FRICTION FORCES MEASUREMENTS FOR SLIDE BEARING TEST STAND IN MARITIME UNIVERSITY GDYNIA USING THE ACOUSTIC EMISSION METHOD

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Abstract

The present paper determines the results of experimental research performed in Gdynia Maritime University and connected with the measurements of hydrodynamic friction forces in slide journal slide bearings by using the Acoustic Emission Method. A new method for mechanical friction force measuring was carried out at this test stand, simultaneously the friction force will be indicated by an optimized Acoustic Emission System. The friction conditions at the test were measured by two different methods. At the one hand the friction power measurement and at the other hand the Acoustic Emission Analysis. One characteristic of the friction power measurement is the rather inert reaction to the oscillations of the slide bearing. The advantage of the method is the fact that one can measure absolute values of the friction power. In opposite to that, the Acoustic Emission Analysis measures the high frequency oscillations caused by the hydrodynamic friction between the oil molecules. The advantage of this method is the fact that this oscillations can be executed directly from the source to the sensor, what enables us to do an "online-measurement". The Acoustic Emission Analysis is (in opposite to the aforementioned friction power measurement) a relative method, which means, that the absolute amount of a RMS-Value depends on the measuring chain.
The results are compared and discussed with other results obtained in experiments performed in University of Applied Science Giessen.

Keywords: *AE- Acoustic Emission, RMS, experimental data, test stand, journal bearing*

1. General remarks about the test stand in Maritime University Gdynia

Two test series were carried out by using the lubricant „Castrol GTX 15W40". To make sure that these tests can be compared to those where the lubricant „Lotos Mineral SAE 15W40" was used, the same test parameter as well as the same course of the measurement were applied [3, 4, 5]. The description of the test stand, the test parameter as well as the Acoustic Emission

Analysis was presented in other papers. For better clarity of the following figures and schemes, a color code of the resulted bearing capacities was established (see Fig. 1).

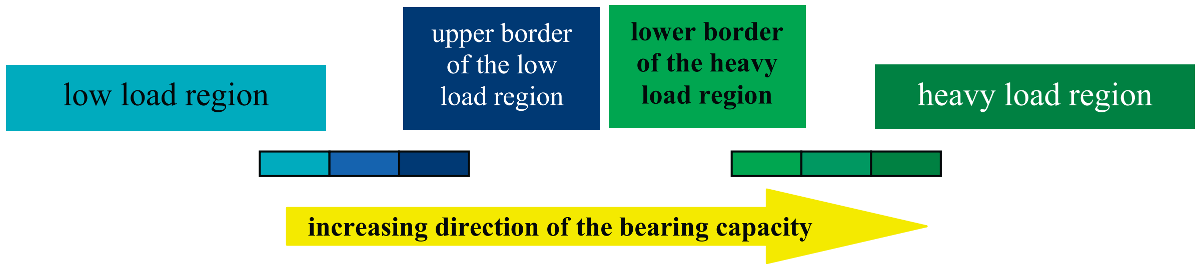

Fig. 1. Color code of the resulted bearing capacities

2. Test series with constant angular velocity and different bearing loads

Fig. 2-4 show the results of the first test series with constant angular velocity and different bearing loads. Fig. 5 combines all test series which are shown in Fig. 2 until Fig. 4 with the extended Sommerfeld-number So η_1. This combination enables us to assess the results at the point of similar hydrodynamic bearing capacity. All of these results (Fig. 2-5) point out the same dependences of the RMS-Value measured by the Acoustic Emission Analysis [1] and the Friction power, calculated from the measured Friction Force in reference to the bearing capacity. These details go along with the theory of the hydrodynamic slide bearings (Stribeck curve). In Fig. 2 one can see the strong fluctuations of the RMS-Values which can be explained by the slightest hydrodynamic bearing capacity. While there is only a small load on the slide bearing it begins to oscillate. This can be mapped by the Acoustic Emission measurement system because of its slight inertia. Because the RMS-Values are only relative ones and depend on amplification, the absolute value/peak has not to be considered.

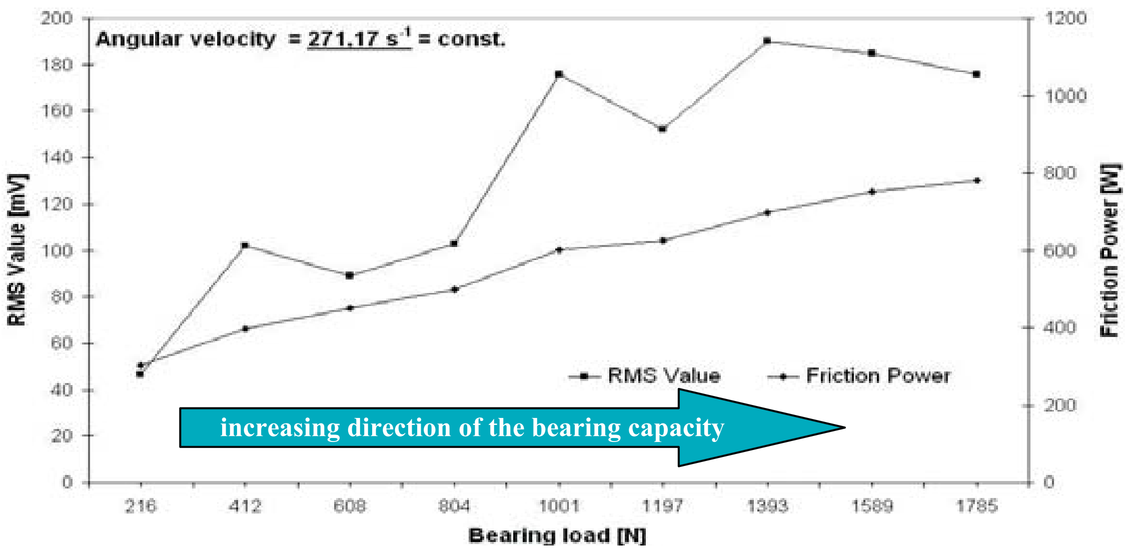

Fig. 2. Comparison between the RMS-Value and the calculated Friction Power at a constant angular velocity of $217.17 s^{-1}$ and bearing loads from 216 N up to 1785 N

Because of the slighter angular velocity we see in Fig. 3 (in opposite to Fig. 2), the hydrodynamic bearing capacity increases. The variation range of the RMS-Values is smaller. If the bearing load increases, the RMS-Values as well as the Friction Power increase, too. In this series (Fig. 2-4) the hydrodynamic bearing capacity is at its maximum in Fig. 4, because of the lowest angular velocity. The curve of the RMS-Values is characterized by its lowest variation range caused by the stable bearing conditions.

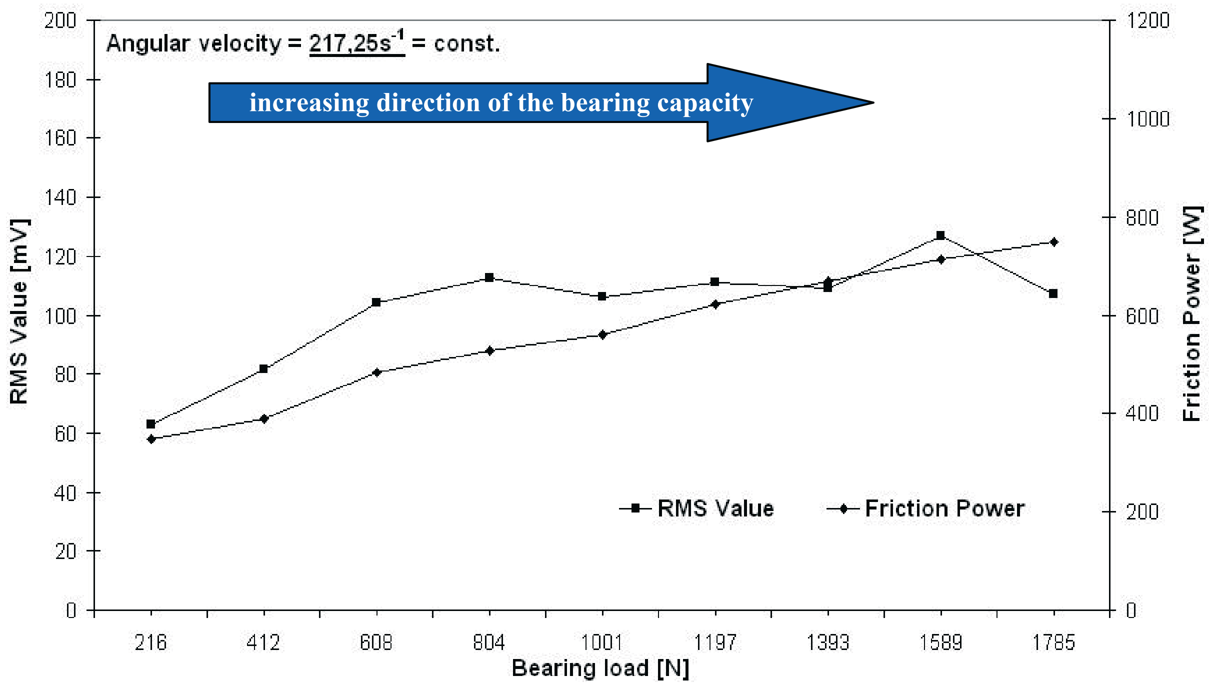

Fig. 3. Comparison between the RMS-Value and the calculated Friction Power at an angular velocity of 217.25s^{-1} and bearing loads from 216 N up to 1785 N

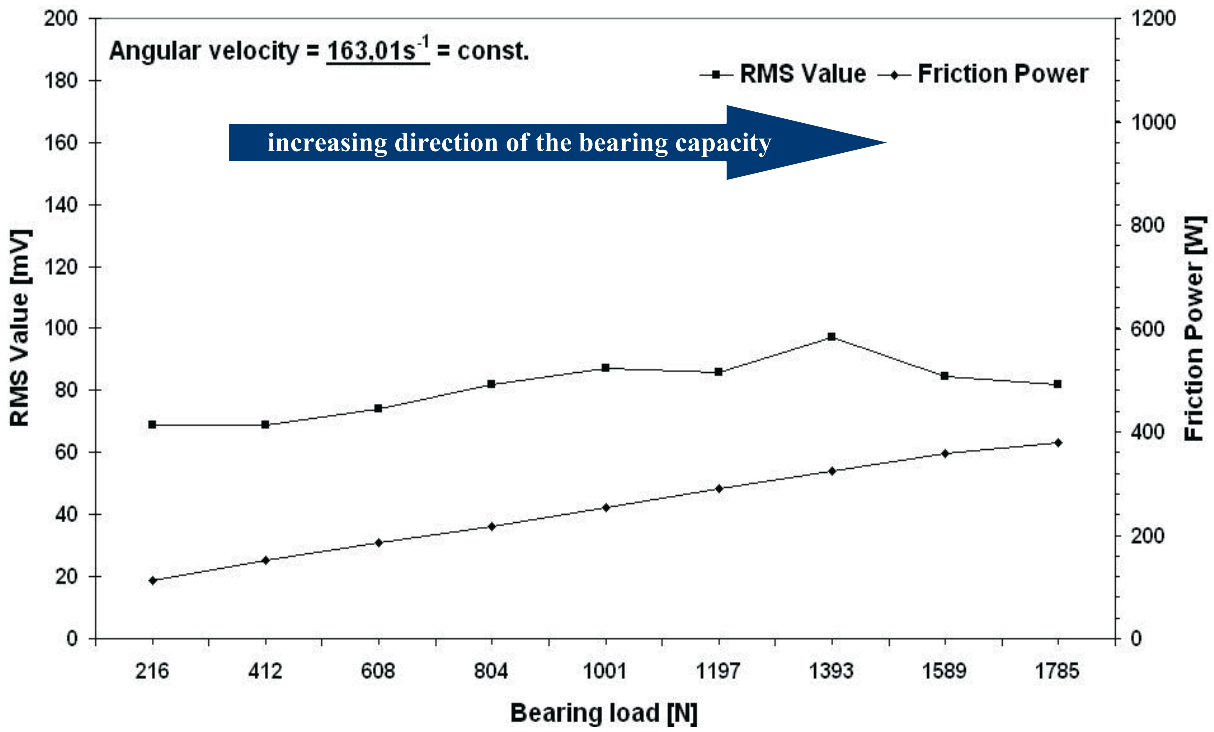

Fig. 4. Comparison between the RMS-Value and the calculated Friction Power at a constant angular velocityof 163.15s^{-1} and bearing loads from 216 N up to 1785 N

Fig. 5 shows that the hydrodynamic bearing capacity increases while the bearing load increases and if the angular velocity decreases. The change of the RMS-Values depends in a higher amount on the changing of the angular velocity than on an alter of the bearing load.

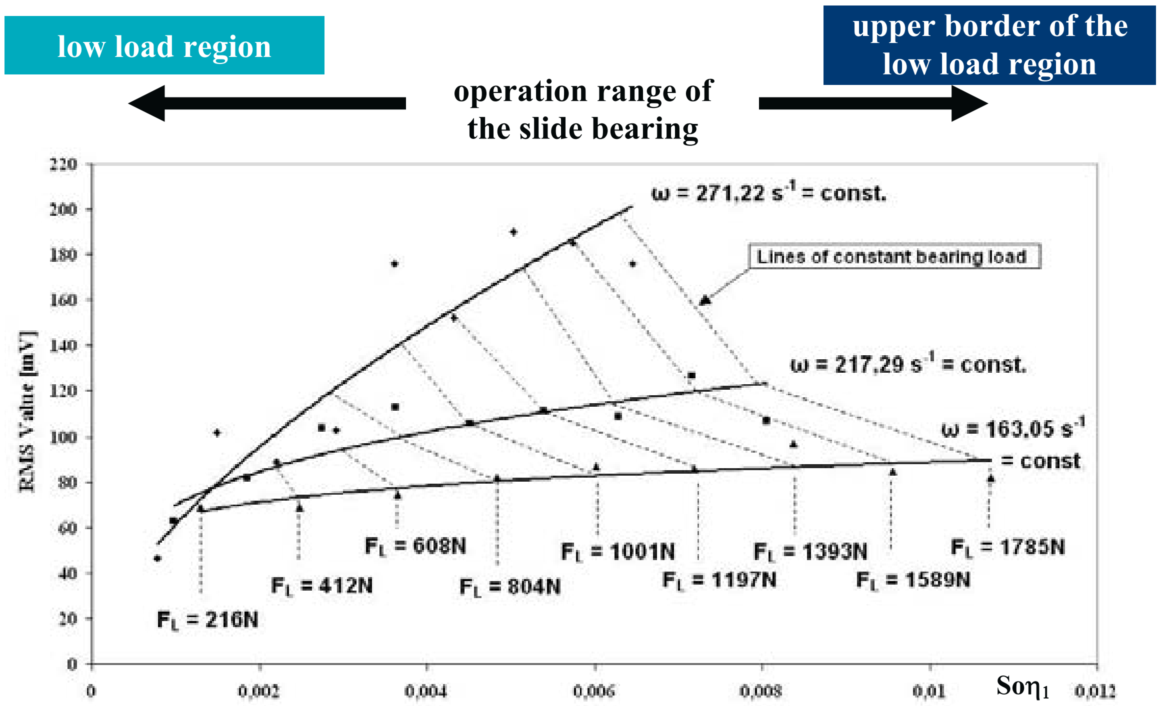

Fig. 5. RMS-Values of different series of measurement versus the extended Sommerfeld-number ($So\,\eta_1$) In this figure the compensated curves out of Fig. 2 - 4 are added

3. Test series with constant bearing load and different angular velocities

In Fig. 6 to 8 one can see the RMS-Values and the friction power at constant bearing load but different angular velocities. In this series, the angular velocities were reduced by 9 steps beginning at 271 s^{-1} down to 28 s^{-1}. The courses of the RMS- and the friction power values are very similar. Because of the nearly inertia free reaction of the Acoustic Emission system, any change of the Friction Force will be shown faster than in case of the Friction Force measurement. This difference will be shown clearest at low bearing loads and high angular velocities (Fig. 6), which lead to oscillations at the bearing because of the low hydrodynamic capacity. An increase of the bearing load (Fig. 6-8) causes higher hydrodynamic capacities and therefore a more stable operation behavior of the slide bearing.

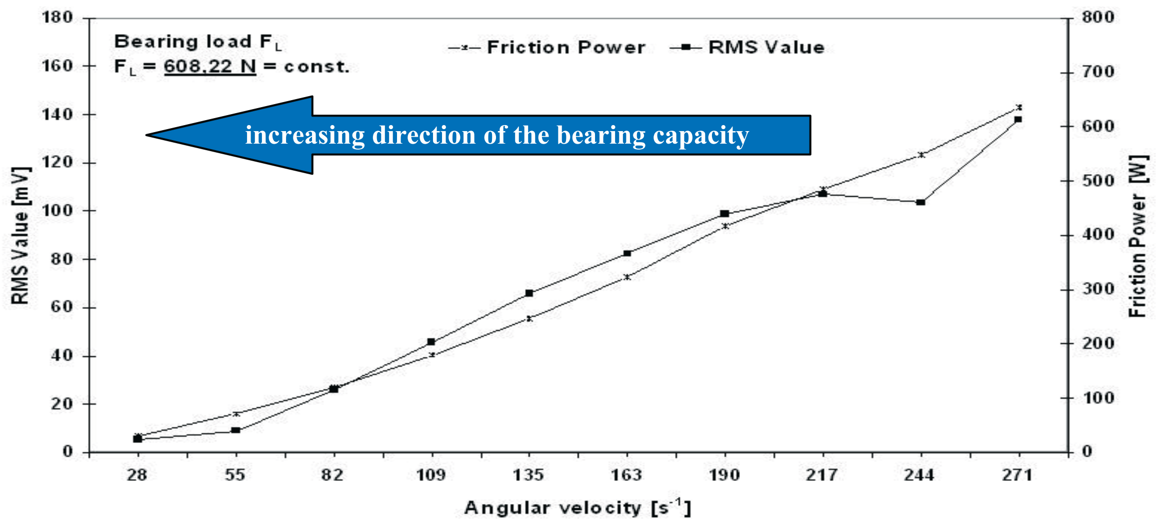

Fig. 6. Comparison between the RMS-Value and the calculated Friction Power at a constant bearing load of 608.22 N and angular velocities from 28s^{-1} up to 271s^{-1}

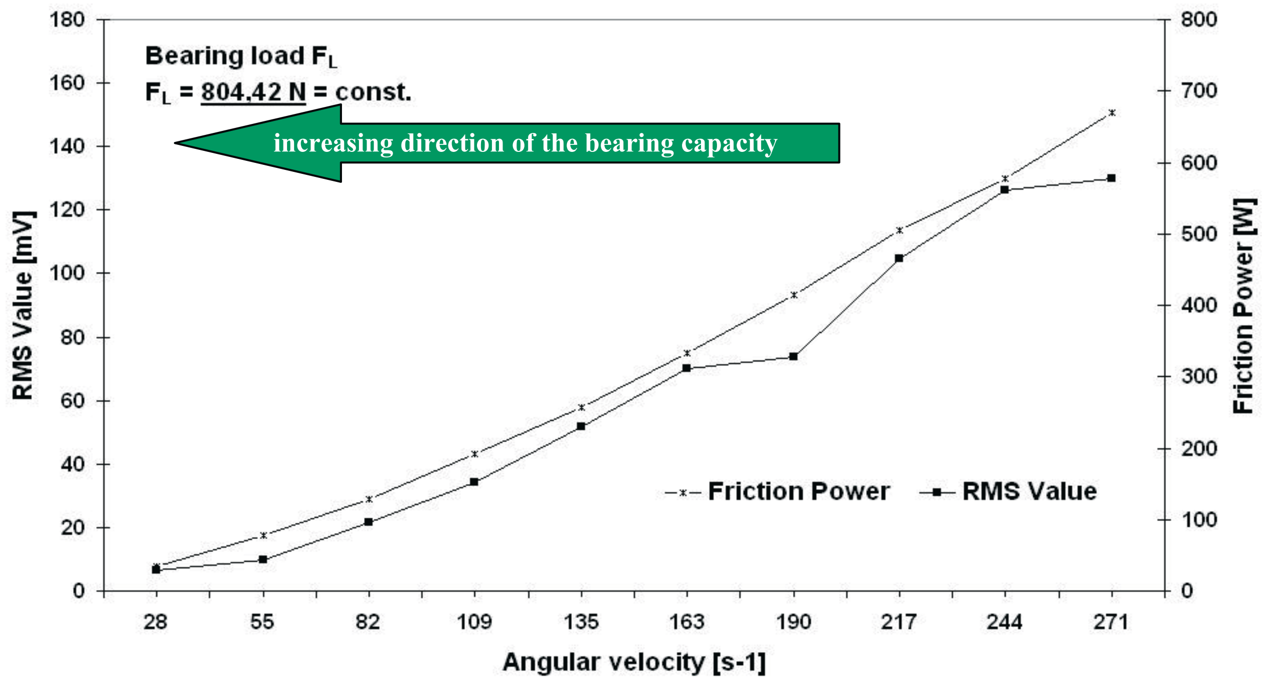

Fig. 7. Comparison between the RMS-Value and the calculated Friction Power at a constant bearing load of 804.42 N and angular velocities from $28s^{-1}$ up to $271s^{-1}$

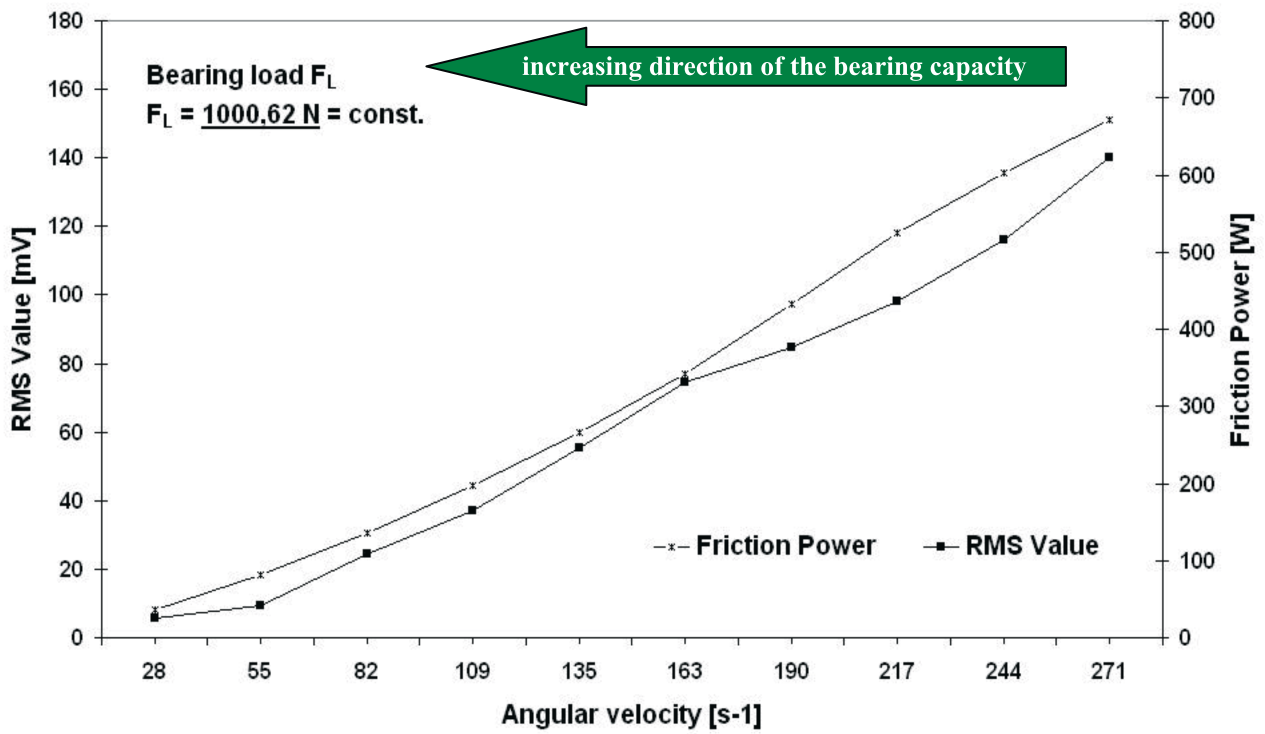

Fig. 8. Comparison between the RMS-Value and the calculated Friction Power at a constant bearing load of 1000,62 N and angular velocities from $28s^{-1}$ up to $271s^{-1}$

In Fig. 9 there are RMS - and Friction Power values combined with equal hydrodynamic bearing capacities each. All of the aforementioned connections are shown much clearer here than in the individual figures.

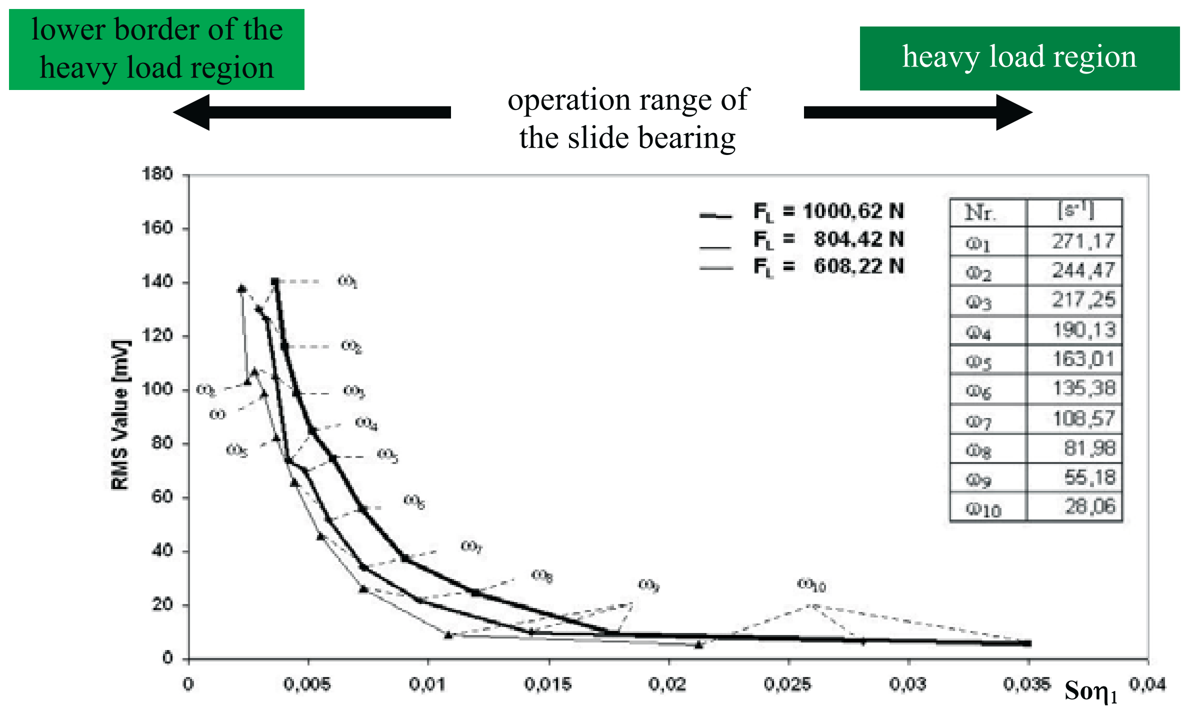

Fig. 9. RMS-Values of different series of measurement versus the extended Sommerfeld number (So η_1), One can see the indication of instabilities of the slide bearing at lower hydrodynamic bearing loads

4. Comparison of the used oils

The oil, that was used in the test series „Castrol Magnatec SAE 15W40", does not show significant differences in the results if compared to the „Lotos Mineral SAE 15W40", which has been used for the test series which are described in point 2. Neither there are differences in Friction Power, nor at the RMS-Values of the Acoustic Emission Analysis. One could have been expected that, because of the significant difference in price. Table 1 shows us all common known information of the two different oil types, which lead us to the fact that both of the oils fit the same characteristics.

Tab. 1. Characteristic values of the used oils

Used oil	Kinematic viscosity ν [mm²/s] at 40°C	Kinematic viscosity ν [mm²/s] at 100°C	Minimum viscosity index	Density ρ [kg/m³]
Lotos Mineral SAE 15W/40	-	13.8	136	-
Castrol Magnatec SAE 15W/40	110	14.38	135	881.0

There is are no further information about the used additives. These differences can not be discovered here, because the test method runs the slide bearing only in the hydrodynamic area. These additives will be used mainly as an improvement of the friction behavior at mixed friction areas. By a chemical reaction during the contact of solid asperities, a low friction layer will be generated at the surfaces of the pairing friction parts (so called anti-friction-coating = AFC) [2].

5. Conclusions

- The Acoustic Emission Analysis answers to the signals at the hydrodynamic friction area by showing a clear dependent relationship between the signals and the shear rate (=function of sliding velocity and gap height),

- The RMS-Values are only relative ones, which means that depending on the details of the measuring chain, different values are possible. The measuring chain is characterized by the dimension of the bearing, wave rot, sensor and amplifier,
- If we do not change the measuring chain, even the measurements in case of similar friction conditions are clearly reproducible,
- Mechanical sensors (load cells), which measure the Friction Forces within the slide bearing, produce absolute measurements connected with a huge inertia and a high damping.

Acknowledgement

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