DETECTION OF ACOUSTIC EMISSIONS DURING GEAR WHEEL TOOTH MESHING

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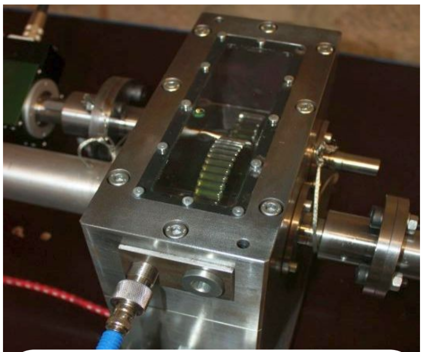
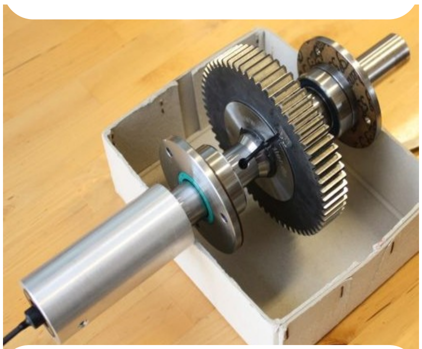


Spur gear test rig for testing of AE-sensors with tribo contacts.



Gear wheel with mounted AE-sensor next to the tooth flanks

View of the prepared gear flank (brown "12 o'clock")

GEARBOX MONITORING THROUGH VIBRATION DETECTION

It is common practice to perform condition monitoring of a gearbox using low-frequency structure-borne sound sensors that are attached to the housing. The imperfections (manufacturing tolerances) of the bearings, shafts and gears in the tribocontact lead to the excitation of elastic waves that propagate through the entire gearbox to the housing.

If the kinematics of the gearbox and structural resonances are known, the frequency analysis of the recorded time signals enables the assignment of speed-dependent events. The signal intensities (amplitudes) that change over time, together with frequency modulations, provide indications of impending faults or incipient signs of wear.

A SENSOR CONCEPT FOR THE MONITORING OF TRIBOCONTACTS IN GEAR FLANKS

Transferring the GMBU tribosensor concept (DE 10 2014 103 231), it is being investigated whether an AE sensor attached to the rotating gear wheel can be used to detect the instantaneous breakdown of the lubricating film as well as developing scuffing wear at an early stage.

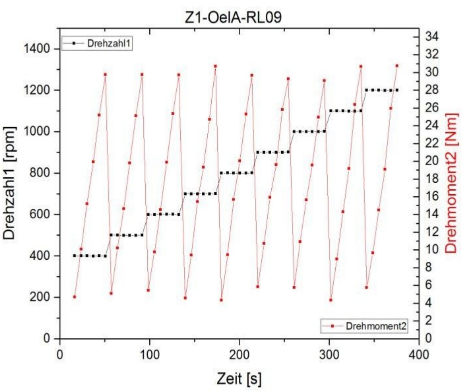
The measurement data should be compared with a commercially available structure-borne sound sensor fixed to the gear housing.

THE STRAIGHT GEAR STAGE AS A TEST SYSTEM

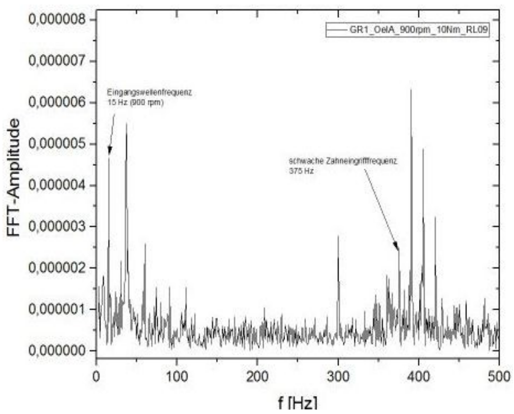
A single-stage spur gear stage was used as the test system for the vibration tests. The two gears are fixed rolling contact bearings. The gear stage is driven by an electric motor and the load is simulated by an electric motor used as a motor brake. This allows the speed and torque in the gear mesh to be varied independently of each other. Oils of different viscosities and mechanical damage to individual tooth flank surfaces of the drive gear was prepared were used to simulate the real meshing situation(see left).

SENSOR SIGNAL INTERPETATION

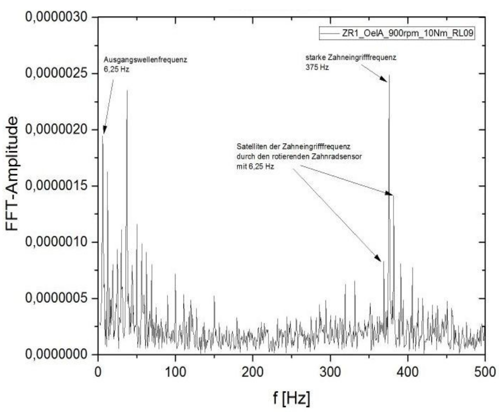
The vibration spectra (0 - 500 kHz) were recorded for both sensors as a function of the speed-torque characteristics. This revealed striking differences in individual resonances, which were analysed using a modal analysis for the stationary and rotating coordinate system (see below and next page).



Load diagram: Determining the torques as a function of the speed.



Spectrum of the housing fixed structure-borne sound sensor .



Spectrum of the AE sensor fixed to the rotating gear wheel.

ANALYSIS FOR THE DETECTION OF LOW FREQUENCY STRUCTURAL RESONANCES

Depending on the stationary and rotating coordinate system, the striking differences in the detectable structural resonances can be explained as a function of the rotational speed. The resonances result from the speed-dependent excitation as eigenmodes of the vibrating gear-shaft ensemble.

ANALYSIS OF HIGH FREQUENCY VIBRATIONS

As expected, the sensor attached to the housing shows significantly higher vibration amplitudes than the gear wheel sensor. The housing sensor not only detects the deflection of the gear shaft vibration sambles, but also vibrations caused by the roller bearings and couplings.

In contrast, the situation at the gear wheel sensor is clearer. The spikes caused by the prepared fault on the tooth flank are clearly visible.

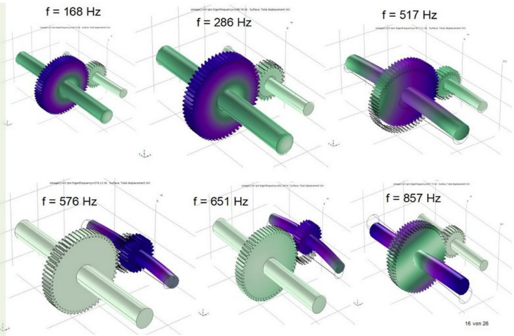
Zooming in on the vibration amplitudes over time reveals further details (see figure right below) that can be traced back to the different viscosities of the lubricating oils analysed.

CONCLUSIONS

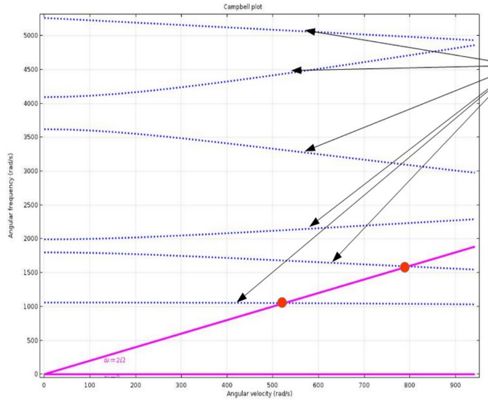
The tribosensor concept shown here offers the potential for a detailed short-term monitoring of a rolling-friction contact between two tooth flanks when monitoring tooth engagement.

Despite the complex gear geometry and the kinematics of the tooth mesh, the AE vibrations can be used to make statements about lubricant film breakdown and the onset of wear processes. It is therefore foreseeable that such a sensor concept is suitable for condition monitoring and predictive maintenance of gear drives.

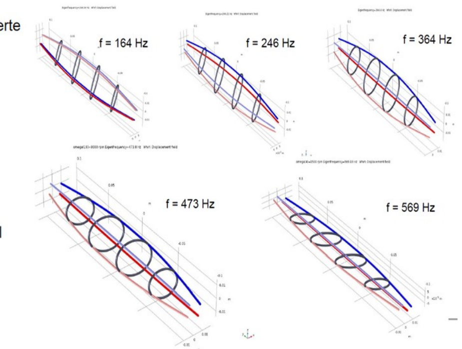
GMBU



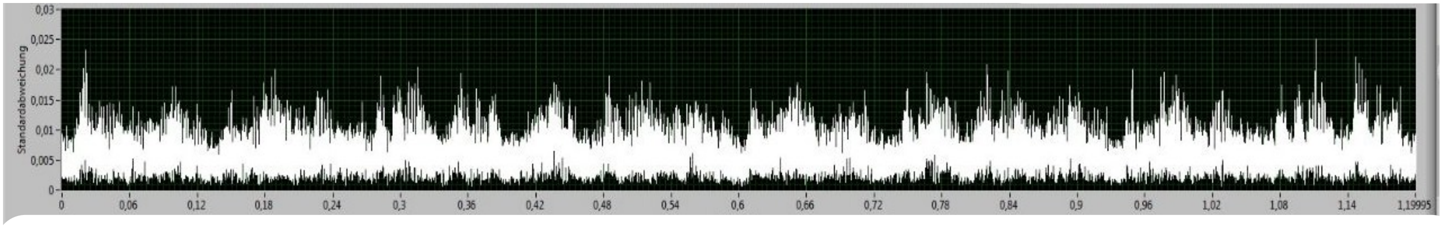
Calculation of the eigenvalues (resonant modes) in the rotating coordinate system (gear wheel sensor).



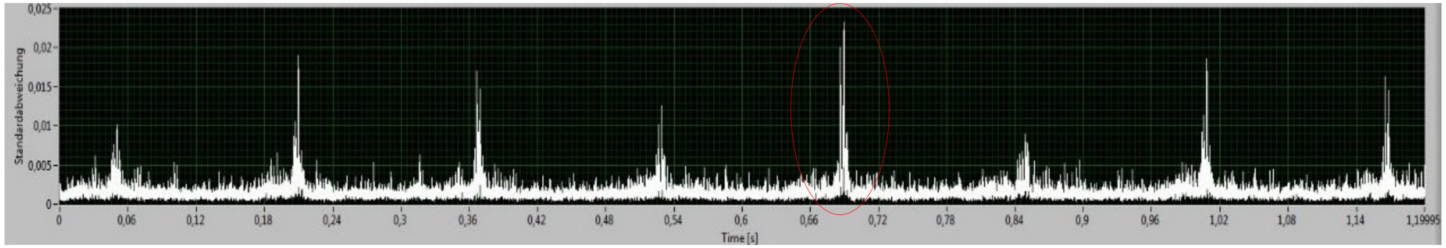
Relationship between speeds and resonances (eigenvalues).



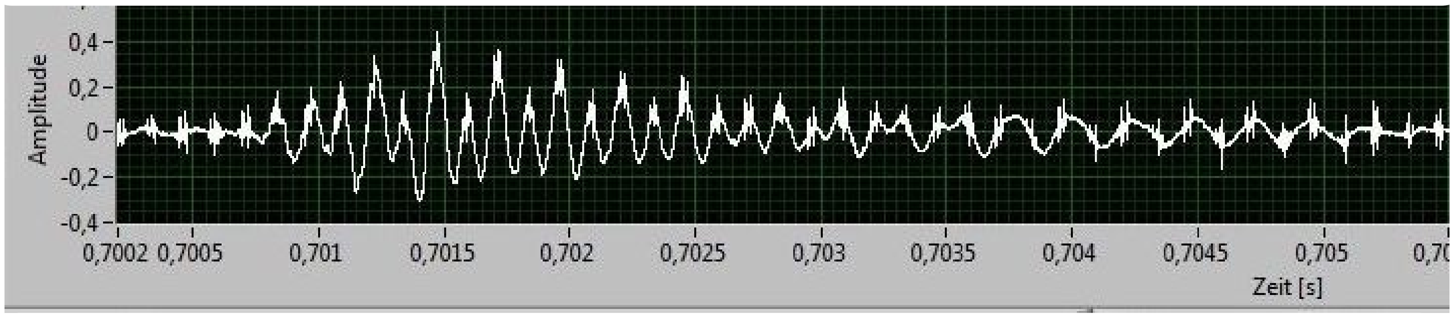
Calculation of the "whirl modes" in the fixed coordinate system (housing)



Time course of the totalised FFT (standard deviation) recorded with the structure-borne sound sensor mounted on the housing surface.



Zeitlicher Verlauf der summierten FFT (Standardabweichung) aufgenommen mit dem Zahnradsensor. Rote Markierung → Detailaufnahme unten



The detailed view (zoom into red marking) of the vibration curve reveals "spikes" on the fundamental vibration, which are associated with the solid contact of the tooth flanks.