Extending the scope of gearbox oil condition monitoring for wind turbines: Identified challenges and recommendations

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Abstract

In the case of geared wind turbines, oil condition monitoring (OCM) facilitates the identification of wear-related damage and degradation processes in the oil. OCM can also provide valuable information about the gearbox condition in order to extend oil change intervals by monitoring the oil cleanliness [1].

As the implementation of oil sensors for OCM is in an early stage, this poster presents the results of a testing campaign on an oil sensor test bench. During this testing campaign, several types of sensors including particle counters, oil properties sensors and water content sensors are tested under several operating conditions. The results of this study show the limitations and advantages of offline and online OCM methods, which allows giving recommendations on the choice of oil sensors. Oil aged in a laboratory and oil extracted from wind-turbine gearboxes in the field are used to perform the tests and provide a deeper understanding of the oil aging process occurring in wind turbines.

Objectives

This analysis aims at providing:

- Insight about oil parameters to monitor oil degradation of wind turbine gearbox oil by offline and online condition monitoring approaches
- Introduction of an assessment method to verify the detection capability of oil sensors
- Identification of changes in key properties of the oil as a function of aging temperature and time

Methods

Oil sensor testing

In order to assess the capability of online and offline OCM methods, namely oil-sensor and oil-sample-based monitoring, an oil sensor test bench, which is illustrated in figure 1, is designed. The oil sensor test bench allows analyzing the detection capability and quality of different types of sensors. This is achieved due to the well defined and reproducible operational characteristics of the test bench. In this analysis, a common gearbox Poly-alpha-Olefin (PAO) with a viscosity grade of 320 in different aging stages is used. The tests include a stepped temperature profile ranging from 40° C to 80° C and a test at 60° C with contaminated oil containing particles of sizes below 100µm with a constant volume flow rate.

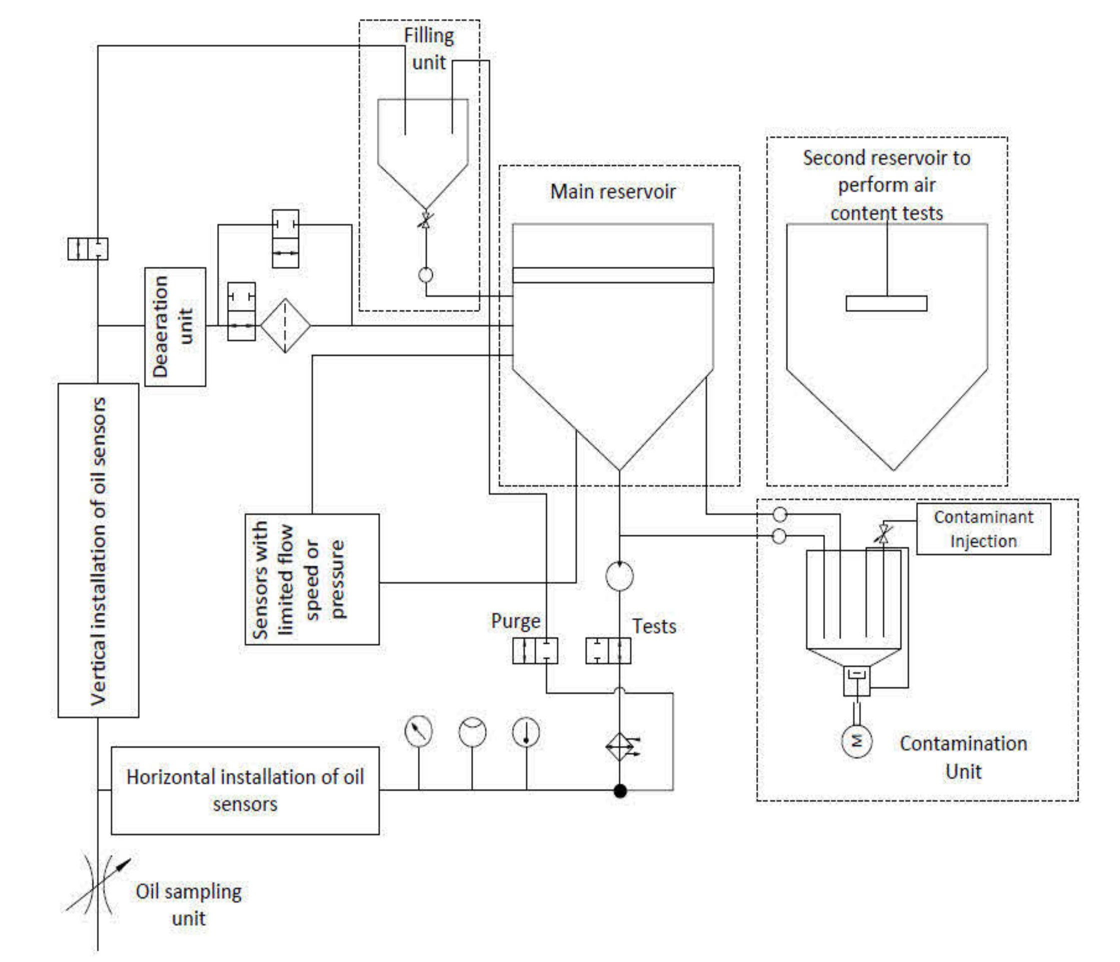

Figure 1: Oil sensor test bench layout

The sensors used in these tests are already in the market and are listed in Table 1. For further information about the sensors, the reader is referred to [1].

Table 1: Sensors under test in the oil sensor test bench

Type of sensor	Number of sensors	Positioning
Temperature sensor	3	Horizontal pipe, main reservoir, contamination unit
Water-content sensor	2	Horizontal and vertical pipe
Oil-properties sensor	2	Horizontal and vertical pipe
Wear-debris sensor	2	Horizontal and vertical pipe
Particle-concentration sensor	1	Parallel pipe connected to the main reservoir

Oil aging

In order to take into account the changes in the oil properties and perform a corresponding analysis, a thermal oil aging process for the same PAO used in the oil sensor test bench is performed in the slave gearbox of a FZG-back to back test rig at the Gear Research Centre (FZG) of the Technical University Munich (TUM) [2]. This oil aging process provides information about the degradation of the gearbox oil. Fresh oil is aged in two different stages based on changes on additive concentration, Total Acid Number (TAN) or viscosity. In collaboration with an oil analysis laboratory and the FZG, the oil aging stages have been defined as described in Table 2.

Table 2: Parameters defining the condition of aged oils

Aging Stage	Description	Changes in TAN	Changes in kinematic viscosity	Changes in the additive concentration
Aging Stage I	aged, but suitable for further use	Minimum increase of 0.3 mgKOH/g	5 % - 10%	decrease of additive concentration of >10%
Aging Stage II	aged and deteriorated, not suitable for further use	Minimum increase of 0.5 mgKOH/g	>10 %	decrease of additive concentration of >20%

Results

Oil sensor testing

Absolute water content by Karl-Fischer Titration for all the samples: 30 – 70 ppm

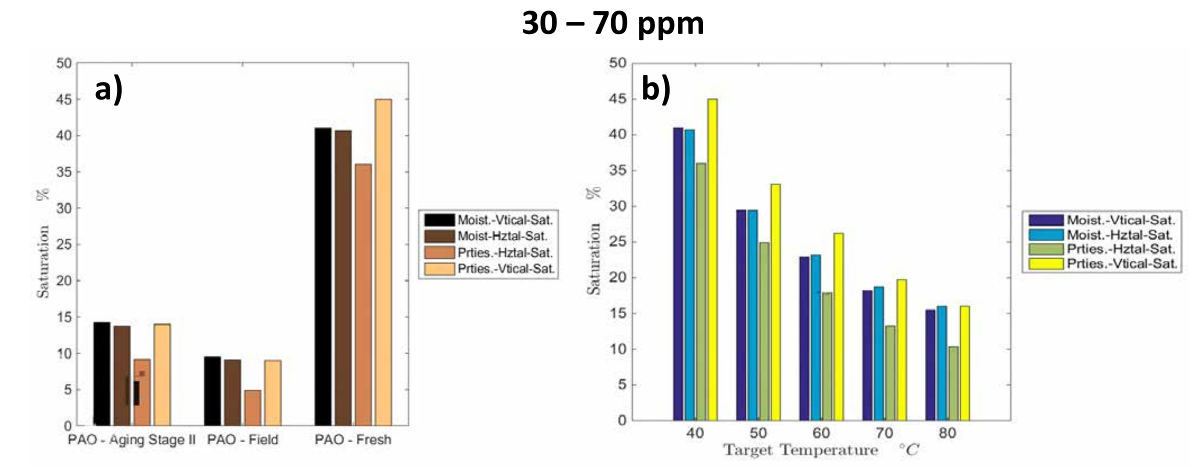

Figure 3. Water saturation levels measured by water-content sensors and oil-properties sensors in horizontal and vertical position: a) Test with oils in different aging stages at a temperature of 40° C, b) Test with fresh PAO at different temperatures

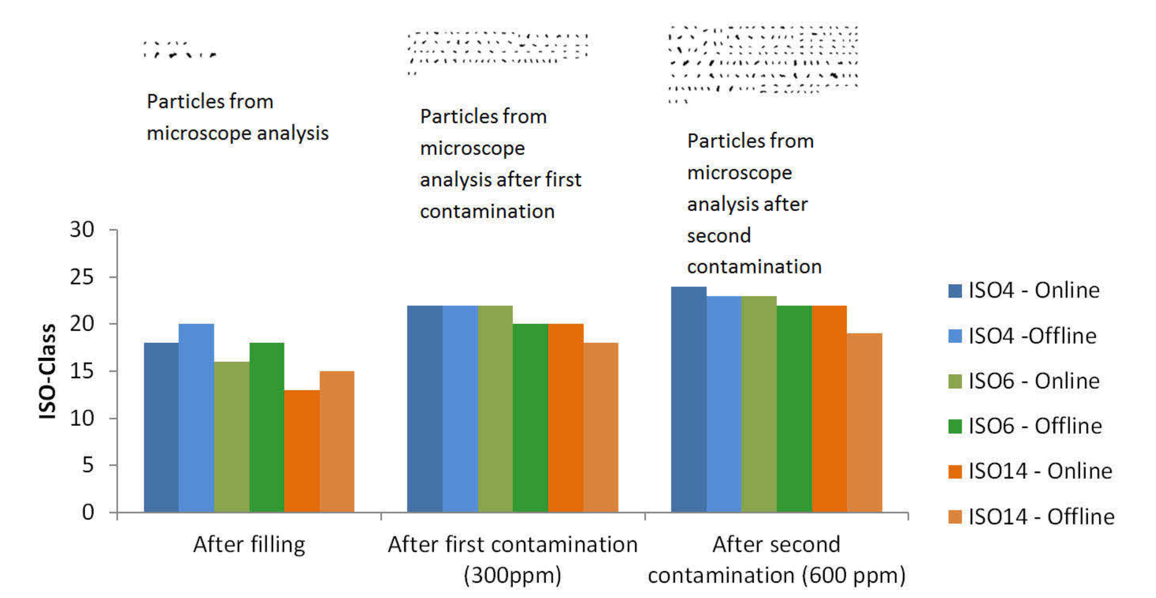

Figure 4. Offline and online particle concentration measurements according to ISO 4406 and their corresponding microscope analysis results

Oil aging

Table 3: Results of the oil aging for the PAO under test with additional results from a wind turbine

Aging Stage	Description	Changes in TAN	Changes in kinematic viscosity	Changes in the additive concentration
Aging Stage I	aged, but suitable for further use	+0.41 mgKOH/g	+10,5%	Phosphor: -32% Sulphur: -50%
Aging Stage II	aged and deteriorated, not suitable for further use	+0.54 mgKOH/g	+6,5%	Phosphor: 26% Sulphur: -42%
Oil from the field	Extracted from a wind turbine with more than 3 years of operation	No changes observed	Lower than 3%	Phosphor: -40% Sulphur: -27%

Conclusions

Both sensor-based as oil-sample methods can be implemented to monitor oil cleanliness. The water saturation levels are found to be influenced by the aging stage and the sensor type. The TAN and the viscosity increases only for thermal aging. Significant changes of Sulphur and Phosphor indicates a decomposition of anti-wear additives. These findings emphasize the importance of understanding the oil aging process and the verification of the sensor output signals before application in wind turbines.

References

1. D. Coronado and K. Fischer, *"Condition monitoring of wind turbines: State of the art, user experience and recommendations"*, VGB research project 383," Available Online: https://www.vgb.org/fue_projekt383.html, Hannover, 2015.
2. ISO, *ISO 14635: Gears - FZG test procedures - Part 1: FZG test method A/8,3/90 for relative scuffing load-carrying capacity of oils*, Geneva: ISO - International Organization for Standardization, 2000.