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Stability Enhancement of High-Speed Rotors on Foil Bearings with the Automatic Mode Switch

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Abstract

The paper features the advantages and disadvantages of the modern generation of the foil bearings. The calculation diagrams are provided for the dynamic characteristics evaluation and the character trajectories of the rotor's center. The technique is described for the rotor's motion stability analysis. The concept of the modernized bearing design is suggested and justified.

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Keywords: foil bearing; bearing capacity; high-speed turbine; rotor's dynamics; pressure distribution; radial gap function; vibration stability.

1. Introduction

Due to the broadening of the frequency ranges of the high-speed rotors, more attention is drawn to the gas lubricated bearings. The most widely used bearings of this type are the gas-dynamic bearings. This class, similarly to the bearings with hard surfaces, are divided into single-foil and multi-foil, the difference between them is in the number of top foils, made usually out of antifriction materials. However, the applicability of such bearings is limited by their load capacity and stability. Russia, China, the USA and other countries are working on solution to this problem [1].

Scientists, considering the load capacity characteristic, divide the foil gas-dynamic bearings into three generations, design differences of which are in the increased stiffness of the top foil, which is achieved by means of introducing various segment and corrugated bump foils or in the new materials with increased stiffness (figure 1).

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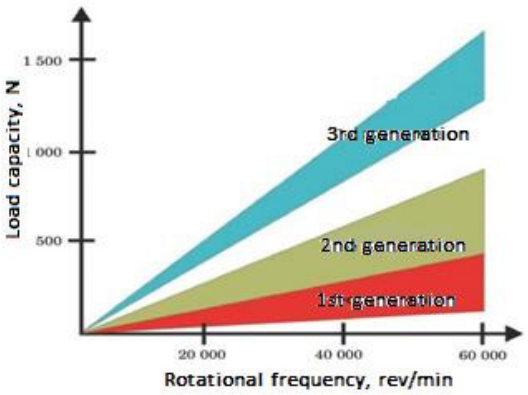

Fig. 1. Generations of the foil bearings.

Single-foil gas-dynamic bearings have a higher load capacity [2], but with an increase in the rotational frequency the vortex instability of the rotor's motion can take place. Multi-foil bearings do not allow this, in other words, they operate under the limited imbalance. If the inner surface of the bearing has a multi-wedge shape, the load is distributed more evenly, which leads to the decrease of the pressure in the radial gap and lower load capacity. So, the load capacity of a multi-foil bearing is lower than of the single-foil bearing, but the rotor stability is higher [3,4].

So, it is reasonable to consider a hybrid bearing – a foil gas-dynamic bearing with a system of operation mode switch, and it would encapsulate the advantages of single-foil and multi-foil bearings, and is free from their disadvantages. Application of such bearings allows significantly increase the reliability of high-speed rotors, increase their life-time expectancy, dynamic characteristics and the range of application.

2. Construction and mathematical modeling

The rotor-bearing system of a modern high-speed turbine with foil gas-dynamic bearings is a complex system, which consists of constantly interacting elements: a rotor, a bearing's sleeve with the foils mounted on it, and a fluid film preventing two surfaces from contact and transferring the load from the rotor to the housing of the machine. Generally, every element which obtains dynamics characteristics (elastic, damping, inertia properties) is able to influence significantly the deformation, thermal and vibration processes. The dynamic behavior of the rotor, supported by the foil gas-dynamic bearings is determined by the non-stationary forces acting on it, disturbing forces and bearing's reactions (figure 2).

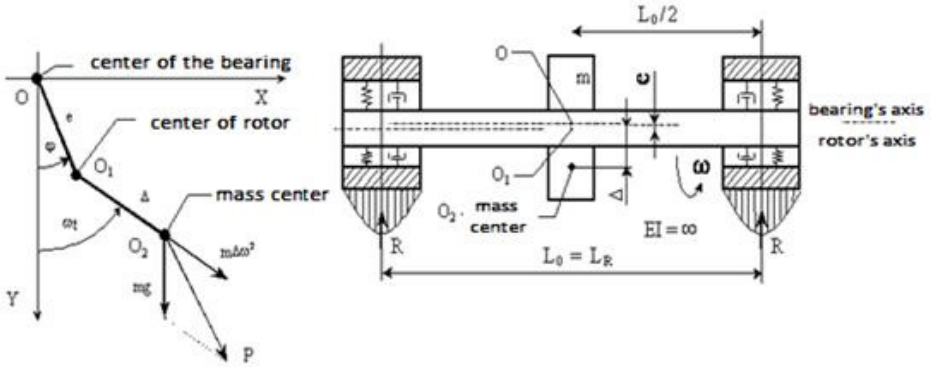

Fig. 2. Diagram of the acting forces.