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USED OIL DEGRADATION DETECTION SENSOR DEVELOPMENT

S. RAADNUI*
Faculty of Engineering
King Mongkut's Institute of Technology North Bangkok (KMITNB)
1518 Pibulsongkram Road, Bang-Sue, 10800, Bangkok, THAILAND
e-mail: s_raadnui@yahoo.co.uk

This paper introduces an on-line condition monitoring of lubricant degradation for oil-lubricated machinery. The system detects the relative variation of lubricant degradation i.e., physical/chemical properties, generated wear particles and ingested contaminants, by using the grid capacitance sensor in an on-line installation. The system consists of grid sensing unit and a multitude of small holes (up to $2mm$. in diameter) between the sensing grids. The oil enters in the top part and flows through the holes and exits at the bottom. In addition, the sensor can also detect large size "metal" particles i.e., $\geq 1000\mu m$ whereas the component being monitored approaches catastrophic failure which cannot be detected by the conventional on-line "Ferrous Debris Monitoring Sensor" such as the Magnetic Chip Detector (MCD). In addition, the system can also be used to distinguish the relative variation of the dielectric constant of lubricant caused by contaminants such as water, fuel dilution, etc.

Key words: lubricant degradation, on-line, sensor.

1. Introduction

The purpose of most methods of early failure detection in oil-lubricated machinery is to discover the degradation of lubricant within the oil circulation system. These methods can be divided into continuously measuring ones and those requiring the taking of an oil sample. A different method is offered by the lubricant itself. The condition of the oil is subject to the influence of many factors which may degrade its two primary functions, namely cooling and lubrication, to a point where severe damage occurs. Accordingly, the lubricant itself is an important source of information in the strategy of defect avoidance comparable to the role of the human blood in the detection and prevention of diseases.

Main parameters which have an influence on the condition of the lubricating oil are:

- elevated temperature,
- presence of air,
- water,
- fuel or other lubricants,
- solid matter: wear debris, dust, dirt, etc.

The lubricant quality detecting is one of the main factors in condition monitoring of the oil-lubricated machinery. Contaminants such as dust, wear debris etc., chemical by-products and physical changes of the used oil normally alter the performance of lubricant. These changes always reflect a change of dielectric constant of the lubricant, therefore any abnormal condition, such as contaminant ingression, generated wear debris, severely chemical and/or physical oil degradation etc., can be detected in timely manner by monitoring the dielectric constant of the used lubricant.

* To whom correspondence should be addressed

The sensor is a grid capacitance sensor, the construction of which is shown in Fig.3. It consists of two series of parallel poles. While the sensor is passed through by lubricating oil in the system, the capacitance of the sensor can be expressed as follows

$$C = \varepsilon_0 \varepsilon_v A/\delta \tag{1.1}$$

where ε_0 is the dielectric constant in vacuum, ε_v is the dielectric constant of the oil between two poles. A is the available area of poles and δ is the distance between two poles. Because ε_v, A, and δ are constant in the sensor, the capacitance of the sensor is determined by ε_v, while the voltage is loaded between the emission pole and the detecting circuit is proportional to the capacitance of the sensor. Measurements of the dielectric constant have been made which show the variation range of the capacitance from *0* to *20* in detecting range. The experiments were conducted on three kinds of contaminants. Figures 1 to 3 illustrate the sensor developed in this particular work. Typical outputs from the sensor is shown in Fig.4.

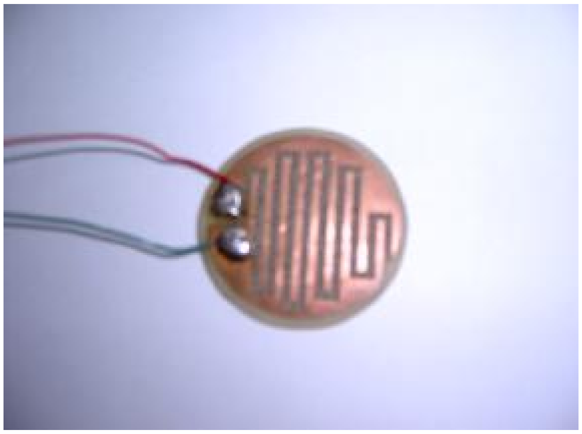

Fig.1. The shape of grid capacitance sensor.

Fig.2. The grid capacitance sensor unit.

Fig.3. The complete set of sensor is connected with the RLC meter.

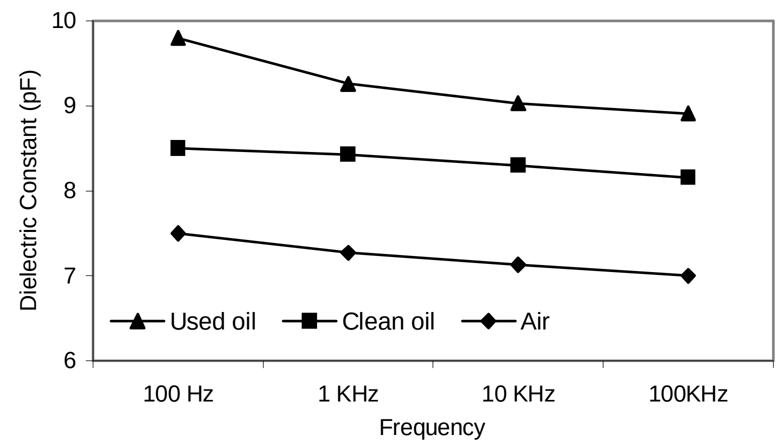

Fig.4. Preliminary results indicating the sensor as per frequency variation.

2. Experimental work

The most important advantages of the application of mathematical statistics in the study of complicated technical systems are, among others, the reduction in experimental expenditure and the determination of unknown phenomena enabling a systematic subsequent examination. The experiments have been performed according to special experimental designs which have varied the level of three important cause variables of the grid sensor.

3. Experimental results and discussion

Figures 5 to 7 present the measurement values from the sensor with variation of contamination levels and also illustrate the effect of measuring time. It can be seen from Fig.5 that the dielectric constant was increased as the level of water contaminant increased. In addition, as the measurement time interval went longer, the dielectric constant also became higher. Figures 6 and 7 show characteristics similar to Fig.5. It can be deduced that the higher level of all contaminants used in this work (dust particles, Ferrous particles and water contamination in the simulated oil samples), the higher value of the dielectric constant values. Further, the longer time the contaminant allows to occupy the sensor cavity, the higher the value of the dielectric constant.

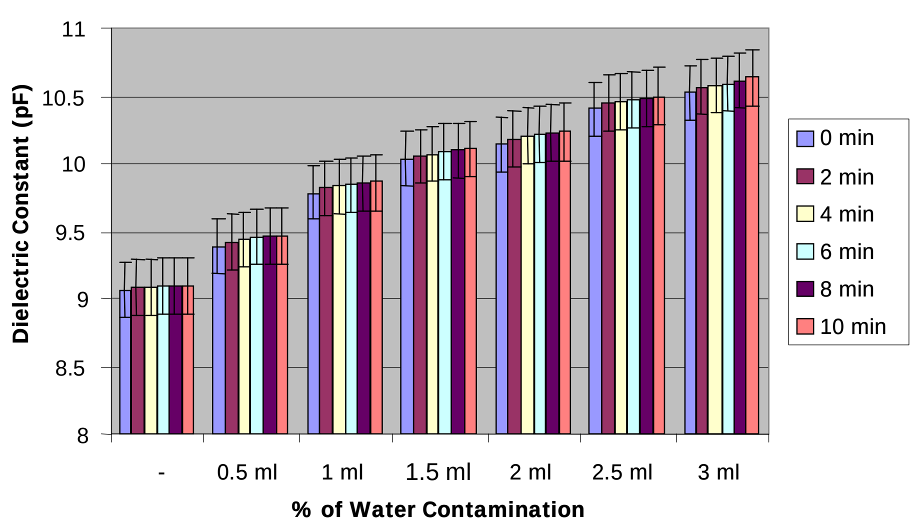

Fig.5. Effect of water contamination as a function of measuring time.

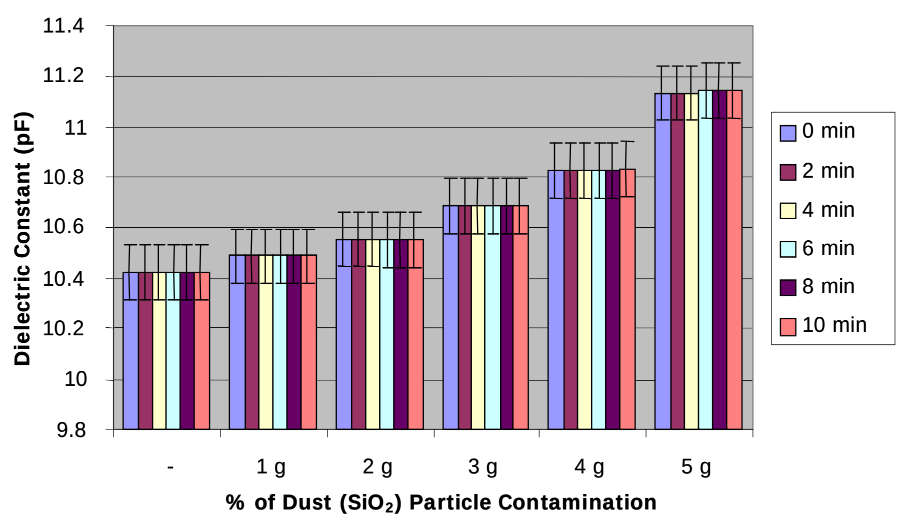

Fig.6. Effect of dirt particle contamination as a function of measuring time.

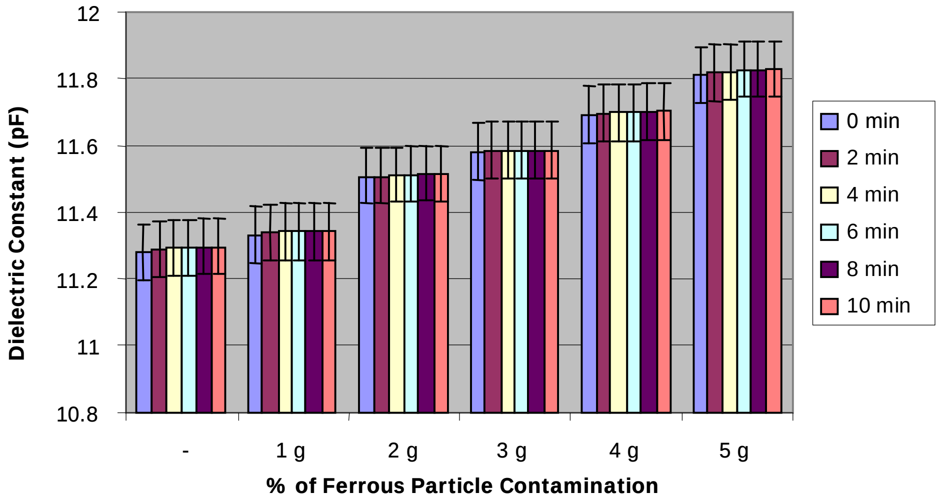

Fig.7. Effect of Ferrous particle contamination as a function of measuring time.

4. Conclusions

The conclusions that could be drawn from the experiment included:

1. The Ferrous particles, water contamination and dust contamination have a significant effect on the average sensor output.
2. The sensor developed can be used to assess oil quality degradation with certain degree of confidence.
3. Future work is needed for evaluating the effects of other metal particles, physical and/or chemical changes during the life of used oil.

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