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Robust Sensor System for Condition Monitoring of Lubricated Rail Vehicle Components

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Summary:
Sensor systems for monitoring lubricated components must provide a high-level of robustness against various environmental impacts like temperature, humidity, and vibrational load to operate reliably over a long-term period. Therefore, a lab-to-field development environment was established to mimic the influence of these factors under controlled laboratory conditions. The sensor-based monitoring of water in grease-lubricated axle box bearings on wheelsets for railway application is presented to account for water content as critical lubricant parameter, as water can damage or even destroy bearings.

Keywords: Humidity sensor, axle box bearing, grease, water content, condition monitoring

Overview and Motivation

A fast and reliable method for evaluating the suitability of a sensor system for an application is provided by the technology readiness levels (TRL) [1]. In the context of this work, suitability means that the sensor system must be sufficiently robust regarding hardware, *i.e.*, sensor components must withstand harsh conditions and environments during operation, as well as software, *i.e.*, easy-to-interpret sensor signals [1]. For this purpose, laboratory-based evaluations [2] or laboratory bench tests [3] can be carried out to simulate the degradation mechanism(s) in sensor performance. The aim is a rapid development of the sensor system up to TRL 5 in the laboratory before field demonstration takes place.

For the sensor development, the step from the laboratory-based validation (TRL 4-5) into the field demonstration (TRL 6) is most important. Key to the solution is the transferability of laboratory results to the field application, which is implemented using the so-called lab-to-field approach (see Fig. 1). Applied to sensors, core element of such an approach is the environment for sensor development that simulates relevant field conditions in the research laboratory.

In this work, the focus was placed on sensor-based monitoring of water in grease-lubricated axle bearings for railway application. This is because water can lead to corrosion as well as cavitation and in further consequence, can stimulate irreparable metal fracture [1]. Thus, key element of the sensor system is the Humidity Sensor in Axle Bearings (HSAB) mounted in the cover of the latter component. In the case of an unwanted penetration of water into the grease the HSAB system will give feedback on an increased air humidity close to the bearing.

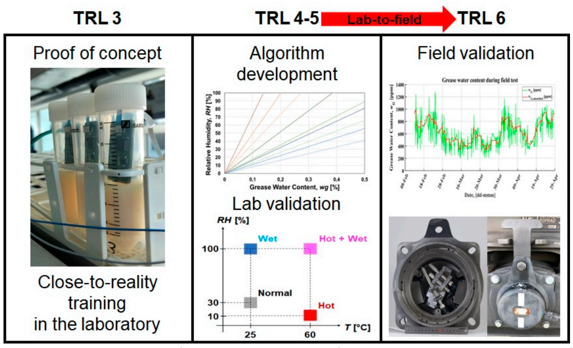

Fig. 1. Lab-to-field approach for the development of sensor systems with stepwise increase in TRL.

Methodology and Results

After the proof of concept, the HSAB system was tested for TRL 4 according to the international standard IEC 60068-2-38, among others, in which the sensor system is exposed to increased, changing climatic loads (see Fig. 2). As the sensor system remained functional after this validation test, the test result was "passed" and thus TRL 4 approved.

For the validation for TRL 5, the sensor system was assembled via a mounting unit inside the bearing cover as planned in the field. The entire system was than equipped onto a shaker and tested beyond the standard IEC 61373 "Category 3 Axle mounted" in which simulated longlife and shock tests with increased amplitude of factor up to 1.7 were carried out.

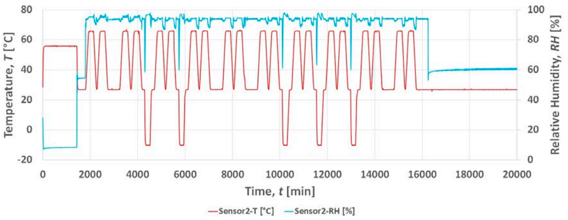

Fig. 2. Measurement results following standard IEC 60068-2-38.

Simultaneously, the entire system was subjected to four relevant climatic conditions at rail application (see Fig. 3). Both functionality and mechanical integrity stayed intact, thus the test result was "passed" and TRL 5 was approved.

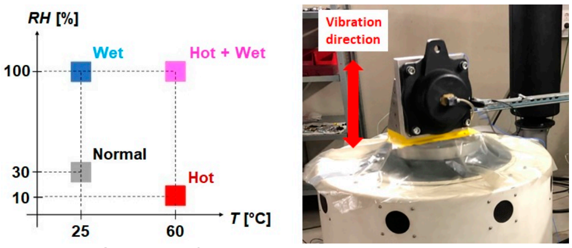

Fig. 3. Setup of mechanical and environmental testing (right) of HSAB system according to diverse climatic conditions (left).

In the last step, the HSAB system was demonstrated in field to achieve TRL 6. Therefore, the fully assembled system was fixed at the axle box of an Y25 bogie of a freight wagon. Also, a reference weather sensor was installed on the bogie to log weather data. Fig. 4 shows the trend of the recorded sensor signals during a drive from Salzburg to Graz (Austria). Deviations between the sensor signals are due to the different positioning of the sensors. As all sensor provided reliable signals with no abnormalities, TRL 6 has been approved.

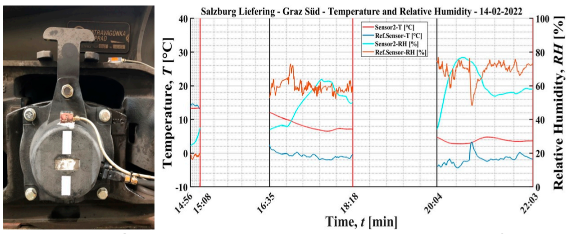

Fig. 4. HSAB system in bearing cover (left) and signals during a drive from Salzburg to Graz (right).

As part of the robustness validation of the HSAB system, also an algorithm under laboratory conditions was developed to correlate the grease water content and the relative air humidity measured by the HSAB system. This algorithm was then used to properly calculate the grease water content throughout the field test (see Fig. 5) based on sensor signals. As can be seen, the water content of the grease remained at acceptable levels (w_G < 1000 ppm). In addition, dry and wet periods in time are clearly detected. Therefore, the HSAB system is considered appropriate and robust to work under rail vehicle operating conditions, which makes a valuable contribution to the reliable and safe operation of freight wagons.

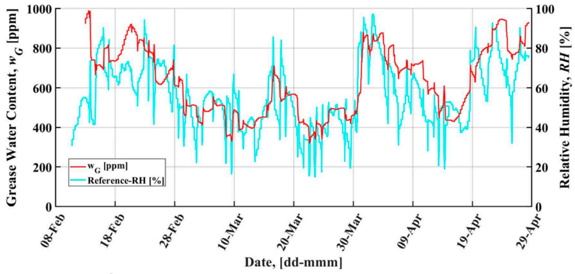

Fig. 5. Calculated grease water content and relative humidity of the reference sensor during field test.

Conclusion

The usability of the lab-to-field approach was demonstrated enabling a rapid development of the HSAB system up to TRL 5 and keeping the efforts for field validation at a lower level. The correlation between grease water content and relative humidity of the environment confirmed the applicability of the HSAB. The grease water content changes due to interaction with the environment at the shaft seal resulting in accordingly changes of the climatic conditions prevailing at the sensors in the bearing cover.

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