Krzysztof WIERZCHOLSKI[*], **Oliwia ŁUPICKA**[*]

CAPACITY ENHANCEMENT WITH FRICTION FORCE DIMINUTION IN HDD SPHERICAL MICRO-BEARING

ZWIĘKSZENIE NOŚNOŚCI ORAZ ZMNIEJSZENIE SIŁ TARCIA W SFERYCZNYCH MIKROŁOŻYSKACH HDD

Key-words:

computer discs, micro-bearings, artificial intelligence

Słowa kluczowe:

dyski komputerowe, mikrołożyska, sztuczna inteligencja

Summary

This paper presents the new methods of friction force calculations occurring in slide hydrodynamic HDD micro-bearings with spherical journals. Moreover the paper presents new ideas for calculation and design of slide hydrodynamic HDD micro-bearings. One of these ideas includes the possibilities to cover the cooperating micro-bearing surfaces with a very thin biological layer of about 80 nm. The thin biological layer contains genetic information that establishes intendment tasks prescribed in genetic material. The means of registration of genetic information in DNA particles inside the thin biological layer is called genetic code. We can

[*] Institute of Mechatronics, Nanotechnology and Vecuum Technique, Technical University Koszalin, PL 75-620 Koszalin, ul. Racławicka 15-17, Poland; krzysztof.wierzcholski@wp.pl, oliwia.lupicka@wp.pl

control a genetic information, and we can select such genetic information inside the thin biological layer to obtain proper carrying capacities and very small friction forces and wear values.

INTRODUCTION

The presented paper describes the operating micro-bearing parameters and particularly friction forces of the spherical HDD micro-bearings. The cooperating micro-bearing surfaces are covered by the very thin superficial layer about, 80 nm height, with biological additions. Such thin layer contains genetic information which establishes intendment tasks prescribed in genetic material. The means of registration of genetic DNA information particles inside the thin biological layer is called as genetic code. We can control a genetic information and we can select such genetic information inside the thin biological layer to obtain proper carrying capacities and very small friction forces and wear values during the exploitation period. Additionally the asymmetric and symmetric grooves on the spherical micro-bearing surface are applied. The depth of the grooves attain about 25 nm. Whirling lubricant flow caused by the grooves lying on micro-bearing surfaces, consolidates the intendment tasks prescribed in genetic material. For example increases the memory carrying capacity and causes the diminution of the memory of friction forces and wear. Moreover the spherical journal bearing with asymmetric grooves generates the asymmetric pressure distributions which implies the eccentricity of the rotor **[L. 3], [L. 4]**.

Symmetric grooves on the journal cause concentric motion of a rotor.

General analysis of this paper considers the dynamic behavior of micro-bearings and makes comparisons with recently obtained results of other authors **[L. 3]**. The lubrication of micro-bearing surfaces is characterized by various bearing geometries form and artificial intelligence.

MECHANICAL AND GEOMETRICAL DATA

Pressure distributions and friction forces in spherical micro-bearings are calculated for radius of the spherical journal from 0.6 mm to 1.0 mm. Lubricant viscosity had value 0.018 Pas. We are taken into account rotating speed 10 000 rpm and radial clearance about 10 micrometer **[L. 2, 3]**. **Fig. 1a, b, c**, show the bearing system of a HDD and particularly a spherical journal **[L. 1, 4, 5]**.

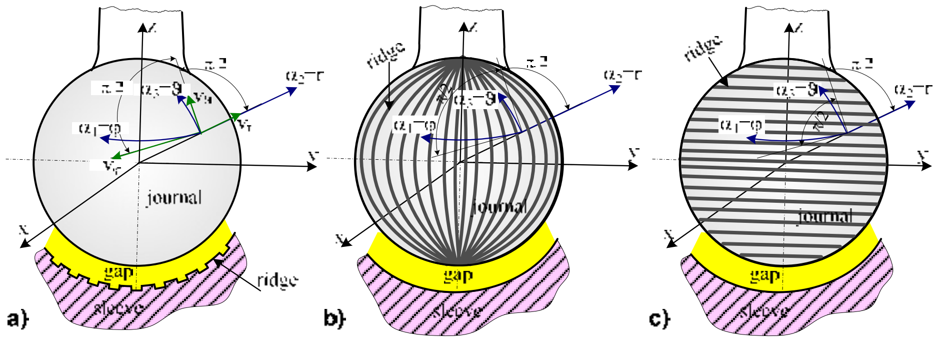

Fig. 1. Spherical journal for hydrodynamic HDD micro-bearing (20 000 rpm after K.Ch. Wierzcholski): a) circumferential grooves on the spherical sleeve, b) longitudinal grooves on the spherical journal, c) circum-ferential grooves on the spherical journal

Rys. 1. Sferyczne czopy mikrołożyska HDD (20000 rpm według Wierzcholskiego): a) obwodowe rowki na sferycznej panewce, b) wzdłużne rowki na sferycznym czopie, c) obwodowe rowki na sferycznym czopie

A NEW IDEAS IN MICROBEARING LUBRICATION

Presented in this paper micro-bearing lubrication is characterized by the following new ideas:

- The dynamic viscosity of oil depends on adhesion forces between fluid particles and cells on the micro-bearing surface and hence oil dynamic viscosity changes in super thin micro-bearing gap- height direction. Micro-bearing gap height in many times is smaller than 1 μm.
- The grooves about 25 nm depth located on the micro-bearing cooperating surfaces in longitudinal and circumferential directions of rotating spherical, journal shapes imply the increases of memory capacity and memory friction force effects and moreover increases the other intelligent micro-bearing properties .
- Registration of genetic DNA information in particles inside the thin biological layer on the bearing surfaces stabilizes the memory capacity effects and has influence on the oil viscosity which often changes in gap height direction.
- The remodeling (or adaptation) of the thin biological layer covering the micro- bearing surface, denotes the continuous process defined by genetic (congenial) factors to change shape and geometry of the micro-bearing gap. Such process implies the oil flow velocity changes in the

gap and therefore leads to the share rate variations of the flow, thus oil dynamic viscosity changes.

- The changes of not isotropic material coefficients such as module of elasticity of superficial layer lying on the micro bearing surface have influence on the gap height changes. This fact leads to the oil velocity changes what produces share rate changes of the oil flow and hence oil dynamic viscosity changes.
- Non Newtonian properties of the oil lead to the changes of the hydrodynamic pressure in super thin micro-bearing gap height direction. This phenomena conduces to the new non-classical hydrodynamic theory of lubrication where we obtain the three dimensional hydrodynamic pressure distribution in micro-bearing gap. Such phenomena is up to now unsuitable in hydrodynamic theory of lubrication.
- Nano-roughness of micro-bearing surfaces leads to the oil micro-flows in arbitrary directions what changes the oil velocity on the movable surface. This situation changes the fundamental conditions of hydrodynamic theory of lubrication and changes exploitation parameters in unexpected form.

MICRO-BEARING SPHERICAL GAP HEIGHT WITH GROOVES

If grooves length is situated in ϑ (meridional) and φ (circumferential) direction then total gap height ε_T of the spherical micro-bearing has the following form respectively:

$$\varepsilon_T(\varphi,\vartheta,t)=\varepsilon\left[(1+\lambda_s\cos\varphi)+\frac{4\varepsilon_{g1}}{\pi}\left(\sin\frac{\pi\varphi}{\varphi_T}+\frac{1}{3}\sin\frac{3\pi\varphi}{\varphi_T}+\frac{1}{5}\sin\frac{5\pi\varphi}{\varphi_T}+...\right)\right] \quad (1)$$

$$\varepsilon_T(\varphi,\vartheta,t)=\varepsilon\left[(1+\lambda_s\cos\varphi)+\frac{4\varepsilon_{g1}}{\pi}\left(\cos\frac{\pi\vartheta}{\vartheta_T}-\frac{1}{3}\cos\frac{3\pi\vartheta}{\vartheta_T}+\frac{1}{5}\cos\frac{5\pi\vartheta}{\vartheta_T}-...\right)\right] \quad (2)$$

for $0\le\varphi<2\pi$, $-\pi R/2\le\vartheta\le\pi R/2$ where λ_s – eccentricity ratio in spherical micro-bearing, ε – radial clearance in spherical micro-bearing, $\varepsilon_{g1}\equiv\varepsilon_g/\varepsilon$, ε_g – ridge height. Symbols φ_T, ϑ_T denote periods of grooves sequence about 65 nm in φ and ϑ – directions respectively.

FRICTION FORCES

This paper presents the friction forces calculation in spherical micro-bearing gaps. The time depended components of friction forces presented in spherical coordinates for circumferential and longitudinal directions $\alpha_1 = \varphi$, $\alpha_3 = \vartheta$ occurring in micro-bearing spherical gaps have the following forms **[L. 6]**:

$$F_{R\varphi}(t) = \iint_{\Omega_c} \left(\eta \frac{\partial v_\varphi}{\partial r} \right)_{r=\varepsilon_T} R \sin\left(\frac{\vartheta}{R} \right) d\varphi \, d\vartheta$$

$$F_{R\vartheta}(t) = \iint_{\Omega_c} \left(\eta \frac{\partial v_\vartheta}{\partial r} \right)_{r=\varepsilon_T} R \sin\left(\frac{\vartheta}{R} \right) d\varphi \, d\vartheta \tag{3}$$

We have circumferential direction $\alpha_1 = \varphi$, gap height direction $\alpha_2 = r$, meridional direction $\alpha_3 = \vartheta$. Symbol R denotes radius of the sphere (see **Fig. 1**). Symbols v_φ, v_ϑ denote lubricant velocity components in φ, ϑ directions respectively. In this case the components of friction forces (3) have the form:

$$F_{R\varphi}(t) = \iint_{\Omega_s} \frac{\partial p(t)}{\partial \varphi} \left[\varepsilon_T(\varphi,\vartheta,t) - \frac{\int_0^{\varepsilon_T(\varphi,\vartheta,t)} \frac{r\,dr}{\eta(\varphi,r,\vartheta)}}{\int_0^{\varepsilon_T(\varphi,\vartheta,t)} \frac{dr}{\eta(\varphi,r,\vartheta)}} \right] d\varphi d\vartheta -$$

$$- \iint_{\Omega_s} \left[\frac{\omega R^2 (\sin^2 \frac{\vartheta}{R})}{\int_0^{\varepsilon_T(\varphi,\vartheta,t)} \frac{dr}{\eta(\varphi,r,\vartheta)}} \right] d\varphi d\vartheta \tag{4}$$

$$F_{R\vartheta}(t) = R \iint_{\Omega_s} \frac{\partial p(t)}{\partial \vartheta} \left[\varepsilon_T(\varphi, \vartheta, t) - \frac{\int_0^{\varepsilon_T(\varphi,\vartheta,t)} \frac{r dr}{\eta(\varphi, r, \vartheta)}}{\int_0^{\varepsilon_T(\varphi,\vartheta,t)} \frac{dr}{\eta(\varphi, r, \vartheta)}} \right] \sin\left(\frac{\vartheta}{R}\right) d\varphi d\vartheta \qquad (5)$$

for $\eta = \eta(\varphi,r,\vartheta)$, $0 \le r \le \varepsilon_T$, $0 \le \varphi < 2\pi\theta_1$, $0 \le \theta_1 < 1$, $R\pi/8 \le \vartheta \le R\pi/2$, $\vartheta = R\vartheta_1$, $\Omega_s(\varphi,\vartheta)$ – lubrication surface, t – time. If liquid dynamic viscosity is constant in gap height direction i.e. $\eta(\varphi,\vartheta)$, then friction force components (4), (5) tend to the following form:

$$F_{R\varphi}(t) = \frac{1}{2} \iint_{\Omega_s} \varepsilon_T(\varphi, \vartheta, t) \frac{\partial p(t)}{\partial \varphi} d\varphi d\vartheta - \\ - \omega R^2 \iint_{\Omega_s} \frac{\eta(\varphi, \vartheta)}{\varepsilon_T(\varphi, \vartheta, t)} \sin^2\left(\frac{\vartheta}{R}\right) d\varphi d\vartheta \qquad (6)$$

$$F_{R\vartheta}(t) = \frac{R}{2} \iint_{\Omega_s} \varepsilon_T(\varphi, \vartheta, t) \frac{\partial p(t)}{\partial \vartheta} \sin\left(\frac{\vartheta}{R}\right) d\varphi d\vartheta \qquad (7)$$

for $\eta = \eta(\varphi,\vartheta)$, $0 \le r \le \varepsilon_T$, $0 \le \varphi < 2\pi\theta_1$, $0 \le \theta_1 < 1$, $R\pi/8 \le \vartheta \le R\pi/2$, $\vartheta = R\vartheta_1$.

The first term in equations (4), (5), (6), (7) describes friction forces generated by the pressure and the second terms denote friction forces caused only by the angular velocity ω of the micro-bearing spherical journal see **[L. 4, 6]**.

RESULTS

Presented paper shows the following scientific results:

- New ideas in the field of slide hydrodynamic micro-bearing exploitation.

- New ideas for micro-bearings in hydrodynamic non-classical theory of the analytical and numerical model formulation.
- Main differences indication between non-classical and classical theory for micro-bearing lubrication.
- Indication of new practical results obtained for operating parameters of micro-bearings by virtue of the new theory conceptions.

REFERENCES

1. Bekir Sadik Unlu, Enver Atik: Determination of friction coefficient in journal bearings. Elsevier, Material & Design, 28, 2007, pp. 973–977.
2. Bharat Bhushan: Nano-tribology and nanomechanics of MEMS/NEMS and BioMEMS, BioNEMS materials and devices. Microelectronic Eng. 84, 2007, pp. 387–412.
3. Jang G.H., Lee S.H., Kim H.W., Kim C.S.: Dynamic analysis of a HDD spindle system with FDBs due to the bearing width and asymmetric grooves of journal bearing. Microsystems Technologies, 11, 2005, pp. 499–505.
4. Wierzcholski K., Miszczak A.: Own scientific highlights obtained in the field of bio and micro-bearings in years 2006-2008. Journal of Kones Powertrain and Transport, Warsaw 2008, Vol. 15, No. 3, pp. 551–554.
5. Wierzcholski K.: A new concept of the changes of memory capacity of fluid dynamics HDD micro-bearings. Tribologia, 2008, 4 (220), pp. 267–274.
6. Wierzcholski K., Miszczak A.: Load Carrying Capacity of Microbearings with Parabolic Journal. Solid State Phenomena, Trans. Tech. Public., Switzerland,Vols. 147–149, 2009, pp. 542–547.

Recenzent:
Stanisław PYTKO

Streszczenie

Niniejsza praca przedstawia nową metodę obliczania sił tarcia występujących w ślizgowych hydrodynamicznych sferycznych mikrołożyskach HDD dysków komputerowych. Mikropowierzchnie mikrołożysk ślizgowych są powlekane cienką warstewką materiału biologicznego zawierającego genetyczne informacje, które realizują zamierzone zadania dla mikrołożyska zapisane w materiale genetycznym. Sposób rejestracji informacji genetycznych w cząsteczkach DNA wewnątrz warstwy materiału biologicznego o grubości około 80 nm nazywamy kodem genetycznym. Możemy również sterować

informacjami genetycznymi oraz dobierać takie genetyczne informacje wewnątrz warstwy biologicznej, aby uzyskiwać właściwe siły nośne mikrołożyska przy minimalnych wartościach sił tarcia oraz wartościach zużycia materiału.

Równocześnie wyszczególnione zostały nowe idee hydrodynamicznego smarowania mikrołożysk ślizgowych o właściwościach sztucznej inteligencji z możliwością zapamiętywania reakcji wzbudzania stosownych parametrów eksploatacyjnych przy zmiennych warunkach obciążenia z możliwością adaptacji do warunków środowiska oraz z możliwością remodelingu.