applied sciences

MDPI

Editorial

Special Issue "Gas Bearings: Modelling, Design and Applications"

Federico Colombo *, Luigi Lentini, Terenziano Raparelli and Andrea Trivella

Politecnico di Torino, Department of Mechanical and Aerospace Engineering, Corso Duca degli Abruzzi 24, 10129 Turin, Italy
* Correspondence: federico.colombo@polito.it

1. Introduction

Gas bearings are widely employed in high-precision devices and in high-speed applications, such as in micro turbomachinery and micro machining tools. In metrology and high-tech industry, the absence of contact between the surfaces that are in relative motion is appreciated due to the possibility of obtaining high-precision motion. Recent trends in small-scaling turbomachinery demand increasingly higher rotational speeds; the advantage is the ability to operate with higher power to weight ratios. Additionally, in this case, gas bearings represent the only solution due to their simplicity and long operating life, with no need for maintenance.

This issue collects research and review papers covering the modelling, design, and application of gas bearings. Each published paper distinguishes itself from the others in the sense that it deals with the problem from an original point of view. Some papers analyze several prototypes to improve their performance, while others concentrate more on the mathematical modelling of bearings, developing analytical or numerical formulations with lumped or distributed parameters. These different approaches show how complex the analysis of gas bearings can be, but they also show how fascinating the process of finding simple solutions to complex problems is.

check for updates

Citation: Colombo, F.; Lentini, L.; Raparelli, T.; Trivella, A. Special Issue "Gas Bearings: Modelling, Design and Applications". *Appl. Sci.* **2022**, *12*, 9048. https://doi.org/10.3390/app12189048

Received: 8 September 2022
Accepted: 8 September 2022
Published: 8 September 2022

2. Outline of the Issue

The papers published in the Special Issue are here summarized in the order of their publication dates. Most of them investigate gas bearings using theoretical and experimental approaches. Numerical models, after they have been experimentally validated, are important tools for the design and optimization of gas bearings. Current models are able to consider multi-physical problems such as fluid–structure interaction, thermal effects, and porous materials. In some cases, tailor-made software is written to solve the equations, and in other cases, commercial software is employed. The experimental results confirm the validity and accuracy of multi-physical numerical models.

In high-precision devices, such as fly cutting machine tools or rotary tables, the deformation of solid parts is often not negligible, as it influences the performance of the aerostatic bearings. In [1], the fluid–structure interaction effect is considered to investigate the static and dynamic performance of an aerostatic spindle. In particular, the thickness of the thrust plate is optimized to reach a compromise between the reduction of the spindle mass and the increase in the thrust bearing stiffness.

Foil gas bearings are particularly useful in turbomachinery, as they are able to sustain high-speed blowers, compressors, and turbochargers without the requirement of an external air supply. Paper [2] describes the thermo-hydrodynamic model of a bump foil thrust gas bearing. The cooling models of the foil structure and thrust plate as well as the influence of temperature on the thermal expansion of the bearing structure are considered. The effects of the bearing speed, thrust load, and external cooling gas on the bearing temperature field are calculated and analyzed.

Paper [3] reviews the state-of-the-art of gas foil bearings in China, many of which have been developed for use in high-speed turbo machinery. Different types of foil bearings are described (bump, multi-leaf, wire, viscoelastic, spring and protuberant), as are their different applications (e.g., fuel cell air compressors, blowers, turbo-expanders, and oil-free turbochargers). The addressed challenges concern thermal management, rotor-dynamic stability, and wear-resistant coatings.

High-tech industry products such as solar panels, chips, and displays are composed of very thin layers of brittle materials that need to be handled with care. An original solution to handle the thin substrates without mechanical contact is proposed in [4]. The system works by floating the substrate on a thin film of air and by creating a viscous traction force on it. The actuator is improved to reach a bandwidth of 300 Hz, while the position control loop of the substrate reaches a bandwidth of 10 Hz with a position error of less than 13 µm. It is a good example of the so-called tribotronics discipline.

It was shown in the literature that the radial error motion of an aerostatic journal bearing is mainly influenced by the shape errors of the shaft. The influence of the shaft roundness and the cylindricity errors on the aerostatic spindle's rotation accuracy is evaluated in [5]. The research proposes an index that is more effective in predicting the spindle's rotation accuracy than the roundness and cylindricity.

Paper [6] presents an elegant analytical model of a porous gas journal bearing after a literature survey on the topic. The analytical model is able to predict the flow and the dynamic force coefficients. An FE model is compared to the analytical one, and a perfect match is found. A validation of the static results with experimental data from the literature is also carried out. The paper represents a useful design guide for the quick selection of physical parameters, both for static performance and for stability analysis.

A partial arc annular-thrust porous journal bearing that can carry both radial and axial loads is investigated in [7]. The analysis is carried out using commercial multi-physical software in order to evaluate the pressure distribution for low eccentricity as well as for low tilting angles and tilting speeds. The dynamic coefficients of tilting motion are then determined using the finite difference technique.

Finally, the modal parameters of an aerostatic spindle are identified experimentally based on the impulse response in paper [8]. Different methods are proposed to identify the damped natural frequencies and the damping ratios of the conical and cylindrical modes of the spindle. The same modal parameters are also evaluated with a non-linear numerical model, and a comparison with experimental results is provided to validate the model.

3. Future of Gas Bearings

The different gas bearing solutions require accurate mathematical models and cannot be easily standardized due to the complexity and variety of the problems. Despite gas lubrication being a well-established discipline since the 1970s, the ever-rising demands of modern technology offer new challenges to obtain higher precision and higher rotational speeds, stimulating researchers to broaden the frontiers of gas lubrication.

Author Contributions: Writing—original draft preparation, F.C.; Writing—review and editing F.C., L.L., T.R. and A.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The editors would like to acknowledge all of the authors for their high-quality contributions to this Special Issue. The MDPI management and staff are also acknowledged for their continuous support.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Gao, Q.; Gao, S.; Lu, L.; Zhu, M.; Zhang, F. A Two-Round Optimization Design Method for Aerostatic Spindles Considering the Fluid–Structure Interaction Effect. *Appl. Sci.* **2021**, *11*, 3017. [CrossRef]
2. Liu, X.; Li, C.; Du, J.; Nan, G. Thermal Characteristics Study of the Bump Foil Thrust Gas Bearing. *Appl. Sci.* **2021**, *11*, 4311. [CrossRef]
3. Hou, Y.; Zhao, Q.; Guo, Y.; Ren, X.; Lai, T.; Chen, S. Application of Gas Foil Bearings in China. *Appl. Sci.* **2021**, *11*, 6210. [CrossRef]
4. Hooijschuur, R.; Saikumar, N.; HosseinNia, S.H.; van Ostayen, R.A.J. Air-Based Contactless Wafer Precision Positioning System. *Appl. Sci.* **2021**, *11*, 7588. [CrossRef]
5. Zhang, G.; Zheng, J.; Yu, H.; Zhao, R.; Shi, W.; Wang, J. Rotation Accuracy Analysis of Aerostatic Spindle Considering Shaft's Roundness and Cylindricity. *Appl. Sci.* **2021**, *11*, 7912. [CrossRef]
6. Andrés, L.S.; Yang, J.; Devitt, A. Porous Gas Journal Bearings: An Exact Solution Revisited and Force Coefficients for Stable Rotordynamic Performance. *Appl. Sci.* **2021**, *11*, 7949. [CrossRef]
7. Hwang, P.; Khan, P.; Kang, S.-W. Parameter Sensitivity Analysis on Dynamic Coefficients of Partial Arc Annular-Thrust Aerostatic Porous Journal Bearings. *Appl. Sci.* **2021**, *11*, 10791. [CrossRef]
8. Colombo, F.; Lentini, L.; Trivella, A.; Raparelli, T.; Viktorov, V. Experimental and Numerical Dynamic Identification of an Aerostatic Electro-Spindle. *Appl. Sci.* **2021**, *11*, 11462. [CrossRef]