The 5rd International Conference on
"Computational Mechanics and Virtual Engineering"
COMEC 2013
24 – 25 OCTOBER 2013, Brasov, Romania

THE INFLUENCE OF PRINCIPAL FACTORS WITH WORKING CONDITIONS FOR HIGH SPEED BEARINGS

Traian BOLFA[1]
[1]*Transilvania* University of Brasov, Brasov, ROMANIA, e-mail: t.bolfa@unitbv.ro

Abstract: *There are big differences between the bearings working at standard speeds and those working at high speeds. Additional effects determined by the speed increase negatively influence the limits of speed.*
Keywords: *high speed bearings, moment of friction in bearings*

1. INTRODUCTION

The bearings speed increase over the limits which are considered “usual” negatively influences the durability by some significant changes of kinematics, dynamics and lubrication. Centrifugal forces intervene, friction forces significantly change, starvation phenomena appear, as well as specific vibrations and noises.
There is an obvious necessity to make some thorough research referring to the issue of bearings working in difficult conditions (high speeds), to elucidate some controversial aspects regarding bearings deterioration, to find new, constructive solutions for achieving reduced friction regimes, to design and manufacture some equipment for bearing testing.
The type and evolution of bearing deteriorations depend on the following factors: material factors (structural homogeneity and chemical composition); constructive factors (shape and dimensions); technological factors (technological operations and regimes, execution precision, control conditions); assembling factors; exploitation factors (load, speed, lubrication, temperature, tightening).

2. THEORETICAL AND EXPERIMENTAL ASPECTS

In order to test the bearings a stand was designed and made having the following technical characteristics: maximum speed, 36000 RPM, with continuous control; maximum radial load, 5000 N; maximum axial load, 1000 N; bearings range used for tests is 20 – 85 mm on the inside, 42 – 130 mm on the outside and with widths of 12 – 22 mm.

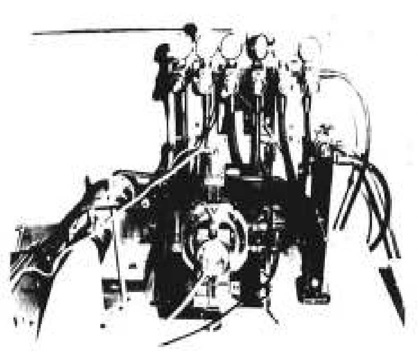

Fig. 1

In Figure 1 and Figure 2 the stand for testing bearings at high speeds is presented. It is made up of testing head, intermediate broach, driving unit, lubrication installation, loading system, electrical installation and frame. The main controlled parameters for characterizing the working of bearings are: speed; temperature, moment of friction; lubricant film thickness.

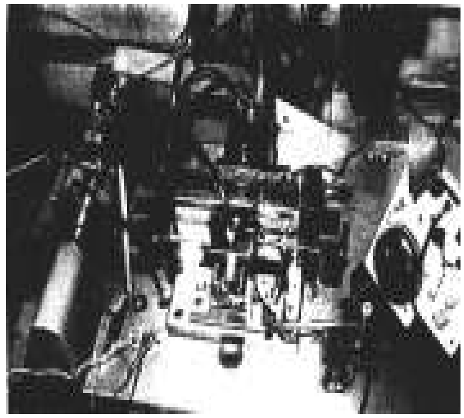

Fig. 2

In order to measure the shaft speed, a photocell transducer was used and to measure the cage speed, a ***Hall*** type magnetic transducer was used. In order to measure temperatures, thermocouples are used mounted in different points of the tested bearing area, coupled at temperature detector adaptors. To measure the moment of friction in the bearing, tensometric transducers are used, mounted on an elastic, gauged lamella controlled by a lever system which forms one piece with the outer part of the bearing (Figure 2 and Figure 3).
All the signals gathered by different transducers are stored, analyzed and processed in electronic equipment which includes a decoder coupled on a computer.
Experimental tests are used for testing ***6306 MAUP*** type radial ball bearings for different types of turbochargers.
Experiments showed that at high speeds the cage has a decisive role in the number of failures (the cages were made of brass).

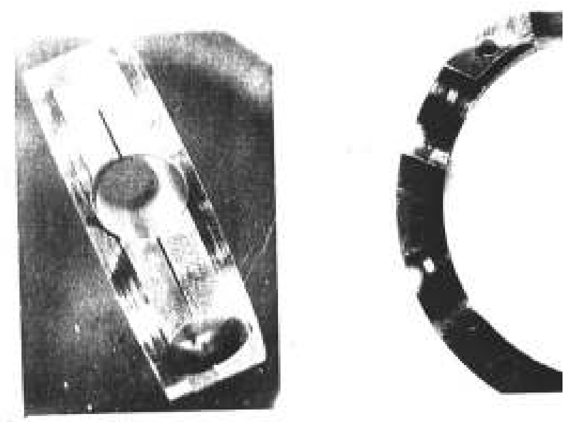

Fig. 3

The repeated knockings between the rolling elements referred to as energy generation and dissipation phenomena lead to an acceleration of the cage oscillations on the direction of the rotation movement and, at the same time, to the loss of stability in the cage movement. In Figure 3, obvious traces of wear can be noticed on the cage leading shoulders as well as in the ball seats.
The limit speed depends on the bearing type, size, inner structure, on the load, lubrication, cooling, working clearance, and cage material, as well as structure (Figure 3).
At the level of contacts between rolling bodies and bearing races, the EHD lubrication conditions are respected (1.3 GPa, contact pressures, 10 – 70 m/s peripheral speeds). At the level of contacts between cage and rolling bodies, the lubrication regimes vary (limit, mixed, etc.)

In accordance with Figure 4, the *EHD* is characterized by the presence of a *h* thick central faceplate which contracts at *h* value because the pressure distribution changes and a pressure peak appears in the exit area.
During practical applications, at directed contact, the minimum h_{min}, lubricant thickness is important, as well as the h_0 central thickness at the faceplate level:

$$h_0 = 2{,}04 \cdot R_x \cdot U^{0{,}74} \cdot G^{0{,}74} \cdot W^{-0{,}074} \cdot \left(1 + \frac{2R_x}{3R_y}\right)^{-0{,}74} \tag{1}$$

where the three parameters (of speed, material and load) are calculated in accordance with relation (1).
The film parameter, λ is of practical interest and it is defined with the relation:

$$\lambda = \frac{h_{min}}{\sqrt{\sigma_1^2 + \sigma_2^2}} \tag{2}$$

where σ_1, σ_2 are the square average deviations of the roughness heights on the two surfaces in contact. At very high speeds, the film thickness considerably reduces because of the starvation phenomenon, as well as of the heat effects. The phenomenon is characterized by the fact that the trace left by the rolling body in the lubricant layer on the bearing race does not have time to recover until the next rolling body passes. When the lubricant film thickness is reduced, several types of lubrication regimes can be used for a bearing depending on λ (for $\lambda \geq 3$, the complete EHD regime is obtained).

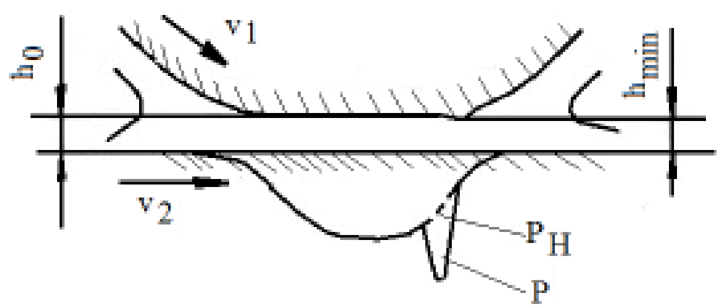

Fig. 4

Starting from the deficiencies noticed during the speed tests for **6306 MAUP** bearings, used for turbochargers, groups of changed bearings were made as follows: the cage clearance was increased from 0.3 mm to 0.4 mm, 0.5mm respectively; the ball seat diameter was changed from 12.1 mm to 12.3 mm, 12.25 mm, respectively; the cage was centered on both rings; the number of balls in bearing was changed from 7 to 8. A higher clearance is the consequence of the cage degradation in contact with the outer ring collar. The radial clearance increases, the moment of friction decreases with about 5 – 10 %, as well as the ring temperature and the cage instability is maintained. Consequently, the lubrication in the ball seats of the cage was improved and other constructive changes were made, with circular channels in the ball seats or with longitudinal channels.
For a further improvement of the lubrication between the cage and the outer ring collar, lubrication holes were made in the outer ring too.
The changes were positively found in the measured parameters leading to the decrease of frictions by improving lubrication.

3. CONCLUSIONS AND RECOMMENDATIONS

There are substantial differences between the bearings working at normal speeds and those working at high speeds. The supplementary effects caused by the speed increase (centrifugal forces, gyroscopic movements, additional frictions) unfavorably influence the speed limits.

The role of the lubricant in maintaining reliability at high speeds is decisive both by accomplishing the EHD film and by controlling thermal effects.
By measurements on ***TALYROND*** an uneven wear on the circumference was evidenced; wear was evident only on certain sectors.
Following the contamination of the lubricant with wear products, an exaggerated increase of temperatures in the tested bearing resulted, and the moment of friction increased.
Starting from these deficiencies of the cage, experimentally determined, the design of some changed bearings was necessary. A series of changes were made for the tested ***6306MAUP*** bearings.
Following the analysis of the research results, the conclusion is that the model which provides a minimum moment of friction at the whole range of speeds and at high speeds corresponds to the type of bearing characterized by the presence of longitudinal lubrication channels in seats and of holes in the outer ring.

REFERENCES

[1]. Bolfa T., *Ph D. Thesis*, Iasi, 1991.
[2]. Gafitanu M., *Rulmenti* vol. I and II, Ed. Tehnica, Bucuresti, 1985.
[3]. Olaru D., *Fundamente de lubrificatie,* Ed. Gh. Asachi, Iasi, 2002.