FATIGUE TEST BEARINGS WITH GEOMETRICALLY MODYFIED SLIDING SURFACE

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Abstract

In the paper a new type of a fatigue test bearing with geometrically modified sliding surface is described. Some of the advantages of these bearings are considered on the bases of comparison to standard solution bearing. Preliminary fatigue test results of the modified bearings are demonstrated and discussed.

1. Introduction

In case of the dynamically loaded journal bearings, fatigue damages can appear when the stresses and strains in the sliding layer are reaching their critical level that is depended not only on the type of the bearing material but also on bearing geometry (e.g. clearance ratio, bearing lining to steel backing thickness etc) and other working parameters.

Recent approach to the bearing processes analysis is based on the model bearing testing combined with the theoretical evaluation of the bearing stresses and strains. Idea of the analysis of the hydrodynamic bearing fatigue properties is presented in the recommendations of the International Standards: ISO 7905/3, ISO 7905/1 [1]. Bearing fatigue strength can be understood as a local load-carrying capacity of the bearing lining for the dynamic mechanical and heat bearing loading, including also the physic-chemical lubricating oil effects. Because of very complex fatigue mechanisms and parameter interrelations, the precise determination of the material fatigue parameters requires the experimental work with the use of specific test stands. Among the stands recommended by ISO 7905 standard, especially effective seem to be MWO machine (with rotating load vector) and SMOK stand (with unidirectional dynamic loadings), shown in the Fig.1 and Fig.2.

Shape and nominal dimensions of half-bearings tested in the MWO and SMOK test rigs at the tribological laboratory of the Gdańsk University of Technology are shown in Fig.3. Two-and three-layer bearing bushes were investigated. The bearings were manufactured by Federal Mogul-BIMET factory at Oliwa.

Nominal total bush wall thickness was of 1.825 mm, while lining thickness was 0.335 μm. Thickness of coating was about 20 μm. Bearing dimensions were as follows: internal diameter D=52.7 mm, bush length L=29.6 mm, assembly clearance ratio within the range of 0.0017-0.0019, surface roughness R_a =0.20 um. Surface parameters of 38HMJ steel shaft were: hardness 60±2 HRC and R_a =0.16 μm. Bearings were lubricated with typical IC engine oil: Selectol SAE 20W/40.

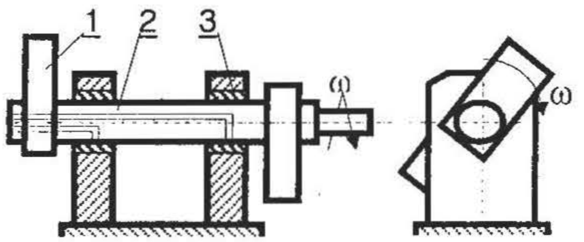

Fig. 1. MWO-stand operational principle, 1 - unbalanced mass, 2 – testing shaft, 3 – tested bearing

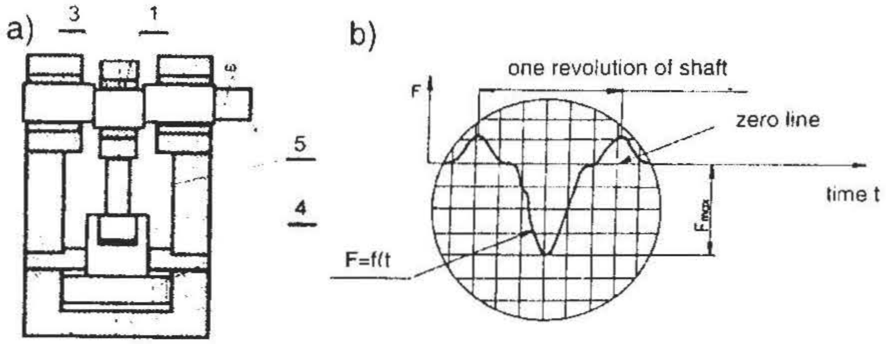

Fig. 2. SMOK-stand operational principle, (a). 1 – tested bearing, 2 – cylinder oil chamber, 3 – eccentric shaft journal, 4 – piston, 5 – connecting rod; (b), typical loading characteristic

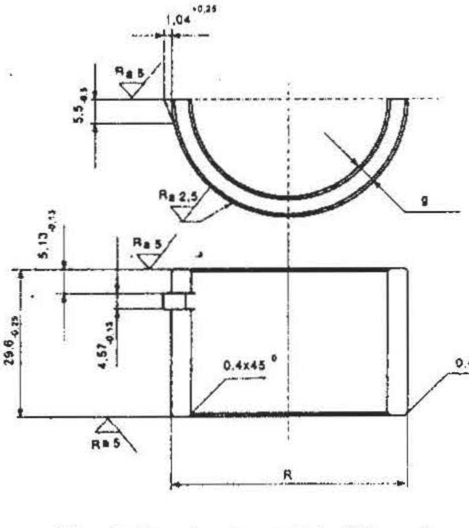

Fig. 3. Standard tested half-bearing

2. Stresses in the bearing shell

- **MWO-test stand**

For any of the radial section of the bush the rotation of the shaft (with unbalanced masses) is producing the same dynamic loading. It is also true that the pressure distribution on sliding surface is the same (in case of the rotational symmetry of the bush shape) for any angular position of the loading vector. The same can be said about stress distribution in the bearing lining.

- **SMOK-test rig**

The oil film pressure distribution (for the device of Fig.2a) on bearing is shown in [2}. The effect of "squeeze action" in the bearing is seen as a substantial reduction in the oil film pressure drop in comparison to MWO machine that results in different circumferential stress ratio in the slide layer of the bearing bush during the loading cycle.

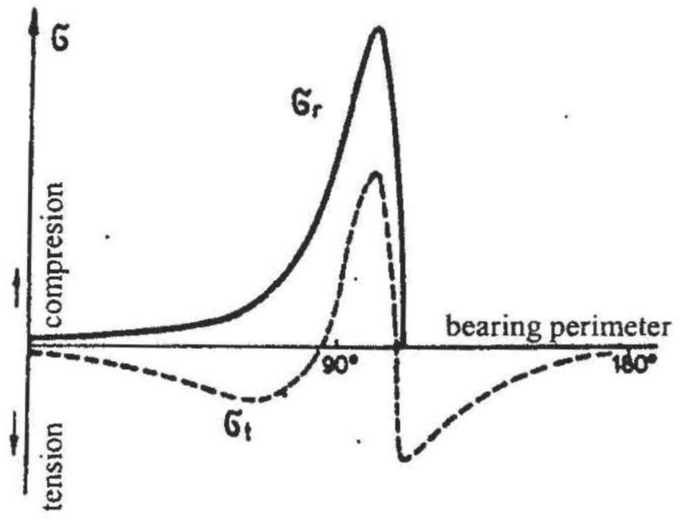

Fig. 4. Distribution of radial σ_R and circumferential stress σ_t in the slide layer of the bearing bush tested in MWO stand

3. MWO and SMOK stands maximum pressure comparison

Investigations with the application of both MWO and SMOK stands allowed noticing the following difficulties in test results interpretations:

- For the same maximum value of loading force, MWO machine is producing more than 2 times smaller maximum pressure in the oil film than SMOK stand. Similar differences are in the critical (damaging) loading force values.
- For the same maximum value of loading force the heat energy dispersed in the MWO tested bearing is much higher than for SMOK bearing. As a result, higher temperature can be observed for MWO bearing.
- Because of the difference in the operating temperature, the seizure load limit for MWO machine may be located at the lower value, in comparison to fatigue load limit, than for SMOK stand. As a result fatigue testing for MWO machine, for standard test bearing, in some cases may be not feasible (Fig.5 and Fig.6).
- The particular area at which fatigue cracks may appear can not be predicted.
- Some irregularities in the oil film shape and dimensions as well as in pressure distributions can occur due to discontinuity of the bearing sliding surface at the half bearing split surface. As a result the fatigue cracks can be localized at this region and can be different than for the perfect cylindrical bearing surface.

It would be advantageous to compensate for these deficiencies. The most of them probably can be eliminated by introducing the modification of the bearing surface geometry of the test standard bearings used in MWO machine. This modification can result in more precisely defined test conditions and less scattered test results.

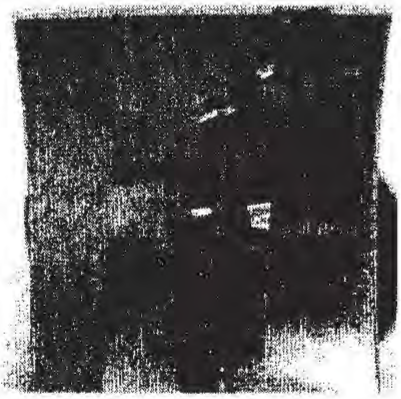

Fig. 5. MB30 bearing after test the seizure limit was achieved under average pressure p=34 MPa

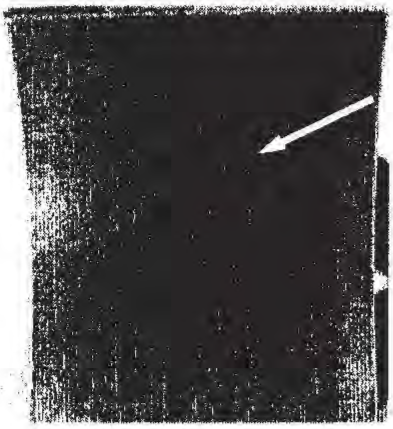

Fig. 6. MB30 bearing after test the fatigue limit was achieved under average pressure p=37.6 MPa

4. Modified bearing

In the Fig.7 and Fig.8 the new test bearing with the geometrically modified sliding surface is presented. The change is introduced by cutting the shell side parts of the bearing with the two inclined planes trough three points: two outer points laying on the split plane and the third at the bearing minimum length.

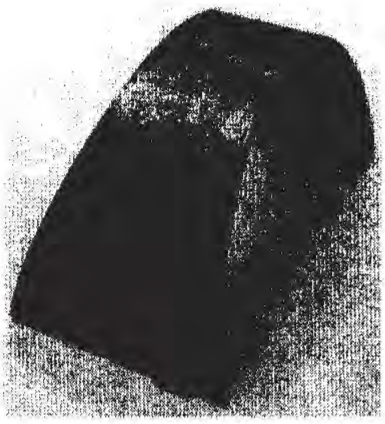

Fig. 7. The picture of the geometrically modified bearing. Minimum to maximum length ratio is 0.5

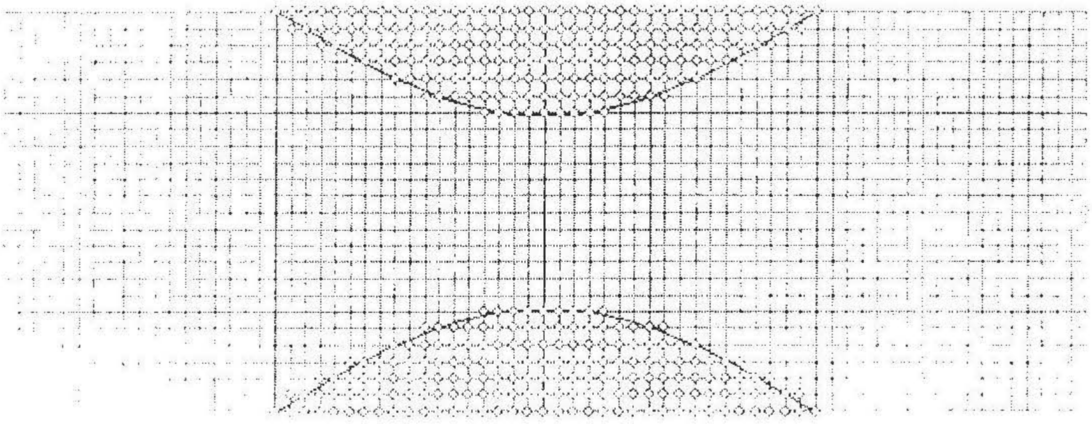

Fig. 8. Development of a geometrically modified bearing

5. Calculation of the maximum pressure

The effect of bearing sliding surface geometrical modification has been estimated by comparison of the maximum pressures, for given load parameters and operational test conditions, for both standard and modified test bearings.

For standard bearing (with uniform length L= 29.6 mm) rotational speed n= 4000 rpm, loading W = 36 kN, the maximum pressure is equal to 96.5 MPa. For the new bearing of modified sliding surface (with the bearing length changing from 29.6 to 14.8 mm) working with the same force loading, the maximum pressure is equal to 321 MPa. These calculation results were obtained for simplified isothermal Reynolds model of journal bearing. In the Fig.9 the change in the eccentricity of the shaft center in the bearing is demonstrated for the new bearing. It is varying from $\varepsilon_1 = 0.85$ to $\varepsilon_2 = 0.94$.

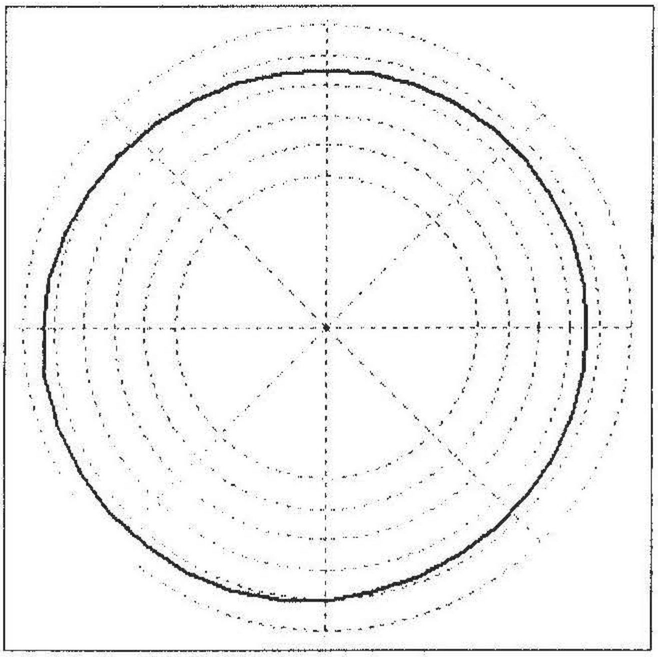

Fig.9. Calculated values of shaft center path ε for rotated force of constant magnitude. Loading force W=36 kN

6. Test results

Bearing material MB 30 has been tested with application of standard shape and modified (new) surface bearing shell. In standard test conditions [3] the critical (damaging) loads where obtained as follows:

- standard shape bearing loading force W_s = 59 kN – Fig.6.
- new shape bearing loading force W_n = 48 kN – Fig.10.

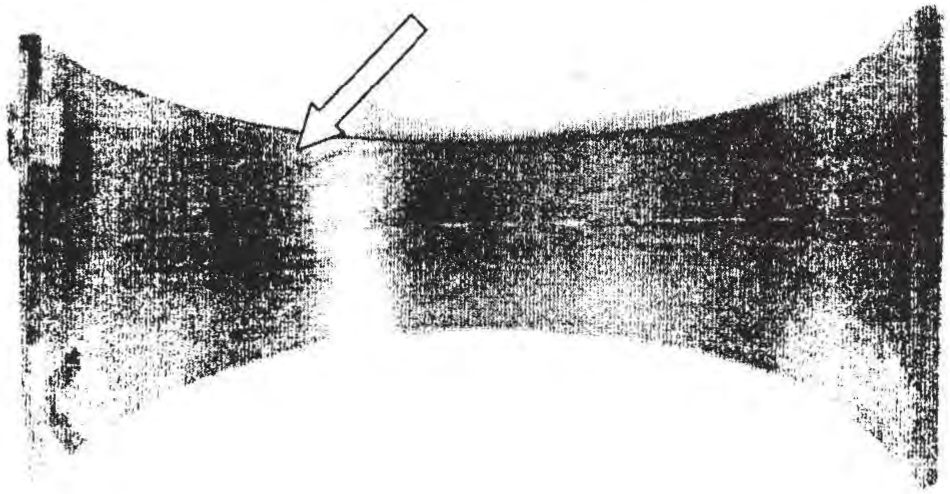

Fig. 10. Fatigue cracks visible on sliding surface of modified bearing. Critical damaging force W=48 kN

7. Conclusions

On the basis of investigations described in the paper the following conclusions can be drawn:

- it is possible to improve the bearing material fatigue strength test for sliding bearing by geometrical modification of sliding surface. In particular this modification seems to be reasonable for application to MWO machine test bearing with rotated loading vector
- by introducing the new bearing it is possible to reduce the critical loading force, lower the maximum temperature and get the position of the damaged area at the desired region of the sliding surface
- there will be better chance to get the fatigue loading limit below the seizure limit of the bearing material

References

[1] ISO 7905/1-4; 1995: Plain bearings – Bearing fatigue: Plain bearings is test rig and in applications under conditions of hydrodynamic lubrication.

[2] Sikora J., Kłopocki J.: Loading pattern effects on fatigue resistance of slide bearing lining. Journal of KONES, Vol 10, No. 3-4, Warsaw 2003.

[3] Sikora J., Kłopocki J., Majewski W.: Testing of fatigue strength limit of slide bearing materials. Journal of KONES, Vol. 10, No.1-2, Warsaw 2003.