EFFECTS OF LOADING PATTERN AND LUBRICANT PRESSURE INFLUENCE ON BEARING ALLOY FATIGUE CHARACTERISTICS[1]

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Abstract

In the paper the fatigue test results of the bearing alloy(AlSn 11,3, Cu 1,2), deposited on a steel backing strip, have been presented. The test samples – in the form of the flat cantilever beam immersed in the lubricant being under pressure – has been subject to the bending dynamic load. Tests were performed with the application of the SKMR-1 fatigue tester that has been built at the Gdansk University of Technology. Limit stress values in bearing strip lining has been evaluated for different loading conditions: pure bending, bending with superimposed constant or variable oil pressures.

1. Introduction

Standard ISO 7905/1 [1], obligatory since 1995, is determining the testing fatigue procedure of hydro-dynamically loaded slide bearings. Because of the fatigue process complexity the material basic fatigue parameters data can be gained mainly by experimental investigation with application of laboratory testers of different level of complexity, different test conditions and methods of experimental results processing. In order to harmonize the test results obtained for the same bearings but different laboratory testers it is necessary to built up the calculating models allowing for evaluation of equivalent stress generated in the bearing lining. At tribological laboratory at Gdansk University of Technology some experiments were performed to find out the interrelations between bearing design (geometry and material), bearing working conditions (nominal pressure on bearing lining and loading pattern, type of lubricant and bearing temperature, sliding velocity etc), and the bearing fatigue strength.

2. Investigation programme and procedure

Investigation has been planed as a verification of the opinion that fatigue strength of bearing material is dependent on the constant or fluctuating pressure effects added to the fluctuating bending stress exerted in the bearing lining.

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- **Tester**

Tester SKMR-1 (Fig.1) has been designed and built according to ISO standard 7905/3 [2] requirements established for testing of the fatigue strength of flat multilayer bearing material strips being at the combined effects of lubricant pressure and fluctuating bending stress. It is possible to control the amplitude and mean value of the bending load as well as the maximum and minimum values of the lubricant pressure. Test specimen (1) is kept in the not moving fixture (2) and loaded in cycles – in a kinematics way. The end of the specimen is being moved so the stresses in it are related to bending deformation of the strip. Desired amplitude of bending stress is obtained due to control of eccentric position of the element (5).

During the test the specimen is immersed in the lubricating oil of specific temperature and pressure. Bending stress is measured by strain gouge system or calculated [3]. The state of the specimen surface is evaluated by micro scoping observations after taking the specimen out from the tester.

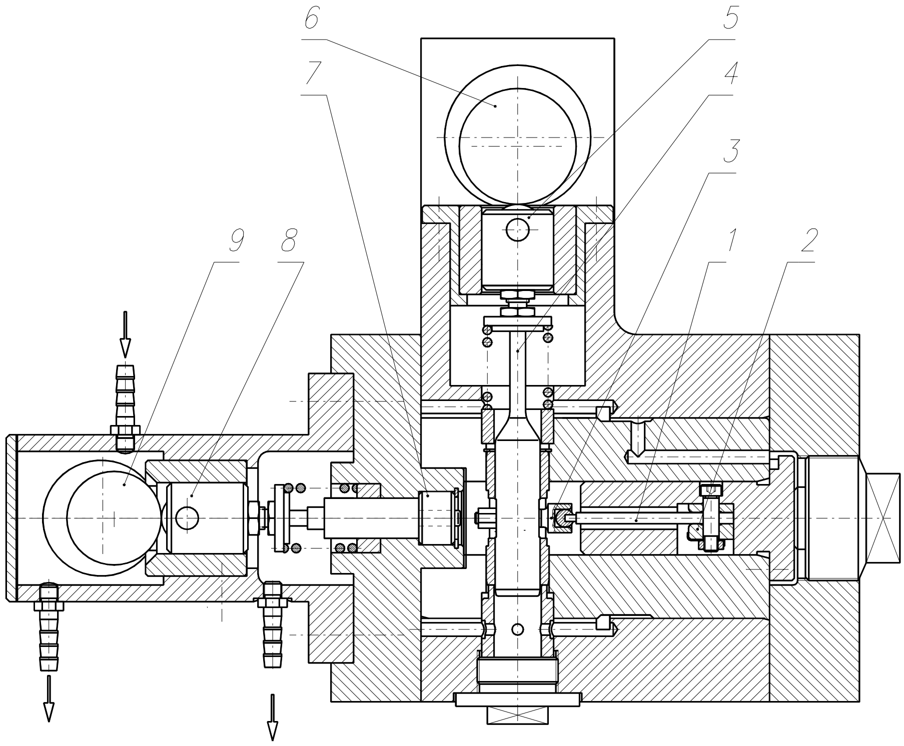


Fig. 1. Scheme of SKMR-1 tester head unit
1 - specimen, 2 - specimen fixture, 3 - movable specimen fixture, 4 - pusher, 5 - roll follower, 6 - eccentric, 7 - pressure generator, 8 - cam follower, 9 - eccentric

- **Test specimen**

Shape and dimensions of the specimen (Fig. 2.) is determined in the ISO 7905/3. It has been produced from two layer sliding strip being a intermediate product for thin half bearings. The total thickness of the strip was about 1,825 mm. Sliding layer part of the tape, having the thickness of about 0,390 mm was made of the alloy: 87,5% of Al, 11,3% of Sn and 1,2% of Cu. Sliding surface roughness was R_a=0,20 um.

- **Test parameters and design of experiments**

Test conditions and loading parameter were adopted according to the procedure of endurance limit determination for SKMR-1. Appearance of the fatigue cracks after basic number of loading cycles, visible as a net of scratches on the sliding surface was considered as reaching the endurance limit for the bearing alloy. Destructive stress amplitude value was to be determined for reversed stress (cycle coefficient of asymmetry was equal to $R=\sigma_{min} / \sigma_{max} = -1$). Tests were performed with rotational speed n=1500 rpm (forced vibration frequency – 25 Hz) and the duration of test was 40 hours ($3,6 \times 10^6$ cycles of loadings). The test specimen chamber has been filled with lubricating oil Selectol Special SAE 20W/40 delivered to the chamber under constant or dynamic pressure. During the investigation the chamber oil has to be cooled intensively. “Two points” method was applied for planning the experiment procedure as well as for test result processing [4]. The method is allowing for reliable determination of the statistic estimators for endurance limits of tested sliding layers.

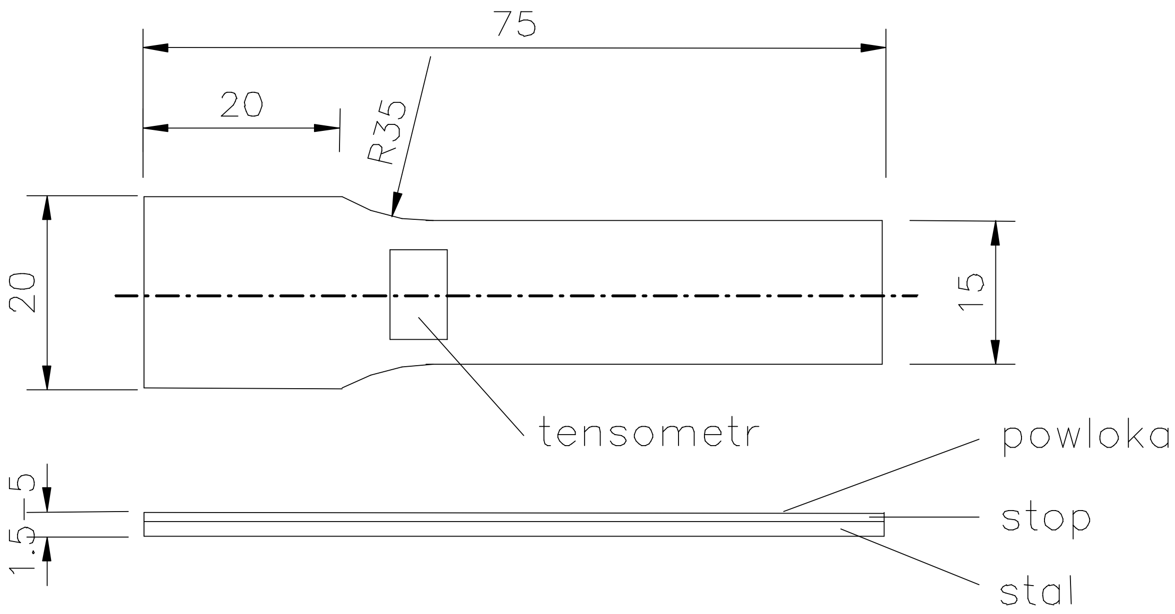


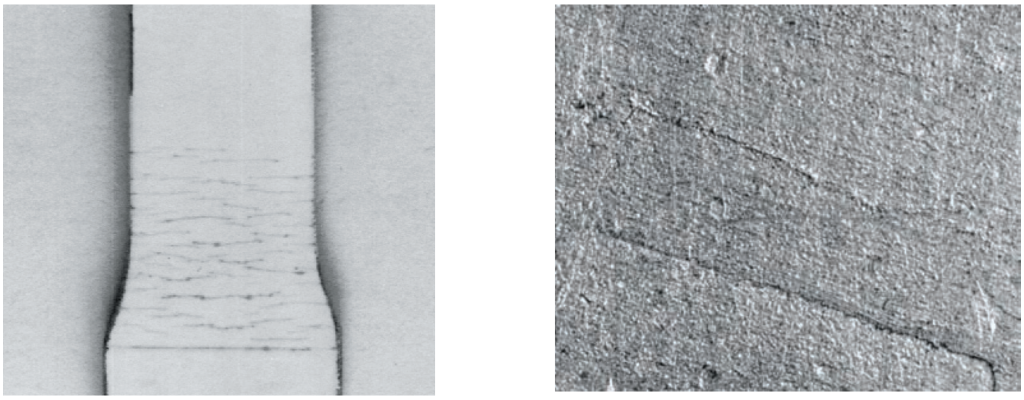
Fig. 2. Plain strip specimen according to ISO 7905/3

3. Test procedure and test results

Three series of fatigue tests with the use of SKMR-1 tester were performed:

- investigation with reversed symmetrical bending (specimen deflections) and without chamber oil pressure,
- investigation with reversed symmetrical bending specimen deflections and with constant value (550 bars) of the chamber oil pressure,
- investigation with reversed symmetrical bending specimen deflections and sinusoidal fluctuating chamber oil pressure defined as mean pressure p_m=550 bars and amplitude pressure p_a=150 bars. Fluctuation of the oil pressure has been realized by piston type generation assuring synchronization of the maximum bending stress and maximum pressure in the chamber.

The number of tested samples has been kept between 14 and 17 in one serie. Starting loadings at the beginning of a series has been selected randomly since the level of critical stress were not known. The result of each test has been evaluated according to assumed definition of boundary state of sliding layer. In order to increase accuracy of classifying the specimen to the group pf damaged samples, the appearing of cracks have been checked with the use of penetrant SPOTCHECK-SKL-SP Magnaflux –three component substance was applied. A specimen after test that has brought cracks about and treated with penetrant is presented in the Fig.3. The sliding surface damage is demonstrated by appearance of red strips on the white background. The bigger is the damages the higher is red color intensity. Magnification of the picture is shown on Fig. 3b. It is also possible to observe the cracks with the microscope (Fig.4). Fatigue cracks are always placed perpendicularly to the longitudinal axis of the specimen i.e. in direction of normal bending stresses in critical section. This cracks are usually short and not regular – what is making them different from the cracks observed on the half bearing shells tested in the bearing test stands [5]. Next figures are showing normal sections of flat samples that were damaged because of fatigue loading. The cracks are developed only in bearing alloy layer (Fig.5) or can go up to the steel backing strip (Fig.6) and are normal to the sliding surface and to the normal stress generated in the sample in the region of the maximum nominal stresses.



a) *b) (enlargement. 25x)*

Fig. 3. View of flat specimen fatigue damages after treating with dye penetrant

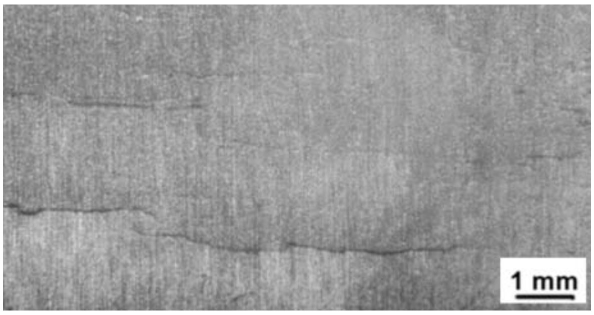


Fig. 4. Microscopic view of flat specimen surface (enlargement 10x)

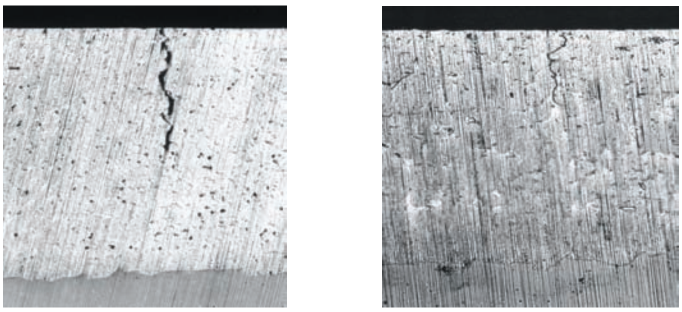


Fig. 5. Fatigue surface cracks in flat specimens (cross-section)

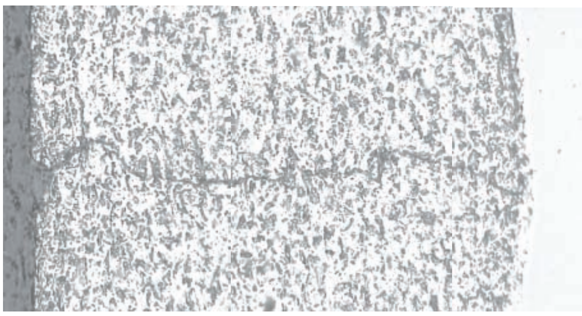


Fig. 6. Fatigue crack of alloy layer (cross-section, enlargement 300x)

4. Statistic test result processing

Test results were processed statistically with application of the worked out procedure [4]. Boundary stress amplitude standard deviations of stresses and “95% confidence” intervals are presented in the table 1.

Table 1. Test results for flat specimen obtained with the use of SKMR-1 device

Selected statistic		Test series		
		without lubricant pressure	with lubricant constant pressure	with lubricant pressure pulsation
Boundry stress amplitude	$S_{0,50}= \sigma_A$ [MPa]	48,4	59,6	58,9
Standard deviation	$s_{\sigma A}$ [MPa]	1,226	1,141	1,293
95% confideace interval	[MPa]	$45{,}9<\sigma_A<50{,}8$	$57{,}0<\sigma_A<62{,}2$	$56{,}3<\sigma_A<61{,}5$

5. Result evaluation

Effects of chamber lubricant pressure on endurance limit of the sliding bearing material visible in the table 1, can be also set up as in the Fig.7.

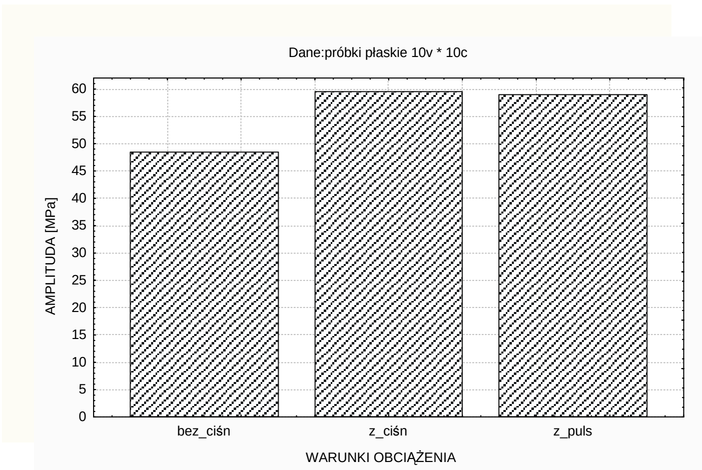


Fig. 7. Influence of loading conditions on stress limit amplitude in tests performed in the SKMR-1 tester

The lowest boundary fatigue stress was obtained for sliding layers that were subject to pure dynamic bending without additional action of chamber oil pressure. In case bending stress is superimposed on the hydrostatic oil pressure of the 500 bars (at least) the increase in sliding bearing alloy fatigue resistance of about 20% was observed. It might be the effect of the change in equivalent compression stress (addition of compression stress resulting from bending to the pressure). Similar effect can be seen when dynamic bending stresses are superimposed on the effects of lubricant pulsating pressure (550 ± 150) bars. There is a significant statistic difference between the first and other series of test results at the level of α=0,05. On the other hand the difference between second and third series of test results can not be stated. It might happen because the lubricant pressure pulsation (±150 bars) value is two low to change the fatigue process. Increase in the oil pressure amplitude and change in the pressure cycle phase can help to analyse the process better.

6. Conclusion

In case the tested bearing material is subject simultaneously to normal (bending) stress and surrounding lubricant pressure the critical fatigue bending stresses are changing. It will probably be important fact that should be taken into account when the life of the sliding bearing are to be predicted on the bases of experimental investigation performed on the bearing test stands. Therefore the most reliable result are obtained with the application of the laboratory stand when the oil pressure film is generated in a model tested bearing.

References

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[2] ISO 7905/3:1995 Plain bearings - Bearing fatigue - Part 3, Tests on plain strips of a metallic multilayer bearing material, 1995.

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