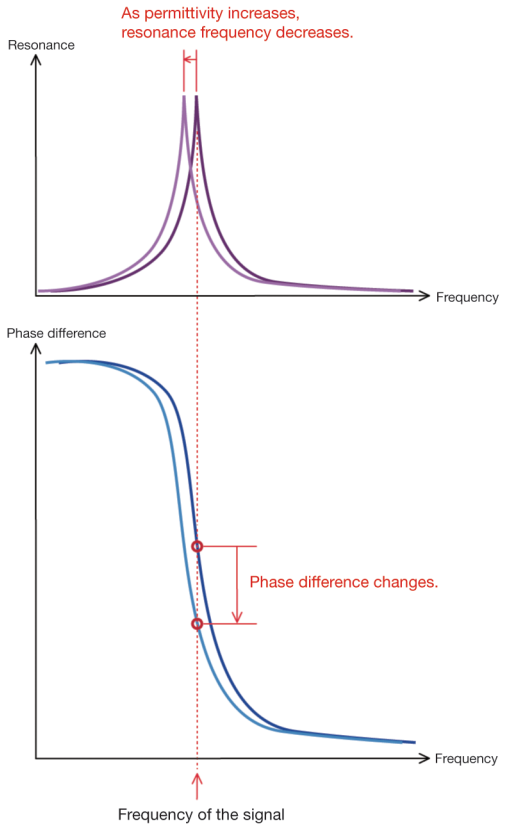

Fig. 1 Principle that a capacitance change is expanded to a change in phase difference and how it is observed

captured as a phase difference because of the steep slope of the curves (Fig. 1).

To enable sensitive detection of changes in capacitance using this method, it is desirable that the phase characteristics curve has a slope as steep as possible at the resonance frequency. When inductance is usually implemented by a coil, however, the coil does not necessarily have components only for inductance, but also those for winding resistance or capacitance between the windings, which can reduce the sharpness of the resonance. Another challenge is that the magnetic field generated by a current flowing through the coil is always expanded to the surroundings because of its inherent nature, leading to an unavoidable problem of interference with the surroundings.

To resolve these problems, we use an electronic circuit to implement the characteristics equivalent to those of the inductance usually implemented by the coil.[7] This does not mean using special electronic devices but only a combination of generally available devices. This circuit is called a General Impedance Converter (GIC) and can virtually convert capacitance into inductance. In the sensor we are developing, we can cause LC resonance to take place between the capacitance of the sensor electrodes and the equivalent inductance with GIC, thereby enabling sensitive detection of very minute changes in permittivity caused by changes in oil property. The GIC thus features the excellent benefit that the whole device can be set up only with general materials at low cost without using special components.

4. Consideration of Oil Degradation

Then, why does the permittivity of oil change (increase) when the oil degrades? One major factor of oil degradation or change in material properties is the oxidation of oil molecules. In other words, the question is why the permittivity of oil changes when the oil molecules are oxidized.

An oil basically consists of a number of combinations of carbon (C) atoms and hydrogen (H) atoms. Unlike water molecules, oil molecules are not permanent dipoles themselves and do not have polarity. This is one of the reasons why water and oil cannot be mixed.

When oil molecules are bonded with oxygen atoms due to oxidation, however, the parts of the oil molecules that are bonded with oxygen atoms will be charged negative. This is because oxygen is located around the top right corner of the periodic table, which means that its atoms have relatively high electronegativity. As a result, the oil molecules will be polarized. With this acting as an additional factor of orientation polarization, the oil molecules will increase in permittivity as a whole.

There are literally many kinds of oil. I find it somewhat strange that countless types of oil are basically made from only two elements: C and H. Incidentally, a computer program is similar to oil in that it also consists of numerous combinations of two types of elements: zero (0) and one (1). Moreover, it is well known that the DNA information of living organisms consists of a sequence of four kinds of bases: adenine (A), guanine (G), thymine (T), and cytosine (C). In fact, these bases can only generate two types of pairs: A-T and G-C. So, the DNA information also consists of only these two patterns of base sequence. In short, all things existing in the world consist of a few or limited number of types of elements. Their characteristics or differences are implemented by numerous combinations of these elements.

In a computer program, 0 and 1 when alone only give the information that they are present there. Then, combining 0s and 1s in a series can represent a meaning as a number or a command. The relationship between the combination and the meaning is not fixed or certain. In language for instance, Japanese is expressed by a combination of 50 notes and English by combinations from a 26-letter alphabet. Even the sound of an identical combination of "a" and "i" may indicate "love" in Japanese or "I" in English.

As human genome analysis has progressed and gene diagnosis technology has advanced, it has become possible to learn which specific diseases you are likely to suffer from in future by examining your DNA. This means that you are now able to understand the meaning of a base sequence of A-T and G-C just by reading it. But I wonder what links the base sequence with its meaning to begin with.

The mechanism by which oil permittivity increases with oxidation is as described above. However, what gave oxygen atoms the property of being likely to be negatively charged in the first place? Of course, this is because oxygen is located around the top right corner of the periodic table, but why do elements located in the top right corner of the periodic table have higher electronegativity? This can be explained through calculation of the electron orbit of atoms based on quantum mechanics as you know, but why are electrons negatively charged to begin with? When you pursue the answer to these questions in this way, you may finally reach a point where nobody can explain what it is all about.

A discipline that pursues the source of matter is particle physics. According to theory, an atom can be divided into quarks, leptons and other elemental particles that have different characteristics. However, nobody can explain why those elemental particles have such characteristics. Different combinations of these elemental particles can constitute various types of atoms or matter, but nobody can explain why a specific combination of the elemental particles forms a specific material or generates the unique property of the material. A familiar example may be metallic elements. The metal with the atomic number 26 is iron and that with the atomic number 29 copper. Iron and copper have obviously different properties. How can you explain the difference in property between the

two metals with different atomic numbers? How could you describe the reason why the element with the atomic number 26 has the property of "iron", not that of "copper"?

I teach my students computer programming. I insistently tell them to always put comments on programs they are writing. The term comment here means words to be added to the relevant parts of a program to explain what is processed in the parts. Comments are made with words describing, for example, what a specific variable here expresses or the meaning of a specific calculation written there. By putting comments on your program, you can re-organize ideas in your mind, being more aware of errors. During writing, you may certainly feel OK with your program while you are thinking in various ways for the program. With no comments, however, you may often forget what made you write this part of the program in this way after a while. In some cases, you might even forget the fact that you wrote the program yourself.

In a computer program in which each line comes with adequate comments, you can ideally read the comments like a series of text describing what the program is processing. In other words, making a program is comparable to writing a paper, as I always tell my students. A program written with alphanumeric characters and mathematical expressions is practically the same as language. Processes of programs can be expressed in words. Machine-level instructions of computer programs consist of combinations of 0s and 1s. Various patterns of a series of 0s and 1s are connected to meaning indicated by their corresponding words.

A specific sequence of 0s and 1s could be reproduced by randomly putting 0s and 1s together. However, such a sequence is made by chance and does not have any specific meaning. For computers, programmers intentionally create a pattern of 0s and 1s to represent the meaning of the program. By using the means of different combinations of elements, programmers can express their intention.

As mentioned above, is it known that base sequences of DNA have their own meaning and the combination including 26 protons, and 26 electrons indicates an element having the properties of a metal called "iron". These are the facts in the real world. Any combinations made by chance should not have any meaning. If such a combination has a meaning, this is contradictory to the assumption that the combination was made by chance. Given that the words "by chance" or "randomly" denote that a thing takes place with no reason or no cause-and-effect relation, evolutionism is an incoherent theory in this sense.

Anything with meaning should involve an entity who has given the meaning as in computer programs that always involve their programmer. The entity who has given the meaning must be a being with intelligence as in the programmer who exercised their wits to create the program. The "meaning" of things is usually expressed by "words". Let me here collectively call "meaning" that can not necessarily be expressed by voice or text (so-called language) "words". Without these "words", all matter in this world is just random assemblies of atoms and molecules.

The Bible says, "In the beginning was the Word". The beginning of the Bible also includes the phrase: "In the beginning God created the heavens and the earth". In Japan where Bible-based philosophy has seldom been proliferated in the local culture, the term "God" (Kami in Japanese) may remind people of somewhat "cheap" words such as Kamiwaza (literally meaning acts of God) or Kamitaiou (super-excellent response). God in the Bible in turn refers to the Creator. The famous phrase "In the beginning was the Word" is followed by "and the Word was with God, and the Word was God". Namely, what created heaven and earth (the Creator) is the Word itself. The Bible declares that the meaning of everything can be sourced to the Word, that is, God.

Even if the base sequence of DNA accidentally represents the DNA pattern of human beings, no living human being could have been created without the “Word” of "life". I heard that 23 types of amino acids were found in asteroid samples brought back by the Japanese space probe Hayabusa. Amino acids are just a small part of the components of the human body. Without activation of a program (i.e., words) to select and combine the necessary parts (levorotatory amino acids), no human body can be created. Even if a human body could be created by this method, it would just be a physical object called a human body without "life" breathed in.

People, particularly Japanese who have grown up with education heavily centered in Evolutionism, usually have no idea about the Creator. This is noted as "original sin" by the Bible. However, the Bible says, "God saw everything that he had made, and behold, it was very good". What was very good when God created heaven and earth changed, which means that everything tended to get worse. When oil changes in property due to oxidation, the phrase of the Bible is elicited as the "degradation" of oil.

The Bible also says, God created man in “his own image". In other words, man was created to concretely express how wonderful the wisdom of God is and how glorious the nature of God is. This can explain the decisive differences between human beings and other animals that can obviously be recognized in the real world. Some species of plant have beautiful flowers. They may come into flower for the purpose of attracting insects for easier pollination. But, if that is the only purpose, do they have to be decorated with those petals that all differ in color, pattern and shape? We feel a sense of beauty when we see flowers. This is because we are what God created in his own image. Is there any other reason?

There is one thing that I have long doubted. Music, especially Western music, may be played in a major scale or in a minor scale. Music played in a major scale generally sounds bright and cheerful while that played in a minor key sounds depressing or sorrowful. The only difference in main chords between the major and minor scales is the third note, i.e., half-tone higher or not. I wonder why these notes sound cheerful or sorrowful just by slightly changing the note pattern. We, as human beings, have been connected to a program (words) that can make us have such specific feelings in response to particular patterns of notes. I cannot understand this in any other way. We can be moved by or feel beauty from a piece of music because we were created by God in his own image. Is there any other reason?

We, who used to be "very good" in the beginning, became unaware of the Creator because of our own "sin". However, the Creator had known very well from the beginning that we would become so. We do not have the capability of making amends for our own "sin". The Bible says, "the wages of sin is death". We were separated from the Creator because of “sin”. As a result, our body "deteriorates" with time and eventually dies. We cannot do anything about this fate ourselves. Then, the Creator prepared an astonishing plan to resolve our fate. That is, behold, he planned to come to the earth as a human being, and to die as a scapegoat for us. This was implemented by Jesus Christ about two thousand years ago. Furthermore, he died by Crucifixion on a cross, which was probably one of the most barbaric ways of dying. Still, the death was beyond his death as he was the Creator. He still exists with the phrase, "I am who I am".

Apostle John, who directly saw Jesus Christ and lived together with him for a while, wrote in the gospel-book, **"For God so loved the world that he gave his one and only Son, that whoever believes in him shall not perish but have eternal life".**

Of course, the only Son here means Jesus Christ himself.

John also wrote in the letter: **"Whoever does not love does not know God, because God is love.**

This is how God showed his love among us: He sent his one and only Son into the world that we might live through him.

This is love: not that we loved God, but that he loved us and sent his Son as an atoning sacrifice for our sins".

In other words, man was created by God "in his own image" to concretely express "God is love" as a visible form to all.

If you believe in Evolutionism assuming that God is nowhere, the oil should change in property with time as you use it, and amino acids should be generated at some point in time, leading in the end to the birth of life. You may believe that oil "evolves", not "deteriorates". All materials necessary to make up amino acids are available: C and H contained in oil and O and N available in the air. Then, assuming that life was created by chance from these materials, does that life-form have “love” on earth?

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