



Thin-film sensors for pressure and temperature measurement in rolling contact

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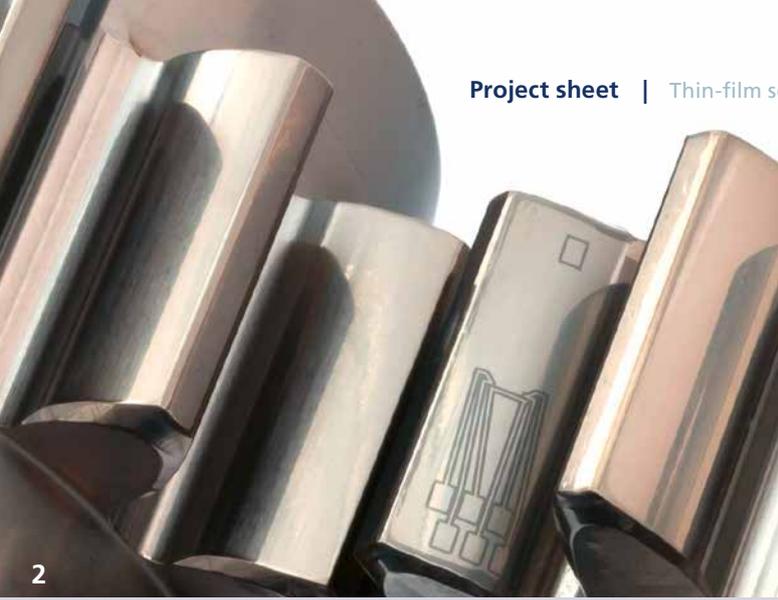
Sensory roller bearing washers.

Knowledge of pressure and contact temperature is of great importance for the design of lubricated rolling contacts. So far, there are only a few approaches for measurements under high contact pressure with mixed friction, i. e. the simultaneous occurrence of fluid and solid friction. In collaboration with the Institute of Machine Design (IMK) at Otto von Guericke University Magdeburg, the Fraunhofer IST has therefore developed a thin-film multi-sensor designed for simultaneous, high-resolution pressure and temperature measurement in rolling contacts under mixed friction and high loads. The measurement data obtained under real operating conditions increases the understanding of the machine element. In addition, this approach enables a critical evaluation and improvement of calculation methods used for the design of rolling contacts.

Wear-resistant thin-film sensors on bearings and gears

A thin-film system optimized for adhesion and wear resistance was deposited directly on the polished raceways of the housing washer of cylindrical-roller-thrust-bearings, on the tooth flanks of gears and on test samples for two-disc tests. On an electrically insulating base coating, consisting of a 4 μm thick aluminum oxide layer (Al_2O_3), 200 nm thin metallic sensor layers are sputtered.

Chromium or a CuMnNi alloy (also known as manganin) is used for pressure measurement and titanium for temperature measurement. Photolithographic structuring using a lift-off process has made it possible to produce extremely fine sensor structures just 4 μm wide on both flat and complex curved surfaces (see Figure 4). This ensures a very high spatial resolution with a high-resolution measurement signal. Finally, a hydrocarbon layer developed for this application is deposited to protect the sensors against wear and for electrical insulation.



2

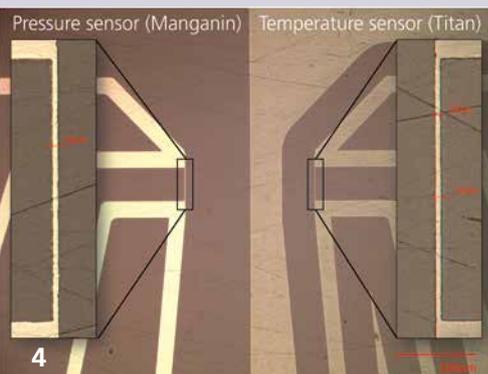
Multi-sensor on a gear flank.

Measurement of pressures and temperatures under mixed friction conditions

The functionality and wear resistance of the components equipped with the thin-film sensors were tested by the IMK in various test rigs under mixed friction conditions. The adjacent diagram shows measurement results from a two-disk test rig. The comparison of pressure and temperature curves with thermo-elastohydrodynamic (TEHD) simulations shows the ability of the developed sensors to record the measured variables in rolling contacts with spatial resolution at high pressures of over 1500 MPa and under mixed friction conditions.

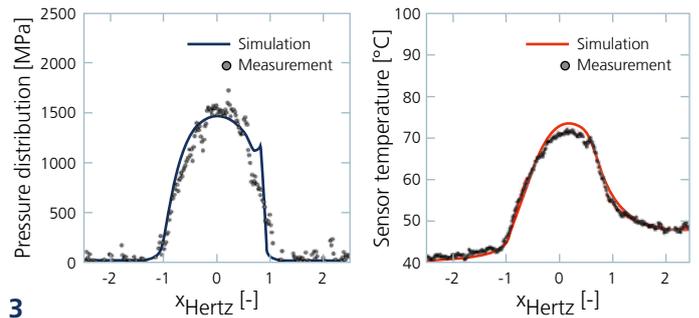
Outlook

In addition to pressure and temperature measurement, a capacitive lubrication gap height sensor is currently being developed so that a multi-sensor for simultaneous detection of all three variables will be available soon. The thin-film sensor technology developed is a valuable tool for the product development of rolling contacts in drive units and can be transferred to other machine elements. It is also conceivable that the sensor technology could be used for condition monitoring in the future.



4

Microscopic image of a pressure and temperature sensor.



3

Measurement of the pressure and temperature distribution in the rolling contact.

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The project

The results described were achieved within the FVA project 789 II "Sensors for mixed friction" on the topic "Development of a thin-film sensor system for temperature, pressure and lubrication gap height in contacts subject to mixed friction" together with the Institute of Machine Design (IMK) at Otto von Guericke University Magdeburg. The project was funded by the German Federal Ministry of Economic Affairs and Climate Action (BMWK) based on a resolution by the German Bundestag and the German Federation of Industrial Research Associations (AiF, funding project no.: 21473BG).

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