International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 15 (2017) pp. 4840-4846

Working Out of an Analytical Model of a Radial Bearing Taking into Account Dependence of Viscous Characteristics of Micropolar Lubrication on Pressure and Temperature

Kamil Samedovich Akhverdiev [1], Murman Aleksandrovich Mukutadze [2], Elena Olegovna Lagunova [3], Konstantin Sergeevich Solop [4]

[1]*Rostov State Transport University (RSTU), Chair "Higher Matnematics", Rostov-on-Don, 344038, Russian Federation.*

[2]*Rostov State Transport University (RSTU), Chair "Higher Matnematics", Rostov-on-Don, 344038, Russian Federation.*

[3]*Rostov State Transport University (RSTU), Chair "Higher Matnematics", Rostov-on-Don, 344038, Russian Federation.*

[4]*Rostov State Transport University (RSTU), Chair "Higher Matnematics", Rostov-on-Don, 344038, Russian Federation.*

Abstract

In the article we discuss the technique and realisation of the exact self-simulated solution of a problem on the infinite of a radial bearing operating in a hydrodynamic mode with an incompressible micropolar liquid lubricant. The solution considers dependence of viscous characteristics on pressure and temperature. Also we consider the performance of the thrust bearing with the adapted shape of the abutment.

Our research is based on the system of the equations of movement of a micropolar liquid incompressible lubrication in the operating clearance for a case of «a thin layer», a continuity equation, and the expression reflecting the law of speed change of energy dissipation of the lubricant environment. We have also taken into account the dependence of viscous characteristics both from pressure and temperature. The field of speeds and pressures has been found, and analytical expressions for a bearing capacity and a friction force have been obtained. We presented the estimation of influence of the parameters characterising dependence of viscosity on pressure and temperature, and also influence of the adapted shape on the basic performance characteristics of the bearing.

Keywords: hydrodynamics, adapted shape of abutment, dependence of viscous characteristics of a micropolar liquid lubricant on pressure and temperature.

Designations

μ' is lubricant dynamic viscosity coefficient, Ns/m^2;

κ', γ' are viscosity coefficients of micropolar lubricant, Ns/m^2;

μ_0 is characteristic viscosity of a Newtonian lubricant, Ns/m^2;

κ_0 and γ_0 are characteristic viscosity of a micropolar lubricant, Ns/m^2;

T´ is temperature ºC;

p' is hydrodynamic pressure in a lubricant layer, Pa;

α', β' are experimental constants;

α, ω' are parameters of a basic shape;

α^* is a discharge angle of a sliding bar with a linear circuit to axis Ox'

r_0 is the pin radius, m;

r_1 is the bearing radius, m;

e is eccentricity;

δ is radial gap, m;

ω is a parameter characterising an adapted shape of a sliding bar;

T_0 is characteristics of temperature ºC;

α is the parameter characterising dependence of viscosity on pressure;

β is the parameter characterising dependence of viscosity on temperature;

υ' is rotation rate of microparticles, m/s;

u', v' are components of lubricating material's velocity vector, m/s;

Q is lubricant consumption per unit time $\frac{m^3}{s}$;

C_p is heat capacity at constant pressure, J/kg·degrees;

Ω is angle speed, s^{-1};

N, N_1 are structural and viscous parameters of a micropolar lubricant, a micrometer.

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 15 (2017) pp. 4840-4846

INTRODUCTION

Performance of any machines and mechanisms, their reliability and durability, and, hence, profitability strongly depends on a design and operation of friction units. Modern machine-building tendencies demand substantial increase of load and speed modes of behaviour of bearing units. However, compensation of growth of specific static and dynamic loadings is impossible by increase of the area of their abutments.

The key to the solution of the problem is in the increase of bearing capacity of bearings as a result of application of an adapted shape of bearing bushings that are adjusted for conditions of hydrodynamics. Besides, it is quite important to specify analytical models of bearings on the basis of the account of dependence of viscous characteristics of a micropolar liquid lubricant both on pressure and temperature. The last defines novelty and relevance of the obtained solution.

Scientific novelty of the offered solution and specification of the analytical model consists in the account of dependence of viscosity of a micropolar liquid lubricant both on pressure and temperature; besides, usage of the adapted shape of the abutment of the bearing provides its increased bearing capacity. The simultaneous account of a complex of variable factors has allowed essential specifying of analytical model and approaching of the obtained results to the real ones.

The purpose of the research was to generate the specified analytical model of a radial bearing working in a mode of hydrodynamic lubrication. It has been done on the basis of introduction in calculations of a self-simulated variable and due to the account of dependence of viscosity of a micropolar liquid lubrication both on pressure and temperature.

Problem statement. We consider the established movement of a viscous micropolar liquid lubricant in the operating clearance of a radial bearing (between a sliding bar and a guide bearing) under conditions of the adiabatic process. The bearing with the adapted profile of a basic surface isn't mobile, and the shaft rotates with an angular speedΩ(Fig. 1). It is supposed that there is a full filling of the operating clearance with lubrication. Besides, we assume that viscous characteristics of a micropolar liquid lubricant depend on pressure and temperature under the following indicative law:

$$\mu' = \mu_0 e^{\alpha' p' - \beta' T'}, \qquad \kappa' = \kappa_0 e^{\alpha' p' - \beta' T'}, \qquad \gamma' = \gamma_0 e^{\alpha' p' - \beta' T'}. \qquad (1)$$

Here μ' is a factor of dynamic viscosity of the lubrication; κ', γ' are factors of viscosity of a micropolar lubricant; μ_0 is characteristic viscosity of Newtonian liquid; κ_0 and γ_0 are characteristics of viscosity of micropolar lubrication; $T'$is temperature; p' is hydrodynamic pressure in a lubricant layer; α', β' are experimental constants.

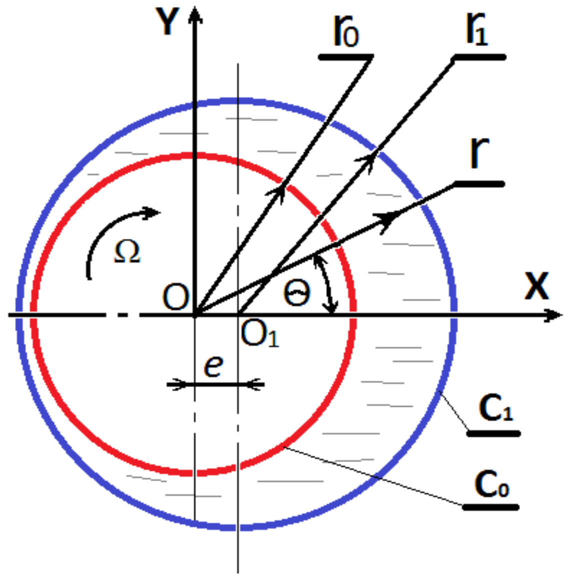

Figure 1: Simulation Scheme

The equation of the shaft contours and the bearing bush in the polar coordinate system r', θ in the center of the shaft are as follows:

$$r' = r_0, \qquad r' = r_1 + e\cos\theta - a\sin\omega\theta, \qquad (2)$$

where r_0 is the pin radius; r_1 is the bearing radius; e is eccentricity; $\frac{e}{\delta}, \frac{a}{\delta}$ is small quantity of the same order $(\delta = r_1 - r_0)$; a, ω are parameters of the contact profile to be determined.

The initial equations and boundary conditions

Taking into account simultaneous dependence of values on temperature and pressure, let us study the system of the equations of movement of the lubricant with micropolar properties as the initial one. We shall consider it for a case of «a thin layer» taking into account (1) and the following continuity equations:

$$\frac{\partial^2 u'}{\partial r'^2} + N^2 \frac{\partial \upsilon'}{\partial r'} = \frac{1}{e^{\alpha' p' - \beta' T'}} \frac{dp'}{d\theta},$$
$$\frac{\partial^2 \upsilon'}{\partial r'^2} = \frac{\upsilon'}{N_1} + \frac{1}{N_1}\frac{\partial u'}{\partial r'}, \qquad \frac{\partial u'}{\partial \theta} + \frac{\partial v'}{\partial r'} = 0. \qquad (3)$$

Dimensional values are connected with corresponding dimensionless values by the following correlations:

$$u' = u\Omega r_0; \quad v' = \Omega\delta v; \quad \upsilon' = \upsilon^* \upsilon; \quad p' = p^* p;$$
$$\mu' = \mu_0\mu; \quad \kappa' = \kappa_0\kappa; \quad \gamma' = \gamma_0\gamma; \quad T' = T_0 T; \quad r' = r_0 + \delta r;$$
$$\upsilon^* = \frac{r_0\Omega}{2\delta}, \quad p^* = \frac{r_0^2\Omega(2\mu_0+\kappa_0)}{2\delta^2}, \quad \delta = r_1 - r_0; \ \beta' = \beta T_0;$$
$$N^2 = \frac{\kappa_0}{2\mu_0+\kappa_0}, \quad N_1 = \frac{2\mu_0 l^2}{\delta^2\kappa_0}, \quad l^2 = \frac{\gamma_0}{4\mu_0}, \quad \alpha = p^*\alpha'. \tag{4}$$

T_0 is a characteristic temperature; α is the parameter characterising dependence of viscosity on pressure; β is the parameter characterising dependence of viscosity on temperature; υ′ is the speed of microrotation; u', v' are components of a speed vector.

Taking into account transition to dimensionless variables in a lubricant layer, omitting character strokes,we will come to the following system of the equations:

$$\frac{\partial^2 u}{\partial r^2} + N^2\frac{\partial\upsilon}{\partial r} = \frac{1}{e^{\alpha p-\beta T}}\frac{dp}{d\theta},$$
$$\frac{\partial^2\upsilon}{\partial r^2} = \frac{\upsilon}{N_1} + \frac{1}{N_1}\frac{\partial u}{\partial r}, \qquad \frac{\partial u}{\partial\theta} + \frac{\partial v}{\partial r} = 0. \tag{5}$$

The boundary conditions are as follows:

$$u=0, \quad v=0, \quad \upsilon=0 \quad \text{when} \quad r = h(\theta) = 1+\eta\cos\theta - \eta_1\sin\omega\theta;$$
$$u=1, \quad v=0, \quad \upsilon=0 \quad \text{when} \quad r=0, \quad \eta=\frac{e}{\delta}; \quad \eta_1 = \frac{a}{\delta};$$
$$p=(0)=p(2\pi)=\frac{p_a}{p^*}; \tag{6}$$

Let us average the second equation of system (5) over the thickness of a lubricating layer. We will get the following:

$$\frac{1}{h}\int_0^h \frac{\partial^2\upsilon}{\partial r^2}dr = \frac{1}{N_1 h}\int_0^h \upsilon dr + \frac{1}{N_1 h}\int_0^h \frac{\partial u}{\partial r}dr. \tag{7}$$

We will obtain the solution of equation (7) as follows:

$$\upsilon = A_1(x)r^2 + A_2(x)r + A_3(x). \tag{8}$$

From boundary conditions (6) it follows that

$$A_3 = 0; \qquad A_2 = -A_1(\theta)h(x). \tag{9}$$

Taking into account (9) forυ, we will get the following expression:

$$\upsilon = A_1(\theta)\cdot(r^2 - rh). \tag{10}$$

Substituting (10) in (7) accurate within members $O\left(\eta\cdot\frac{1}{N_1}\right)$, $O\left(\eta_1\cdot\frac{1}{N_1}\right)$, $O\left(\frac{1}{N_1^2}\right)$, we will obtain the following:

$$\upsilon = -\frac{1}{2N_1 h}(r^2 - rh), \qquad \frac{\partial\upsilon}{\partial r} = -\frac{1}{2N_1 h}(2r-h). \tag{11}$$

Taking into account (11), the system of equations (5) in the approach accepted by us is as follows:

$$\frac{\partial^2 u}{\partial r^2} - \frac{N^2}{2N_1 h}(2r-h) = \frac{1}{e^{\alpha p-\beta T}}\frac{dp}{d\theta},$$
$$\upsilon = -\frac{1}{2N_1 h}(r^2 - rh), \quad \frac{\partial u}{\partial r} + \frac{\partial v}{\partial\theta} = 0. \tag{12}$$

Precise self-similar solution

We will search for the exact self-simulated solution of system (12) satisfying to boundary conditions (6) as follows:

$$u = \frac{\partial\psi}{\partial r} + U(r,\theta), \quad v = -\frac{\partial\psi}{\partial\theta} + V(r,\theta),$$
$$V(r,\theta) = -\tilde{v}(\xi)h'(\theta), \quad U(r,\theta) = \tilde{u}(\xi), \quad \xi = \frac{r}{h(\theta)},$$
$$\psi(r,\theta) = \tilde{\psi}(\xi), \quad \frac{1}{e^{\alpha p-\beta T}}\frac{dp}{d\theta} = \frac{\tilde{C}_1}{h^2(\theta)} + \frac{\tilde{C}_2}{h^3(\theta)},$$
$$\upsilon(\xi) = -\frac{1}{2N_1}(\xi^2 - \xi). \tag{13}$$

Taking into account (13) from system (12) in our approximation, we will obtain as follows:

$$\tilde{\psi}''' = \tilde{C}_2, \qquad \tilde{u}''(\xi) = \tilde{C}_1 + \frac{N^2}{2N_1}(2\xi - 1),$$
$$\tilde{u}' + \xi\tilde{v}' = 0, \qquad \upsilon(\xi) = -\frac{1}{2N_1}(\xi^2 - \xi),$$
$$\frac{dp}{d\theta} = \frac{1}{e^{\alpha p-\beta T}}\left(\frac{\tilde{C}_1}{h^2(\theta)} + \frac{\tilde{C}_2}{h^3(\theta)}\right). \tag{14}$$

$$\tilde{\psi}'(0) = 0, \quad \tilde{\psi}'(1) = 0, \quad \tilde{v}(0) = \tilde{v}(1) = 0,$$
$$\tilde{u}(0) = 1, \quad \tilde{u}(1) = 0, \quad \int_0^1 \tilde{u}(\xi)d\xi = 0. \tag{15}$$

We can find the solution of system (14) taking into account the boundary conditions (15), connected with a definition of speed field, by direct integration. As a result, we will obtain the following:

$$\tilde{\psi}'(\xi)=\frac{\tilde{C}_2}{2}\left(\xi^2-\xi\right),\quad \upsilon(\xi)=-\frac{1}{2N_1}\left(\xi^2-\xi\right),$$
$$\tilde{u}(\xi)=\tilde{C}_1\frac{\xi^2}{2}+\frac{N^2}{2N_1}\left(\frac{\xi^3}{3}-\frac{\xi^2}{2}\right)+\left(\frac{N^2}{12N_1}-\frac{\tilde{C}_1}{2}-1\right)\xi+1. \tag{16}$$

Here $\tilde{C}_1=6$, and we will define $\tilde{C}_2$ from the condition $p(0)=p(2\pi)=\frac{p_a}{p^*}$ and

equation (14).

$$\tilde{C}_2=-\frac{\tilde{C}_1\tilde{J}_2(\theta)}{\tilde{J}_3(\theta)}, \tag{17}$$

where $\tilde{J}_k(\theta)=\int_0^{2\pi}\frac{\mu(\theta)}{h^k(\theta)}d\theta.$

Predictably, given $N_1\to\infty,\quad \nu\to\infty$ the received results completely coincide with the result for a case of Newtonian liquid.

Definition of hydrodynamic pressure

We will define dimensionless hydrodynamic pressure in a lubricant layer from the following equation:

$$\frac{1}{\mu(\theta)}\frac{dp}{d\theta}=\frac{\tilde{C}_1}{h^2(\theta)}+\frac{\tilde{C}_2}{h^3(\theta)}. \tag{18}$$

For the solution of the equation (18) at first we will define as the function depending from θ. When determining $\mu(\theta)$ we use the expression reflecting regularity of change of speed of dissipation of energy of the lubricant environment::

$$\frac{dH'}{d\theta}=\frac{2\mu_0\mu\Omega^2r_0^2h(\theta)}{\delta}\int_0^1\left(\frac{\tilde{\psi}''(\xi)}{h^2(\theta)}+\frac{\tilde{u}'(\xi)}{h(\theta)}\right)^2d\xi. \tag{19}$$

Then the rise in temperature is defined by the following expression:

$$\frac{dT'}{d\theta}=\frac{dH'}{d\theta}\cdot\frac{1}{C_pQ}=\frac{1}{C_pQ}\cdot\frac{2\mu_0\mu\Omega^2r_0^2h(\theta)}{\delta}\int_0^1\left(\frac{\tilde{\psi}''(\xi)}{h^2(\theta)}+\frac{\tilde{u}'(\xi)}{h(\theta)}\right)^2d\xi. \tag{20}$$

Where Q is the lubricant loss per time unit; C_p is a heat capacity at constant pressure; r_0 is the pin radius, m; Ω is angle speed.

$$Q=\Omega r_0\delta\int_0^1\psi'(\xi)d\xi=\frac{-\delta\Omega r_0\tilde{C}_2}{12}. \tag{21}$$

Let us differentiate expression $\mu=e^{\alpha p-\beta T}$ with respect to θ, then we will obtain the following:

$$\frac{d\mu}{d\theta}=\mu(\theta)\left(\alpha\frac{dp}{d\theta}-\beta\frac{dT}{d\theta}\right)=\mu(\theta)\alpha\frac{dp}{d\theta}+\frac{\mu(\theta)\beta 24\mu_0\Omega r_0h(\theta)}{T^*C_p\cdot\delta^2\tilde{C}_2}\cdot\int_0^1\left(\frac{\tilde{\psi}''(\xi)}{h^2(\theta)}+\frac{\tilde{v}'(\xi)}{h(\theta)}\right)^2d\xi. \tag{22}$$

Taking into account equation (18), for definition $\mu(\theta)$ we come to the following differential equation:

$$\frac{1}{\mu^2(\theta)}\frac{d\mu}{d\theta}=\frac{\alpha\tilde{C}_1}{h^2(\theta)}+\frac{\alpha\tilde{C}_2}{h^3(\theta)}+\frac{24\mu_0\beta\Omega r_0h(\theta)}{T^*C_p\delta^2\tilde{C}_2}\cdot\int_0^1\left(\frac{\tilde{\psi}''(\xi)}{h^2(\theta)}+\frac{\tilde{v}'(\xi)}{h(\theta)}\right)^2d\xi. \tag{23}$$

Integrating this equation, we will receive the following:

$$\frac{1}{\mu(\theta)}=1-\alpha\tilde{C}_1J_2(\theta)-\alpha\tilde{C}_2J_3(\theta)-\tilde{K}\left[\Delta_1J_3(\theta)+\Delta_2J_2(\theta)+\Delta_3J_1(\theta)\right], \tag{24}$$

where $\tilde{K}=\frac{24\mu_0\beta\Omega r_0}{T^*C_p\delta^2\tilde{C}_2},\qquad \Delta_1=\int_0^1\left(\tilde{\psi}''(\xi)\right)^2d\xi,$

$\Delta_2=2\int_0^1\left(\tilde{\psi}''(\xi)\cdot\tilde{v}'(\xi)\right)d\xi,\qquad \Delta_3=\int_0^1\left(\tilde{v}'(\xi)\right)^2d\xi,\qquad J_\kappa(\theta)=\int_0^\theta\frac{d\theta}{h^\kappa(\theta)}.$

Let us solve equation (24) for $\mu(\theta)$, then we will receive the following:

$$\mu(\theta)=\frac{1}{1-\tilde{K}\left[\Delta_1J_3(\theta)+\Delta_2J_2(\theta)+\Delta_3J_1(\theta)\right]-\alpha\tilde{C}_1J_2(\theta)-\alpha\tilde{C}_2J_3(\theta)}. \tag{25}$$

Further we will replace function $\mu(\theta)$ with its average integrated value as follows:

$$\tilde{\mu} = \int_0^{2\pi} \mu(\theta) d\theta = \quad (26)$$

$$= \int_0^{2\pi} \left[\frac{1}{1 - \tilde{K}\left[\Delta_1 J_3(\theta) + \Delta_2 J_2(\theta) + \Delta_3 J_1(\theta)\right] - \alpha\left(\tilde{C}_1 J_2(\theta) + \tilde{C}_2 J_3(\theta)\right)} \right] d\theta.$$

Let us solve the received equations for Δ_1, Δ_2, Δ_3, $\tilde{C}_2$, $I_3(\theta)$, $I_2(\theta)$, $I_1(\theta)$ to within the second-order term $O(\eta^2)$, $O(\eta_1^2)$, $O(\eta\eta_1)$, we will get the following expressions:

$$\tilde{C}_2 = -6\left(1 + \frac{\eta_1}{2\pi\omega}(\cos 2\pi\omega - 1)\right),$$

$$\Delta_1 = 3\left(1 + \frac{\eta_1}{\pi\omega}(\cos 2\pi\omega - 1)\right),$$

$$\Delta_2 = -6\left(1 + \frac{\eta_1}{2\pi\omega}(\cos 2\pi\omega - 1)\right),$$

$$\Delta_3 = \frac{N^4}{720 N_1^2} + 4. \quad (27)$$

Taking into account (27), finally for $\tilde{\mu}$, we will receive the following expression:

$$\tilde{\mu} = 1 + K\beta\left[\left(\pi^2 - \frac{\eta_1}{2\omega}\left(\frac{\sin 2\pi\omega}{\omega} - 2\pi + \pi(\cos 2\pi\omega - 1)\right)\right) - \left(\frac{N^4}{720 N_1^2} + 4\right)\right. \quad (28)$$

$$\left. \times\left(\frac{\pi^2}{3} - \frac{\eta_1}{6\omega}\left(\frac{\sin 2\pi\omega}{\omega} - 2\pi\right)\right)\right] + \frac{6\alpha\eta_1}{\omega}\left(\frac{\sin 2\pi\omega}{\omega} - 2\pi - \pi(\cos 2\pi\omega - 1)\right),$$

where $K = \frac{24\mu_0 \Omega r_0}{T^* c_p \delta}$.

Taking into account (18) and (28), dimensionless hydrodynamic pressure is defined by the following expression:

$$p = \tilde{\mu}\left(\tilde{C}_1 \tilde{J}_2(\theta) + \tilde{C}_2 \tilde{J}_3(\theta)\right) + \frac{p_a}{p^*} = \quad (29)$$

$$6\tilde{\mu}\left(\eta \sin\theta + \frac{\eta_1}{\omega}(\cos\theta\omega - 1) - \frac{\eta_1 \theta}{2\pi\omega}(\cos 2\pi\omega - 1)\right) + \frac{p_a}{p^*}.$$

Findings of the research and their discussion

Taking into account (29) and (16) for bearing capacity and friction force we will obtain the following expressions:

$$R_x = \frac{3\tilde{\mu} r_0^3 \Omega (2\mu_0 + \kappa_0)}{\delta^2}\left(\eta\pi + \eta_1(1 - \omega^2)(\cos 2\pi\omega - 1)\right),$$

$$R_y = \frac{3\tilde{\mu} r_0^3 \Omega (2\mu_0 + \kappa_0)}{\delta^2} \eta_1 \sin 2\pi\omega,$$

$$L_{fr} = \frac{\tilde{\mu}\Omega r_0}{2\delta}\int_0^{2\pi}\left[\frac{\psi''(0)}{h^2(\theta)} + \frac{\tilde{u}'(0)}{h(\theta)}\right] d\theta = \frac{\tilde{\mu}\Omega r_0}{2\delta}\left(\frac{N^2}{12 N_1} + 1\right)\left(2\pi - \frac{\eta_1}{\omega}(\cos 2\pi\omega - 1)\right). \quad (30)$$

Below is the range of the parameters in all expressions:

$\eta = \eta_1 = 0.3\ldots1$; $\omega = 0\ldots1$; $K = 0.1\ldots0.5$; $\alpha = 0.01\ldots1$; $\beta = 0\ldots1$;

$T = 30\ldots100$ ºC; $\mu = 0.068\ldots0.0078 \frac{N\cdot s}{m^2}$; $P_a = 0.08\ldots0.101325$ MPa;

$\delta = 0{,}015 \cdot 10^{-3}\ldots0.07 \cdot 10^{-3}$ m; $r_0 = 0.019985\ldots0.04993$ m;

$\Omega = 100 \ldots 1800 s^{-1}$; $\mu_0 = 0.0595 \frac{N\cdot s}{m^2}$.

According to the results of the numerical analysis we have constructed graphs (Fig. 2–7), allowing us to draw the following conclusions.

1. As a result of the carried out theoretical researches, we revealed the basic laws of interrelation of viscous characteristics of a micropolar lubricant with pressure and temperature in a lubrication layer, and also impact of the adapted shape of an abutment of the bearing bushing and structural and viscous parameters (N and N_1)ofa micropolar lubricant.
2. It was established that viscous characteristics of a micropolar lubricant under the conditions of hydrodynamic lubrication are intensively increased when parameter β drops, it is caused by dependence of temperature on pressure. To a lesser extent it happens during the reduction of α parameter caused by dependence of viscosity on pressure, which similarly influences the bearing capacity of a thrust bearing.
3. Application of the bearing bushing with the adapted shape provides stable max of the bearing capacity in the researched range of factors, which can be additionally increased during the values of viscous parameter of a micropolar lubricant.

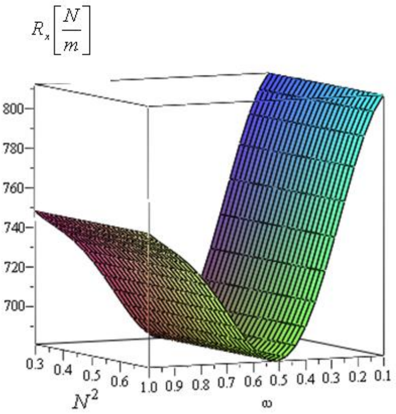

Figure 2: Dependence of a component of a vector of the supporting force on the following parameters: ω, characterising an adapted shape of the abutment, and structural and viscous parameter N^2.

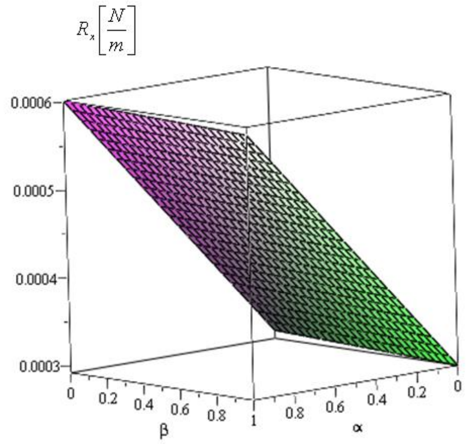

Figure 3: Dependence of a component of a vector of the supporting force of the bearing on the following parameters: β, caused by dependence of temperature on pressure, andα, caused by dependence of viscosity on pressure.

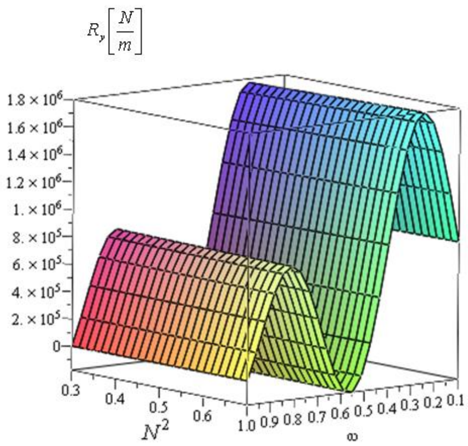

Figure 4: Dependence of a component of a vector of the supporting force on the following parameters: ω, characterising an adapted shape of the abutment, and structural and viscous parameter N^2.

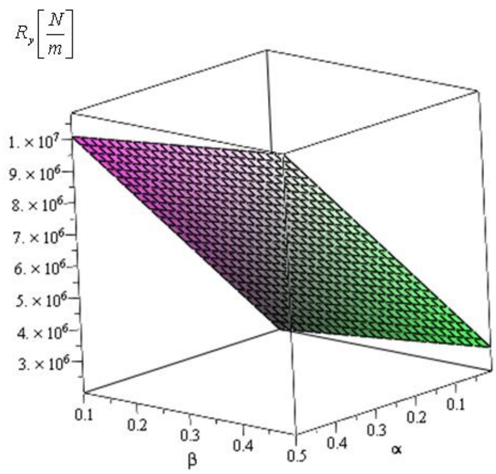

Figure 5: Dependence of a component of a vector of the supporting force of the bearing on the following parameters: β, caused by dependence of temperature on pressure, and α, caused by dependence of viscosity on pressure.

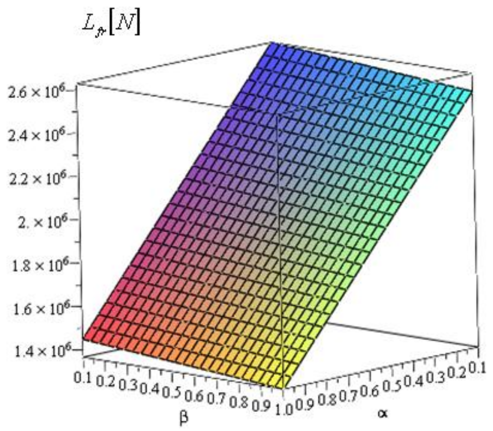

Figure 6: Dependence of friction force of the bearing on the following parameters: β, caused by dependence of temperature on pressure, and α, caused by dependence of viscosity on pressure.

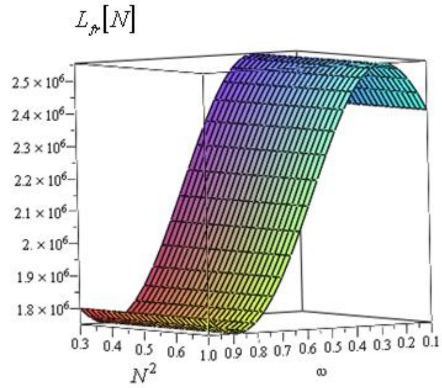

Figure 7: Dependence of friction force of the bearing on the following parameters: ω, characterising an adapted shape of the abutment, and structural and viscous parameter N_1

ACKNOWLEDGEMENTS

The publication has been issued in the scope of realization of fellowship of OJSC «RZD» No. 2210370/22.12.20016 for development of scientific and pedagogical schools in the area of the railway transport.

REFERENCES

[1] Akhverdiyev K.S., Vovk A.Yu., Mukutadze M.A., Savenkova M.A., Analytical method for prognosis of values of micropolar lubrication criteria providing stable operation of radial sliding bearing. Journal of Friction and Wear. – 2008. – V. 29, No. 2. – P. 184–191.

[2] Mukutadze M.A., Mathematical Model of a Compressible Micropolar Hydrodynamic Lubrication of a Radial Bearing with Adapted Shape of Its Bearing Surface. Bulletin of Don State Technical University. – 2011. – V. 11, No. 8 (59). – P. 1400–1404.

[3] Akhverdiev K.S., Mukutadze M.A., Mukutadze A.M., Radial bearing with porous barrel. Proceedings of Academic World: International Conference, 28th of March, 2016, San Francisco, USA. IRAG Research Forum : Institute of Research and Journals, 2016. – P. 28–31.

[4] Akhverdiev K.S., Mukutadze M.A., Vovk A.Y., Semenko I.S., Hydrodynamic Calculation of a Radial Bearing Operating in a Non-Stationary Mode on a Viscoplastic Lubricant Possessing Micropolar Properties. Bulletin of Rostov State Transport University. – 2008. – No. 4(32). – P. 131–138.

[5] Zadorozhnaja E.A., Karavaev V.G., Estimation of a heat state of a heavy-loaded bearing taking into account rheological properties of a lubricant. Internal combustion engines. All-Ukrainian research journal. – Kharkov: Publishing house «Kharkov Polytechnical Institute». – 2012. – No. 2. – P. 66–73.

[6] Zadorozhnaja E.A., Solution of a thermo-hydrodynamic problem of lubrication of heavy-loaded plain bearers taking into account rheological properties of a liquid lubrication. Problems of mechanical engineering and reliability of machines. – 2014. – No. 4. – P. 70–81.

[7] Matveev, V.A., Orlov O.F., Determination of dynamic viscosity of the substance depending on pressure and temperature. The Bulletin of Bauman MSTU. Series «Sciences». – 2009. – No. 3. – P. 116–118.

[8] Albagachiev A.J., Kozhemjakina V.D., Chichinadze A.V., Frictional, wear and temperature characteristics of materials during high-speed slippage in machines and devices. Friction and lubrication in machines and mechanisms. – 2010. – No. 3. – P. 19–29.

[9] Prokopyev V.N., Rozhdestvensky Y.V., Karavaev V.G., Zadorozhnaja E.A. [etc.], Dynamics and lubrication of tribo-units of piston and rotary machines: A monograph. Chelyabinsk. SUSU Publishing Center, 2010. – Part 1. – 136 p.

[10] Prokopyev V.N., Rozhdestvensky Y.V., Karavaev V.G., Zadorozhnaja E.A. [etc.], Dynamics and lubrication of tribo-units of piston and rotary machines: A monograph. Chelyabinsk. SUSU Publishing Center, 2011. – Part 2. – 221 p.

[11] Prokopyev V.N., Zadorozhnaja E.A., Karavaev V.G., Levanov I.G., Improvement of a calculation method of the heavy-loaded plain bearers greased with non-newtonian oils. Problems of mechanical engineering and machines reliability, 2010. – No. 1. – P. 63–67.

[12] Akhverdiev K.S., Mukutadze A.M., Research of Drive Factor of Damper with Double-Layer Porous Ring with Compound Feed of Lubricant Material. International Journal of Applied Engineering Research. – 2017. No. 1 – P. 76–85.