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Sensor Concepts for Gear Damage Detection in Wind Power Drives

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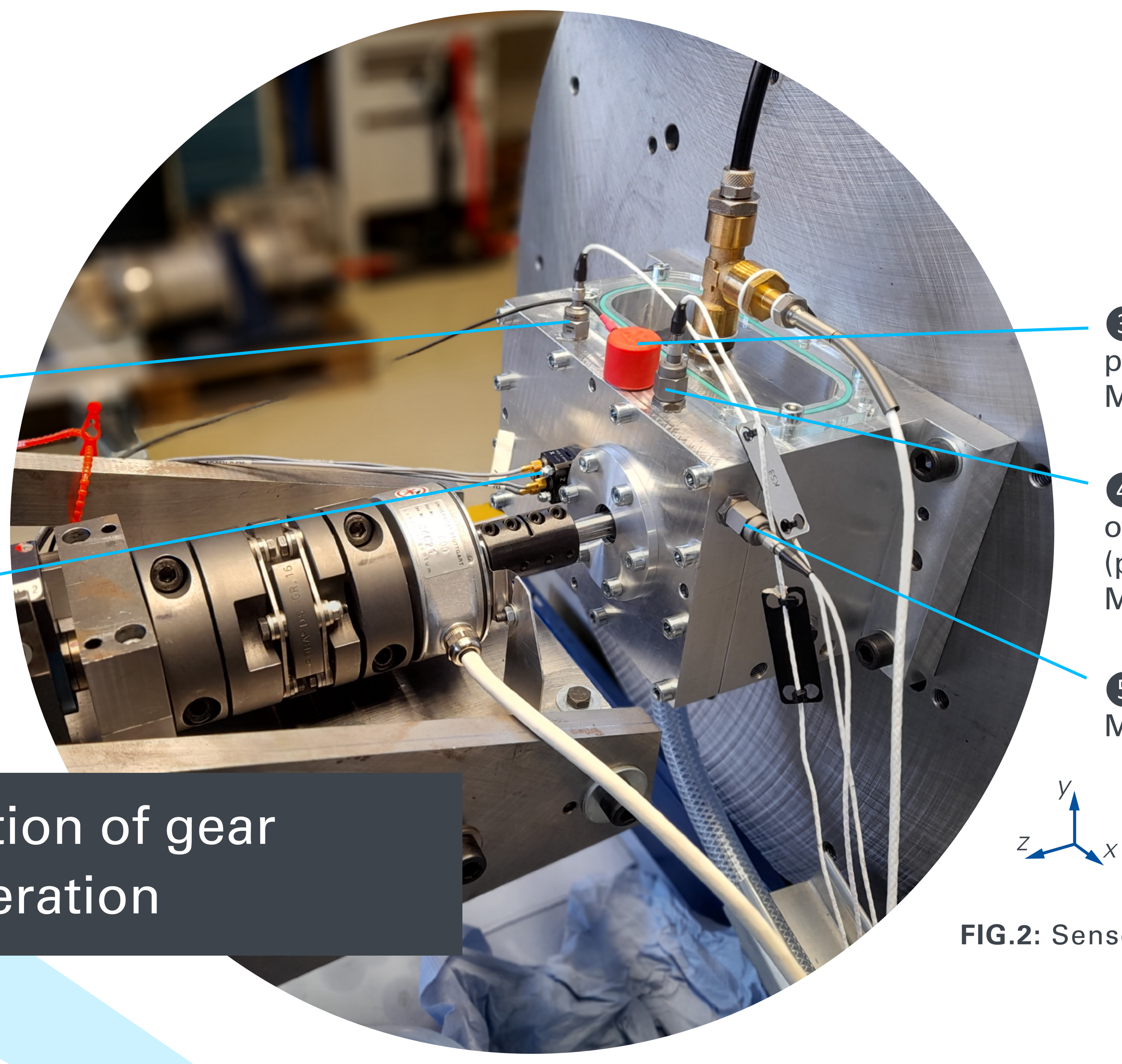


Objective: Best sensor concept for detection of gear damage in wind power drives during operation

FIG.2: Sensor types and positions on the test gearbox.

In order to be able to make rapid modifications to the measurement equipment and to be able to simulate many operating conditions in a short time, the experimental investigations are carried out on a scaled down substitute system (FIG.1).

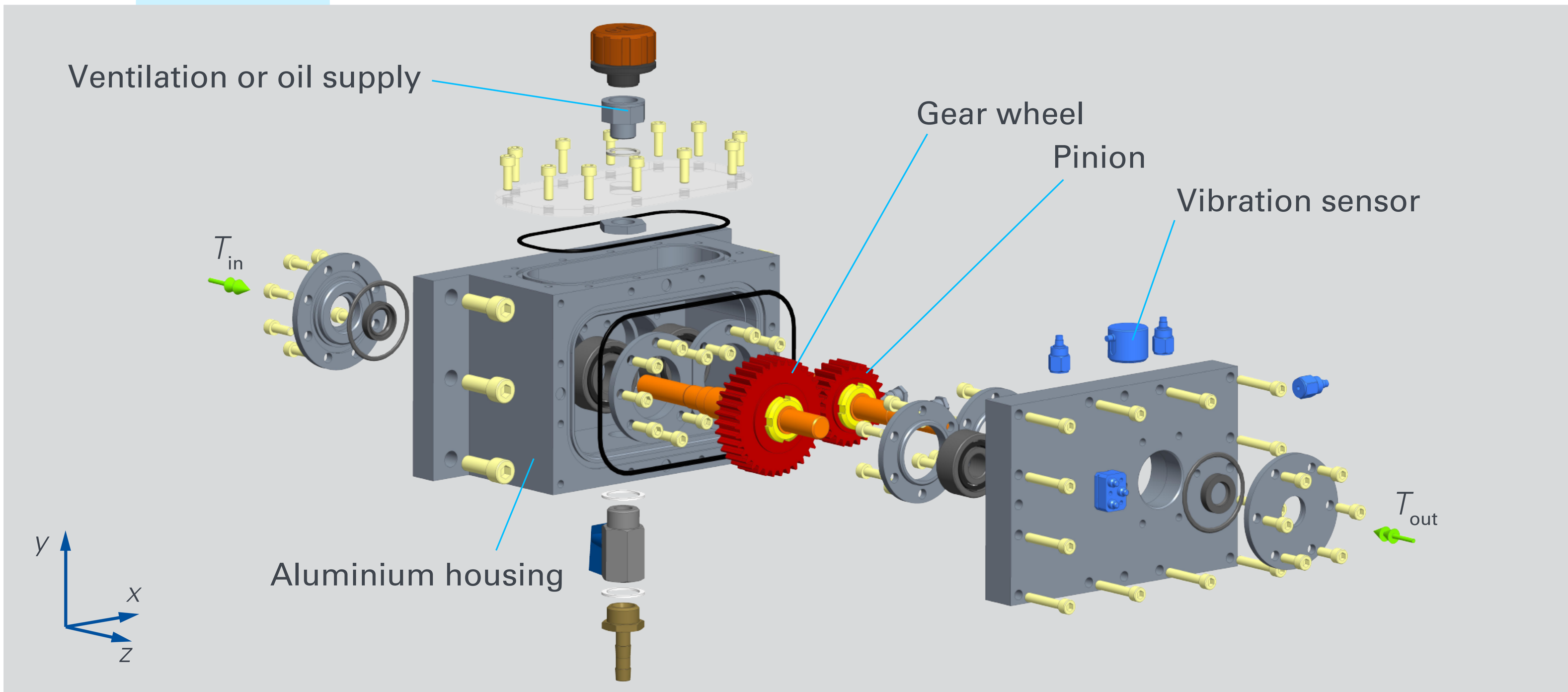
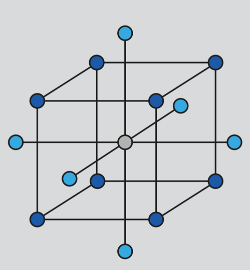


FIG.1: Test gearbox: single stage spur gearbox, tested on a load test bench with two electric motors. Equipped with vibration sensors (blue) and manufactured pitting damage on the pinion. Gear ratio 36/25.

The tooth flanks of the test gears are manufactured with artificial pitting damage at different stages. The test plan is designed following the theory of design of experiments (DOE) (TAB.1).



	Speed n_{in} /Hz	Torque T_{out} /Nm	Pitting size /%	Viscosity η /mPas
Level -2	1.2	6	0.300	8
Level -1	5.9	12	0.725	81
Level 0	10.6	18	1.150	154
Level 1	15.3	24	1.575	227
Level 2	20	30	2.000	300

TAB.1: Central composite design (CCD) test plan with 4 factors and 5 levels per factor. Oil viscosity is set via the fluid temperature. 31 base runs with 3 replications, 93 additional reference test runs without pitting, 100 s measuring period.

The test gearbox is equipped with 3 vibration sensor types at 5 mounting positions (FIG.2). Vibration data from the sensors are transformed from the time domain into the frequency domain. Pitting damages can be detected at the harmonics of the gear mesh frequency (GMF) and the corresponding sidebands (FIG.3).

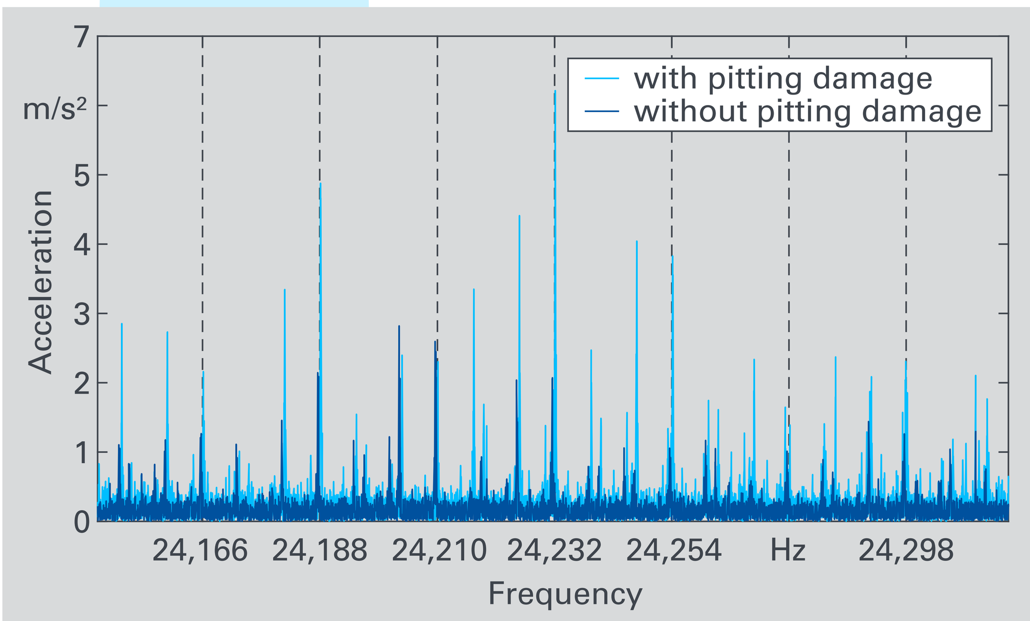


FIG.3: Left: Segement of the frequency spectrum (44th harmonic of the GMF at 24,232 Hz) Sonotetc T20 sensor, n_{in} = 15,3 Hz, T_{out} = 24 Nm, pitting size 0,575 %, η = 81 mPas.
Top: Pinion with manufactured pitting

Results

The percentage changes of the frequency bands without pitting and with pitting are consolidated to one target value. This is achieved by calculating the RMS value in the specified frequency range. The CCD is statistically evaluated using this target value, along with the measured values of the speed, torque, viscosity, and the pitting sizes. The resulting R^2 values are used to evaluate the robustness of the different sensor concepts (FIG.4).

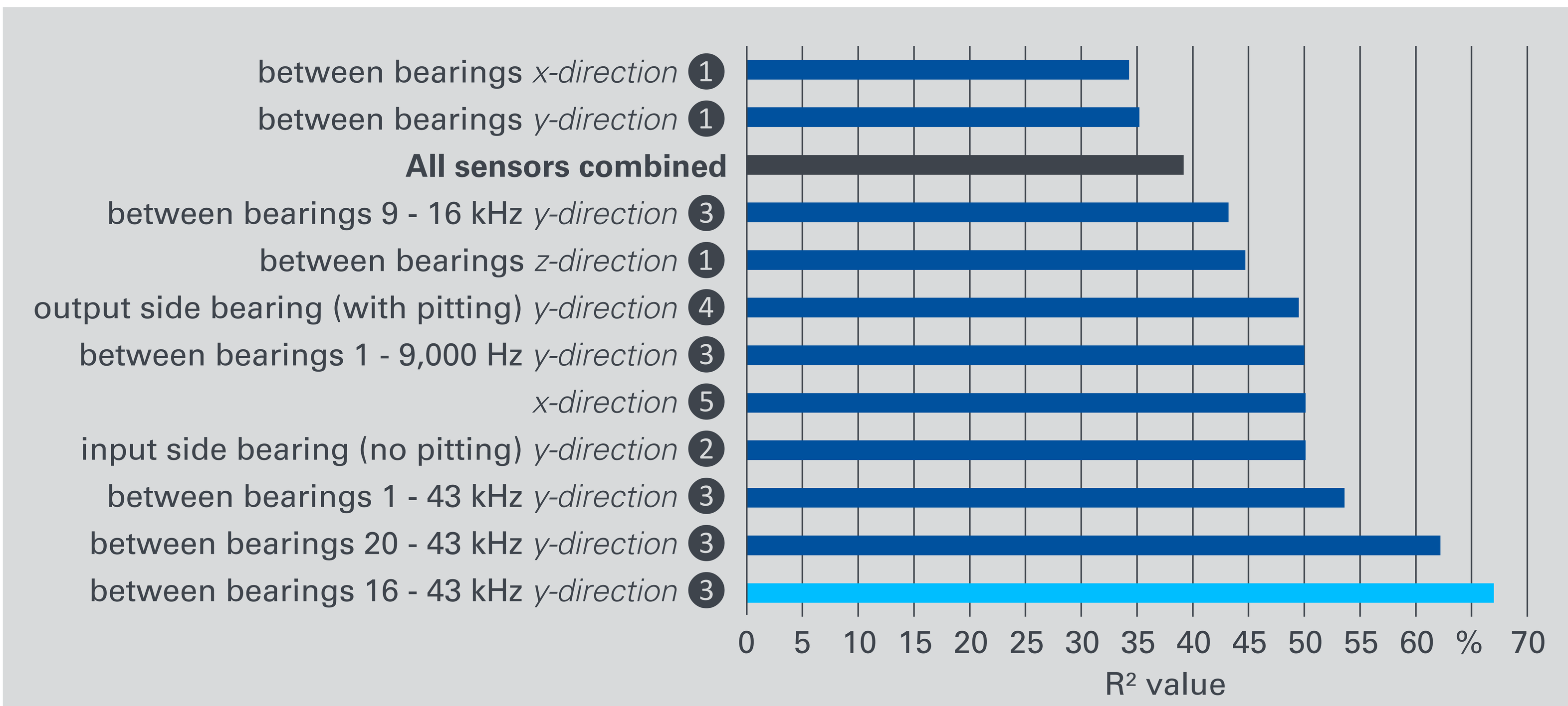


FIG.4: R^2 values of different sensors and sensor positions. The R^2 value is a measure of how well the variation in the frequency band caused by a pitting damage can be detected by a sensor under different operating conditions. The large frequency range of the Sonotec T20 sensor allows an evaluation in 5 different frequency ranges.

Conclusion and Outlook

Vibration measurement in high frequency ranges is most suitable and most robust for pitting detection during operation. With the best sensor concept in place, it is possible to detect gear damage like pitting at a very early stage of 0.3 % pitting size. The findings on the current test gearbox will provide fundamental knowledge that will enable the implementation in wind power drives (FIG.5).

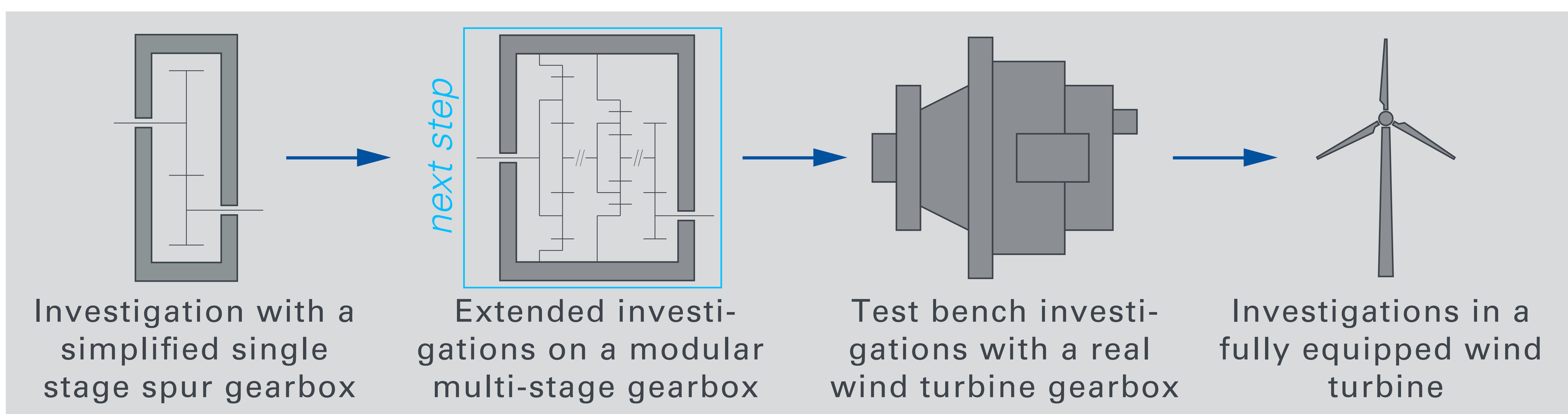


FIG.5: Next steps towards an implementation in wind power drives

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