PO. ID
A003

Results on built-in vibration sensors inside planetary gears

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Abstract

The Internet of Things refers to a network and virtual representations of individual objects (e.g. machine part) in an internet-like structure. This representation enables the comparison of the behavior of the real world object to a virtual counterpart. On the virtual counterpart the reactions of loads or an estimation of remaining life time can be simulated. To realize those industrial visions each object's needs to have cheap and reliable systems that monitor the object conditions during the full lifetime. Only with these data a mapping of the virtual object will be possible and, therefore, an estimation of the remaining life can be provided. This work will describe a method that covers these challenges on condition monitoring of a wind turbine planetary gear, especially the planet meshing and the planet bearing using a measurement system mounted on the planet gear carrier. [1]

Objectives

The goal is to measure vibrations inside the gearbox on the planet carrier with a standard acceleration sensor and transmit the data to a receiver wireless. Because the sensor and the transducer are installed on the rotating machine part, they can be placed close to the vibration source. Measuring the vibration directly on the planet gear carrier, as presented in this work, enables the use of conventional analysis methods to monitor the bearings of the planets. This will provide more reliable results of the condition of the gear mesh and planetary bearings as at the moment with conventional condition monitoring systems possible. [2]

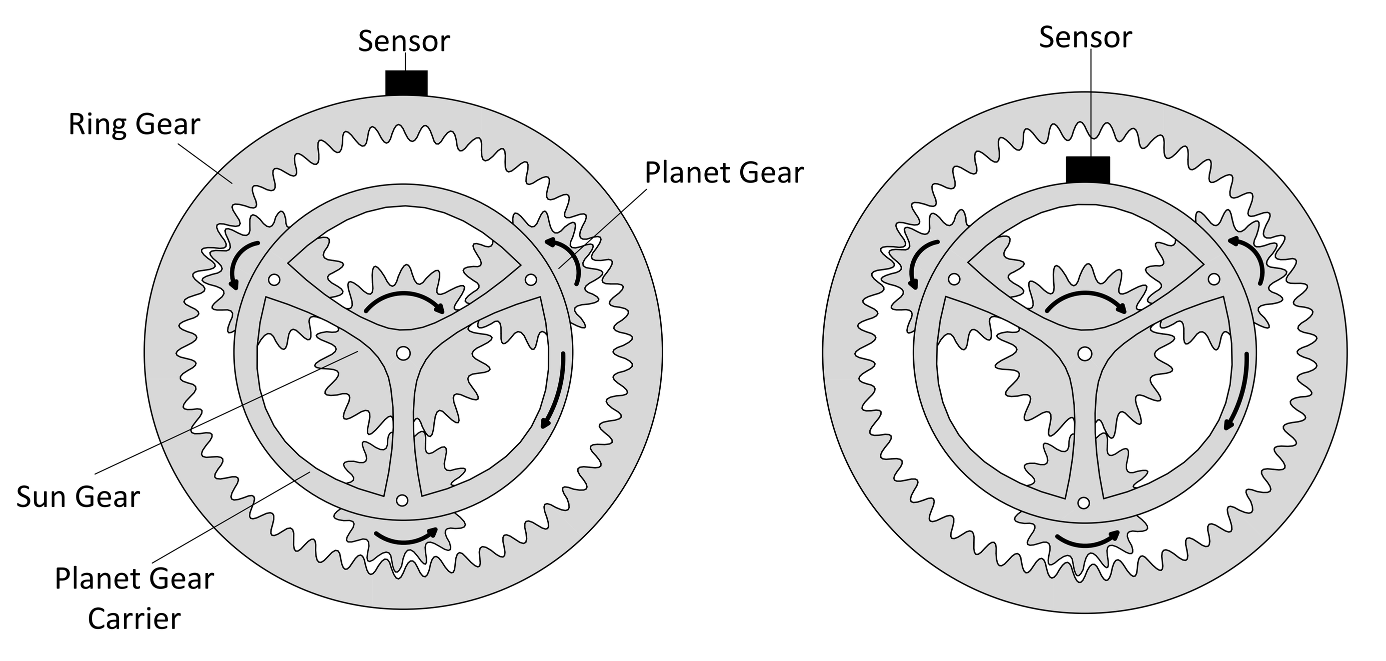


Figure 1 shows the design of an planetary gear with attachment of the sensor to the outside of the ring gear (left) and planet gear carrier (right). [3]

Methods

The complex and time-variant transfer function between damage and sensor is the main problem of planetary gearbox condition monitoring. A damage in a planet bearing produces several transfer paths of the signal to the sensor (Figure 2). For the transfer of the signal, the following adverse factors are important:
(1) lubrication of the planet bearing and the planet mesh,
(2) gap between planet bearing and planet mesh,
(3) rigidity of the planet mesh and the gear structure and
(4) position of the planet gear respectively to the sensor.
This leads to a substantial time-varying attenuation of the vibration signal. Despite extensive analysis, damage detection of rolling bearings of planet gearboxes with accelerometers on the planet gear housing is very difficult. This work is part of the i-MaSS project (integrated machine sensor system) and is a new approach for a measuring transducer installed directly on the planet carrier. [3] [4]

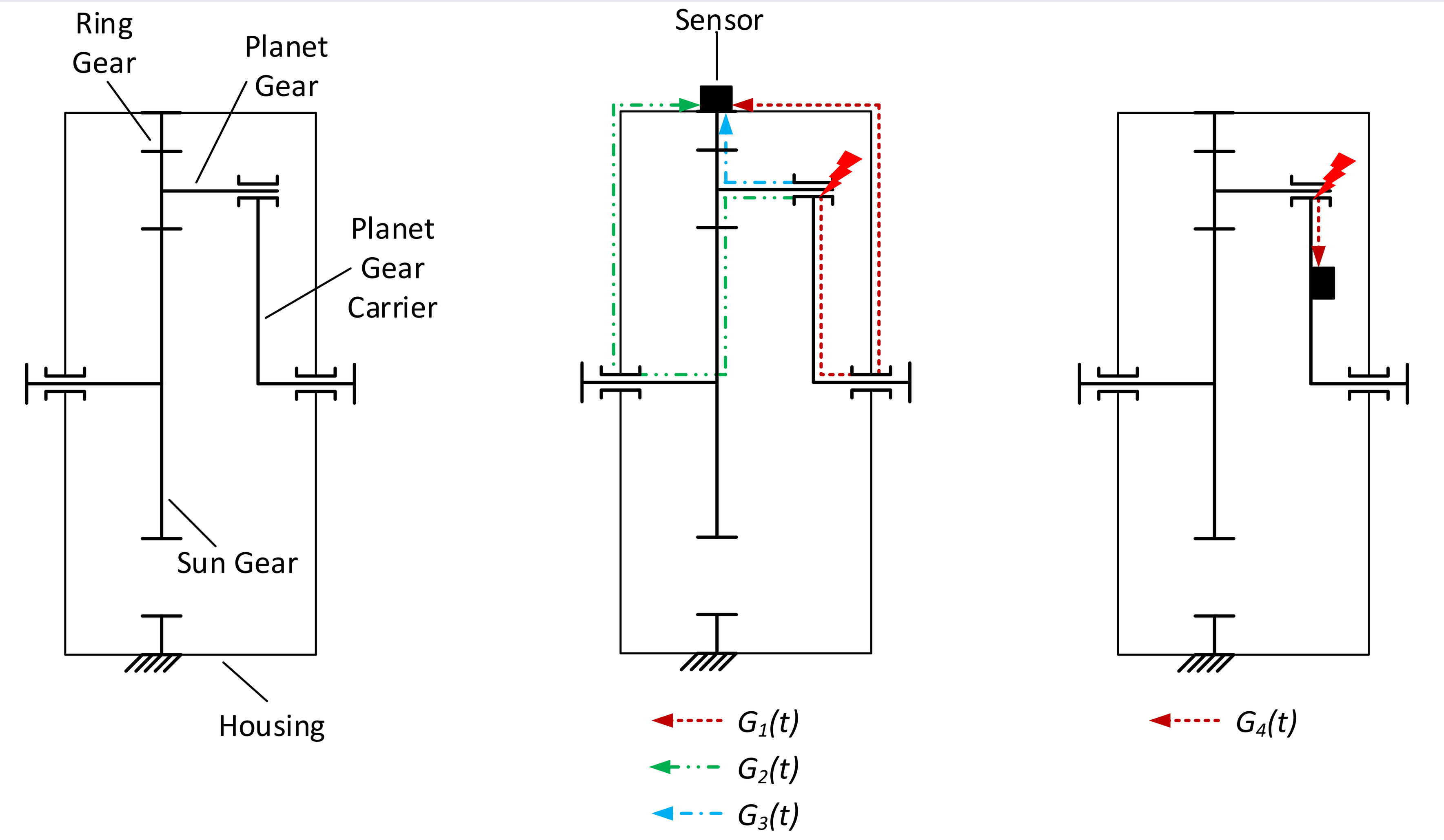
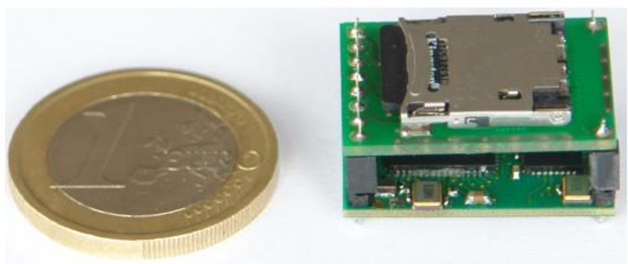


Figure 2 shows transfer paths of a planet bearing fault to the sensor, which result in transfer functions *G(t)*. The vibration excitation, which, for example, occurs on the planet bearing, is transferred (function $G_1(t)$) to the accelerometer by the rolling elements of the bearing, the outer ring of the planet bearing, the planet gear, the mesh between planet and ring gear, the ring gear and respectively the housing (left). By installing the sensor on the planet carrier, only the time-invariant transfer function $G_4(t)$ is relevant (right).

Results

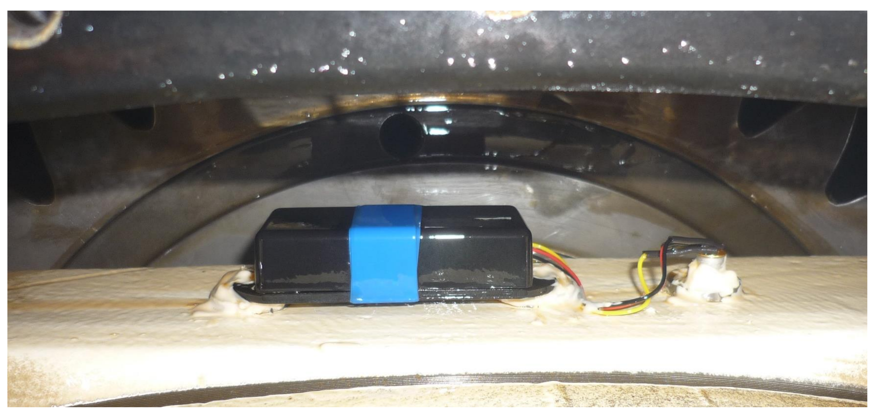
A first state of the hardware that is developed, is able to connect to sensors such as strain gauge, accelerometer, temperature sensor, etc. The required energy is provided by a lithium-ion battery. To reduce the energy consumption an intelligent energy management system is integrated. Data preprocessing and transmission is conducted on the main circuit board. On the secondary circuit board a micro SD card is installed. All measurement data can be stored. The data transfer to the PC is realized via wireless low power protocol. [1]



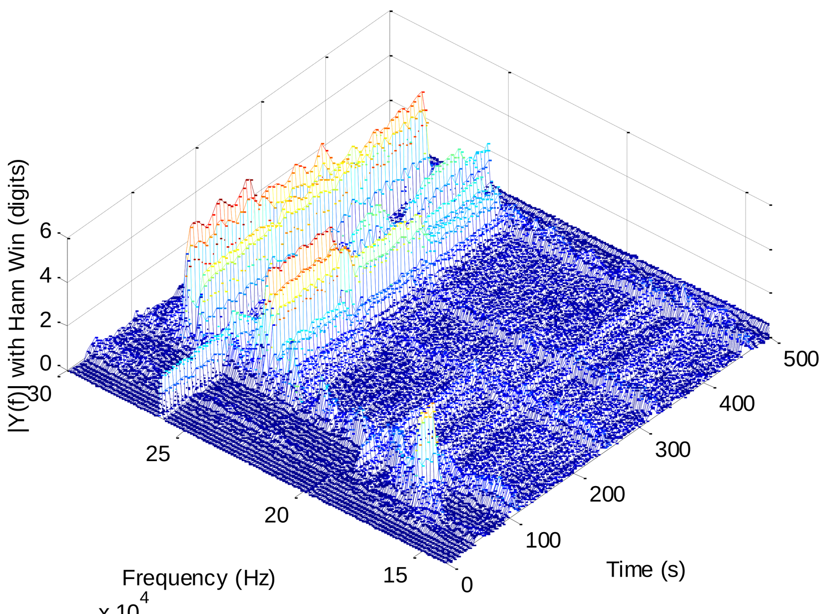
Design of the developed measurement system. Technical Description:
- Sample frequency 4kHz
- Data storage in device for more than 60 hours continuous measurement (storage can be accessed wireless)
- Start of measurements with timer or wireless by operator
- Resampling of the acceleration data is done in post processing, no speed signal required

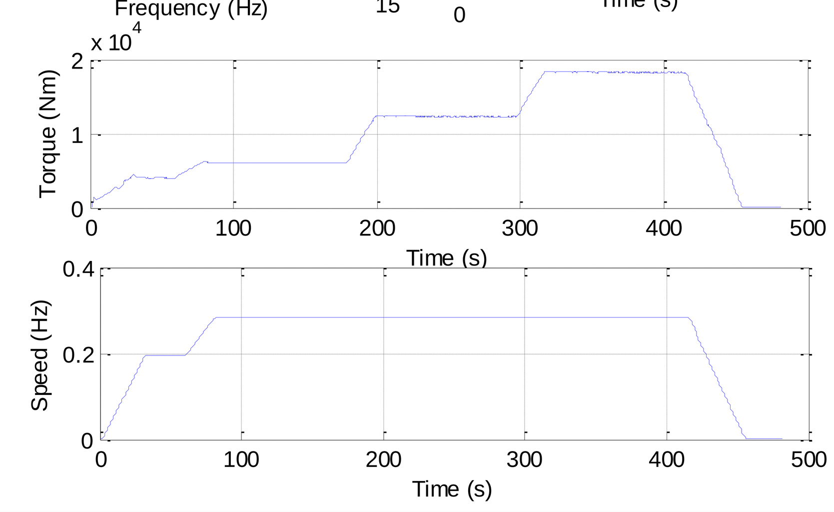
The sensor is tested with two wind turbine planetary gearbox applications so far:

Test bench measurement on a planet carrier of a 2MW wind turbine gearbox:

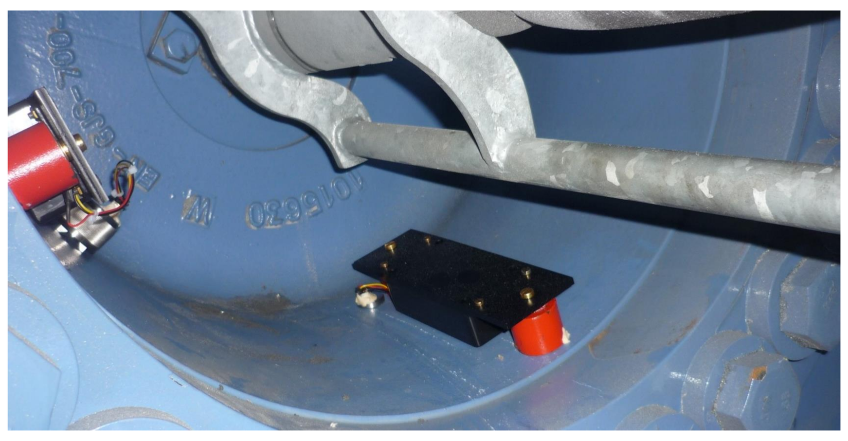


The measurement was performed on a standard 2MW planetary gearbox on the first gear stage. The sensor was mounted with magnets on the planet carrier trough maintenance holes and the vibration was measured in radial direction. While the test different speed and torque were applied. Speed, torque and the vibration waterfall diagram are shown on the right.

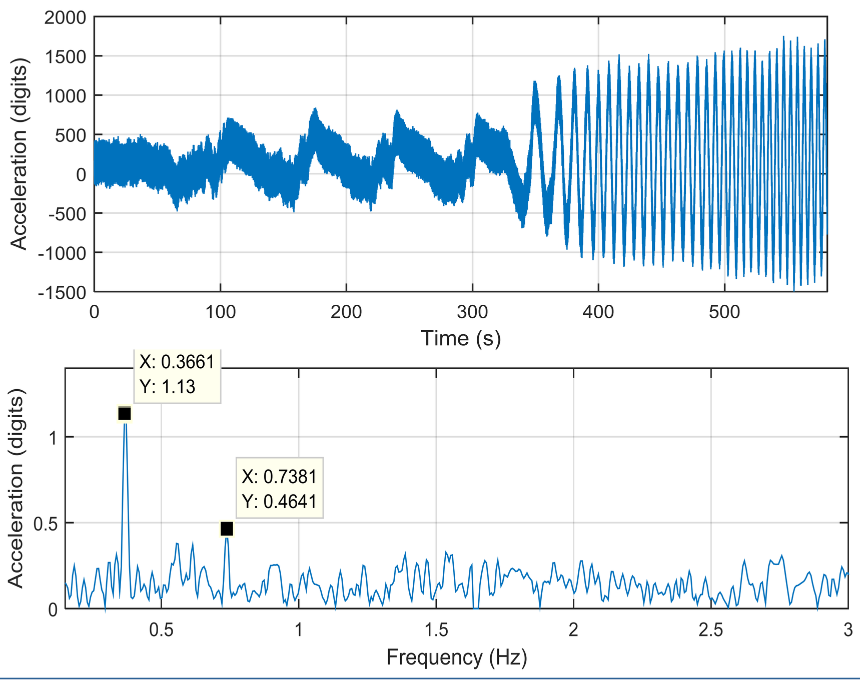




Field measurement on a planet carrier of a 2.5 MW wind turbine gearbox:



The sensor was installed on the outside of the planet carrier (which is close to where the connection to the rotor). The top diagram shows the influence of the gravity on the vibration signal, the measurement shows the vibration signal during start-up. The bottom diagram shows the envelop spectrum during constant speed.



Conclusions

The introduced new approach allows acquiring vibration data as well as temperature and deformation data directly on the vibration source on rotating parts inside gearboxes of wind turbines. Hence, the known deficits of condition monitoring of planet bearings can be solved. The innovative sensor system provides a tool to verify and improve the simulation of new designs of gearboxes.

Acknowledgement

The i-MaSS project is funded by the "NRW-EU Ziel 2" program and the "Europäischen Fonds für regionale Entwicklung" (EFRE).

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Regionale Wettbewerbsfähigkeit und Beschäftigung

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