

## Research Article

### Segmented Hybrid Gasostatic Bearing Optimization

Prodan Nikolay Vasilevich and Bulat Mikhail Pavlovich

Saint-Petersburg National Research University of Information Technologies, Mechanics and Optics,  
Kronverksky pr., 49, Saint-Petersburg, 197101, Russia

**Abstract:** The purpose of research-development of methods of numerical optimization rotatable support pads gasostatic hybrid bearing. In the world's aerospace engineering the gas-dynamic bearings are currently most common. They are characterized by the supporting layer of different designs, which ensures the workability of the rotors during starts and stops. The main problem of this bearing type, apart from the construction complexity is the wear of this supporting layer. Gas-static bearing has no such defect, since there is no physical contact between solid surfaces. This study presents the results of the hybrid bearing's calculation, combining both technologies. The slotted nozzle of non-conventional shape that mirrors the solution of Reynolds equation's isoline is studied. The dependences of the main parameters on the speed of the shaft's rotation are discussed. The aerodynamic resistance of pads for different regimes of operation is investigated.

**Keywords:** Computational methods, gas-dynamic bearing, gas dynamics, gas-static bearing, hybrid bearing, hybrid bearing pad

#### INTRODUCTION

At the present stage of aerospace technology progress the fundamentally new combined air-jet engines, which have to operate in a wide range of parameters, are being developed (Bulat *et al.*, 2012). There are specific requirements for the design of such motors transmission assemblies. It is desirable to exclude the oil lubrication systems from such transmissions. One of the promising lines of work in this area is considered to be the development of contactless turbo-machine rotors (Bulat *et al.*, 2013; DellaCorte *et al.*, 2000), including air bearings. By the principle of creating lift force, they are all divided into gas-static (lift force is generated by the air, supplied under high pressure by the external device), gas-dynamic (lift force generated by the interaction of rotor and bearing moving parts with a thin viscous layer) and hybrid (both effects take place). Operation principle of the classical gas-static bearing is considered in works of Bulat and Uskov (2012a).

Gas-Dynamic Bearings (GDB) are characterized by having the support layer of different designs, in the form of cellular parts or folded ribbons and petals, which provide workability of rotors during starts and stops. GDB creates enough lift force only when the rotor's speed reaches 20% of the maximum. Prior to this the bearing operates under dry friction regime. At each start and stop the wear of antifriction coating, applied to the contact surface of the petals occurs, so

the resource of such bearing depends directly on the operating regime and the number of starts and stops. However, their main drawback is a small load capacity. Maximum known weight of rotors on gas-dynamic supports does not exceed 20 kg, resource 8-10 thousand h.

Gas-Static Bearings (GSB) are free from these drawbacks, since there is no physical contact between solid surfaces and the load depends on the pressure of supplied air. Thus, the increased air consumption in the GSB is compensated absolutely by the fire safety, as well as resource independence on the number of starts and stops.

The last statement is explained by the fact that the lift force, generated by pressured gas supply, weakly dependent on the shaft's rotating speed. The shaft can be hung on the air suspension and then unwind. When stopping the rotation speed can be decreased to 0 and then the shaft can be lowered to the support by reducing air supply pressure.

Hybrid bearings equipped with segments turnable under the influence of aerodynamic forces, combine the advantages of GSP and GDB. When starting and braking they use air positive pressure in lubricating layer, so that the dry friction of the rotor and the bearing surface is absent. At nominal modes segments are rotated to the optimum angle and the lift is completely created by the Bernoulli effect. Aim of this study is to develop a methodology for calculating of the rotatable segments that have the property of static

**Corresponding Author:** Bulat Mikhail Pavlovich, Saint-Petersburg National Research University of Information Technologies, Mechanics and Optics, Kronverksky pr., 49, Saint-Petersburg, 197101, Russia

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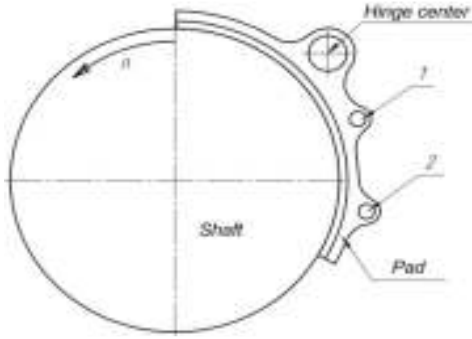


Fig. 1: Scheme of the pad

stability of the angle of rotation and rotation frequency of the rotor.

### METHODOLOGY

Examples of petal GDB segmented hybrid GSB calculation and the statement of calculation problem can be found in works of Beschastnykh and Ravikovich (2010) and Beschastnykh *et al.* (2009), as well as Listopadov and Shershnev (2006).

The initial system of equations for the calculation of the lubricating layer is given in work (Bulat and Uskov, 2012a). Methods for solving the Reynolds equation (Grassam and Powell, 1964), which is the basis for the theory of gas lubrication, are given in work (Bulat and Uskov, 2012b). Below we consider the results of calculation of the bearing segment with crescent-shaped slotted nozzle that mirrors the shape of Reynolds's equation solution isoline.

Figure 1 is a scheme of the pad, which was calculated. The pad is fixed in the center of the joint and is able to rotate relative to it.

It is necessary to investigate the dependence of the GSB's insert parameters on the shaft's rotating speed with a fixed angle of the inserts to the rotor's surface.

### Background:

- Average gap (by the lane connecting the axes of shaft's rotation and the joint) 20  $\mu$ , the output gap- 10  $\mu$
- Pressure at segment contour is atmospheric
- The pressure in the supply channels-0.4 MPa
- Rotation speed: 3000, 6000, 12000, 24000 rpm
- 3D model is presented in Fig. 2. Pads vary by the

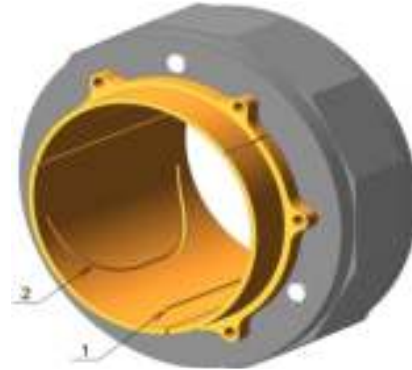


Fig. 2: 3D model of the GSB with self-adjusting inserts

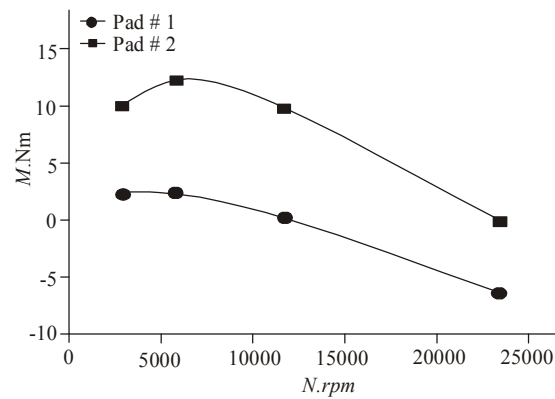


Fig. 3: Dependence of the main momentum, relative to the joint on the shaft's rotation speed

supply system sizes and nozzles. Pad 1 has a direct slotted nozzle 1 and the curved slotted nozzle 2 of the same width -2 mm. Diameter of supply throttle -1 mm. Pad 2 has a direct slotted nozzle of the width 2.8 mm and the width of the curved slotted nozzle -2 mm, throttle diameters -2 and 1.6 mm, respectively.

### RESULTS AND DISCUSSION

Figure 3 shows that at low rotation speeds, the momentum of pressure force seeks to rotate the pad to the increase of attack angle. At high speeds the momentum's sign is changed. Thus, the insert, installed with unfixed rotation axis possesses the stability during the change of attack angle, depending on rotation speed.

Table 1: Results of numerical simulation

	Calculate area with 1 mm gap				Calculate area with 2 mm gap			
	3000	6000	12000	24000	3000	6000	12000	24000
Rotor's rotation velocity, rpm	3000	6000	12000	24000	3000	6000	12000	24000
Gas consumption $Q$ , r	0.680	0.670	0.650	0.600	1.260	1.440	1.280	1.070
Momentum, relative to the joint, $M$ , H*m	2.629	2.654	0.498	-6.242	10.518	12.637	10.200	0.190
Pressure force longwise the axis, that through the rotor's rotations center and joint's rotation center, $F_m$ , H	782	822	972	1333	1258	1080	1274	1636
Main pressure forces vector $F$ , H	772	811	952	1287	1260	1092	1275	1601

The results of numerical simulation (momentum and resultant force) of three-petal hybrid gas bearing with forced air supply into the gap allow simulate the dynamics of the rotor using the procedure, described in the work of Beschastnykh and Ravikovich (2010).

The design of the self-aligning bearing insert is possible. The problem is to choose the nozzle geometry and position of the axis of the hinge so that the insert has the property of the angle rotation stability.

Results of pad's calculation are summarized in Table 1.

#### ACKNOWLEDGMENT

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