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A short study on self-balancing of vertical rotors mounted in passive contactless bearings

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1. Introduction

Energy losses and wear of the support elements of high-speed rotors can be reduced by mounting the rotors in stable passive contactless bearings, the operation of which is based on magnetic levitation. The goal of the conducted research was to investigate applicability of self-balancing device added to vertical rotors supported by bearings showing low stiffness and damping, which is a specific property of passive magnetic bearings.

Energy losses and wear of the support elements of high-speed vertical rotors can be reduced by mounting the rotors in passive contactless bearings, the operation of which is based on a stable magnetic levitation. This is offered by utilizing interaction between the activated superconducting material and a permanent magnet or interaction between two permanent magnets separated by diamagnetic material.

The dynamical response of rotors on unbalance excitation depends on stiffness and damping of the support elements and eccentricity of the rotor center of gravity. In cases when the unbalance is induced during running the rotating machine like due to occurrence of ice layers or liquid drops on rotating parts, sedimentation of dust particles, or by variable deformation of the rotor flexible components, the technical solution making its reduction possible consists in application of a self-balancing device. It consists of movable weights attached to the rotor that due to their inertia effects take such a position, at which they compensate the rotor unbalance [1], [2]. This paper deals with applicability and efficiency of self-balancing devices added to vertical rotors supported by bearings having very low stiffness and damping, which corresponds to the properties of magnetic frictionless bearings.

2. The investigated rotor system

The investigated system (Fig. 1) is an axisymmetric vertical rotor consisting of a shaft and one disc. The rotor is loaded by a driving moment acting on the rotor in the direction of its axis of rotation (axis x), and by the disc unbalance. The lateral movement of the rotor is affected by external damping. The driving moment sets the rotor into rotation of controlled angular velocity. The rotor bearings show very little stiffness and no damping. To eliminate lateral vibration of the rotor produced by the unbalance excitation, it is equipped with a self-balancing device formed by two balancing weights. The weights can move on circular trajectories in the plane perpendicular to the rotor axis. They are coupled with the rotor by contact couplings in the radial and axial directions and by a viscous one in the tangential direction.

In the computational model the rotor is considered absolute rigid, stiffness of the bearings linear, and external damping and damping between the disc and the balancing weights viscous and linear. Because of the rotor symmetry, the disc motion is planar.

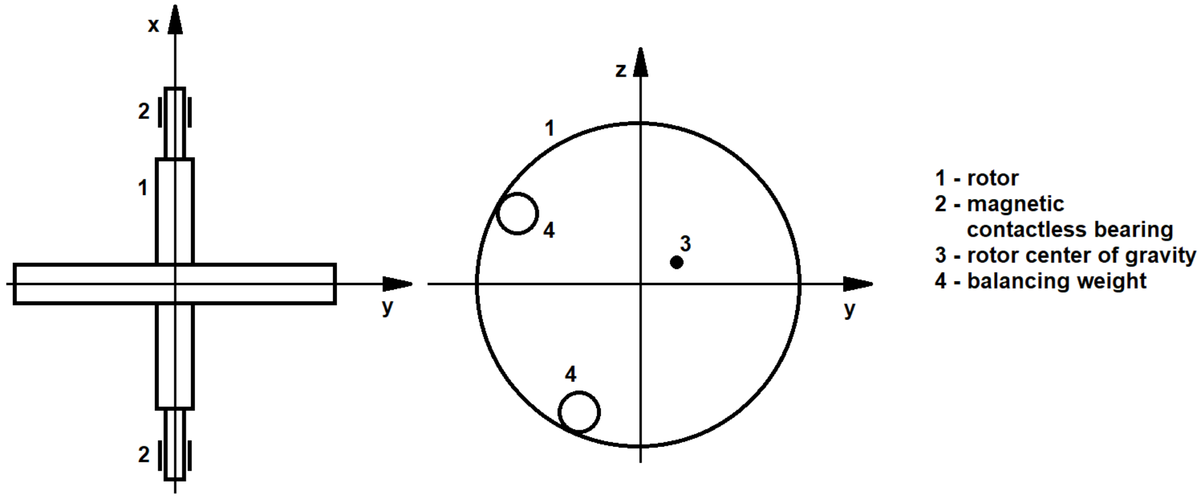

Fig. 1. The investigated rotor

The goal of the investigations was to determine time history of the disc center displacement after the rotor run-up to study efficiency of the self-balancing device.

3. Results of the simulations

The technological parameters of the investigated rotor are: mass of the rotor 130 kg, radial stiffness of one bearing 0.01 N/m, eccentricity of the disc center of gravity 50 μm, the number of balancing weights 2, mass of each balancing weight 21 g, radius of movement of each balancing weight 300 mm, and the damping coefficient of the coupling between the balancing weight and the rotor disc 1 Ns/m. The rotor angular velocity is time variable and approaches to the steady state value of 500 rad/s. Its time history is depicted in Fig. 2.

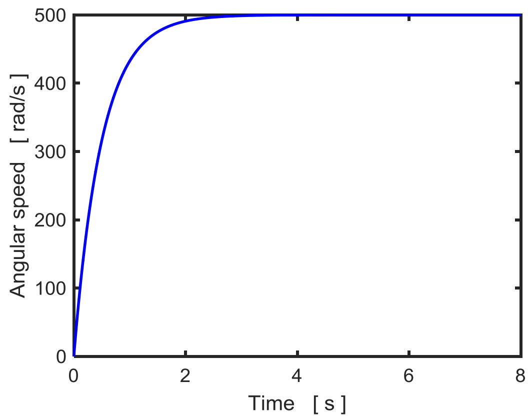

Fig. 2. Time history of angular velocity of the rotor rotation

The task was to analyze efficiency of the self-balancing device of a rotor supported by bearings of very low stiffness.

A simple analysis gives the undamped natural frequency of the rotor system 0.012 rad/s, which implies the rotor runs in the over-resonance area. If no self-balancing device were applied, the disc center would move after vanishing the transient component of the vibration on a circle, the radius of which would approach with rising speed to the disc eccentricity (50 μm).

No external damping was applied in the first investigated case. Fig. 3 shows the time history of the disc center displacements in the y and z directions. The simulation results indicate that no self-balancing effect can be observed.

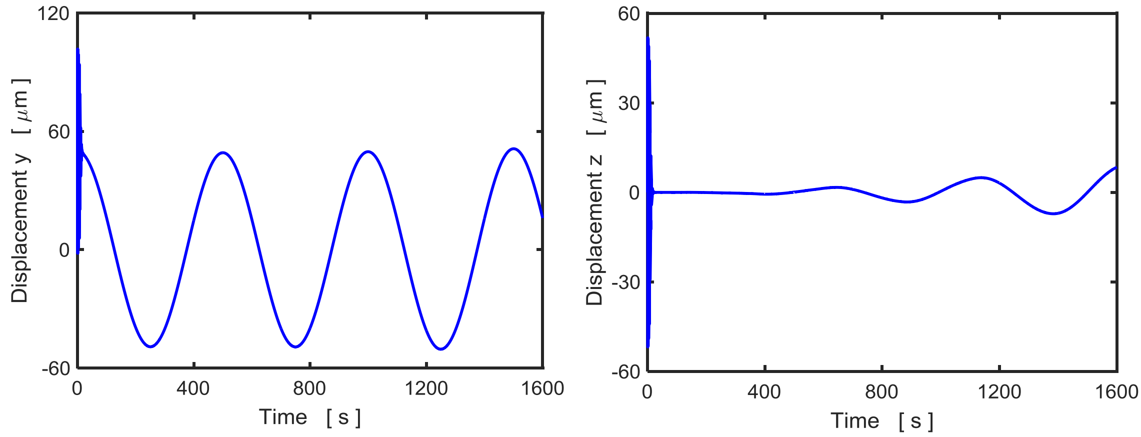

Fig. 3. Time history of the disc center displacements (no external damping)

In the second investigated case, the external damping of non-constant magnitude was added. Its initial value of 1000 Ns/m was reduced to zero during the time interval between 15 and 20 s from setting the rotor into rotation as depicted in Fig. 4.

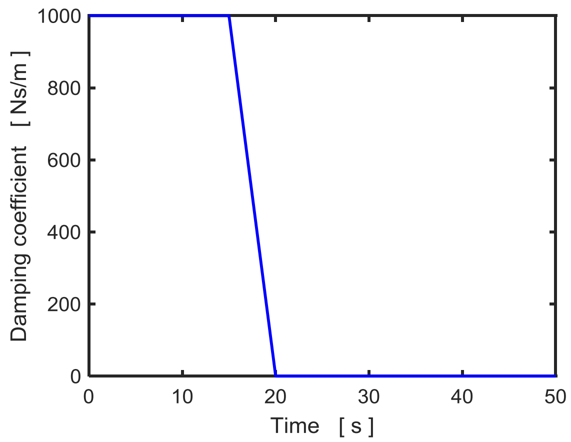

Fig. 4. Time history of viscous external damping coefficient

The time history of the disc center displacements in the y and z directions can be seen in Fig. 5. The steady state orbit is drawn in Fig. 6.

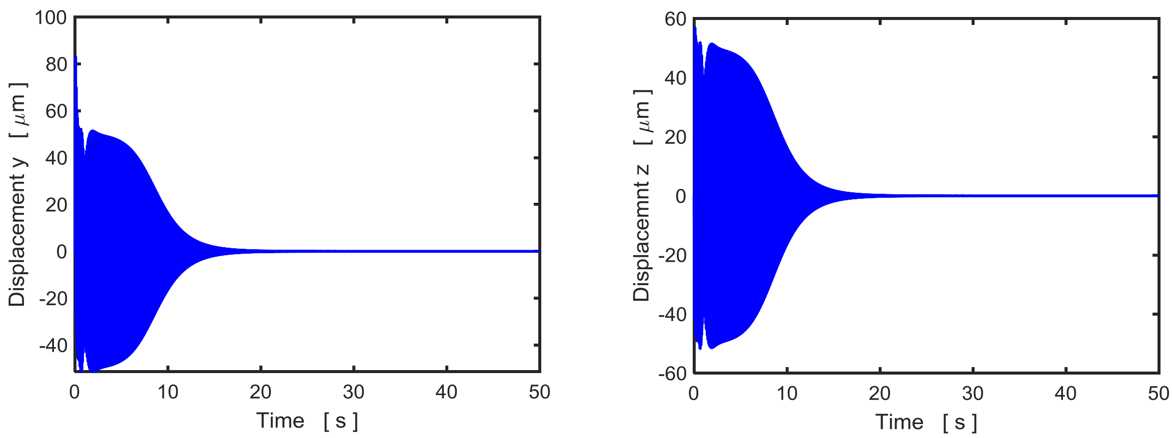

Fig. 5. Time history of the disc center displacements (external damping applied)

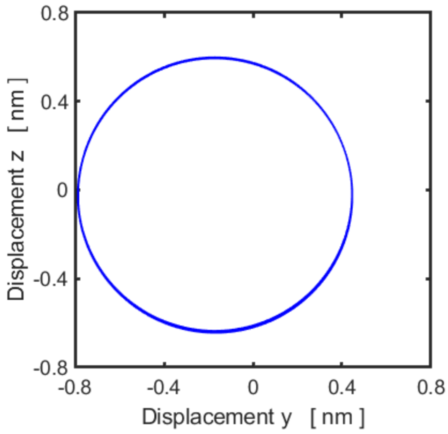

Fig. 6. The steady state orbit of the disc center (external damping applied)

The simulation results show that after some period of the transient vibration the self-balancing effect starts, and the vibration amplitude of the disc center approaches to zero.

4. Conclusions

The results of the analysis of self-balancing of vertical rotors supported by bearings of low stiffness show that (i) the self-balancing effect can be achieved only if the rotor vibration is affected by some amount of external damping, (ii) if the external damping is applied the self-balancing device makes it possible to reduce the rotor vibration amplitude, (iii) because of low stiffness the steady state orbit can be slightly moved from the initial position of the disc center, and (iv) decrease of the external damping does not induce transient vibration of increased magnitude.

Acknowledgements

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References

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