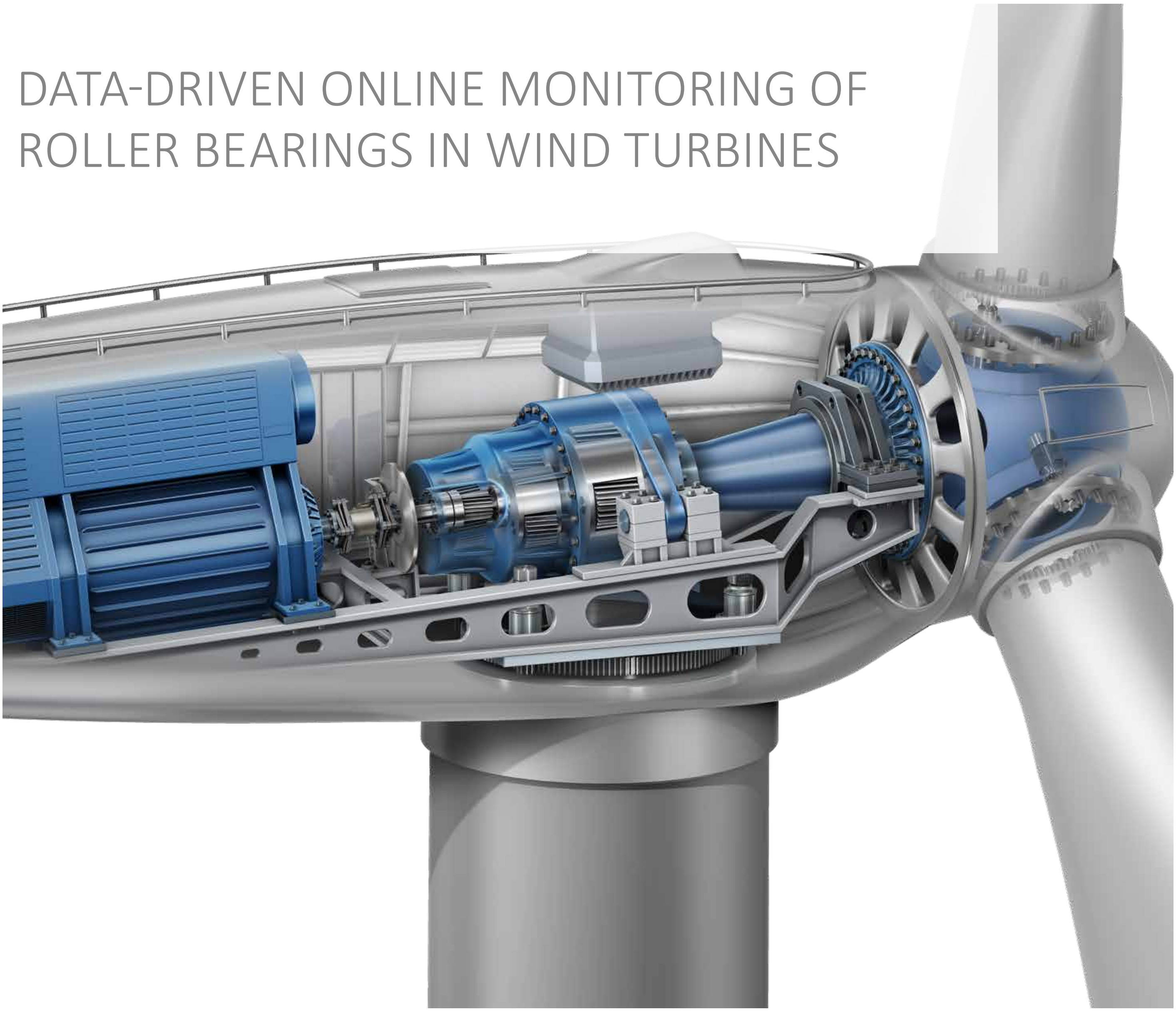
EDITORIAL

DATA-DRIVEN ONLINE MONITORING OF ROLLER BEARINGS IN WIND TURBINES



Summary

As highly-stressed components, roller bearings in the drive train of wind turbines are subject to countless influences from "manufacture, assembly and operation." Bearing-specific changes in state can be detected at a relatively early stage through structure-borne sound-based traditional methods of roller bearing monitoring and diagnostics. In connection with the monitoring of larger fleets, data-driven procedures help to prioritize irregularities by extracting characteristics from measured overall readings and diagnostic characteristics and assigning them to defined roller bearing conditions based on standards and guidelines.

The prerequisite for these type of applications, however, are powerful and continuously measuring CMs, which work as edge devices and support IIOT-relevant protocols, such as MQTT.

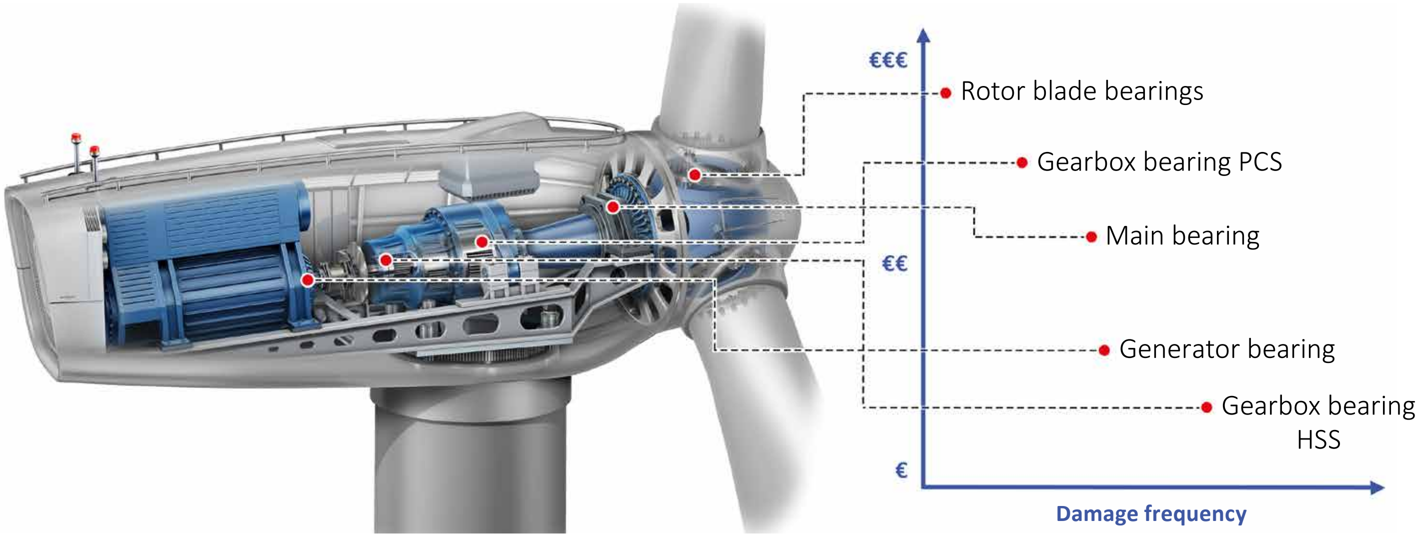
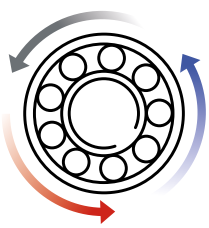


Image 1: Connection between frequency of roller bearing damage in wine turbines with gears and the resulting financial expenditure caused

1. Introduction

Roller bearings installed in the drive train of wind turbines perform key tasks. Large main bearings support the slowly rotating rotor shaft. Large and smaller roller bearings guide gear and generator shafts. The pitch drives of the rotor blades as well as the azimuth drive of the nacelle also have roller bearings. The behavior of wind turbines is highly dynamic. Running speeds and load ratios adapt to current prevailing wind conditions. Spatially and temporally fluctuating wind fields lead to increased vibration stress and therefore to more stress on the roller bearings. That is also why damage to the drive train of wind turbines is often due to premature roller bearing damage.
Experience has shown that roller bearings on the fast drive train side, especially on the gear outlet, are affected more frequently. Image 1 schematically shows the correlation between frequency of damage to the aforementioned roller bearings and the associated financial expenditure for repair. The expenditures when rotor main bearings, planetary stage bearings in the main gear and on rotor blade bearings themselves are damaged are particularly high, because the repairs are costly. Factors that influence the actual service life of roller bearings can be found in the areas of "manufacture, assembly and operation." The initial prerequisites for achieving the planned service life of bearings are selecting the correct bearings for the application and a flawless bearing production, but simple assembly errors can also cause unwanted forces and distortions in the roller bearings. Finally, the actual operating conditions define how long an appropriately designed roller bearing runs in a good condition. Image 2 shows a summary of some of the factors that influence the service life, which are often closely interlinked.

Manufacture	Installation	Operation
Material	Forces	Lubricant supply
Dimensional accuracy	Fit	Machine vibration
Tolerance fields	Inclination	Static/dynamic load
Surface quality	Deviation from play tolerances	Operating parameter
Radial bearing clearance		Operating example
...	...	...



Service life of the roller bearing

Image 2: Some factors influencing the service life of rolling bearings

Criticality	1	2	3	4	5
Raceway damage in the roller bearing	None	Straight visible pittings	Spreading over several millimeters	Widespread, over the majority of the pass distance	Very pronounced
Trend of broadband overall values	Increase only when lack of lubrication	Slight increase in peak values, increasing fluctuations	Significant increase in peak values, slight increase in effective values	Slower increase in peak values, more pronounced increase in effective values	Slight increases in peak and effective values with significant fluctuations
Amplitude spectra	No pattern change	No pattern change, low level increase above 1 kHz	Ball pass frequencies easily identifiable and level increase above 1 kHz	Strong level increase over 1 kHz	Very high level above 1 kHz, dominant ball pass frequencies
Envelope spectra	No pattern change	First order of ball pass weakly visible	1st order of ball pass frequencies clearly visible, harmonics weakly pronounced	Frequency pattern strongly pronounced, levels of the harmonics of the ball pass frequency approaching the level of the 1st order	Frequency pattern strongly pronounced, lines of ball pass frequencies washed out
a-time signal	Without dominant peaks	Individual less dominant peaks	Periodically repeating peaks	Periodically occurring dominant peaks	Periodically occurring dominant peaks
Envelope time signal	Low noise floor, speed-dependent	Low noise floor	Low noise floor	Increased, speed-dependent noise floor	Increased, speed-dependent noise floor

Table 1: Relationship between diagnostic features and damage stages (criticalities) of a rolling bearing based on VDI 3832

2. Traditional vibration methods for roller bearing condition diagnostics

Rotating roller bearing components generate measurable, high frequency, structure-borne sound vibrations as a result of rolling, friction and impact processes on components of the roller bearing. During roller bearing diagnostics in the context of preventative and proactive plant maintenance, structure-borne noise measurement methods can be used to detect roller bearing damage at early stages. Time signals as well as the resulting derived amplitude and envelope spectra form the basis for diagnosing roller bearings. In the early damage phase, there are broad excitation areas in the high frequency acceleration spectrum (also greater than 10 kHz), since the structure-borne sound signals become "more energetic" with declining raceway quality.

Discrete roller bearings faults generate consequences of pulsed shock excitations with bearing-specific ball pass frequencies from the external race, inner race, rolling element and from the cage. The envelope method is particularly sensitive to damage. The damage stage can be determined by amplitude changes and, in the late stage of damage, also by frequency deviations. If the bearing kinematics are known, the fault location in the bearing can also be localized. The highly-dynamic time signal of the acceleration offers added security in the diagnostics process because the characteristics of the rolling kinematics often are reflected within the roller bearing. Table 1 provides an overview of additional criteria for the damage diagnosis of roller bearings according to VDI 3832, which diagnosis experts like to use, but which is also very time-intensive. As part of a continuous roller bearing monitoring, it is more efficient to process measured time signals into scalar overall readings and to carry out the previously described, deeper diagnostic steps only when necessary, i.e. If there are changes in the overall readings trend.

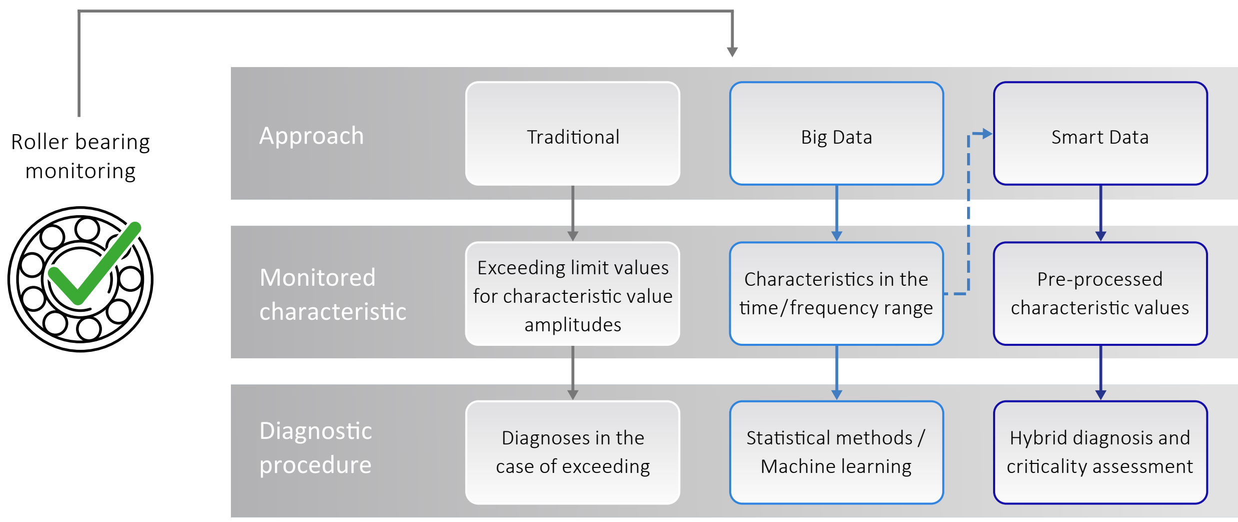


Image 3 Approaches to data-driven condition monitoring not only on rolling bearings

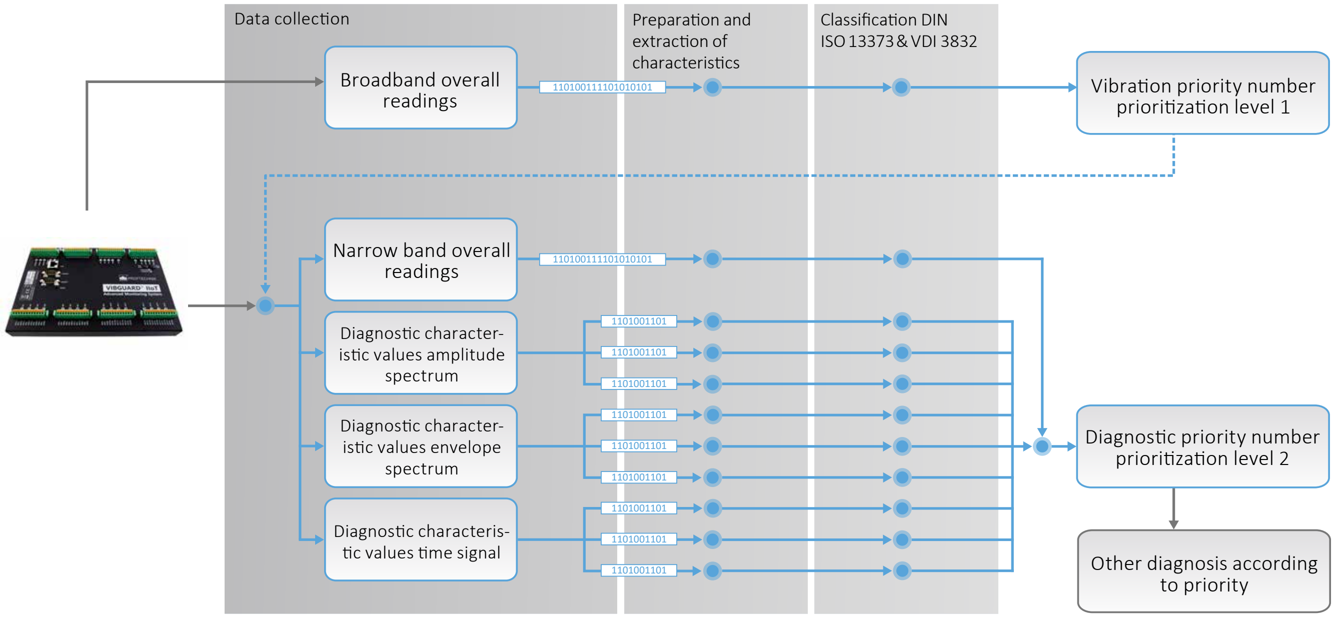


Image 4: Diagram for the data-driven condition monitoring process

3. Data-driven methods for roller bearing condition diagnosis

More and more data-driven analysis methods are being discussed in the era of “industry 4.0” and “predictive maintenance.” (Also see image 3). Such “big data” methods rely on collecting as comprehensive data volumes as possible, extracting characteristics using data mining methods and using (semi-skilled) models to issue event probabilities. The challenges of these applications are, on the one hand, to master handling large data volumes, while on the other hand the often complex analysis processes and the generation of the output forecasts is usually hardly transparent. That’s why they have not yet become prevalent in roller bearing condition diagnostics in the wind industry.

“Smart data” applications, on the other hand, aim to extract useful characteristics from large data volumes using often similar analysis methods, which users can understand and often use as a starting point for additional analyses.
There are statistical methods for extracting characteristics, which transfer overall reading trends from the time domain into the frequency domain, determining representative parameters from this information. Such statistical processing offers a high level of added value in particular for wind turbines with highly transient operating behavior.

However, if rolling bearings in large numbers of plants are to be monitored resource-effectively in the end, it makes sense to prioritize the characteristics extracted as an irregularity. Limit values of the DIN ISO 13373-3 (broadband overall values) or characteristics of the VDI 3832 can be used for prioritization.
Image 4 shows the sequence of such data-driven condition monitoring. The CMS is virtually an additional data supplier for overall readings and diagnostic characteristic values already prepared in the CMS. If large numbers of plants or many different types of bearings are to be monitored, the classification is followed by a weighting process that assigned pre-defined meanings to extracted features, depending on the characteristics. The determination of these weighting factors is based on expert knowledge and experience.

The prerequisite for such a procedure is that potent measurement systems are available, which quickly measure across many channels in a time synchronized manner and can issue frequency-selective and order-selective overall readings and diagnostic characteristic values straight out of the CMS. As an example of this, VIBGUARD has named the IIoT online CMS system from PRUFTECHNIK, which as an “edge device” also offers data reduction options and also supports IOT-relevant protocols, such as MQTT. The evaluation of vibration and diagnostic priorities can then take place at a higher level in the control center.

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About PRUFTECHNIK:
PRUFTECHNIK is a global provider of maintenance technology with a broad range of products, services and training programs designed specifically to meet the needs of maintenance professionals in the fields of shaft alignment, vibration analysis, condition monitoring and non-destructive testing. Numerous manufacturing companies around the world rely on our solutions to ensure a reliable and condition-oriented maintenance of rotating machines.

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