ANALYSIS OF SURFACE TOPOGRAPHY OF SLIDE JOURNAL BEARINGS AND MICRO-BEARINGS

Andrzej Miszczak

Gdynia Maritime University
Faculty of Marine Engineering
Morska Street 83, 81-225 Gdynia, Poland
tel.: +48 58 6901348, fax: +48 58 6901399
e-mail: miszczak@am.gdynia.pl

Abstract

In this paper, the author presents the results of measurements of the slide journal bearings and micro-bearings sleeves and journal surfaces. The study was performed with the atomic force microscope (AFM) NT-206. The results of measurements of surface topography are presented in the form of a 2D and 3D map of surface topography and also in the form of profiles for selected cross-sections of examined surfaces. Additionally, the height distributions of surface roughness are presented. The Atomic Force Micsroscope NT-206 allows investigating the surface of sample with maximum scanning area 32μm x 32μm and with the maximum value of roughness ±1μm. The measurements can be carried out in three modes: static (contact) mode, dynamic (non-contact) mode, dynamic intermittent mode. The author used the contact mode. The application of this mode of operation, in the case of samples with a hard surface, for example, the journal of a bearing, enables to obtain a good mapping of the measured surface. The presented in this paper results of surface topography measurements, include the calculated values of the R_a *and* R_q *parameters and also the maximum value of the distance between the lowest and the highest surface inequality. The obtained results allow evaluating the amount and type of wear of researched elements in the micro-scale and they also are useful in the design of such surface layers of co-operating components, in order to obtain optimum tribological properties. When considering the impact of the surface roughness on the change of height of bearing gap, and consequently the change of flow and operating parameters, the information about average distribution of roughness value is required. With such measurements, it is possible to obtain these data. In the presented research the micro-bearings from personal computers hard drives, as well as classic bearings and sleeves, were investigated.*

Keywords: *surface topography, atomic force microscope, static contact mode, height distributions of surface roughness*

1. Introduction

Surface topography has a significant impact on the operating conditions of sliding friction pairs. The height of the roughness of sliding surfaces of slide journal bearings is in the range from several nanometres to hundreds of micrometres. Of course, this is due to differences in the size of the sliding surface, their purpose and the method of treatment. During the flow of a lubricant in the bearing lubrication gap, the surface roughness height, its distribution or also the surface anisotropy, have an important impact on the conditions of such flow.

When performing the design calculations on the flow and operating parameters of bearings with a small diameter (e.g. from 1 mm to 50 mm), one should take into account the impact of roughness height on the lubrication gap height changes of such bearing. In the Reynolds equation, the height of the oil film occurs in the third power, therefore the change in this height strongly influences on the flow and operating parameters of the slide journal bearing. Such an effect may be taken into account, inter alia, by using the stochastic method [1, 3, 4]. This method involves determining the probabilistic expected value operator on the pressure and bearing gap height function occurring in the Reynolds equation [4]. To perform these random procedures, it is necessary to find the probability density function for abovementioned quantities. This function can be determined from the measured distribution of surface topography ordinates and the distribution of roughness tops on the sliding cooperating surface [4].

The measurements of the ordinates of surface topography with a significant height of roughness tops can be performed on the contact or contactless profilometers. If the roughness heights are lower, the surface topography can be measured with the atomic force microscope.

The aim of this work is to measure the ordinates of surface topography of the slide journal bearings and micro-bearings sleeves and journal, including an analysis of the obtained results.

Measurements of surface roughness tops in nanoscale can be executed with atomic force microscope. In researches, the author of this paper used the Atomic Force Microscope NT-206 (see Fig. 1) produced in MTM in Minsk, Republic of Belarus.

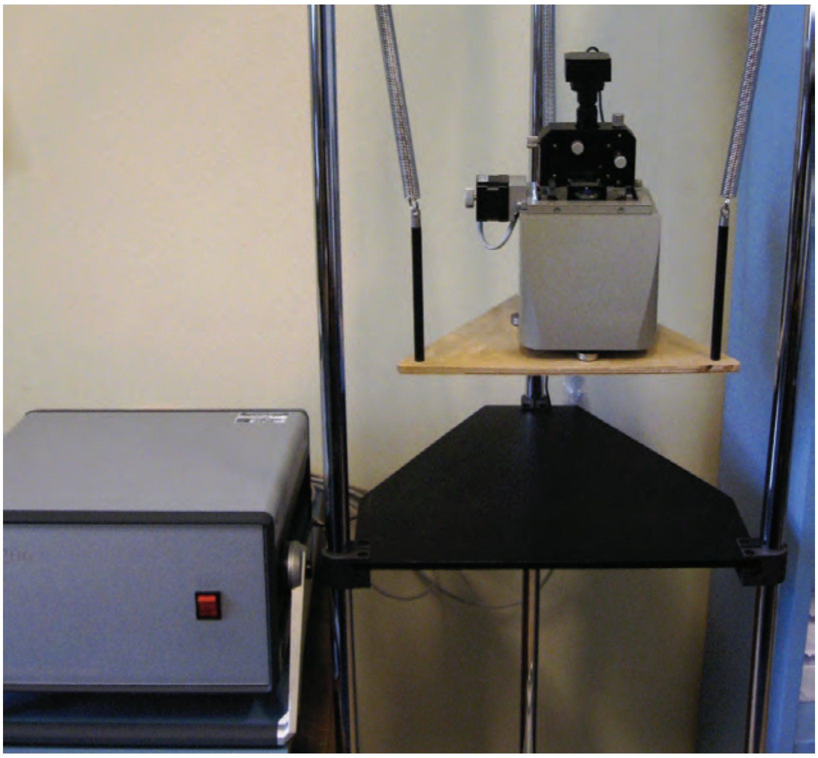


Fig. 1. Photo of atomic force microscope NT-206

The Atomic Force Microscope NT-206 enables to measure samples with maximum roughness value ±1μm. Maximum field in one scanning process is up to 32μm x 32μm. Measurements were proceeded with resolution 256x256 points. The scanning process was performed in a static (contact) mode [2].

The surface topography measurements were made for the new and used journal and sleeves of slide journal bearings and micro-bearings. The obtained results allow evaluating the amount and type of wear of the investigated sliding surfaces.

2. The measurements of surface topography

There is shown the surface topography of the non-used as well as used sliding bearing's classical bimetal sleeves with a diameter of 45 mm on the Fig. 2. Fig. 2a presents the 2D and 3D views as well as cross-section and height distribution of surface roughness for the new, non-used bimetallic sleeve while in the Fig. 2b shows the same 2D and 3D views, cross-section and height distribution of surface roughness for the used one.

There is shown the view of the sleeve's surface obtained from the camera placed in the AFM is in Fig. 3. Fig. 3a shows the scanning area and the tip while scanning the non-used sleeve's surface in under the laser is switched off. In turn, in Fig. 3b is shown a view of the used sleeve's surface while the laser is activated. On this photograph are visible the micro scratches formed as the resulting

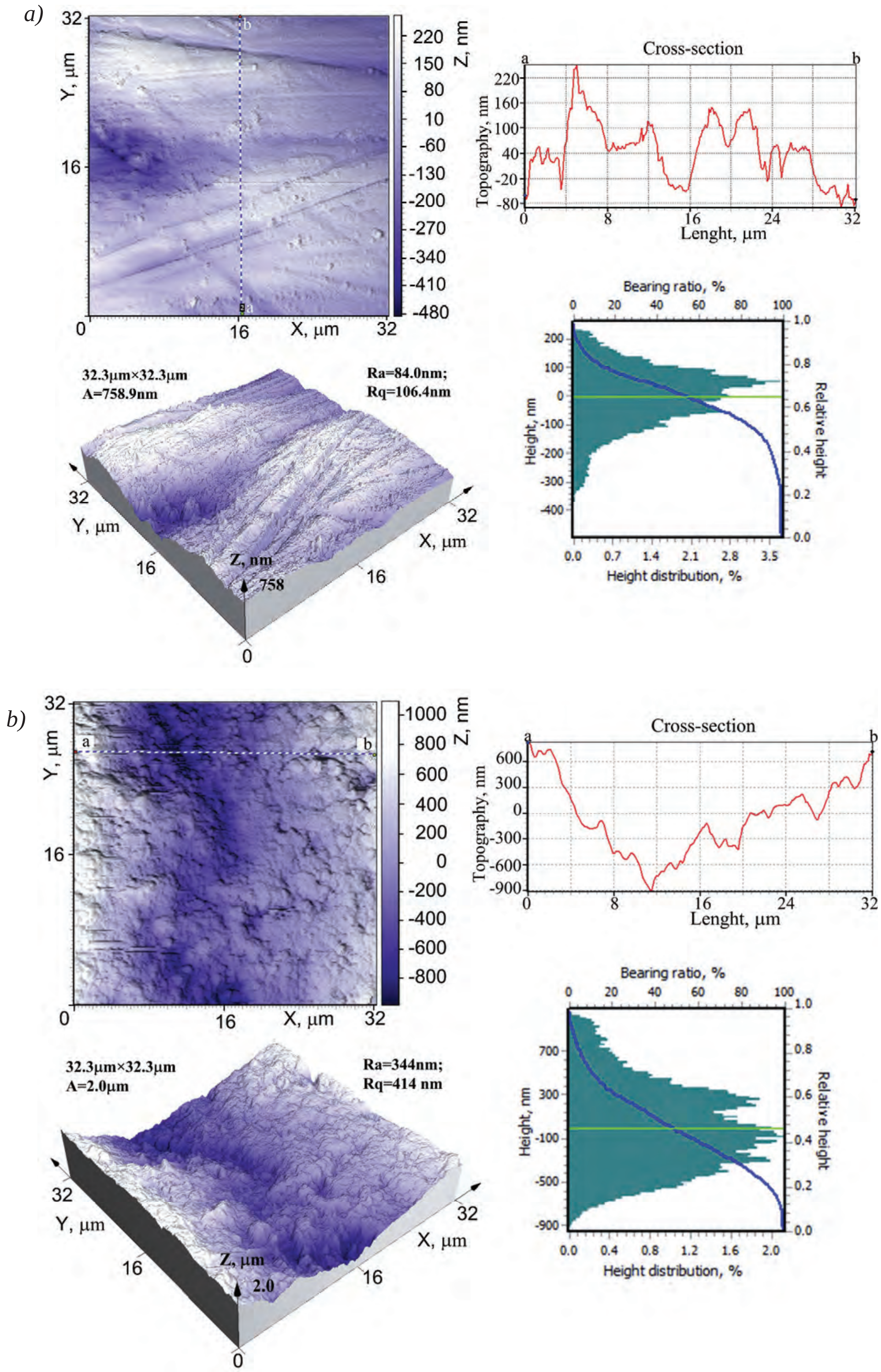
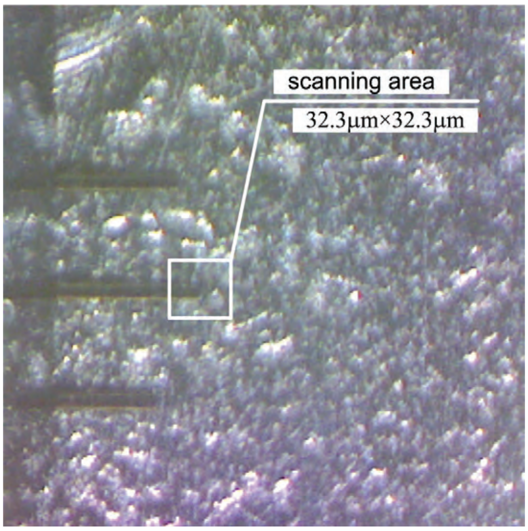


Fig. 2. Surface topography of bimetallic bearing sleeve – 2D, 3D view and cross-section and also height distribution of surface roughness, for non-used bearing sleeve (a), and used bearing sleeve (b)

of the hard inclusions presence contained in the lubricating oil. Surface area shown in Fig. 2a contains such a micro-scratch. Its height and width can be determined on the basis of cross-section shown on the right side of the Fig. 2b. The width of micro-scratch is about 30µm and its depth about 1.5 µm. It is not possible to measure using the atomic force microscope for the wider and deeper scratches. In such a case, the measure should be performed by profilometer.

a)



b)

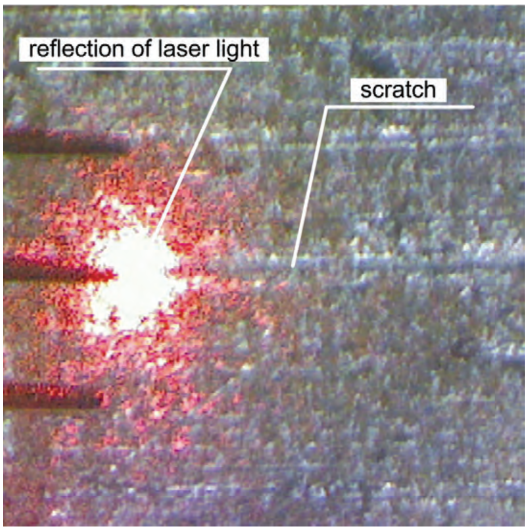
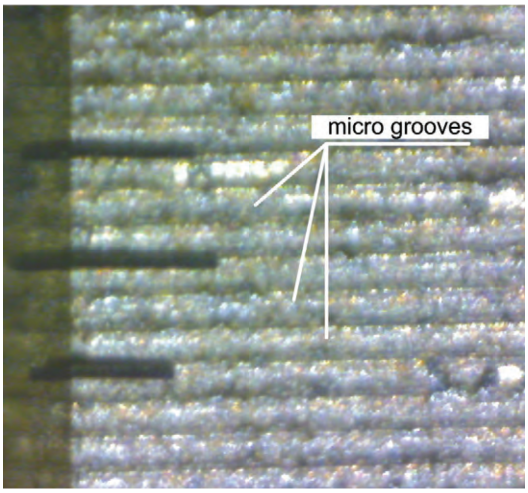


Fig. 3. AFM camera view of the sleeve's surface: scanning area and the tip scanning the non-used sleeve surface (a), and scanning area of the used sleeve surface (b)

Another sleeve subjected to AFM study was sliding sleeve made of bronze with a diameter of 100 mm. There are visible the regular micro-grooves at the surface of the non-used sleeve which correspond the tool treated that surface. The height difference between the top and the bottom exceed often 2 µm. The width of such micro-tip (micro-groove) reached 30-40 µm. There are visible worn micro-tips and micro-scratches on the surface of the used sliding sleeve caused by solid particles contained in the lubricating oil (see Fig. 4a and 5a).

a)



b)

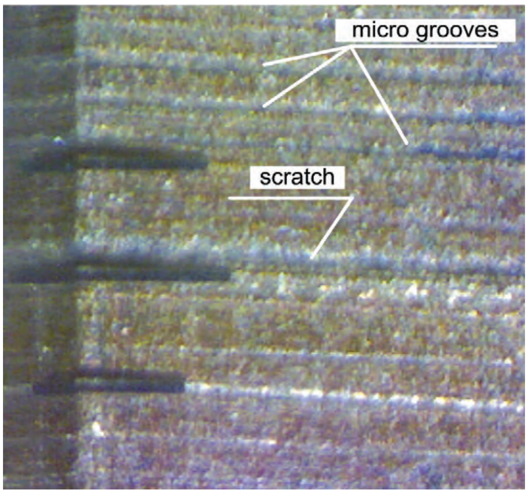


Fig. 4. AFM camera view of the sliding sleeve surface: non-used sleeve surface (a), and used sleeve surface (b)

Figure 5a shows the topography of the non-used sliding sleeve surface and in Fig. 5b there is shown the topography of the used sliding sleeve surface area.

Figure 6 shows the topography of the used sliding sleeve surface area in close proximity of the scratches.

The surface topography of non-used and used sliding micro-bearings applied in 3.5" HDD are shown in Fig. 7 and 8. In particular, case Fig. 7a shows the test surface of the non-used sleeve. Moreover, Fig. 7b shows the topography of the used sleeve surface. Surface topography of disused journal applied in 3.5" HDD is presented in Fig. 8a. Fig. 8b presents the same journal after 8500 hours of continuous operation. Surface roughness specified by R_a indicators for both journal and sleeve of new micro-bearings is in the range 18-41 nm, but for the used micro-bearings Ra index value is higher, and reaches 42-93 nm.

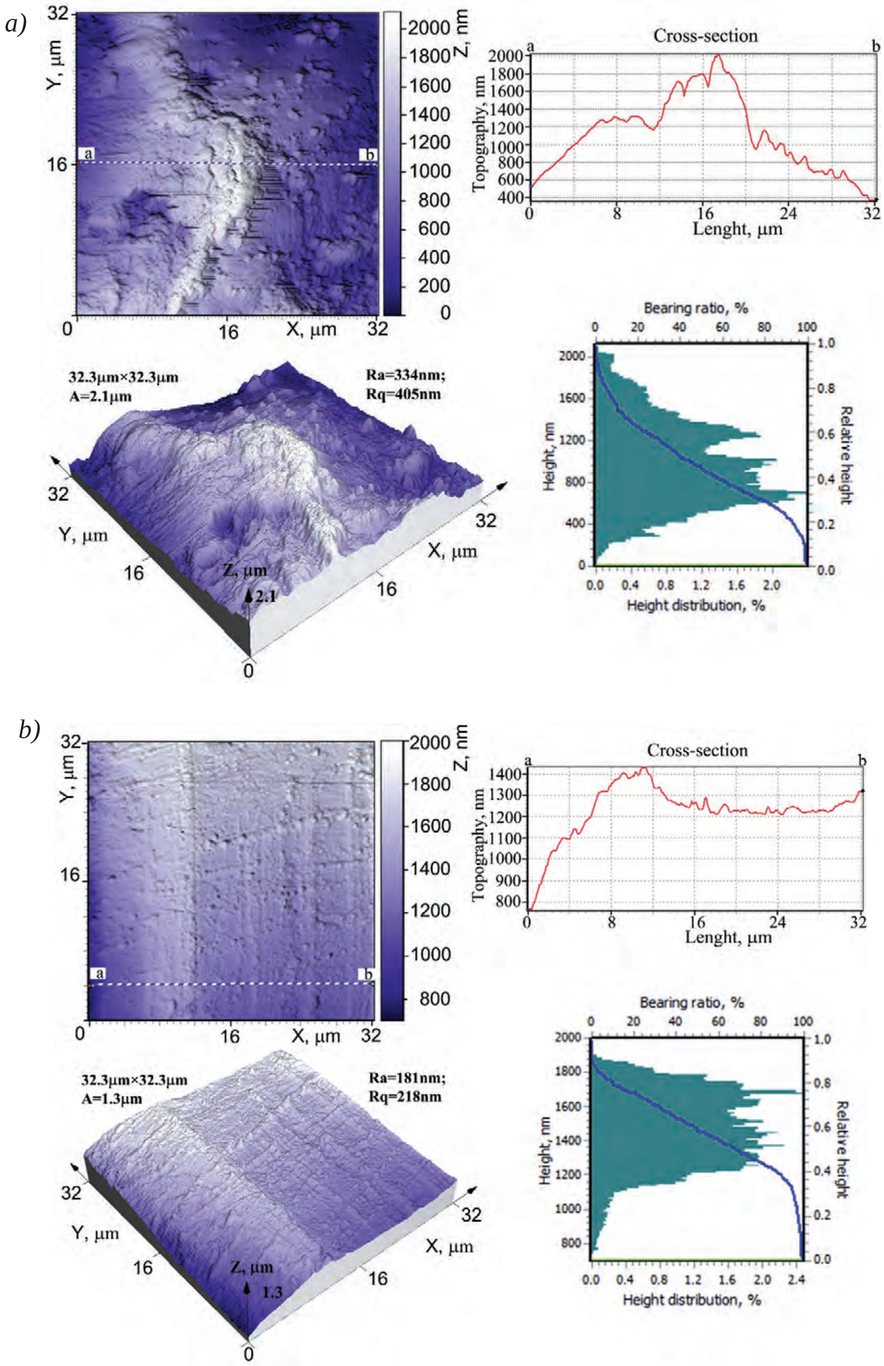


Fig. 5. Surface topography of bronze bearing sleeve – 2D, 3D view and cross-section and also height distribution of surface roughness, for non-used bearing sleeve (a), used bearing sleeve (b)

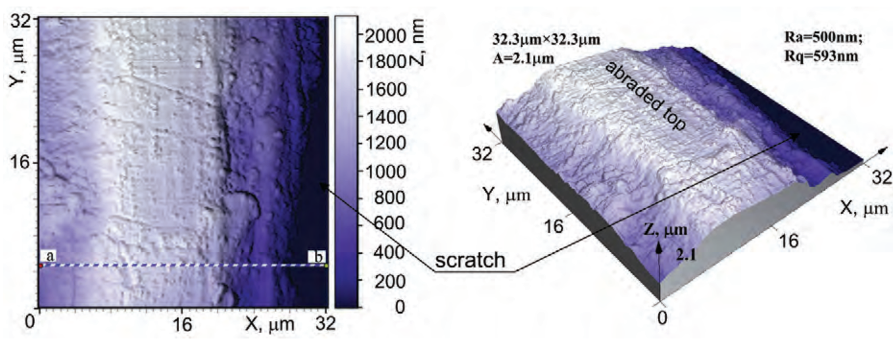


Fig. 6. Surface topography of bronze bearing sleeve in 2D and 3D view in close proximity of the scratches

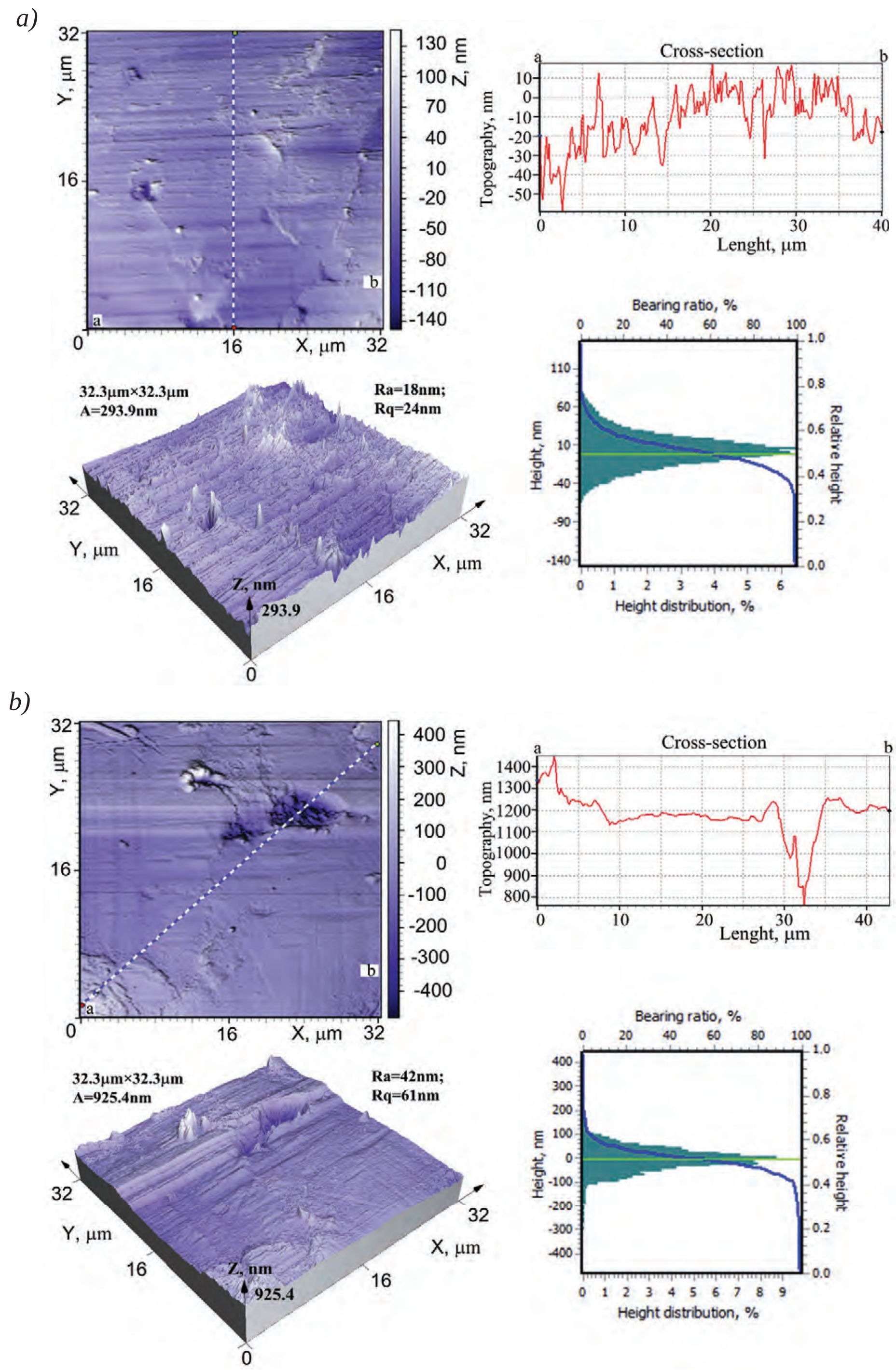


Fig. 7. Surface topography of 3.5" HDD micro-bearing sleeve – 2D, 3D view and cross-section and also height distribution of surface roughness, for non-used micro-bearing sleeve (a), and used micro-bearing sleeve (b)

3. Conclusions

1) The surface roughness specified by R_a and R_q indicators is usually higher for used bearing's sleeves or journals compared to the respective roughness indicators of non-used bearing's sleeves or journals, especially when there are micro-scratches on the surfaces.
2) The altitude of the surface roughness for sliding bearings with large diameter is larger than for the ones with smaller diameter or micro-bearings sleeves as well.
3) There are visible the signs of the matching tools in the form of micro-grooves on the non-used element's surface. Micro-tips subject to attrition during the operation.

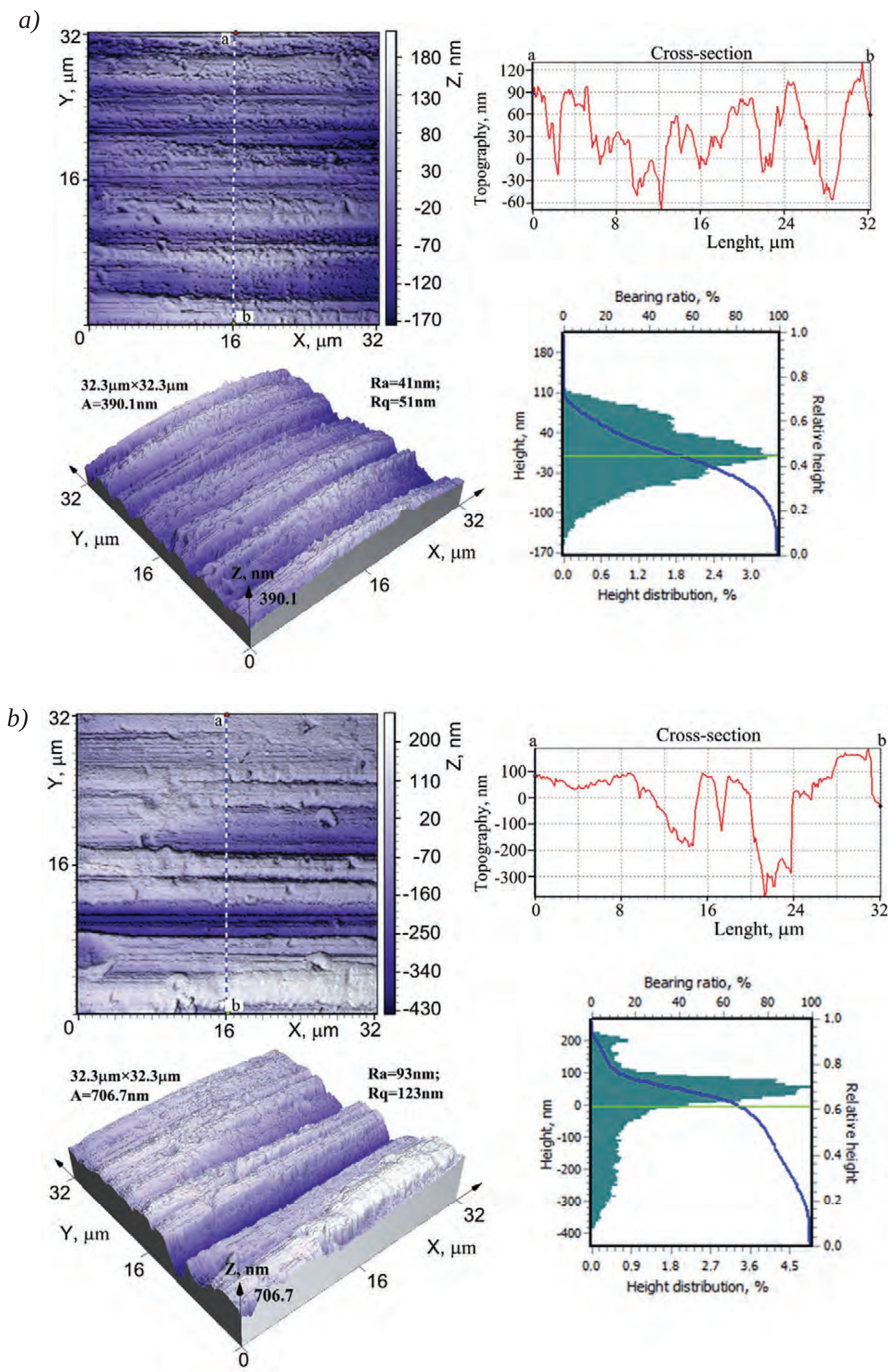


Fig. 8. Surface topography of 3.5" HDD micro-bearing journal – 2D, 3D view and cross-section and also height distribution of surface roughness, for non-used micro-bearing journal (a), and used micro-bearing journal (b)

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