On-line surveillance of lubricants in bearings by means of surface acoustic waves

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Abstract—**The acoustic wave propagation in a bearing filled with lubricants and driven by pulsed excitation of surface acoustic waves has been investigated with respect to the presence and the distribution of different lubricants. Experimental setups, which are based on the mode conversion between surface acoustic waves and compression waves at the interface between a solid substrate of the bearing and a lubricant are described. The results of preliminary measurements at linear friction bearings and rotation ball bearings are presented.**

I. INTRODUCTION

The condition monitoring of the lubricant in a bearing during operation is a challenging task [1, 2], which has been tackled recently by ultrasonic reflection techniques [3]. The mode conversion of surface acoustic waves propagating on boundary planes between solid and liquid materials, on the other hand, allows another approach: If the gap between two solid surfaces as formed by the inner surfaces of a bearing is filled with a liquid, in particular with a lubricant, a crosstalk effect occurs, if a surface acoustic wave has been excited on one of these surfaces. This crosstalk can be explained by the excitation of another surface acoustic wave on the opposite surface by the compression wave in the liquid resulting from mode conversion of the initial acoustic surface wave; thus an acoustic waveguide is formed by such a configuration [4 - 6]. In addition, the mode conversion results in an attenuation of surface acoustic waves travelling along one of the inner surfaces in a delay line configuration. This effect can be used in bearing constructions, which do not allow the realization of an acoustic waveguide.

Investigations of liquid-filled acoustic waveguide sensors have shown that such surface acoustic waves can efficiently be excited and detected on solid structural materials including steel via piezoelectric interdigital transducers. With sufficiently thin plates these transducers can be attached to the outer surfaces of the guiding plates, so they are not in contact with the liquid [7]. Transferring this design concept to bearing constructions does not only allow a non-invasive surveillance of the presence and the distribution of a lubricant but in addition of properties of the lubricant, which are related to its compressibility and density.

In this contribution, results of first experiments with respect to the measurement of the presence and the composition of a lubricant film in a linear friction bearing using the waveguide configuration and a rotating ball bearing using the delay line configuration are presented.

II. EXPERIMENTAL SETUP

In all experiments, interdigital transducers made of PZT (6 mm x 4 mm x 1 mm) with an operating frequency of 1 MHz were attached to metallic components of a bearing in such a way that surface acoustic waves were excited and detected on the surfaces of the bearings.

A. Linear friction bearing

With linear friction bearings, Rayleigh waves were excited on one of the inner surfaces and an acoustic crosstalk signal on the opposite surface was measured.

For these measurements a dovetail guide from Norelem Type 21030 was used with a dimension of 80 mm x 50 mm x 25 mm (Fig. 1). The dovetail guide consists of a lower fixed plate and an upper moveable carriage. The gap between these two plates was filled with a lubricant as shown in figure 2.

Figure 1. Photo of a linear friction bearing used for the measurements

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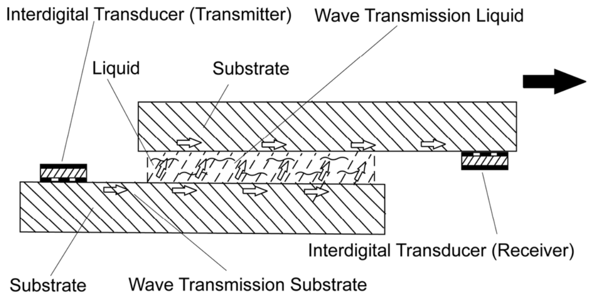

Figure 2. Concept of the setup used at a linear friction bearing

B. *Rotating ball bearing*

At the rotating ball bearing, Lamb waves were excited on the surfaces of the outer ring by interdigital transducers attached on the outer surface of the outer ring (Fig. 3 and 4). The receiver signal of the Lamb wave transmission along the surface of the outer ring was measured.

An inclined ball bearing of type 7212 B-MP from FAG was used for the measurements. The diameter of the outer ring was 110 mm and the thickness was 4 mm. The two interdigital transducers were attached on the outer surface of the outer ring at a distance of 31 mm.

Figure 3. Foto of a rotating ball bearing used in the measurements

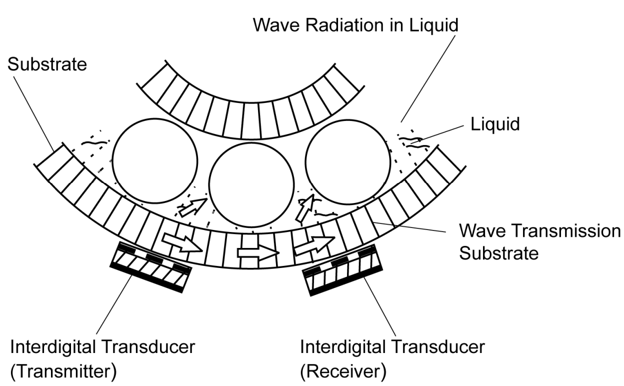

Figure 4. Concept of the setup used at a rotating ball bearing

Measurements of the surface acoustic wave transmission were performed in pulse mode, in which the receiver signals resulting from a burst excitation, were recorded by a digital storage oscilloscope and both the transmission and the maximum amplitude of the receiver signals were determined (Fig. 5).

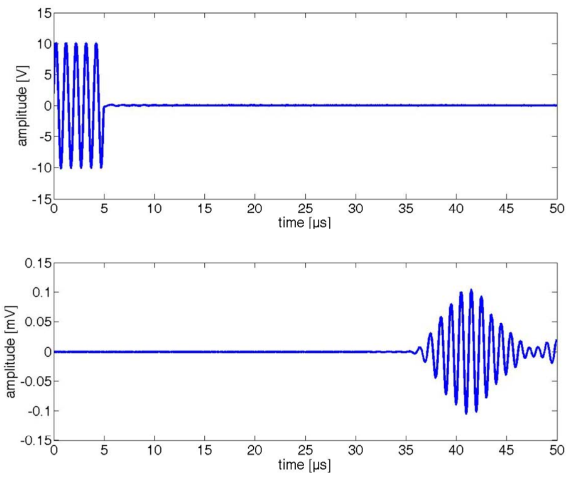

Figure 5. Excitation burst and receiver signals as measured by a digital storage oscilloscope at the linear bearing of figure 2

III. RESULTS

A. *Linear friction bearing*

The careful removal of the lubricant from the bearing resulted in a very weak acoustic crosstalk between the two inner surfaces and correspondingly a weak receiver signal. As soon as the lubricant was filled in again, a substantial increase of the receiver signal could be recorded (Fig. 6). Not only the signal amplitude, however, but also the transit time of the transmitted wave pulse changed (Fig. 7). Exchanging the type of lubricant, e.g. from oil to grease, on the other hand, it is only of minor influence both on transit time and on signal amplitude (Fig. 7).

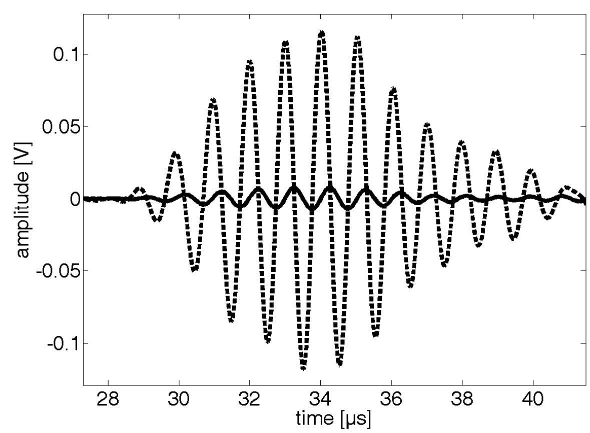

Figure 6. Change of receiver signal with lubricant

--- receiver signal in presence of oil

- receiver signal without a lubricant

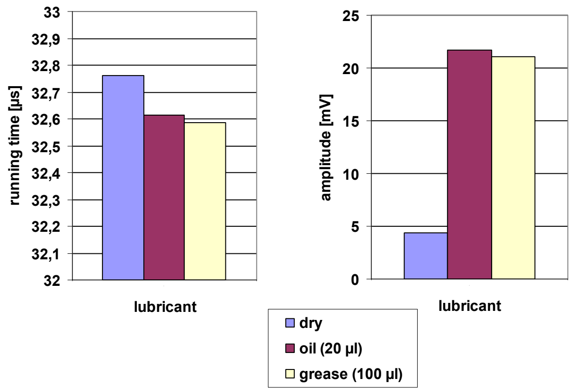

Figure 7. Change of transmission time and amplitude with different lubricants in a linear friction bearing

B. *Rotating ball bearing*

In these experiments, only the transmission on the same surface and no crosstalk could be measured up to now (Fig. 8).

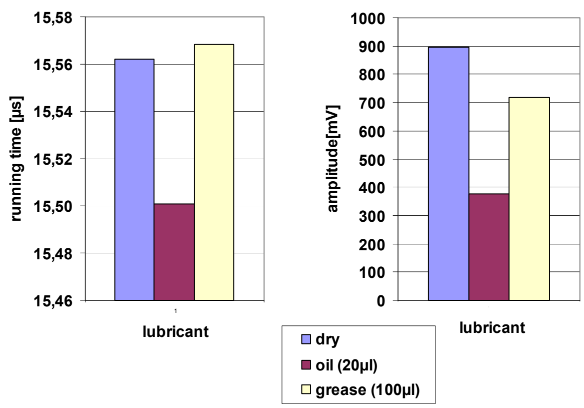

Figure 8. Changes of transmission time and amplitude with different lubricants in a rotating ball bearing

It turned out, however, that an attenuation of the transmission signal on the outer ring could be detected with both lubricants. The transmission time, on the other hand was affected in a different way with oil and grease as lubricant.

IV. Discussion and Conclusion

A. *Linear friction bearing*

From the result obtained with the linear friction bearing it is obvious that the presence of a lubricant can easily be detected (Fig. 7) – both via changes of the transit time and the amplitude of the crosstalk signals.

The differences between the two lubricants oil and grease, however, are too small for a further discrimination with respect to the type of lubricant. A substantial increase in sensitivity has to be achieved for that purpose, e. g. by increasing the signal amplitude or the operation frequency of the interdigital transducers.

B. *Rotating ball bearing*

The results allow the detection of the presence of oil, but with respect to grease as a lubricant, the changes of the measured quantities compared to the lubricant-free situation are not as pronounced as with oil; in particular with respect to the transmission time the opposite behavior was observed. For an understanding of these phenomena the acoustic wave propagation within the bearing has to be investigated in more detail – taking into account that the gap between the inner surface of the outer ring and the rotating balls will be filled in differently with grease compared to oil.

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