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Case Study

Research on influence of water content to the measurement of wear particle concentration in turbine oil online monitoring simulation

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ABSTRACT

Water pollution is one of the most susceptible pollution of turbine oil. Based on the testability of turbine oil's operating characteristics, which includes viscosity, density, dielectric constant, moisture and degree of wear particle contamination and so on, a turbine oil online monitoring simulation platform was designed. It is used to simulate the flow of turbine oil in an independent circulation system. In the process of experiment, we can get the effect to operating characteristics of turbine oil while water is involved in. Appropriate sensors were selected to design the testing workbench, and the monitoring environment was well controlled. Then the dielectric constant and particle concentration were chosen as experimental characteristic parameters. Dielectric constant reflects the water content in oil. The variation of dielectric constant and particle concentration under different temperatures and water content of turbine oil can be analyzed. And the mechanism was discussed. The influence of temperature and water content to the measurement of particle concentration can also be observed and fundamental mutual effect of them can be found. Experiment result shows that the temperature and water content of oil have influence to some extent on the monitoring results of turbine oil wear particle concentration, and a correction method also can be found to resolve this problem.

1. Introduction

Lubricant working condition monitoring is an effective technology that has been commonly used for many years, although the traditional way which is even still being used nowadays to justify the status of lubricant is to measure different parameters in lab. However, with the researching and developing of sensors for oil physical and chemical conditions measurement [1,2], online monitoring of lubricant in real time become a new way to approach the working condition of oil in a very short time period [3,4]. It takes advantage of a very short time interval and in-situ sampling, so this monitoring technology would not miss very important fault information and sudden events in oil that can reflect the health status of turbine bearing. A prognosis health system can be built up based on the monitoring of some working parameters of mechanical system, and some method can be used to predict the working condition of bearings and some other parts in machines [5–11].

Some research groups and companies focused on oil monitoring technology for couple of years, and most of related work are about sensor development and instrument detection of oil parameters in lab [12]. The most popular sensors in nowadays are mainly produced by Kittiwake (metal particle content sensor), Argo-hytos company whose main products are particle concentration and water pollution sensors and MEAS company whose main product is fluid characteristics sensor. Wu T's work mainly analyzes the images of on-line wear debris by on-line Ferro graph instrument [3,13]. This is a new way to detect the wearing condition of engine oil. But the turbine oil and hydraulic oil [14] are relatively “clean” compared with engine oil, because the particle concentration is low and particle size is small. It is usually monitored by optical blocking particle concentration sensor. Cuffaro V, et al. researched on the spline coupling damage under misalignment condition according to monitoring of fretting wear debris in oil by lab instrument [15]. < answer the 2nd question of Reviewer #1 > Haiden et al. developed a microfluidic chip and dark-field imaging system for size measurement of metal wear particles in oil [16]. Jiang Zhe's lab did a lot work in lubricating oil condition monitoring. They design an integrated oil condition sensor for detecting both wear debris and lubricant properties [17]. And they are doing some work about designing a new microchannel that enables continuous three-dimensional particle focusing, so as to monitoring the shape of debris in oil [18]. < answer 1st question of Review #2 > This technology is used to monitor the shape of

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wear debris to diagnosis the potential fault. Water in oil measurement has been well researched for many years, especially the physical and chemical process. When water content in oil increases to over permitted level, it starts to corrode mechanical tribology parts. However, the mutual effect between water and wear particles hasn't been researched. And the influence of water content to the measurement of particle concentration is still unknown.

Effect of water pollution on the quality of the turbine oil is a very complicated process, including many influence factors, such as temperature, lubricant pressure, flow rate and so on. And a series of physical and chemical reaction may happen while the lubricant is working. By turbine oil working condition online monitoring technology, the dielectric constant, water content and particle concentration are measured. And through these parameters, the lubricating oil quality can be reflected. These parameters keep changing with the decreasing of remain useful life of steam turbine oil. Sometimes, a pollution decay constant may be used to describe this process. And at the same time, the monitored parameters also can have complex interconnection with each other.

2. Turbine oil water pollution and particle concentration monitoring simulation platform

Experiment design of oil monitoring system for main equipment is roughly divided into two parts. The first part is oil circulation control station, mainly include: servo motor and oil tank (as 1 shown in Fig. 1), and the tank contains gear pump, the electromagnetic valve, oil filter, electrical heater and some other equipment. Turbine oil flows from the oil circulation control station to oil online monitoring system. After flowing through electromagnetic valve, oil arrives in a buffer pool to slowdown the flow rate to make the measurement of sensors stable. And sensors are located in buffer pool. Eventually, oil flows back to the oil tank. The whole system ensures the circulation of oil fluent, and at the same time provides security control of the temperature. The system structure diagram is shown in Fig. 2. It can be seen that the yellow lines mean the turbine oil tube system, and the red lines mean the signal circuit for data acquisition to industry PC.

The second part mainly includes the sensor integrated cabinet and protocol converter. The oil is driven into a cabinet in which all sensors are plugged, and the oil in the cabinet is measured through these sensors. The protocol converter can collect data from different sensors and send packed measurement data up to industrial computer through Ethernet. This module makes the sensor data acquisition transparent to computer (Figs. 3–5).

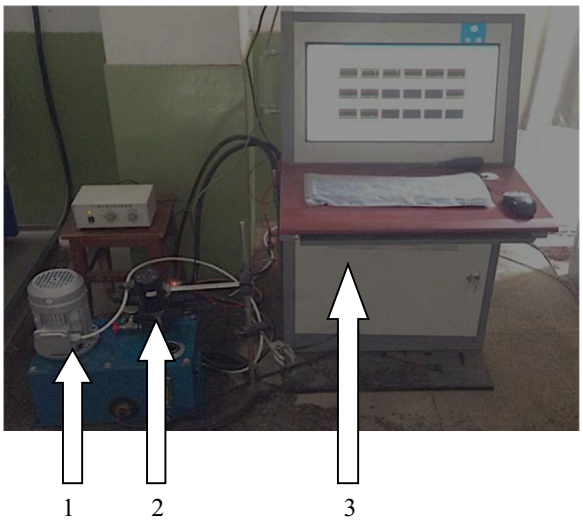

Fig. 1. Steam turbine oil water pollution monitoring system platform, 1- Oil control station, 2-Motor stirrer, 3- Sensor integrated cabinet and PC.

We choose 46 # turbine oil in the experiment, this lubricating oil is suitable for large power steam turbine, large and medium-sized shipbuilding and other industrial steam turbine, and lubrication seal of hydraulic turbine set. The basic parameters of turbine oil is shown in Table 1.

Based on the key requirement of industry for turbine oil working condition monitoring, we used the oil circulation system to study the online monitoring and oil condition variation. In experiment, the chosen parameters were temperature, viscosity, density, dielectric constant, particle concentration, water content (oil humidity). The sensors that had been installed are fluid characteristics sensor, moisture sensor and laser particle monitor.

Sensors selected in online monitoring platform needs to be immersed in the lubricating oil, and the sensor should be installed as far as possible in a protected small room. Thus, we designed an "oil pool", and the fluid characteristics sensor and moisture sensor are put into it. The particle monitor has a current-limiting structure which will induce to the pressure decrease in circulation tube, so another bypass was added to parallel with "oil pool".

2.1. Fluid characteristics sensors

According to the mainstream technologies of the turbine oil online monitoring sensor, we selected the Measurement Specialties (MEAS) FPS2800B12C4 fluid properties sensor. This sensor can monitor oil temperature, density, viscosity, dielectric constant at the same time, and is highly integrated. Also it is known as the four in one oil properties sensors. The sensor is an important part of the experiment design in oil monitoring system, and multi-parameter measurement of FPS sensor is the key to monitor oil performance.

When considering the long-term application in monitoring system, sensor needs to be kept in good condition. We installed the sensor to the pressure side of the oil duct, so that we can ensure that the sensing elements are in contact with the stable and continuous flow of fluid, which can detect the state of lubrication oil in the system adequately.

2.2. Moisture transducer

We select German ARGO HYTOS LubCosH2O oil moisture transducer. The principle of the sensor is to measure water content in oil by detecting dielectric constant, because different amount of water content will result in lubricating oil dielectric constant changing significantly. Through comparing the dielectric constant of lubricating oil with a certain amount of water with the dielectric constant of pure oil, and then collecting dielectric constant signal from sensor, lubricating oil water content can be calculated.

Moisture measurement is calculated based on dielectric constant under a certain temperature. If the temperature appears deviation, the dielectric constant will follow the change of dielectric constant deviation. This will increase the error of measured data, so we choose moisture transducer to monitor the water content and temperature at the same time, and use the measured temperature to correct the measured water content.

2.3. Particle concentration sensor

Due to the wear process will produce grinding grain, iron and other impurities, so the number and size of particles in oil is able to reflect the mechanical abrasion of the bearing and status of working environment. Particle monitoring is accomplished by