FRICTION FORCES MEASUREMENTS BY THE ACOUSTIC EMISSIONFOR SLIDE BEARING TEST STAND IN UNI OF APPLIED SCIENCE GIESSEN

Burkhard Ziegler

University of Applied Sciences Gießen-Friedberg
Wiesenstr. 14, 35390 Gießen, Germany
tel:+49 6413092226, fax:+49 641 3092911
e-mail: Burkhard.Ziegler@mmew.fh-giessen.de

Krzysztof Wierzcholski

Maritime University Gdynia
Morska Street 81-87, 81-225 Gdynia, Poland
tel:+48 58 6901348, fax:+48 58 6901399
e-mail: wierzch@am.gdynia.pl

Andrzej Miszczak

Maritime University Gdynia
Morska Street 81-87, 81-225 Gdynia, Poland
tel:+48 58 6901348, fax:+48 58 6901399
e-mail: miszczak@am.gdynia.pl

Abstract

The present paper describes the results of measurements performed in University of Applied Science Giessen and determined hydrodynamic friction forces in journal slide bearings by using the Acoustic Emission Method. It describes the use of the Acoustic Emission Analysis as an indicator of the bearing friction at slide bearings. The investigations were made at two different test stands. The test stand at Maritime University Gdynia covers the hydrodynamic operation range, the test stand at University of Applied Science Giessen the mixed friction area.The successive steps of measurements of the hydrodynamic friction forces are presented in this paper. Hardness and roughness of cooperating surfaces is in this paper particularly described. The friction values and its boundary conditions at the test were measured for the low bearing load and for the high bearing load. In both cases the dependencies between friction forces and time are exactly obtained. During the measurements the temperature is taken into account. 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 Maritime University Gdynia.

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

1. Test stand parameters in University of Applied Science Giessen

By using the adapted test stand, the following tests, in the mixed friction area, were done. To characterize the pairing friction parts their roughness is measured by a roughness tester Fa. Perthen pertometer C50), see Fig. 1 and the hardness with a hardness tester (emco TEST M4C 075 G3R), see Fig. 2. The material of the test rings is analyzed by an emission spectrometer (belec vario lab), where the analyzing document is shown in Fig. 3.

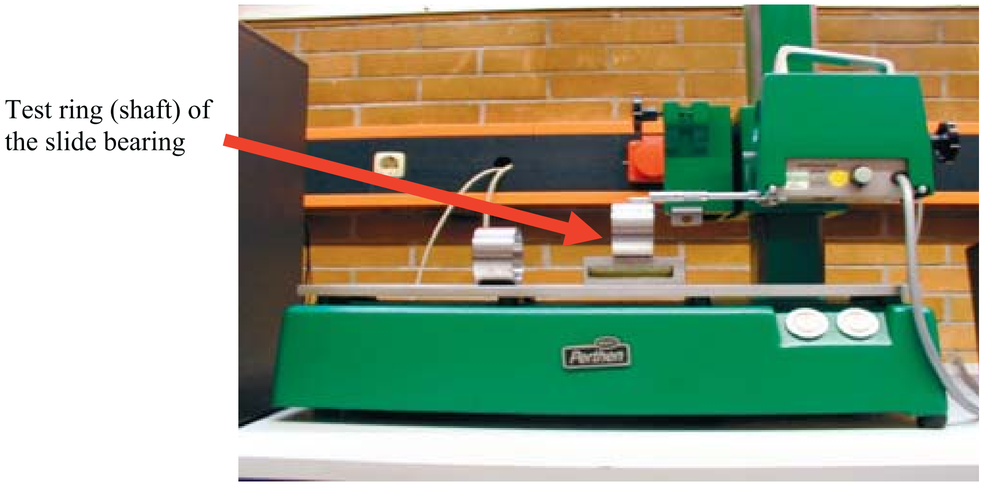
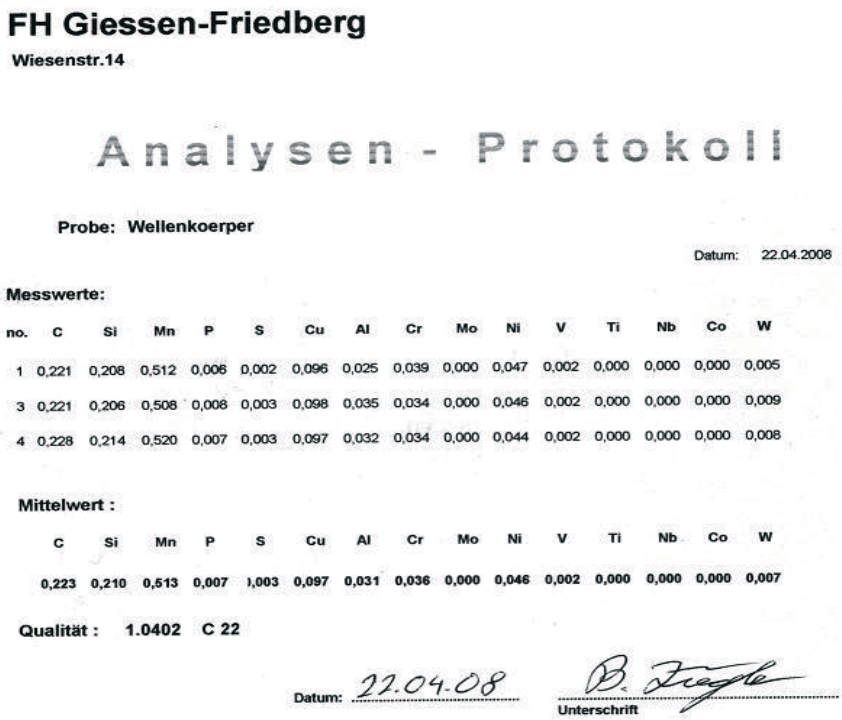


Fig. 1. Used roughness tester

Fig. 2. Surface of the test rings. It is easy to see the dark area of identification, the black lines are grooves caused by the lathing operation. The measured hardness is 165HV



FH Giessen-Friedberg
Wiesenstr.14

Analysen - Protokoll

Probe: Wellenkoerper

Datum: 22.04.2008

Messwerte:

no.	C	Si	Mn	P	S	Cu	Al	Cr	Mo	Ni	V	Ti	Nb	Co	W
1	0,221	0,208	0,512	0,006	0,002	0,096	0,025	0,039	0,000	0,047	0,002	0,000	0,000	0,000	0,005
3	0,221	0,206	0,508	0,008	0,003	0,098	0,035	0,034	0,000	0,046	0,002	0,000	0,000	0,000	0,009
4	0,228	0,214	0,520	0,007	0,003	0,097	0,032	0,034	0,000	0,044	0,002	0,000	0,000	0,000	0,008

Mittelwert :

C	Si	Mn	P	S	Cu	Al	Cr	Mo	Ni	V	Ti	Nb	Co	W
0,223	0,210	0,513	0,007	0,003	0,097	0,031	0,036	0,000	0,046	0,002	0,000	0,000	0,000	0,007

Qualität : 1.0402 C 22

Datum: 22.04.08 B. Ziegler
Unterschrift

Fig. 3. Document of the element analysis of the test rings, measured by the emission spectrometer

For the sleeve we have following data: (acc. to Fa Glyco), multilayer copper bearing, G18 Fa Glyco PbSn14Cu8, surface hardness 25 HV, (acc. to own measurements), width = 38 mm, inner diameter d_1 = 80 mm [1, 2].

For the shaft, test rings we have following data: width = 40 mm, external diameter d_2 = 70mm, material: C 22, surface hardness: 165 HV, roughness of the surface: $R_z = R_{max}$ = 13.9 μm, R_a = 3.4 μm [3-4, 6].

According to the existing dimensions of the bearings and using the dependences, which was developed out of the geometrical dimensions of the suspension, the relative bearing clearance ψ has the following form:

$$\psi = \frac{d_1 - d_2}{d_2} = \frac{80mm - 70mm}{70mm} = 0{,}1428, \tag{1}$$

where:
d_1 - inner diameter,
d_2 - shaft diameter.

Within this relative bearing clearance range it is common sense, that a line contact and therefore a mixed friction will happen. This produces heavy operation condition for both slide journal bearings under test.

The truncation condition in these tests are:
- reaching test time limit,
- reaching the wear limit indicated by acoustic emission,
- reaching the wear limit indicated by friction force or bearing sleeve temperature.

The following order must be adhered to for starting the test:
① start-up the oil supply for the hydrostatic bearings,
② power-up the measuring devices,
③ 1h stand-by time for warming up the whole system,
④ start-up the lubricant oil delivery to the bearings under test,
⑤ adjust the shaft speed,
⑥ stress the bearings by respective bearing load,
⑦ test until reaching the truncation conditions.

2. Experiment performed with a low bearing load

The parameters of this experiment are as follows: bearing load: 90 N; number of revolutions: 310 rpm, truncation condition: reaching the test time limit.

We can see in Fig. 4 and Fig. 5 the so called run-in phase of the slide bearing, in which the asperities of the friction partners will be smoothed during the solid contacts. After that the so called operation range follows, in which only negligible friction is characteristic.

At the region „X" in Fig. 4 the RMS-Values rise. As reasons are conceivable: a) abrasion particles pass the bearing clearance but with solid contacts to both of the surfaces or b) local contact of the bearing surfaces causing micro friction. Both measuring methods presented in Fig. 4 react to the state of friction changes. Because of its inertia, the friction force measurements show a higher damping in general.

The measurements presented in Fig. 5 are similar to the measurements indicated in Fig. 4 but without local increasing of the friction by virtue of abrasion particles.

In Fig. 6 one can see, that the outer bearing under test (No. I) starts with a minimal lower temperature (1°C). This results from the larger distance to the heat source and the losses on the way to the outer bearing. Generally, the temperatures of both bearings rise continuously. The gradient of the rise of the temperature within the run-in phase is higher than within the operation range [5]. The temperature measurement reacts with a time lag, because of its heat capacity caused high inertia, that means, it shows a high damping regarding the changes of the friction processes within the bearings.

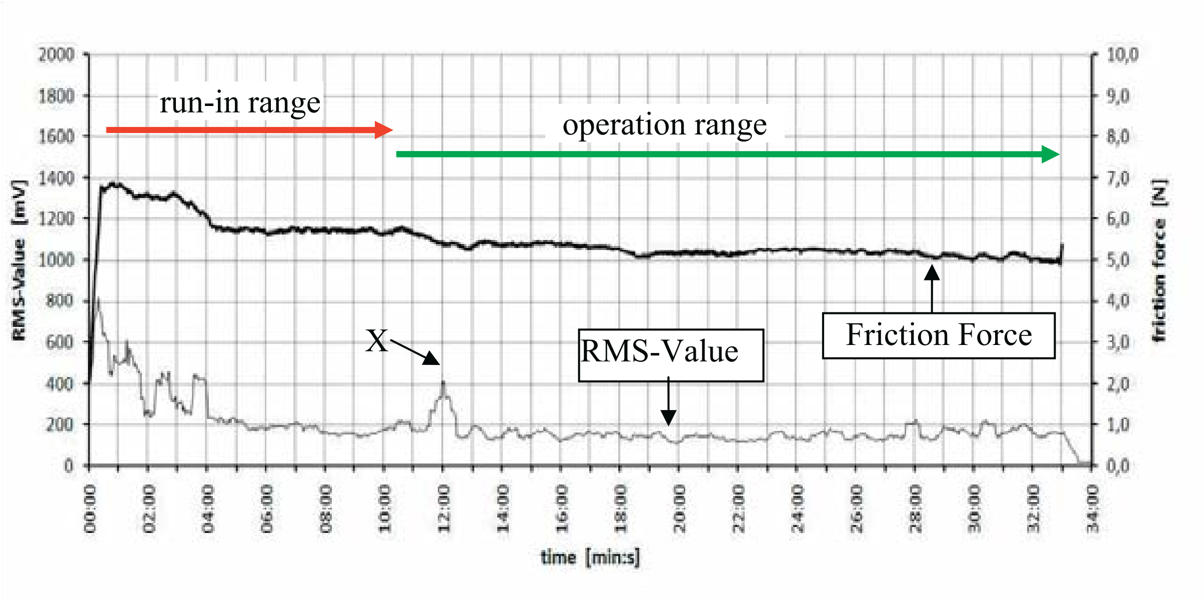


Fig. 4. Slide bearing under test No. I. RMS-Value and friction force vs. test duration

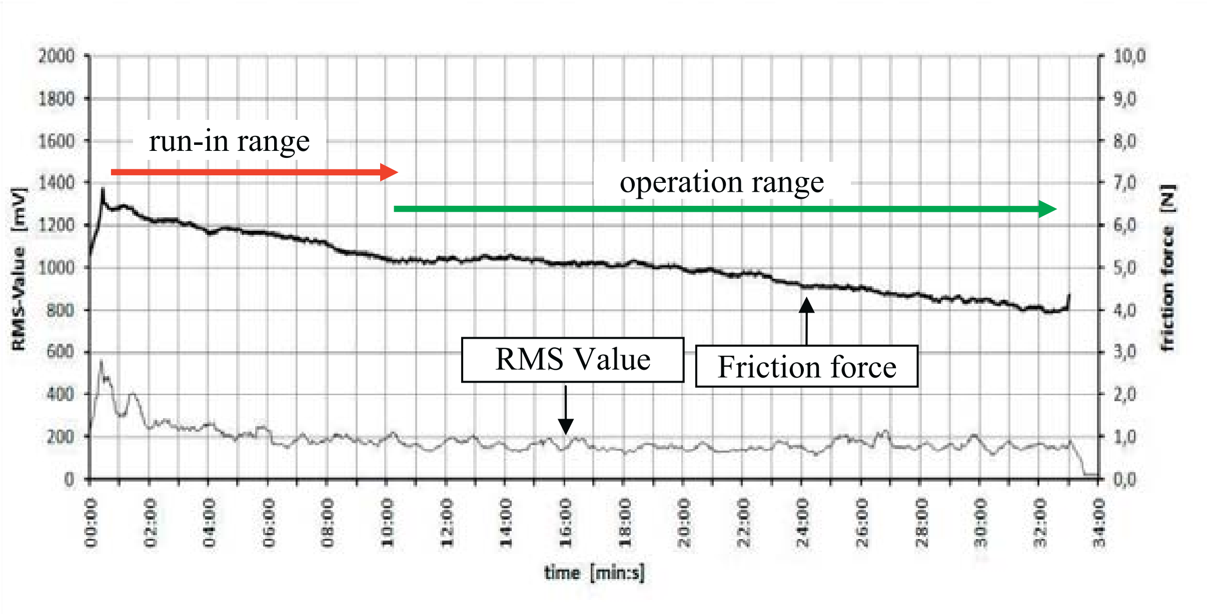


Fig. 5. Slide bearing under test No. II

3. Experiment with a higher bearing load

The parameters of this experiment are as follows: bearing load: 120 N; number of revolutions: 310 rpm, truncation condition: reaching the wear limit indicated by Acoustic Emission (RMS-Value).

Because of a supply delay, this experiment was done with only one new pair of bearing sleeves. Therefore, the bearing under test was used until it left its operation range and changed into the worn-out region. To identify the borderline between the operation range and the worn-out region, a high increase of one of the measurements (Friction Force, RMS-Value, temperature) was defined as then given.

Fig. 7 shows the wear-out process of the slide bearing. It started at the run-in range with smoothing of the asperities, followed up by the operation range and finally the worn-out range, where the wear lifespan came to its end. The bearing would have been destroyed, if we would have gone further. At the region „X" the RMS-Values rise. The reason may be abrasion particles pass the bearing clearance but with solid contacts to both of the surfaces or local contact of the bearing surfaces causes micro friction. The high increasing of the RMS-Value indicate the attaining of the worn-out range. Because of its inertia, the Friction Force measurements do not indicate all fast changes of the friction conditions. There is no increasing of the friction force while the slide bearing reaches the worn-out region.

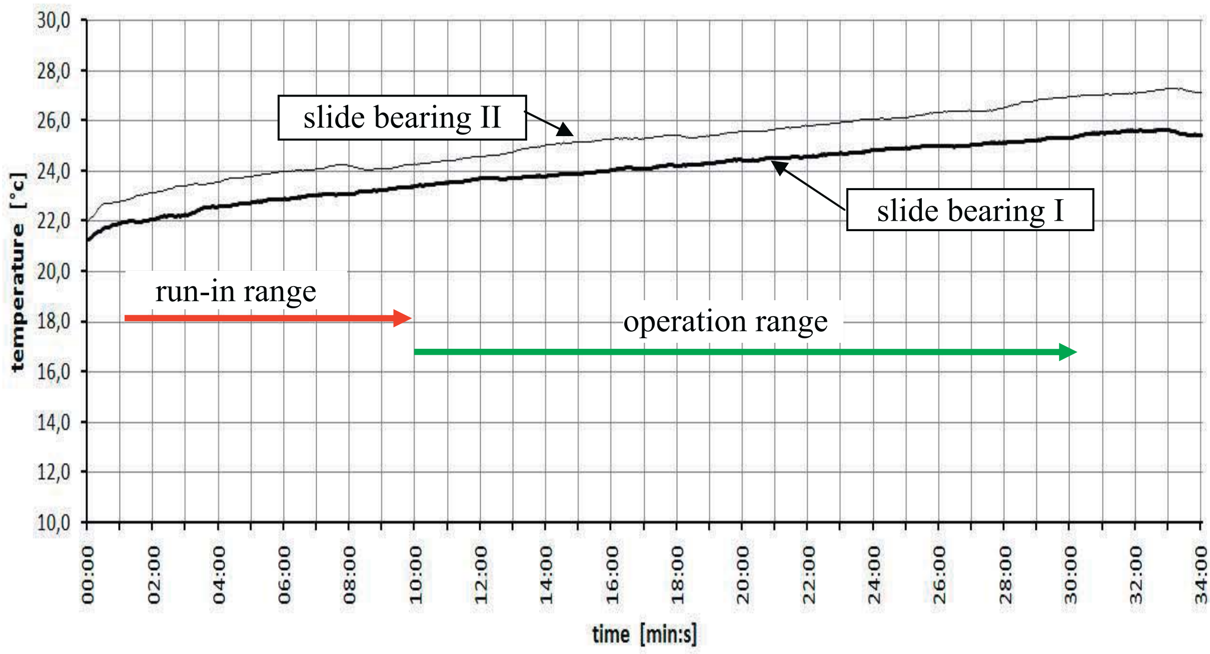


Fig. 6. Temperature of both bearings under test. The temperature of bearing No. II is about 1°C higher than the temperature of bearing No. I

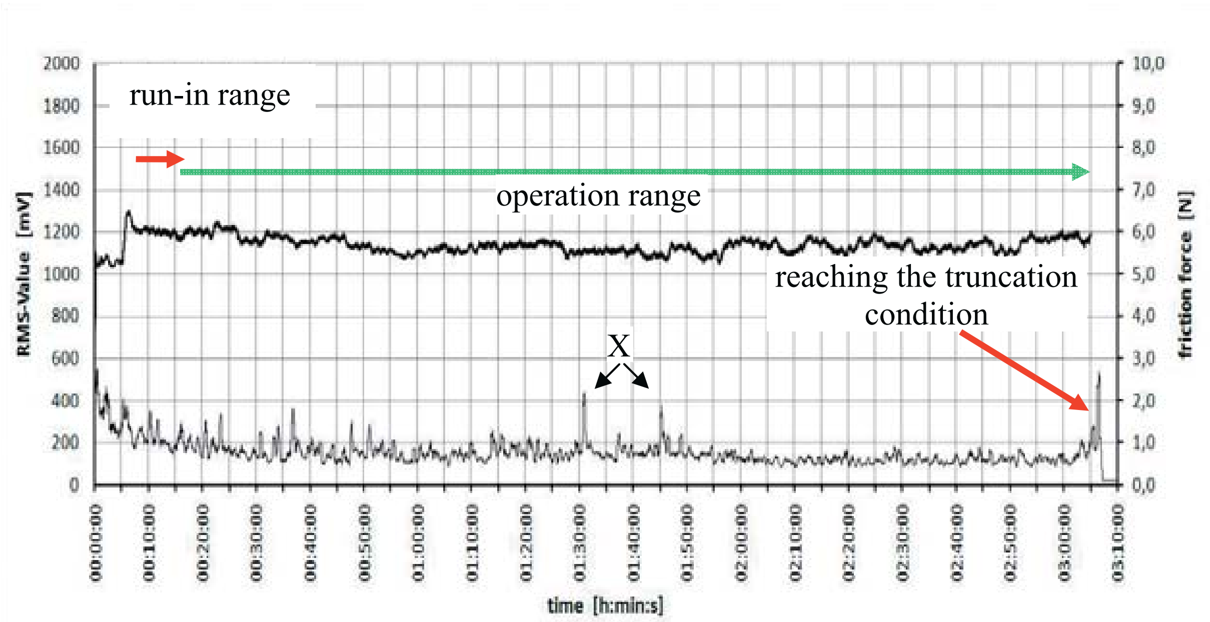


Fig. 7. Test No. 2, bearing No. I, RMS-Value and Friction Force vs. duration of test (3hours 19 min)

Fig. 8 one can see the increasing of the temperature during the test, caused by the friction into the bearing. The RMS and the friction force measurements show the same dependent relationships as described in the experiment of section1.

The start temperature equals the start temperature of the test with the lower bearing load (Fig. 6 bearing I). The temperature rises continuously. The gradient of the rise of the temperature decreases during the test duration. There is no increasing of temperature while the slide bearing reaches the worn-out region.

Fig. 8. Test No. 2/ temperature of bearings No. 1

4. Conclusion

This report describes the use of the Acoustic Emission Analysis as an indicator of the bearing friction at slide bearings. The investigations were made at two different test stands. The test stand at Maritime University Gdynia covers the hydrodynamic operation range, the test stand at University of Applied Science Giessen the mixed friction area. The following conclusions can be deduced:

1. The Acoustic Emission Analysis reacts at both examination areas -the mixed friction as well as the hydrodynamic friction one- without any remarkable delay to the changes of the friction conditions within the bearing clearance.
2. The Acoustic Emission Analysis responses severely to the solid friction processes, which are caused by abrasive particles in the mixed friction areas.
3. The data of the measurement of the bearing temperature, which indicate the friction conditions within the slide bearing, show a huge inertia, because of the heat capacity of the bearing sleeve. The following conclusion can be deduced: as higher the friction at the bearing as higher the transformed energy and therefore the temperature of the sleeve. The temperature depends also on the loose of heat by radiation and convection.
4. All aforementioned details and their conclusions make sure that the Acoustic Emission Analysis has an appropriate field of action in bio-bearings.

Acknowledgement

The present research is financially supported within the frame of the TOK–FP6, MTKD-CT-2004-517226.

References

[1] American Society of Testing Materials, *Standard Guide for Determining the Reproducibility of Acoustic Emission Sensor Response,* American Society for Testing and Materials, USA, pp. 976-94, 2003.

[2] Chao, Zhang, Zixia, Yi, Zhiming, Zhang, *THD Analysis of Higd Speed Heavily Loaded Journal Bearings Including Thermal Deformation, Mass Conserving Cavitation, and Turbulent Effects*. Transactions of the ASME, Journal of Tribology, Vol. 122, pp. 597-602, 2000.

[3] Czichos, H., Habig, K.-H., *Tribologie - Handbuch Reibung und Verschleiß*, Vieweg & Sohn Verlag, Wiesbaden, 2003.

[4] Dwyer-Joyce, R. S., Harper, P., Drinkwater, B. W., *A Method for the Measurement of hydrodynamic Oil Films Using Ultrasonic Reflection,* Springer Verlag, Tribology Letters, Vol. 17 No. 2, pp. 337-348, 2004.

[5] Ma, M.-T., Taylor, C. M., *An experimental investigation of thermal effects in circular and elliptical plain journal bearing*, Tribology International, Vol. 29 No. 1, pp. 19-26, 1996.

[6] Niemann, G., Winter, H., Höhn, B.-R., *Maschinenelemente*, Band 1, *Berechnung und Konstruktion von Maschinenelementen*, Springer, Berlin, 2001.