

Thin-film sensors on thrust bearing washers for temperature measurement directly in the mechanical rolling contact

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Summary:

The article shows the production and evaluation of directly deposited thin-film temperature sensors on a thrust cylindrical roller bearing washer in and near the tribo-mechanical rolling contact. The production was carried out using sputtering, photolithography and etching processes. Due to the frictional forces, a 12 % (3.6 °C) higher temperature was measured in the mechanical rolling contact and a 5.3 % (1.6 °C) higher temperature near the mechanical rolling contact compared with the conventional temperature sensor on the outside of the bearing washer.

Keywords: thin-film sensors, direct deposition, bearing washer, temperature measurement, harsh environment

Introduction

Frequent maintenance of systems and machines can prevent downtimes and reduce costs. To improve maintenance intervals, conventional machine elements, such as gears or rolling bearings, can be used in combination with a compact electronics solution by means of sensor integration for intelligent system monitoring [1,2]. Commercial applications for large rolling bearings are already available. Here, the operating states are monitored via condition monitoring systems (CMS) with external vibration and temperature sensors [3]. However, in order to maximize information about local bearing conditions (normal and tangential forces, temperature), the measuring position must be located directly in the bearing. For this purpose, thin-film strain gauges and temperature sensors can be used as an array directly or in the immediate vicinity of the tribological contact on the rolling element raceway [4,5]. This article focuses on manufacturing directly deposited thin-film temperature sensors on thrust roller bearing washers and qualify them in a component test bench.

Sensor Manufacturing

For the production of the thin-film sensors, sputter deposition was used. Thus, thin-film strain sensors and temperature sensors were applied, whereby this contribution focuses on temperature sensors. An axial cylindrical roller bearing

washer (GS89312) was used as substrate. The mean roughness depth R_z was $0.68 \pm 0.06 \mu\text{m}$ and the arithmetic mean roughness value R_a was $0.08 \pm 0.01 \mu\text{m}$ as tactilely determined (HOMMEL-ETAMIC W5, JENOPTIK). First, the bearing washer surface was cleaned using acetone and isopropanol. A sputter etching process was then carried out in the SenVac Z550 sputtering system to increase the adhesive strength of the subsequent insulation layer out of alumina (Al_2O_3), which was applied with a power of 350 W. A 6 μm thick layer was deposited in steps of 1 μm with intermediate chemical cleaning steps. The layer for the temperature sensors was produced using the Kenotec MRC sputtering system with a power of 200 W and shadow masks dividing the washer area into different regions for strain gauges and temperature sensors. An adhesion promotion layer of titanium with a thickness of 10 nm was applied before the sensor layer made of platinum with a thickness of 230 nm was deposited. Finally, a 500 nm thick gold layer was applied to the edge of the bearing washer for the contact pads. Once the layer system of the sensors had been applied, the thin-film sensors were structured using photolithography with the resist AZ 10XT. Ion beam etching was used to remove the material that was not covered by the resist. After removing the resist, a 4 μm thick alumina layer was applied as a wear protection layer using the SenVac Z550 sputtering system and the

settings described above. The bearing washer with the thin-film sensors is shown in Figure 1.

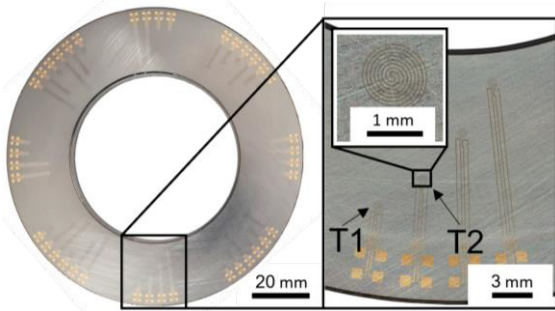


Fig. 1. Thrust roller bearing washer with sensors.

Measurement Results

To characterize the temperature sensors, the temperature coefficient of resistance (TCR) was determined using a hot plate and calculated according to (1) with the temperatures $LT = 20\text{ }^{\circ}\text{C}$ and $HT = 80\text{ }^{\circ}\text{C}$.

$$TCR = [(R_{HT} - R_{LT})/R_{LT}]/[HT - LT] \quad (1)$$

The temperature sensors had an average TCR of $744.6 \pm 90.3\text{ ppm}/^{\circ}\text{C}$. For the investigations of the integrated sensors, the bearing washer was mounted in an FE8 test rig (DIN 51819-1:2016-12), which enables cylindrical roller thrust bearings to be loaded and operating under constant operating conditions. The selected rotational speed was 500 rpm and an axial load of 7.5 kN was applied, corresponding to an Hertzian pressure in the roller-raceway contacts of 750 MPa. Grease (ISOFLEX NBU 15) was selected as lubricant. After a test period of 60 minutes, the highest temperature of $33.6 \pm 0.1\text{ }^{\circ}\text{C}$ was measured with the thin-film sensor (T2) directly in the mechanical rolling contact. This was followed by the thin-film sensor (T1) close to the mechanical rolling contact with a temperature of $31.6 \pm 0.1\text{ }^{\circ}\text{C}$. A temperature of $30 \pm 0.1\text{ }^{\circ}\text{C}$ was measured with the PT100 temperature sensor at the edge of the bearing washer (Figure 2).

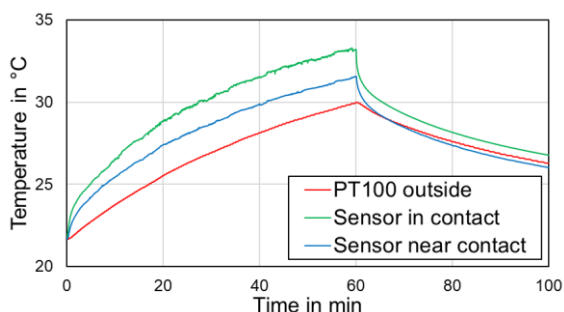


Fig. 2. Temperature signals from differently positioned sensors.

Due to the frictional heat caused by the frictional forces and the high sliding components caused by the contact kinematics, the meas-

ured temperatures in and near the rolling bearing contact are higher than the temperature of the PT100 at the edge of the bearing washer. The test was repeated four times with reproducible signals.

Conclusion

Thin-film temperature sensors were applied to a thrust roller bearing washer to measure the temperature in and near the mechanical rolling contact. The sensors were produced using cathode sputtering, photolithography and ion beam etching. Due to the frictional forces, various temperatures were measured in and near the tribo-mechanical contact as well as at the edge of the bearing washer when it was tested in a component test rig. The results show that after 60 minutes, a temperature 12 % ($3.6\text{ }^{\circ}\text{C}$) higher in the mechanical rolling contact and 5.3 % ($1.6\text{ }^{\circ}\text{C}$) higher near the mechanical rolling contact could be determined with the directly deposited sensors than with a conventional PT100 at the edge of the bearing washer. Thus, a more accurate and faster temperature determination is possible with the help of thin-film sensors directly in the tribo-mechanical contact, as well as more precise validation of simulation models.

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