Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 206 (2017) 527–532

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Industrial Engineering, ICIE 2017

# Energy-Efficient Trajectories Rotors Supported on Radial Fluid-Film Bearings

S.V. Majorov, L.A. Savin, A.Y. Koltsov*

*Orel State Univesity, 29, Naugorskoe sh, Orel 302020,Russia*

**Abstract**

The problem of rotor machines modification requires development of new approaches to the design of specific nodes. As bearings are considered to be the most important elements of rotor machines, such approaches can imply optimization application. The present paper considers the approach for enhancing energy efficiency of rotor machines by means of generating optimal trajectories using the example of fluid-film bearings. The authors provide the means to analyze the obtained trajectories types. The paper also covers the approach for setting the criteria of rotor's trajectories energy efficiency. Besides, the paper presents the results of the conducted numeric analysis that led to the hypothesis about the existence of non trivial rotor energy-efficient orbital trajectories.



*Keywords:* energy-efficient; rotor system; fluid-film bearing; rotordynamics; hydrodynamic lubrication theory.

## 1. Introduction

The rotor with fluid film bearings is active-dissipative system in which the complex of hydrodynamic and heat transfer processes, and also different types of axial and lateral vibrations is realized. Viscosity, surface wettability, compressibility, phase transitions, turbulence, multiphase, rheological properties, technology factors, thermal, elastic, inertial processes acting important role for load-carrying capability of a fluid film [1-6]. Providing the sufficient bearing capability in rotor systems with bearings of liquid friction it is always connected with a task of orbital stability of movement of a rotor [7-12]. At the same time often the questions connected with an efficiency operating evaluation of such systems from the point of view energy costs pass into the background. However in

* Corresponding author. Tel.: +7-910-309-8250; fax: +7-486-241-9849.
*E-mail address:* sergeyostu@yandex.ru

1877-7058 
10.1016/j.proeng.2017.10.511

some cases, what is especially characteristic of autonomous systems the question of energy efficiency rises especially sharply. In this work the hypothesis about existence of rotor energy-efficient orbital trajectories is made, and also on the basis of a computing experiment the proof of her justice is provided.

## 2. Fluid-film bearing modeling

Main complexity of rotor-bearing modeling is calculation of fluid film bearing reaction.(Fig. 1). Fluid film bearing design model represented Fig. 1.

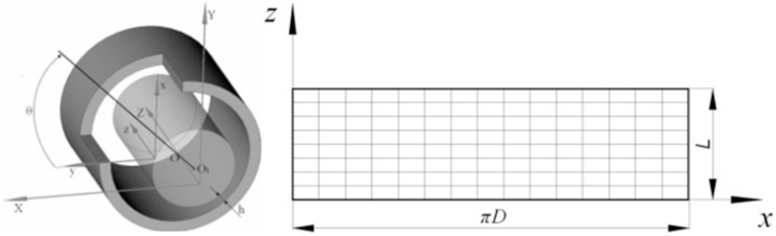


Fig. 1.Fluid film bearing design model (D – bearing diameter; L – length bearing)

The majority of works by calculation of fluid film bearing reaction is based on the solution of the Reynolds Eq. (1). And here, determination of the pressure distribution is a complex boundary problem based on the Reynolds equation. Using the operators of the partial first derivatives in the forms of $\partial/\partial x$ and $\partial/\partial z$, this equation reads:

$$\frac{\partial}{\partial x}\left[\frac{h^3\rho}{\mu K_x}\frac{\partial p}{\partial x}\right]+\frac{\partial}{\partial z}\left[\frac{h^3\rho}{\mu K_z}\frac{\partial p}{\partial z}\right]=6\frac{\partial}{\partial x}\left(\rho U h\right)-12\rho V, \tag{1}$$

where $x$ and $z$ are the circumferential and axial coordinates of bearing's sweep, respectively; $p$ represents the pressure inside the bearing; $\mu$ and $\rho$ are the viscosity and density of the fluid accordingly; $h$ is the radial gap function; $K_x$ and $K_z$ are the turbulence coefficients in the directions of turbulence, namely in the $x$ and $z$ directions, correspondingly, that determine the effective viscosity when the flow is turbulent considering the Reynolds stress. In expression Eq. (1), $U$ and $V$ are the values of the circumferential and radial velocities of the surface points of the shaft. The form of Eq. (1) is not exclusive and can vary depending on the different types and operational conditions of the bearing, more detail on the forms of Eq. (1) can be found in [1-5].However there are works [6] in which modeling is based on solution Navier-Stokes equation(NS equation).

Expressions for terms in Eq.(1) can be find at following references [1,3,5].The radial gap function can be expressed by following term:

## 3. Fluid-film bearing reactions

The pressure field $p(x,z)$ findings from Eq (1) is basis for determination of the hydrodynamic forces operating on a rotor shaft namely reactions of $R_X$ and $R_Y$ of a lubricant layer in the $X$ and $Y$ directions and $M_{fr}$ friction moment.

These terms can be determined by the following expressions

$$R_X=-\int_0^L\int_0^{\pi D} p\left(x,z\right)\cos\frac{2x}{D}dxdz-\int_0^L\int_0^{\pi D}\tau\left(x,z\right)\sin\frac{2x}{D}dxdz\ ; \tag{2}$$

$$R_Y=-\int_0^L\int_0^{\pi D} p\left(x,z\right)\sin\frac{2x}{D}dxdz+\int_0^L\int_0^{\pi D}\tau\left(x,z\right)\cos\frac{2x}{D}dxdz\ ; \tag{3}$$