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IDENTIFYING THE INFLUENCE OF DESIGN PARAMETERS OF A HYDROSTATIC BEARING IN AN AIRCRAFT FUEL PUMP ON ITS STATIC CHARACTERISTICS

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The object of this study is hydrostatic processes in the sliding bearings of gear-type aviation fuel pumps.

The problem of the influence of the design parameters of the fuel pump bearing on its static characteristics was solved. Load-bearing capacity, lubricant consumption, and operating temperature conditions were considered as static characteristics. The determination of these characteristics was based on the pressure distribution function in the working fluid layer. An option was adopted with two load-bearing chambers located on the working surface of the hydrostatic bearing. Three options for the circumferential arrangement of chambers relative to the line of action of the external load were studied. A quantitative assessment of the effect of increasing the temperature of the working fluid on the consumption of lubricant and bearing capacity is given.

It has been established that with an increase in the angle of position of chambers relative to the line of action of the external load, the flow rate of the working fluid in the bearing increases, and its load-bearing capacity decreases. With a clearance in the bearing of 0.0225 mm, with an increase in the angle of the chambers from 30° to 40°, the flow of working fluid through the bearing increases by approximately 1.64 times. When the gap increases to 0.0425 mm and the angle of the chambers changes from 30° to 40°, the flow rate of the working fluid increases by approximately 1.2 times. The load-bearing capacity of the bearing with an increase in the chamber position angle from 30° to 40° decreases with a gap of 0.0225 mm by approximately 1.6 times, and with a gap of 0.0425 mm by approximately 1.93 times.

An increase in the temperature of the working fluid leads to a decrease in the load-bearing capacity of the bearing by 2.5 % and an increase in the flow rate of the working fluid in the bearing by 4.6 %.

The results allow for more rational design of hydrostatic bearings for fuel gear pumps

Keywords: hydrostatic bearing, gear pump, load-bearing capacity, flow balance, temperature regime

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1. Introduction

One of the important units ensuring reliable operation of an aircraft engine is the fuel pump. Due to a number of advantages, gear-type pumps are now widely used in fuel systems. Rolling bearings are most widely used as shaft supports for gear-type fuel pumps. However, due to changing operating conditions, plain bearings are becoming increasingly common. Pratt Whitney developed a geared motor. Sliding bearings are used as bearings for internal gears. In the classification of sliding bearings, hydrostatic bearings occupy an important place. These bearings are able to withstand heavy loads and have a very long service life at high rotation speeds. One of the main advantages of hydrostatic bearings is the ability to use the working fluid of the machine, in this case, kerosene, as a lubricant. Kerosene is under high pressure in the pump, which also indicates the possibility of using hydrostatic bearings. The operation of these bearings involves the use of both hydrostatic and hydrodynamic effects. They provide guaranteed fluid friction. The main criterion for the performance of these bearings is the minimum thickness of the working fluid layer separating the rubbing surfaces.

The practical design of hydrostatic friction bearings requires extensive theoretical and experimental studies of the characteristics of these bearings. The lack of information on the design of hydrostatic bearings for gear-type fuel pumps makes research on this problem relevant.

2. Literature review and problem statement

Paper [1] discusses the characteristics of lead-bismuth bearings with internal feedback in the main pumping system of a nuclear power plant. Lead-bismuth pumps use high-temperature liquid lead-bismuth as a lubricant in internal dynamic and hydrostatic bearings. In the cited work, the lubrication feasibility of a lead-bismuth bearing is investigated through numerical simulation. The pressure distribution, load carrying capacity, minimum film thickness, and power loss of a lead bismuth bearing are evaluated by rotation speed, eccentricity, and pressure drop. The findings show that the load-bearing capacity of the lead-bismuth hybrid bearing is mainly dependent on static pressure, with some support from dynamic pressure. Throttling is carried out through a feedback groove. The peculiarity of lead-bismuth grease is that it has low dynamic viscosity and high density. However, the work does not pay attention to thermal processes in the bearing, which, due to the characteristics of the lubricant used, can have a significant impact on the characteristics of the bearing. In [2], an elastic-hydrodynamic model of a hybrid sliding bearing for gear fuel pumps of aircraft engines is considered. The radial load applied to the gears due to increased pressure in the pump is fully absorbed by the hybrid plain bearing. Low viscosity aviation fuel is used to lubricate the bearings, making the design and analysis of sliding bearings particularly challenging. A numerical model was built to analyze the future design of hybrid plain bearings for fuel pumps. The main task was to determine the equilibrium position of the neck during stationary operation at partial and full load. A simple and reliable methodology has been devised to determine the pressure distribution in the lubricant for various bearing designs and operating conditions. However, the cited work does not pay attention to the turbulent flow of lubricant, which is typical for low-viscosity fluids and can have a significant impact on the characteristics of the bearing. Paper [3] discusses a new method for optimizing hydrostatic porous plain bearings used in hydraulic turbomachines. The hydraulic turbine machine uses a hydrostatic plain bearing equipped with a porous carbon-based bushing reinforced with carbon fiber. The bearing exhibits high load-carrying capacity but consumes excessive lubricant under pressure. The study focuses on maximizing the load capacity and minimizing the feeding power. The theoretical model is based on the Reynolds lubrication equation and the Darcy equation. A new numerical method based on the finite difference method is proposed to calculate bearing characteristics accurately and quickly. However, the cited work does not pay attention to the joint solution of the Reynolds equations and the balance of flow through the bearing, and the lubricant consumption for the considered bearing design will be significant. Study [4] discusses the optimization of the surface texture of the shoe and swashplate in EHA pumps. Well-designed surface textures have improved the tribological properties and efficiency of the electrohydrostatic drive pump under high speed and high-pressure conditions. The study proposes a multi-objective optimization model to obtain a design with arbitrary surface textures to improve the mechanical and volumetric efficiency of an EHA pump. The model consists of a lubricant film model, a dynamic component model that takes into account rotational motion. Experimental results showed a reduction in wear and an improvement in mechanical and volumetric efficiency by 1.4 % and 0.8 %. However, the work does not pay attention to the use of methods to significantly reduce wear on working surfaces through the use of hydrostatic effects in the lubricant layer. Paper [5] considers the problem of reducing friction losses in hydrodynamic bearings, the adjustable design of which provides additional opportunities for improving their dynamic and tribological properties. Viscous friction in bearings with active lubrication is reduced by adjusting the rotor position. The cited work provides a theoretical justification for the mechanism of this effect for cases of purely laminar lubricant flows in plain bearings. Conditions that ensure minimization of friction losses in hydrodynamic and hybrid bearings are determined on the basis of equations describing viscous friction in a liquid film. Adjusting the position of the shaft made it possible to optimize the distribution of tangential stresses in the liquid film. In addition, it is proposed to reduce the reduction in total friction losses by reducing lubricant consumption and power losses for its pumping. However, the work does not pay any attention to the turbulent flow of the lubricant, and the turbulent flow of the lubricant has a significant impact on the total power loss. Paper [6] discusses the development and application of a numerical analysis method for studying the hydrostatic and hydrodynamic characteristics of rotor systems with sleeve bearings. The bearing journal has a non-uniform geometry with pockets and grooves. The pressure of the fluid supplied to the pockets is a quadratic function of the shaft speed. An effective solution strategy involving both analytical and numerical methods was applied. A study was conducted on a bearing assembly commonly used in sodium-cooled fast reactor coolant pumps. As a result of the study, some specific dynamic characteristics of such bearings were identified. Based on such a parametric study, a rotor dynamic stability diagram was constructed for practical application. However, the work does not pay attention to the consideration of the equation of motion of the rotor inside the bearing, taking into account the unbalance of the rotor. This would make it possible to determine the dynamic characteristics of the bearing more accurately. Study [7] examines the influence of the morphology of a worn surface on the adaptive friction characteristics of a sliding pair in a hydraulic pump. The hydraulic pump hydrostatic bearing shoe pair has better friction reduction and anti-wear ability than ordinary sliding friction pair. Based on fractal theory, a model has been built to mathematically characterize the morphology of the shoe surface. Using the numerical analysis method, the influence of various fractal parameters on the friction coefficient and other operating parameters of the shoe was obtained. However, the work does not pay attention to the use of hydrostatic pressure to significantly reduce wear and total friction losses in the bearing. Paper [8] discusses the developed counter-rotating (CR) axial pump-turbine (RPT) unit. The paper proposes a power take-off (BOM) design in which the electrical machines and bearings are integrated into the CRRPT rim. In addition, active hydrostatic bearings are offered due to their longer service life compared to roller bearings and better starting and stopping behavior compared to hydrodynamic bearings. However, the work does not pay attention to the use of more efficient segmented designs of hydrostatic bearings, which provide a wider range of stable operation compared to conventional sleeve hydrostatic bearings. In [9], non-contact seals are considered as hydrostatic-dynamic bearings capable of effectively damping rotor vibrations. Models of the rotor and seal support systems of a shaftless pump were studied to assess the influence of these systems on the oscillatory characteristics of the rotor. Analytical dependences were derived to calculate the dynamic characteristics and stability limits of the rotor. However, the work does not pay attention to taking into account additional significant factors, such as rotor imbalance, which significantly affect the dynamics of the rotor and its stability of movement. Work [10] examines the influence of the design and operational parameters of the hydrostatic bearing of a gear-type fuel pump on its main characteristics. Determination of bearing characteristics was based on the pressure distribution function in the lubricant layer. It was determined from the joint solution of the Reynolds equations and the cost balance. The load-bearing capacity was determined by numerical integration of the pressure distribution function in the lubricating layer. Lubricant consumption was determined by calculated pressures in the chambers. Calculations showed that the fuel extraction for the operation of the hydrostatic support amounted to 1 % of the fuel pumped by the pump. However, the work does not pay attention to the analysis of the influence of the position angles of the load-bearing chambers and the increase in the temperature of the working fluid on the main characteristics of the bearing. Study [11] considers the operating conditions of an aircraft engine gear pump. It is emphasized that it operates in a wide temperature range, at high speeds, under heavy loads on shafts and supports, and other harsh conditions. This leads to a difficult lubrication condition for its plain bearing. In the paper, a typical static and dynamic sleeve bearing design was used for a gear pump. It has been established that the lubricant temperature and shaft rotation speed have a significant effect on the load-bearing capacity of the bearing. However, the work does not pay attention to the influence of lubricant flow turbulence on the bearing capacity. In [12], the characteristics of a hydrostatic bearing with an annular throttle damper in a spherical pump are considered. The article solves the basic Reynolds equation in spherical coordinates and studies the characteristics of a hydrostatic bearing. Load capacity, pressure drop coefficient, and lubricant film hardness variations are discussed in detail. The findings make it possible to design highly efficient spherical pumps. However, the work does not pay attention to the consideration of more efficient designs of the working surfaces of the hydrostatic bearing, taking into account the specifics of the pump's operation. Paper [13] considers the problem of increasing the productivity and energy efficiency of a machine tool using hydrostatic linear guides with a small liquid film thickness. For the new modern operating conditions of machine tools, it is proposed to switch from conventional roller bearings to hydrostatic guides. The use of hydrostatics made it possible to increase the rigidity and damping of the supports. The problem of losses in the pump, which consist of pressure and fluid flow, is considered. However, the work does not pay attention to the analysis of various designs when moving from roller bearings to hydrostatic bearings. In [14], the hydrodynamic reliability of lubrication of sliding bearings of gear aircraft pumps operating at high speeds is considered. An elastohydrodynamic lubrication model was established to take into account the elastic deformation of the bearing bushing by combining the Reynolds lubrication equations with an influence matrix. The peak pressure of hydrodynamic lubrication was taken as a reliability criterion. The peak pressure of bearings with an elastic bearing sleeve was found to be lower than that of rigid bearings. However, the work does not pay attention to a very important reliability criterion – the minimum clearance in the bearing. Study [15] discusses online monitoring of the thickness of the oil film of a plain bearing in an aircraft gear fuel pump. It is noted that bearings in aircraft fuel pumps operate under extreme conditions of high temperature and high pressure. Lubricant film breakdown is the main cause of lubrication failure and abnormal wear. However, the work does not pay attention to the analysis of hydrostatic effects in the lubricant layer, which exclude rupture of the lubricant film.

In the literature [1–15], there is no information on the study of the influence of the circumferential arrangement of load-bearing chambers on the working surface of a bearing on its load-bearing capacity and flow of working fluid. The influence of changes in the temperature of the working fluid at different positions of the load-bearing chambers in the bearing on its load-bearing capacity and fluid flow has also not been considered.

3. The aim and objectives of the study

The purpose of this work is to identify the influence of the design and operational parameters of the hydrostatic bearing of a fuel gear pump on its static characteristics. This makes it possible to establish acceptable limits for the design parameters of the bearing to ensure its performance.

To achieve the goal, the following tasks were set:

– to identify the influence of the angles of the circumferential arrangement of the load-bearing chambers on the working surface of the hydrostatic bearing on the flow rate of the working fluid and its load-bearing capacity;

– to establish the magnitude of the increase in the temperature of the working fluid in a hydrostatic bearing and identify its effect on the flow of working fluid and the bearing capacity.

4. The study materials and methods

The object of the study is hydrostatic processes in the sliding bearings of gear-type fuel pumps. For a hydrostatic bearing with two load-bearing chambers, it is proposed to study the effect of different circumferential arrangements of the chambers on the flow rate of the working fluid and the load-bearing capacity of the bearing. The increase in the temperature of the working fluid in a hydrostatic bearing was determined and its effect on the flow rate of the working fluid and the bearing capacity was studied.

When constructing mathematical dependences, the assumption was adopted that the pressure gradient across the thickness of the lubricant is small in comparison with pressure gradients in other directions. The inertial terms in the Navier-Stokes equations were assumed to be small in comparison with the viscous ones. The external load on the bearing was assumed to be constant. When deriving theoretical dependences for calculating the characteristics of a hydrostatic bearing, methods of fluid mechanics were used. The bearing characteristics were determined based on the pressure distribution function in the lubricant layer. An iterative method was used to determine the pressures in the chambers. The calculation continued until the specified accuracy was achieved. The pressures on the interchamber bridges were determined numerically using the finite difference method.

The numerical implementation of the constructed mathematical dependences was carried out in the Excel software (developed by Microsoft, USA). Drawings of the results were prepared in the graphic editor «Compass» (russia).

The diagram of the hydrostatic bearing of a gear-type fuel pump under consideration is shown in Fig. 1, 2.

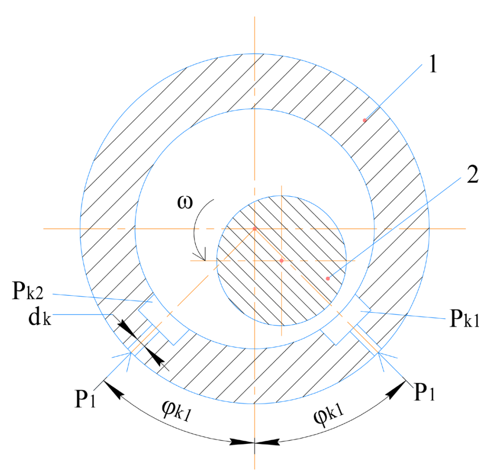

Fig. 1. Diagram of a hydrostatic bearing with two carrier chambers

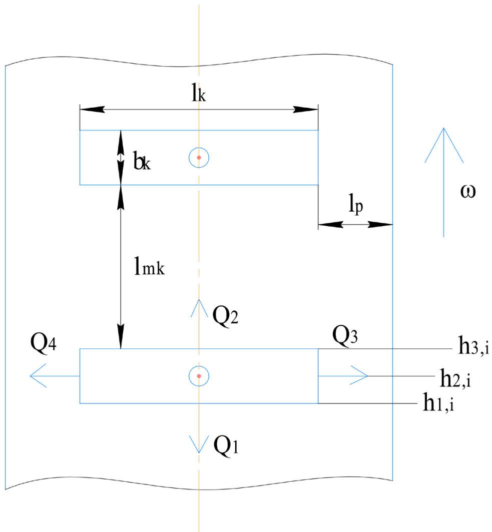

Fig. 2. Sweep of the working surface of a hydrostatic bearing

In the above diagram of hydrostatic bearing 1, there are two supporting chambers on the working surface, the pressure in which is indicated by P_k. Shaft 2 rotates inside the bearing with angular velocity ω. The working fluid is supplied to the supporting chambers under high pressure P_1. At the entrance to the chambers, inlet pressure compensators with a small diameter dk are installed. The working fluid located inside the pump, in this case kerosene, is used as the working fluid. Having passed through the slot path of the bearing, the working fluid enters the drain through the ends of the bearing.

Angle φ_{k1} shows the circumferential position of the supporting chambers on the working surface of the hydrostatic bearing. The magnitude of this angle affects the flow of working fluid through the bearing and its load-bearing capacity. Determination of the load-bearing capacity and flow rate of the working fluid is related to the pressure distribution function inside the working fluid. The pressure distribution function in the working fluid layer was determined from the joint solution of the Reynolds equations and the flow balance.

The mathematical dependences necessary to calculate the load-bearing capacity and flow rate of the working fluid of the hydrostatic bearing of the fuel pump are given in [10].

Thermal calculation of a hydrostatic bearing makes it possible to quantify the increase in the temperature of the working fluid and evaluate its effect on the change in the bearing capacity and the flow of working fluid through its slot path.

The determination of the increase in the temperature of the working fluid was calculated using the following relationship [16]:

$$\Delta T = \frac{N_C}{Q \cdot C \cdot \rho}, \qquad (1)$$

where Q is the flow rate of the working fluid; ρ – density of the working fluid; C – heat capacity of the working fluid; N_C – total power loss due to friction and lubricant pumping.

The flow rate of the working fluid was determined by formula (7).

Power loss for pumping N_{pp} was determined by the flow rate of the working fluid Q and the supply pressure of the working fluid to the supporting chambers P_1:

$$N_{pp} = Q \cdot P_1. \qquad (2)$$

Frictional power losses were estimated as follows:

$$N_{tp} = \frac{\mu \cdot \omega^2 \cdot R_p^3 \cdot L_p \cdot 2 \cdot \pi}{\delta_0}, \qquad (3)$$

where μ is the dynamic viscosity of the lubricant; ω – angular speed of shaft rotation; R_p – bearing radius; L_p – bearing length; $\delta_0 = R_p - R_s$ – radial clearance in the bearing; R_s – shaft radius.

Total power losses due to friction and pumping:

$$N_C = N_{tp} + N_{pp}. \qquad (4)$$

The above formulas make it possible to estimate the thermal mode of operation of the fuel pump bearing.

5. Identification of the influence of bearing parameters on its load-bearing capacity, lubricant consumption, and heating

5. 1. Identification of the influence of the circumferential arrangement of load-bearing chambers on the characteristics of a hydrostatic bearing

The study of the bearing capacity and flow rate of the working fluid of a hydrostatic bearing was carried out based on solving the flow balance and Reynolds equations. The pressure distribution function in the working fluid layer was determined by numerical solution of these equations. The numerical implementation of the flow balance equation makes it possible to determine the pressures in the load-bearing chambers in an iterative manner. Given the initial values of pressure in the chambers, the following values of pressure in the chambers were determined, which were used as initial values for the next iterations. The initial pressure values in the chambers were assigned based on experience in the design of hydrostatic bearings. They must be less than the supply pressure due to hydraulic losses in the channels in front of the chamber. When setting the initial pressure values in the load-bearing chambers, it is necessary to set larger values in the lower, more loaded chambers, and smaller values in the upper ones. Depending on the position of the shaft in the bearing, this difference can be significant, especially if the calculation is performed at large eccentricities. The more accurately the initial pressure values in the chambers were set, the fewer number of iterations the required result was obtained.

When determining pressures on the interchamber bridges, the boundary pressures were the pressures in the chambers and the pressure drop across the drain at the ends of the bearing. The pressures on the interchamber bridges were determined from the solution of the Reynolds equation. This equation was solved numerically using the finite difference method. When writing the Reynolds equation in finite-difference form, the surface between the chambers was covered with a regular grid. Partial derivatives in the Reynolds equation were written as finite differences using a five-point template. By specifying the initial values at the grid nodes and using the method of longitudinal-transverse sweep along the rows and along the columns, the pressures at the grid nodes were determined at the next step. The initial values at the grid nodes were set to be identical and equal to half the average pressure value in neighboring chambers. The obtained pressure values at the grid nodes at the first iteration were used as initial ones for the next iteration. The iteration process continued until the specified accuracy was obtained at all grid nodes.

After determining pressures in the chambers and on the interchamber bridges, the bearing capacity was calculated. It was defined as the sum of the load-bearing capacities of the chambers, inter-chamber, and end bridges of the bearing in projections on the vertical and horizontal axes. The pressure on the surface of the chambers was assumed to be constant. When determining the load-bearing capacities of inter-chamber jumpers, the Simpson method was used. The flow rate of working fluid through the bearing was determined by a formula based on the calculated pressures in the chambers.

Calculation of the load-bearing capacity and flow rate of working fluid for hydrostatic bearings with two load-bearing chambers was carried out at the following values of design and operational parameters:

1. Bearing diameter D_p=14.5 mm.
2. Shaft rotation frequency ω=855 s^{-1}.
3. Bearing supply pressure P_1=8 MPa.
4. Bearing length L_p=13 mm.
5. Working fluid kerosene TC–1 at a temperature of 100 °C.
6. Chamber length l_k=9 mm.
7. Chamber width b_k=4 mm.

The results of calculating the flow rate of the working fluid and the load-bearing capacity of the hydrostatic bearing of the fuel pump at various angular positions of the supporting chambers and various clearances are shown in Fig. 3, 4.

From Fig. 3, 4 it is clear that with an increase in the angle of the chambers relative to the line of action of the external load, the flow rate of the working fluid in the bearing increases, and its load-bearing capacity decreases. With a clearance in the bearing of 0.0225 mm, with an increase in the angle of the chambers from 30° to 40°, the flow of working fluid through the bearing increases by approximately 1.64 times. When the gap increases to 0.0425 mm and the angle of the chambers changes from 30° to 40°, the flow rate of the working fluid increases by approximately 1.2 times. The bearing capacity with an increase in the chamber position angle from 30° to 40° decreases with a gap of 0.0225 mm by approximately 1.16 times, and with a gap of 0.0425 mm by approximately 1.93 times.

The above analysis reveals that the angle of the chambers relative to the line of action of the external load significantly affects the static characteristics of the bearing.

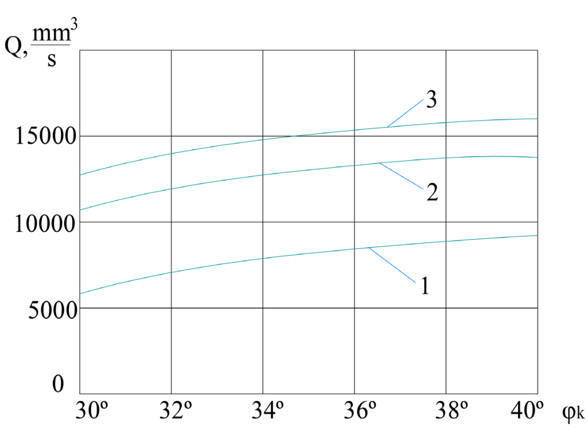

Fig. 3. Dependence of fuel consumption through the bearing on the angle of position of the chambers on the working surface: 1 – clearance in the bearing δ_0=0.0225 mm; 2 – clearance in the bearing δ_0=0.0325 mm; 3 – bearing clearance δ_0=0.0425 mm

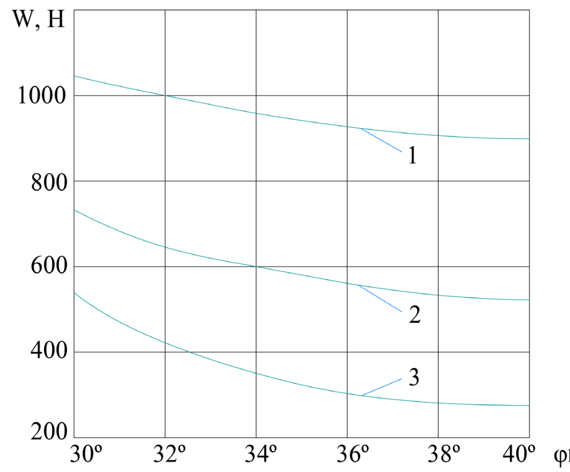

Fig. 4. Dependence of the load-bearing capacity of the fuel pump bearing on the angle of the chambers on the working surface: 1 – clearance in the bearing δ_0=0.0225 mm; 2 – clearance in the bearing δ_0=0.0325 mm; 3 – bearing clearance δ_0=0.0425 mm

5. 2. Identification of the influence of increasing the temperature of the working fluid on the characteristics of a hydrostatic bearing

The results of temperature change in the bearing are shown in Fig. 5.

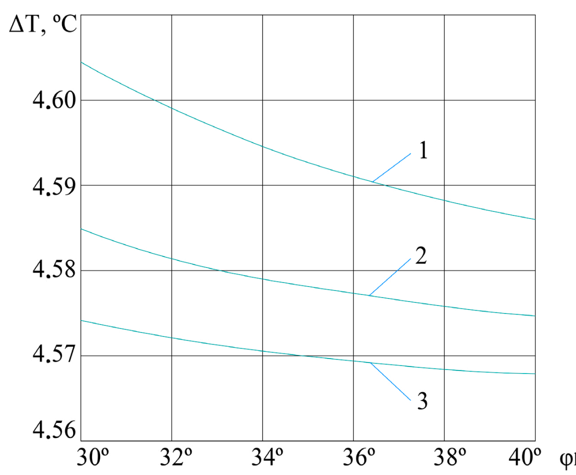

Fig. 5. Dependence of change in the temperature of the working fluid in the bearing on the angle of position of the chambers on the working surface: 1 – clearance in the bearing δ_0=0.0225 mm; 2 – clearance in the bearing δ_0=0.0325 mm; 3 – bearing clearance δ_0=0.0425 mm

Fig. 5 shows that the temperature of the working fluid when passing through the slot path of the bearing changes slightly. With increasing angles of the chambers on the bearing surface, the temperature of the working fluid tends to decrease. An increase in the clearance in the bearing leads to a decrease in the increase in the temperature of the working fluid as it passes through the slot path of the bearing. The calculation results showed that changing the temperature of the working fluid in a hydrostatic bearing has a minor effect on its static characteristics. An increase in the temperature of the working fluid in the studied range of parameters leads to a decrease in the bearing capacity by 2.5 % and an increase in the flow rate of the working fluid by 4.6 %.

The above analysis allows for a more rational design of hydrostatic bearings and shows that they can be recommended as supports for fuel pump shafts.

6. Discussion of results of investigating the static characteristics of a hydrostatic bearing with two carrier chambers

A feature of the proposed method is associated with assessing the possibility of using hydrostatic bearings operating on fuel pumped by the pump as shaft supports for gear-type pumps. An unconventional arrangement of load-bearing chambers on the working surface of a hydrostatic bearing is proposed. The above analysis of the influence of design parameters on the static characteristics of a hydrostatic bearing was not considered in [1–16]. The results allow for a more rational design of hydrostatic bearings and show the possibility of their use in aircraft fuel pumps. The results of calculating the load-bearing capacity, flow rate of working fluid, and thermal operating conditions are shown in Fig. 3–5.

From Fig. 3 it can be seen that for all considered gaps in the bearing, with an increase in the angle of the chambers on the working surface, the flow rate of the working fluid increases. With a clearance in the bearing of 0.0225 mm, with an increase in the angle of the chambers from 30 °C to 40 °C, the flow of working fluid through the bearing increases by approximately 1.64 times. When the gap increases to 0.0425 mm and the position angle changes from 30 °C to 40 °C, the flow rate of the working fluid increases by approximately 1.2 times. This is due to the fact that as the angle of position of the chambers increases, they enter the area of large gaps in the bearing and the resistance to lubricant leakage decreases.

From Fig. 4 it can be seen that the load-bearing capacity of the bearing with increasing angle of the chambers decreases with a gap of 0.0225 mm by approximately 1.16 times, and with a gap of 0.0425 mm by approximately 1.93 times. This is due to the fact that as the angle of the chambers increases, the gap in the chamber area increases, and the pressure in the lubricant layer decreases.

Fig. 5 demonstrates that with an increase in the angle of the chambers, the temperature of the working fluid decreases slightly. This is due to the fact that the consumption of working fluid increases and it heats up less. When the working fluid is heated, its viscosity decreases and therefore a decrease in load-bearing capacity of approximately 2.5 % was found.

The proposed solutions and the reported results make it possible to design hydrostatic bearings more rationally and recommend them for use in fuel pumps.

The advantage of this study is an integrated approach associated with solving a complex hydrodynamic problem. The proposed method allows for practical calculations of hydrostatic bearings for gear-type fuel pumps.

A limitation inherent in this study is the need for thorough cleaning of the working fluid to avoid clogging of the nozzles installed at the inlet to the chambers.

The disadvantage of this study is the lack of experimental data confirming the results of theoretical studies.

The development of this research may consist in conducting dynamic studies of the operation of the bearing as part of a gear-type fuel pump.

7. Conclusions

1. It has been established that when the chamber position angle increases from 30° to 40°, the flow rate of the working fluid increases from 1.64 times with a gap of 0.0225 mm and by 1.2 times with a gap in the bearing of 0.0425 mm. The bearing capacity with an increase in the chamber position angle from 30° to 40° decreases by 1.6 times with a gap in the bearing of 0.0225 mm, and by 1.93 times with a gap of 0.0425 mm.

2. It has been established that the increase in the temperature of the working fluid, depending on the angle of the chambers and the clearance in the bearing, ranges from 4.568 °C to 4.605 °C. An increase in the temperature of the working fluid in the studied range of parameters leads to a decrease in the bearing capacity by 2.5 % and an increase in the flow rate of the working fluid by 4.6 %.

Conflicts of interest

The author declares that he has no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

All data are available in the main text of the manuscript.

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