Krzysztof WIERZCHOLSKI*, Andrzej MISZCZAK, Andrei KHUDOLEY*****

THE INTELLIGENT OPERATION OF NANO-GROOVED MICROBEARING SURFACES IN COMPUTER HDDS

NANOROWKI NA POWIERZCHNI MIKROŁOŻYSKA KOMPUTEROWEGO HDD JAKO WKŁAD DO INTELIGENTNEJ EKSPLOATACJI

Key words:

HDD-microbearing, nano-profiles of work surfaces, intelligent operation

Słowa kluczowe:

HDD mikrołożyska, nanoprofile powierzchni roboczych, inteligentna eksploatacja

Summary

The nano- and micro-grooves on two cooperating micro-bearing surfaces depend strongly on the intelligent operation of computer HDDs. Therefore, the

* Koszalin University of Technology, Institute of Mechatronics, Nanotechnology and Vacuum Technique, PL 75-453 Koszalin, ul. Śniadeckich 2, Poland; e-mail: krzysztof.wierzcholski@wp.pl.

** Maritime University Gdynia, Morska Street 81-87, 81-225 Gdynia, Poland; e-mail: miszczak@am.gdynia.pl.

*** Luikov Heat and Mass Transfer Institute of National Academy of Sciences of Belarus, Minsk, e-mail: khudoley@yahoo.com.

main topic of this paper is concerned with the influence of micro- and nano-structures in cooperating surfaces on intelligent micro bearing behaviour. The measurements are performed for a new, unused cooperating journals and sleeve surfaces of micro bearings in a new Hard Disc Driver 2.5, Samsung, HM 160 HI, 5400 rpm, utilising a atomic force microscope and scanning electron microscope and micro-x-ray analysis. The structure and geometry of nano-grooves and the composition of the roots in the material of the journal and sleeve alloy enables one to indicate the proper micro-bearing operation process and hydrodynamic lubrication model. These surfaces are radically different in comparison to cooperating surfaces occurring in micro bearings inside the computer ventilator. The presented measurements indicate that, in the micro-bearing gap, the changes of lubricant viscosity in the gap height direction have important implications on the HDD operation. In classical bearings such influences never occur.

INTRODUCTION

An efficient exploitation of sidle HDD micro bearings requires intelligent features, which include memory with a simultaneous capability to the carrying capacity, friction forces, and wear control. The memory of micro bearings is based on modern AFM measurements and CDF programs, which are able to response to unforeseen damages during exploitation. The actual stresses in an intelligent material can be defined by the history of their deformations and damages **[L. 1, 2, 7]**. Recently, HDDs need to have a much higher recording densities and performances. One of the core technologies for realising higher performance in HDDs may be the design and development of high-velocity spindle motors supported by a microbearing HDD system **[L. 1, 3, 4]**. There have been numerous presentations about microbearing systems for HDD spindles during the past few years, and most designs were about applying oil-lubricated hydrodynamic bearings in both radial and axial supports **[L. 1, 5, 6,]**. The flow of the lubricant in a cylindrical micro-bearing gap is generated by the rotation of the journal with the angular velocity ω and rotational speed 20000 rpm with an oil viscosity $18 x 10^{-3}$ Pas **[L. 3]**. A coupled journal and thrust hydrodynamic bearing has been recently used in the precision spindle of a computer hard disk drive (HDD), replacing the conventional ball bearings, due to its outstanding low noise and vibration characteristics **[L. 1, 3, 5]**. It means that the symmetrical herringbone grooves of the journal bearing generate the concentric motion of the rotor at the origin, but asymmetric grooves generate the concentric rotation with the small eccentricity ratio. Groove location has an influence on the dynamic performances in HDD bearings. This paper presents the measurements of working surfaces of an unused microbearing HDD 2.5”, Samsung, HM 160 HI, operating at 5400 rpm. The diameter of the journal is

3 mm, radial the clearance is $3.15x10^{-6}$ m (3.15 μm), the groove angle is 30°, and the groove type is herringbone. The HDD used for the sample measurements is presented in **Fig. 1**.

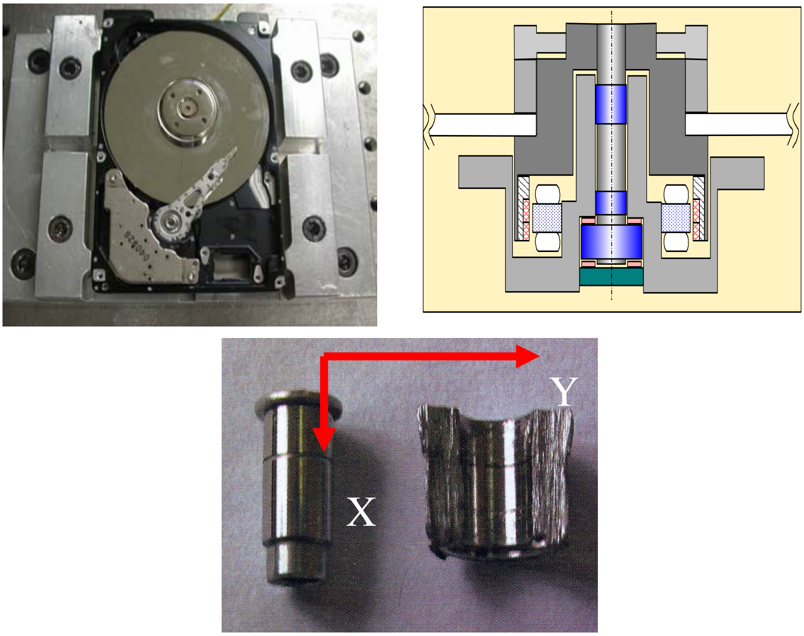

Fig. 1. The view of computer HDD and measured unused surfaces with nano-ridges and grooves in the cylindrical slide microbearing journal and sleeve HDD, 2.5``, Samsung HM 160 HI

Rys. 1. Widok komputerowego HDD oraz nowych niezużytych nieuszkodzonych powierzchni czopa i panewki z niewidocznymi gołym okiem nanożeberkami i rowkami w cylindrycznym mikrołożysku ślizgowym komputerowego dysku twardego 2,5``, Samsung HM 160 HI

SURFACE IN INTELLIGENT HDD MICROBEARING

In this section the measuring of the asymmetric and symmetric grooves on the cylindrical HDD micro-bearing surface are presented. The depth of the grooves is 25 nm. The intelligent feature is the whirling lubricant flow caused by the grooves lying either on the cooperating micro-brakes or clutch or micro-bearing surfaces. The HDD microbearing **[L. 3, 4]** is presented in **Fig. 2.** The y-axis is situated in the height direction of the liquid layer. Symmetric grooves of the micro-bearing journal generate the concentric motion of a rotor at the origin, but asymmetric grooves generate the concentric rotation with the eccentricity ratio of 0.2.

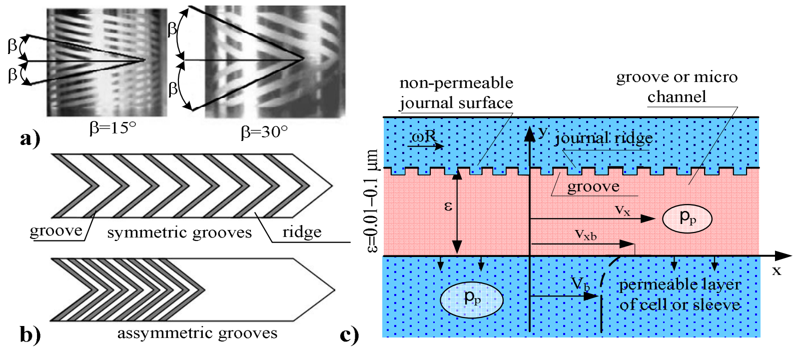

Fig. 2. The micro-bearing gap: a) various groove angles in journal, b) symmetric and asymmetric grooves, c) gap restricted by the cooperating surfaces and the grooves in the micro-journal

Rys. 2. Szczelina mikrołożyska: a) różne kąty rowków na czopie, b) symetryczne i asymetryczne rowki, c) szczelina ograniczona współpracującymi powierzchniami oraz rowkami na mikrowałku

The measurement of the surfaces using a scanning electron microscope is illustrated in **Fig. 2**, and the results are presented in **Fig. 3.** The surface is presented in **Fig. 3a** (173.60 × 10^{-6} m × 173.60 x 10^{-6} m or 173.60 μm × 173.60 μm) and an enlargement is showed in **Fig. 3b** describing a region of 8.680 μm × 8.680 μm. In journal surface are visible very close and confined irregularity of the roughness. **Fig. 3b** shows that the extension of the irregularity has about 3 μm. A lot of small grazes from mechanical treatment are visibly.

a) b)

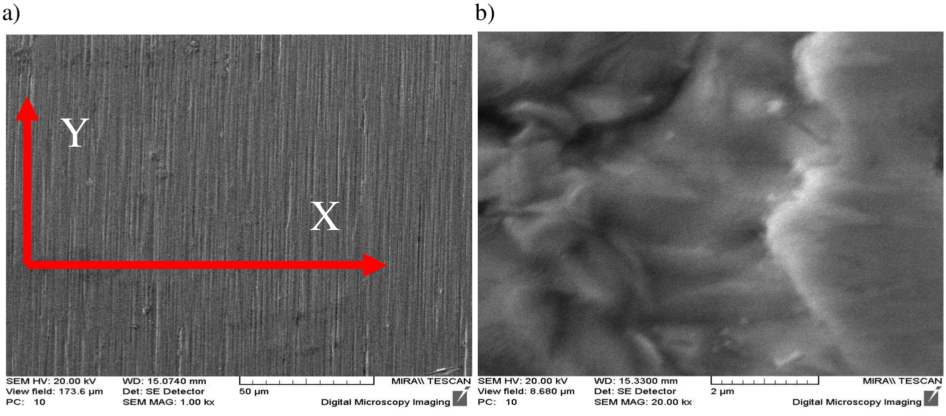

Fig. 3. The work surface of the journal in micro bearing HDD: a) view field 173.60 x 10^{-6} m × 173.60 x 10^{-6} m (173.60 μm × 173.60 μm), b) view field: 8.68 × 10^{-6} m × 8.68 × 10^{-6} m (8.680 μm × 8.680 μm)

Rys. 3. Obrazy powierzchni roboczej czopa mikrołożyska HDD: a) widok pola 173,60 · 10^{-6}m × 173,60 · 10^{-6} m (173,60 μm × 173,60 μm), b) widok pola: 8,68 · 10^{-6} m × 8,68 · 10^{-6} m (8,680 μm × 8,680 μm)

Figure 4 shows the working surfaces of the sleeve in two scales. **Fig. 4a** presents the square surface of 1.74 mm × 1.74 mm, and **Fig. 4b** is an enlargement (20x) of an area of 86.80 μm × 86.80 μm. The herringbone grooves indicated in **Fig. 2b** are now visible in **Fig. 4a** and more exactly in **Fig. 4b.**

a) b)

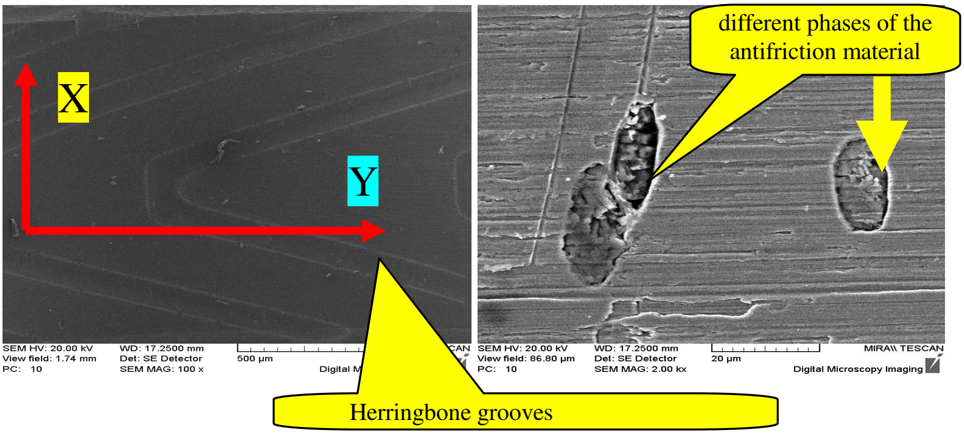

Fig. 4. The image of working surface of the sleeve in the micro bearing of a HDD: a) view field 174 x 10^{-5} m × 174.60 x 10^{-5} m (1740 μm × 1740 μm), b) view field: 86.8 x 10^{-6} m × 86.8 x 10^{-6} m

Rys. 4. Obrazy powierzchni roboczej panewki w mikro-łożysku HDD: a) widok pola 174 · 10^{-5} m × 174,60 · 10^{-5} m, widok pola: 86,8 · 10^{-6} m × 86,8 · 10^{-6} m

The width of the groove is about 8 μm, and two visible two impurities are shown in **Fig. 4b** (7 μm × 30 μm and 6 μm × 15 μm).

THE ROUGHNESS OF JOURNAL AND SLEEVE SURFACES IN A HDD MICROBEARING

The roughness often destroys the nano-groove architecture, but a slight roughness may be helpful and increase the intelligent features. **Fig. 5** presents the roughness measurements of the journal surface in 3D space obtained using an Atomic Force Microscope (AFM) in a view field of 20100 nm × 20100 nm × 301.1 nm, and the average roughness measurements of Ra = 35.2 nm and Rq = 44.8 nm were obtained.

The cross-section of journal surfaces is also important for hydrodynamic lubrication. The cross-section along the sample is presented in **Fig. 5** and **Fig. 6** illustrates the height of the roughness profile of the journal surface.

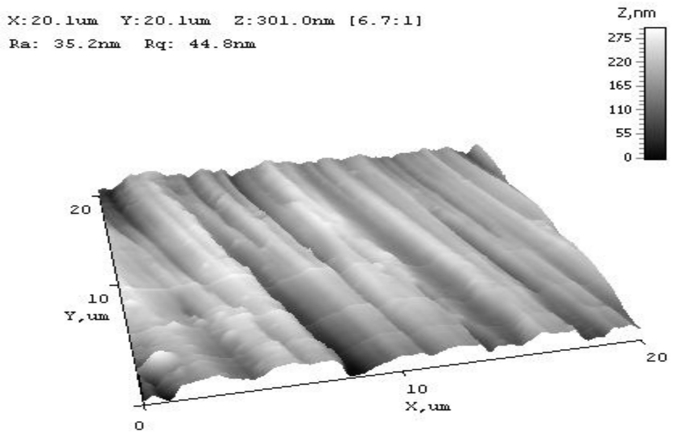

Fig. 5. The image 3D of the working surface of the journal in a micro bearing HDD (Ra = 35.2 nm)

Rys. 5. Widok 3D powierzchni roboczej czopa w mikrołożysku HDD (Ra = 35,2 nm)

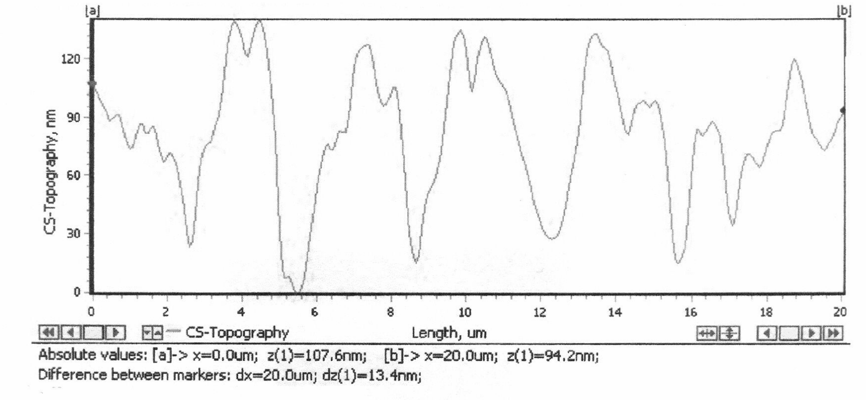

Fig. 6. The cross section of the working surface of the HDD-micro-bearing journal presenting the roughness height in nano-meters versus sample length in micrometers

Rys. 6. Przekrój poprzeczny powierzchni roboczej czopa w mikrołożysku HDD pokazujący wysokości chropowatości w nanometrach po długości próbki w mikrometrach

It is easy to see in **Fig. 5** and **Fig**. **6** that the roughness peaks in the journal surface are about 70 nm. The irregular ditches in the AFM structure have diametrical directions that is the result of technological treatment.

Fig. 7 indicates the obtained roughness measurements of the sleeve surface and ditch profiles in 3D space. The image was obtained using atomic force microscopy (AFM) for the view field of 10200 nm × 10200 nm × 250.9 nm taking into account Ra = 34.8 nm and Rq = 43.0 nm.

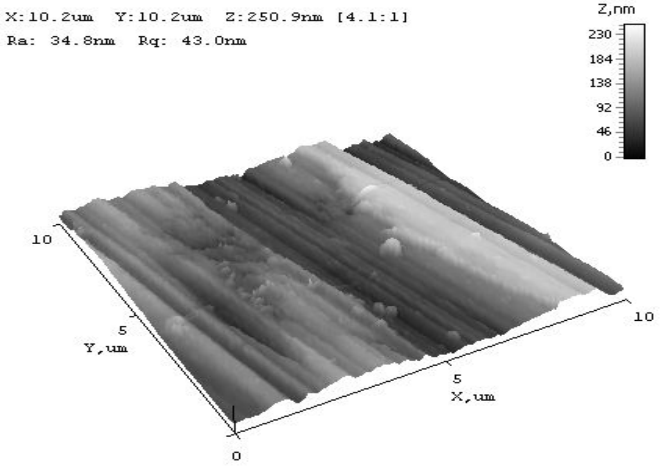

Fig. 7. The image 3D of the working surface of the sleeve in micro-bearing HDD (Ra = 34.8 nm)
Rys. 7. Widok 3D powierzchni roboczej panewki w mikrołożysku (Ra = 34,8 nm) uzyskany na AFM

During the cooperation between journal and sleeve in HDD micro bearings, surface cross sections of the sleeve are very important, where the height roughness profile and ditches are presented. **Fig. 8** illustrates the cross section of the sleeve surface presented in **Fig. 7**.

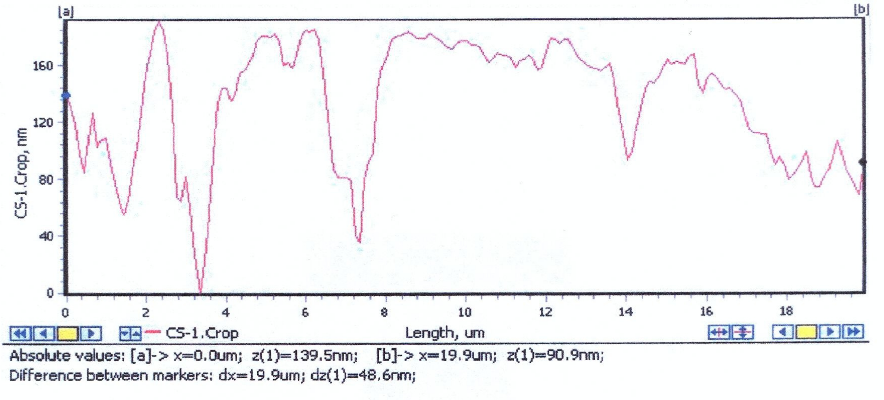

Fig. 8. Cross section of the working surface of the HDD-micro-bearing sleeve presenting roughness and groove height in nano meters versus sample length in micrometers
Rys. 8. Przekrój poprzeczny powierzchni roboczej panewki w mikrołożysku HDD pokazujący wysokości chropowatości i wysokość szczeliny w nanometrach po długości próbki w mikrometrach

The mutual relation between roughness profile on the journal and sleeve surfaces in micro bearing presented in **Figs. 5 through 8** are very important for lubrication. **Figs. 7** and **8** show that the roughness on the sleeve surface is about 70 nm in height, and the ditches are 150 nm deep and 3000 nm wide. The ditches have approximately a triangular shape, where the lateral slopes are very steep and have the diametrical (crosscut) direction. That is a result of the technological treatment.

MODULUS OF ELASTICITY STUDIES IN SUPERFICIAL LAYER

The performed measurements indicate that the modulus of elasticity E of the superficial layer laying on the micro-bearing sleeve surface has various values. The modulus of elasticity measurements were performed using AFM by the indentation of diamond probe with 100 nm radius of tip **[L. 8]**.

- If the modulus of elasticity E of the superficial layer increases, then the deformations are negligibly small and gap height is narrower; therefore, the average oil flow velocity is higher. In this case, the higher non-Newtonian oil velocity implies a lower oil dynamic viscosity.
- If the modulus of elasticity E of the superficial layer decreases, then the deformations are large and gap height is wider and extensive; therefore, the average oil flow velocity is lower.
- In this case, the lower non-Newtonian oil velocity implies a higher oil dynamic viscosity.

It is easy to see that the changes in the elasticity modulus of the superficial layer in micro bearings implies that the oil dynamic viscosity changes which in turn changes the carrying capacity values.

The load carrying capacity may be controlled by changes in the values of the elasticity modulus of the superficial layer material **[L. 2]**.

FINAL REMARKS

The obtained results of the performed measurements prove that the geometry and architecture of the nano-grooves and its section profiles have an immediate influence on the capacity, friction forces, operation stability, and hydrodynamic rigidity during micro bearing exploitation at 5400 rpm in a HDD 2.5", Samsung, HM 160 HI.

Using the author's initial investigations and considerations, we can obtain increases in the micro-bearing carrying capacity and memory capability by generating various geometries and shapes of HDD micro-bearing shafts and sleeve surfaces.

There is a connection between the intelligent micro-bearing properties and the nano-groove architecture of cooperating surfaces.

The presented investigations are necessary in the field of multifunctional material production for a superficial layer lying on the HDD micro-bearing surfaces, taking simultaneously into account intelligent properties **[L. 2].**

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Streszczenie

Rezultaty badań naukowych dysków komputerowych przeprowadzone w ostatnich trzech latach w USA, Chinach i Japonii wykazały, że inteligentne właściwości eksploatacyjne HDD uzyskuje się dzięki mikro- i nanorowkom znajdującym się na powierzchniach mikrołożysk ślizgowych.

Autorzy zauważyli, że w nieużywanych komputerowych HDD produkowanych na Tajwanie i Chinach kontynentalnych a także w Japonii występują różne geometrie nanorowków na powierzchniach mikrołożyska. Powierzchnie te zasadniczo różnią się od powierzchni mikrołożysk występujących w wentylatorkach komputera [L. 8]. Dlatego też są rozpatrywane w oddzielnym artykule. Specyficzna geometria rowków umożliwia niespotykaną w klasycznych łożyskach zmianę lepkości czynnika smarującego po grubości warstwy. Ten fakt powoduje wytworzenie dodatkowych sił nośnych, które przy świadomym ukształtowaniu geometrii nanorowków są celowo wykorzystywane w trakcie procesu eksploatacji twardych dysków komputerowych. W niniejszej pracy została przedstawiona analiza pomiarów dwóch nowych niezużytych współpracujących powierzchni mikrołożyska o obrotach 5400 rpm występujących w dysku twardym komputera HDD 2,5`` Samsung HM 160 HI wyprodukowanym w Chinach. Celem pracy jest interpretacja opracowanych pomiarów zawierających wymiary i geometrię oraz profile przekrojów poprzecznych nanorowków dla powierzchni roboczych czopa i panewki. Uzyskane wyniki pomiarów pozwalają ocenić i porównać zmiany geometrii nanorowków i ich profili przekroju poprzecznego w trakcie eksploatacji. Badania takie mogą być również pożyteczne dla konstruktorów w trakcie projektowania i budowy mikrołożysk HD.