LIMITATION OF CRANK MECHANISM BEARINGS WEAR DUE TO THE APPLICATION OF NEW MATERIALS AND TECHNOLOGIES

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Abstract. Results achieved in a course of analytic calculations, experiments and operational tests are used to choose an optimal design of engine crank mechanism bearings. This paper presents the results of operational tests carried out for bearing shells manufactured using new materials, technologies and design.

1. Introduction

When starting and stopping an engine as well as at sudden change in load or velocity an increased wear of the bearing shell running surface occurs which affects the geometry of lubricating gap and the oil film load capacity. In order to reduce the wear as well as to increase the mechanical and fatigue strength and tribological properties, the research that should conform material and technological requirements is carried out. Due to the constant increase in diesel engine performance and extension of its life there is a need for application of new bearing materials, unconventional bearing shell running surface and new technologies of overlay spreading.

The results achieved through a theoretical analysis and those obtained in test stand and run experiments are used for the selection of optimum engine bearing design which reduces the wear.

2. Calculation of hydrodynamic parameters

Results of computations are obtained using the computer programs that enable the determination of bearing basic hydrodynamic parameters. These computations cover following topics:

- bearing load,
- journal center path,
- oil film minimum thickness in lubricating gap,
- lubricating layer maximum pressure,
- bearing run temperature,
- friction power.

The results achieved constitute a basis for the operational reliability assessment of tested bearings. So called specific loads calculated from the load course are compared with the
values admissible for a given bearing alloy. The course of change in the bearing oil film minimum thickness, calculated from the journal center path coordinates, composes a basis for judgment on the kind of friction which occurs between the journal and shell, and their resistance to wear. An exemplary course of the oil film minimum thickness $h_{\text{min}}$ vs. crankshaft angle $\alpha$ has been presented in Fig. 1. The admissible thickness of the oil film $h_{\text{adm}}$ for which fluid-film lubrication becomes the mixed one has been marked in the diagram.

$$d_{\text{bearing}} = 0.61 \text{ mm}, \quad \eta = 0.94 \times 10^3,$$

Material of shell: steel + cost bronze (CuPb23Sn1) + PbIn

![Fig. 1. Course of oil film minimum thickness in a crank bearing of six cylinder diesel](image)

$(P = 101.5 \text{ kW, } n = 2600 \text{ rpm})$

The maximum values of hydrodynamic pressure are utilized for an estimation of required fatigue strength of bearing material as well as for the determination of places particularly prone to fatigue rupture. Fig. 2 presents a diagram illustrating the dependence of admissible maximum hydrodynamic pressure in oil film $(p_{\text{max}})_{\text{max}}$ on the bearing diameter drawn for various bearing materials used for the crank bearings.

![Fig. 2. Maximum oil film pressure vs. bearing diameter for various materials](image)

1 - AlSn20, 2 - AlSn6, 3 - AlZn4.5, 4 - CuPb22Sn, 5 - sputtered AlSn20 [3]

* Assumed for run-in modern engine bearings $h_{\text{adm}} = 1 \mu \text{m}$ [7].
3. Experimental research leading to reduction in bearing wear

Test stand and operational research on application of new bearing materials as well as tests on introduction of unconventional design solutions concerning slide surface of bearing shell and new technologies of manufacturing are carried out in order to increase the resistance to wear of crank mechanism bearings.

Nowadays, inhomogeneous materials with extremely fine matrix are used for dynamically loaded bearings, because only that kind of material can satisfy the contrary requirements regarding bearing material properties and fulfill the tasks put forward. The common feature of all bearing materials produced is a relevant strength of a bond with steel base. It should guarantee a required stiffness of a bearing necessary for proper interference fit that prevents the shell rotation with the rotation of journal. Today, the bimetal and trimetal shells combining various bearing materials, and shells of inhomogeneous composition of slide layer (e.g. rillenlager) or fine-grained slide layer with evenly distributed soft inclusions (obtained by the process of sputtering) are most frequently applied for the engine main and crank bearings.

The test stand experiments allow to evaluate the wear of bearing slide surface and to establish the bearing operation life till the earliest symptoms of its wear. Results of tests carried out for three types of bearings, i.e. trimetal ones (steel + AlZn4.5 + PbSn18Cu2.5; steel + CuPb22Sn + PbSn18Cu2), rillenlager bearings (steel + AlZn4.5 + PbSn18Cu; steel + AlSn6CuNi + PbSn18Cu) and sputtered bearings (steel + AlZn4.5Mg + AlSn20 – sputtered; steel + CuPb22Sn + Ni – sputtered + AlSn20 – sputtered; steel + AlSn20 – sputtered have been presented in Fig. 3. The lowest wear, approximately equal to the journal and shell asperities (reaching 5 μm) and the longest lifetime characterize the sputtered bearing. The rillenlager and trimetal bearings featured an elevated wear reaching 16 μm after a different runtime. The runtime of a rillenlager bearing was three times longer than that of the trimetal bearing.

![Diagram](image)

*Fig. 3. The wear of highly loaded crank mechanism bearings in a research test: trimetal, rillenlager and sputtered one [5]*

*A thin nickel barrier layer is often placed between layer and running surface in order to prevent an overlay material diffusion into, for example lead bronze and to avoid formation of brittle compounds in the contact area of bronze and overlay.*

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Besides the test stand experiments, bearings have been subjected to the run tests as well. The MIBA company of Austria [3] has carried out the run tests with different types of bearings installed in different engines (medium-speed engine, large high-speed engine and engine for commercial vehicles). In the case of commercial vehicle engines different shells have been applied. These shells differed with a type of bearing material and the way the bearing slide surface has been overlaid. The following bearing types have been tested:

- trimetal one (steel + aluminum–zinc + nickel + electroplated overlay – PbSn18Cu2 and steel + cast bronze + Ni + PbSn18Cu2),
- rillenlager one (steel + aluminum–zinc + nickel + electroplated overlay – PbSn18Cu2),
- sputtered one (steel + aluminum–zinc + sputtered AlSn20).

Fig. 4 presents the cross-sections of bearing shells tested.

![Cross-sections of bearing shells](image)

**Fig. 4. Bearing shell cross-section: a) trimetal, b) rillenlager and 3) sputtered ones**

The bearing shells have been installed in an engine of 40 kW cylinder power, running at 2100 rpm. The SAE 15W/40 lubricating oil has been used with the lubricating oil pressure of \( p = 1.5 \text{ MPa}. \) The hydrodynamic parameters of the bearing have been as follows:

- mean specific pressure \( p_{\text{mean}} = 61 \text{ MPa}, \)
- maximum oil pressure in the lubricant layer \( p_{\text{max}} = 380 \text{ MPa}, \)
- minimum lubricant layer thickness \( h_{\text{min}} = 0.8 \text{ \( \mu \)m}, \)
- bearing oil temperature \( t_{o} = 130^\circ \text{C}. \)

Bearing run – time was 500,000 km, and afterwards the shells have been dismantled and thoroughly inspected (see Fig. 5).

The check of sliding surface condition showed: the wear of an electroplated overlay down to a layer of nickel for the trimetal bearing, the wear of running surface down to 8 \( \mu \)m (i.e. a half of nominal groove depth) in a load zone of grooved bearing, the traces of conforming without any visible wear in sputtered bearing (Fig. 5). Results of running tests for a trimetal bearing are as follows: the bearing is not useable due to the lack of failure reserve; further operation means too high risk of seizure. The rillenlager bearing has a sufficient wear reserve and further use is possible for another 500,000 km. In the case of the sputtered bearing - it can be reinstalled without any reservations but estimation of remaining service life is impossible with the current test data

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Fig. 5. Bearing shell sliding surface after 500,000 km: a) trimetal, b) rillenlager, and c) sputtered ones

4. Conclusions

The efforts presented in this paper are aimed at the possibilities of extending the engine bearing life. A reduction in bearing wear can be achieved by the use of new materials, new technologies and new concept of layers and running surfaces. However, it should be remembered that an increase in strength properties does not mean an improvement in tribological properties and ability of mutual conformation of collaborating surfaces of journal and shell.

World bearing producers undertake a research on new kinds of bearing overlay, among others on a lead-tin-ceramic overlay which should assure a substantial increase in wear resistance without any load capacity drop, and is to be applied both in rillenlager and trimetal bearings. On the other hand, experiments are being lead on a new generation of bimetal aluminum bearings purposed for medium and heavy load engines. Properties of these bearings should be similar to those of trimetal ones while the price should be equal to the price of a bimetal bearing.

Bearing shells for modern engines are made according to technologies and of materials that assure longer service life and better engine performance.
References


OGRANICZENIE ZUŻYCIA ŁOŻYSK MECHANIZMU KORBOWEGO DZIEKI ZASTOSOWANIU NOWYCH MATERIAŁÓW I TECHNOLOGII

Streszczenie. Wyniki uzyskane w toku obliczeń, badań stanowiskowych i eksploatacyjnych wykorzystywane są do optymalnego zaprojektowania łożysk ślizgowych mechanizmu korbowego silnika spalinowego. Niniejszy artykuł przedstawia wyniki badań stanowiskowych i eksploatacyjnych przeprowadzonych dla łożysk zaprojektowanych zgodnie z najnowszymi tendencjami i wykonanych z nowych materiałów, według najnowszych technologii.

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