

Review of Doctoral Thesis

1. PhD candidate
Ing. Michal Michalec/ Michal.Michalec@vut.cz
2. Name of PhD programme
Design and Process Engineering (Mechanical Engineering Design)
3. Title of PhD thesis
Performance and safety improvement of large-scale hydrostatic bearings
4. Principal supervisor
doc. Ing. Petr Svoboda, Ph.D. / Petr.Svoboda@vut.cz
5. Co-supervisor
Ing. Petr Šperka, Ph.D./ Petr.Sperka@vut.cz
6. Reviewer
Prof. Dr. Michel Fillon/ michel.fillon@univ-poitiers.fr
Poitiers University
7. Overview of the scope of PhD thesis¹
Very good
The objectives of the thesis are the bearing performance improvement on one hand, and the insurance of safe operation on the other hand, of large hydrostatic thrust bearings. An experimental device was designed and experiments were performed on a twin hydrostatic pad of 4 recesses each. A numerical model was proposed by the means of a CFD software for optimizing the position and the size of the recesses in order to minimise the power losses. This modelling has been validated firstly by the means of experimental and theoretical data. The comparison to the classical analytical methods has underlined the main advantages of the proposed numerical model. The powerful and the more accurate proposed methodology has been demonstrated. In the last section, the influence of the manufacturing and assembly errors including the mechanical components misalignment on the thrust bearing performance has been studied and the limits of these imperfections has been analysed with and without a compliant pad support. This experimental study has permitted the suggestion of using this current method to evaluate the level of eventual errors on real applications. Finally, these research works bring new and original results for a better understanding of the large hydrostatic thrust bearings functioning.

¹ Overview of the scope of PhD thesis is a short description of objectives of PhD thesis's research and summary of main findings and scientific achievements.



8. Significance of the topic and clarity of problem statement

Very good

The topic is clear and accurately presented; the choice of this topic is also very original, knowing that only few studies have been performed during the last decades, and especially on large hydrostatic thrust bearings. Even if analytical methods for the evaluation of the hydrostatic thrust bearing performance are enough sufficient nowadays for roughly designing them, the strong review of the knowledge in this field done by the PhD candidate has permitted to show the lack of the methodologies for the accurate optimization of the pad geometry and of the analysis of the effects of manufacturing and assembly errors on the behaviour of the hydrostatic bearings. The applications concern the large hydrostatic thrust bearings operating under steady state regime, at low runner velocity.

9. Knowledge of existing literature

Very good

The previous research works on hydrostatic lubrication in general as well as on hydrostatic bearings and their hydraulic equipment have been nicely and extensively presented in a complete review paper by the PhD candidate. From the reviewer's point of view, some aspects were not necessary to be included in this review paper, as the research concerns the large hydrostatic thrust bearings. For example, the influence of surface texturing which has been and is still mainly dedicated to hydrodynamic lubricated contacts, both journal and thrust bearings; very few published works are concerned with the analysis of the influence of the surface texturing in hydrostatic lubricated contacts and not very significant were obtained. To be noted that the reference on the initiation of hydrostatic lubrication by Girard can be found in "*Hydrodynamic Lubrication – Bearings and Thrust Bearings*", by J. Frêne et al., Tribology Series, 33, Editor: D. Dowson, Elsevier, 1997.

10. Choice of methods and technical soundness

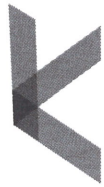
Very good

The methodologies chosen by the PhD candidate are very appropriate and suitable for strong analysis of the behaviour of large hydrostatic thrust bearings. Both experimental and numerical approaches for the determination of the performance of such bearings are an excellent proposal. Then, the validation of the accurate CFD modelling with the comparison with the experimental data and the analytical predictions is welcome and highly beneficial for the credibility of the parametric study (optimization of the pad geometry for more efficiency) performed in a second step. Even if the proposed methods sound technically correct, one can regret that the numerical simulations used (needed) the experimental value of the film thickness; a fully autonomous method would include the film thickness prediction.

11. Quality, originality and significance of the results

Very good

The methodological way chosen has permitted new results, both numerical and experimental results. The results are significant and original due to the fact of the specific hydrostatic lubrication device of large size developed and used in the laboratory and of the well instrumented twin pad thrust bearing. The results have been obtained for realistic operating conditions, similar to the industrial applications. By this means, the limits of acceptable manufacturing and assembly errors as well as the safe range of misalignment were specified for the current configuration; they are of primary importance for practical applications. In addition, the parametric study on the recess size and location optimization has underlined the high quality of the results and has given ways of improving the performance of these large size hydrostatic bearings.



12. Quality of attached papers

Very good

The review paper as well as the other research works have been peer-reviewed and published in various and renown international scientific journals with a high Impact Factor. I have no doubt of the high quality of the works and the results presented and discussed in these journals.

13. Overall assessment, strengths and weaknesses (based upon the above evaluation categories 8–12)

Very good

A serious and complete review paper on hydrostatic lubrication has been published showing a strong knowledge of the problems and the previous works on hydrostatic thrust bearings. A very original and well instrumented test device designed and developed has permit to get new and of high significance experimental data. A great experience and understanding of the large hydrostatic thrust bearings from both theoretical and experimental points of view. Various and numerous numerical simulations and novel optimization proposal of size and location of recess for more efficient large hydrostatic bearings (lowest power losses). In the near future, the numerical method should be enhanced by predicting the film thickness alone (without using the experimental value)

14. Questions and comments

To be noted that the reference on the initiation of hydrostatic lubrication by Girard can be found in "Hydrodynamic Lubrication – Bearings and Thrust Bearings", by J. Frêne et al., Tribology Series, 33, Editor: D. Dowson, Elsevier, 1997. How the surface texturing on the pad lands can improve the hydrostatic thrust bearing performance? How, in practice, can you manage the presence of compliant pad supports and the requirement for high precision (i.e. high stiffness) for a telescope application, for example? In the studied configurations, hydraulic resistance were employed but it seems that they were not considered during the numerical simulations: why?

15. Conclusion

PhD thesis is an independent scientific work that presents a novel solution to a significant problem in the research area and demonstrates the candidate's ability to conduct independent research.

YES

16. Date and signature

25/03/2024

Please note

Review of Doctoral Thesis

1. PhD candidate

Ing. Michal Michalec/ Michal.Michalec@vut.cz

2. Name of PhD programme

Design and Process Engineering (Mechanical Engineering Design)

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Performance and safety improvement of large-scale hydrostatic bearings

4. Principal supervisor

doc. Ing. Petr Svoboda, Ph.D. / Petr.Svoboda@vut.cz

5. Co-supervisor

Ing. Petr Šperka, Ph.D./ Petr.Sperka@vut.cz

6. Reviewer

dr hab. inż. Michał Wodtke/ michal.wodtke@pg.edu.pl

Politechnika Gdańska

7. Overview of the scope of PhD thesis¹

Very good

The dissertation is devoted to the problems of increasing the energy efficiency and operational safety of large-scale hydrostatic bearings. The thesis provides a detailed review of the state of the art, which reveals potential areas for further research. A new two-parameter optimization method based on numerical calculations has been proposed to increase the energy efficiency of hydrostatic bearing operation (CFD – only fluid flow was considered). It makes it possible to reduce the energy consumption for multi-pocket bearing pads by optimizing their geometry. The problem of increasing the operational safety of hydrostatic bearing was analyzed using experimental tests on a unique two-pad test bench. This was carried out by introducing predefined assembly errors of the hydrostatic multi-section bearing (both pad and cooperating slider) and then examining the operation of the bearing system. The main scientific achievements of the dissertation can be summarised as follows: a) development of an experimentally verified numerical model of a hydrostatic bearing and its use to propose a new two-parametric method for optimizing the geometry of the bearing pad, b) experimental investigation of the hydrostatic bearing assembly errors on its operation and the possibility of compensating them using flexible support, c) an experimental investigation of the effects of assembly errors of the divided slider in stationary and low-speed sliding conditions on the performance of the hydrostatic bearing.

¹ Overview of the scope of PhD thesis is a short description of objectives of PhD thesis's research and summary of main findings and scientific achievements.



8. Significance of the topic and clarity of problem statement

Very good

In recent years, there has been a clear trend towards increasing the demands on machine components, such as reduction of energy consumption or ensuring their safe operation under increased loads. The methods known from the literature for defining the optimized geometry of hydrostatic bearings are based on single-parameter optimization. The calculation results of the new two-parameter optimization method for HS bearing pad geometries proposed in the dissertation show, that energy savings can be achieved while maintaining the same safety margin. Furthermore, large hydrostatic bearings, due to their size easily exceeding 2m in diameter, are often designed and used as multi-section bearings with divided sliding collars. Factors, that are usually not considered at the design stage, i.e. manufacturing or assembly errors, can play a significant role in their safe operation. A study of the impact of such errors on the performance of a hydrostatic bearing system, which was analyzed and documented in the dissertation, is valid from a practical and scientific point of view. For the abovementioned reasons, I believe, that the topic of the dissertation is up-to-date and fits well into tribology and bearing systems engineering science. In addition, the problem discussed and solved within the dissertation was well and clearly defined.

9. Knowledge of existing literature

Excellent

The review of existing literature, appended to the dissertation, on the design, operation, and efficiency enhancement of hydrostatic bearings was published in the high-ranked scientific journal Engineering Science and Technology (2021, IF = 5.7, with 70% author contribution). It provides a comprehensive summary of the existing state of knowledge from 209 references including scientific journals, reports, and books. This review is supplemented by references that were published between the publication of the review article and the year of publication of the doctoral thesis. Generally, the Author demonstrated a very good knowledge of the existing state of the art in the broad subject of the work. It includes the calculation and optimization methods used, design, the impact of sliding surface manufacturing errors, utilized materials, lubrication systems, and their components. The summarized state-of-the-art includes references to all the most important sources, including recent literature. Alternatively, it could be considered to supplement it with guidance from existing normative recommendations (e.g., ISO 12167 and ISO 12168) and research on the use of hydrostatic systems as components of active bearing lubrication, which can be used to optimize rotor dynamics (papers of Professor I. Santos et al., e.g., Journal of Tribology Transactions of ASME 2004, TI 2017 and some others).

10. Choice of methods and technical soundness

Very good

Both theoretical and experimental methods were used in this study. For the theoretical analyses of the hydrostatic bearing, a computational fluid dynamics tool CFD using the finite volume method with interpolation of the obtained results implemented in the MATLAB environment was used. CFD tools are very common in scientific research on various aspects of lubricated bearing systems. The calculations carried out in this work were preceded by an analysis of the boundary conditions and imposed simplifications, as well as the results of the mesh independence study, and their quality does not raise doubts. Experimental tests were performed on a unique test rig, which allows simultaneous testing of two independent hydrostatic bearing segments also under low-speed sliding conditions. Several parameters were monitored during tests, i.e. oil pressure at the oil supply to the recesses, hydrostatic film thickness, oil temperature in the HS pockets, load, and lubricating oil flow rate. Although the determined measurement errors of selected parameters are quite significant in proportion to the measured values (e.g. pressure or film thickness), the results obtained are a valuable source of information. Measurements



for individual bearing operational conditions were repeated several times to eliminate random errors. In summary, the experimental techniques utilized in the dissertation and the measured parameters are typical for studies of this type of object and were performed properly.

11. Quality, originality and significance of the results

Good

The reviewed dissertation is one of the first works dealing with the impact of errors (surface, assembly) and two-dimensional optimization on a large hydrostatic thrust bearing operation. The results, both from theoretical and experimental investigations, do not raise any major concerns. In the case of CFD analyses, the novelty is to investigate the effect of two independent parameters on the energy performance of the bearing. As a result, it was proved theoretically that the energy demand can be reduced without reduction of the safety margin. The experimental results presented in this paper, obtained for a multi-segment hydrostatic bearing with predefined assembly errors, are original and have not been published in the literature so far. However, it seems that for their full interpretation, it would be advisable to carry out complementary structural analyses of the system (e.g., using FEM) to conclude the actual stiffness of the bearing components (segment and slider) and their influence and magnitude (or lack of influence) on the obtained test results. The limitations of the bench also did not allow tests to be carried out under conditions closer to those encountered in real applications (especially for higher specific pressures). The results obtained are qualitatively important for designers of large hydrostatic bearings from the point of view of minimizing energy requirements and permissible manufacturing and assembly errors of bearing components. They also indicate the scale of the benefits of using flexible support of the bearing pads to compensate for possible assembly errors of the bearing components.

12. Quality of attached papers

Very good

Four scientific papers are attached to the dissertation. They contain a detailed literature review and documentation of the developed research methodology and its results. Papers in the majority were published in renowned, high-ranked journals of proven quality with global impact that have a high IF (Impact Factor). They passed a detailed reviewing process and were accepted for publication. They contain details of the applied methodology. They have a clear and logical structure and are written using correct technical language and appropriate terminology. They contain a thorough description of the methodology used and the research results obtained and provide a rich source of documentation of the scientific activities. They are also cited in the scientific literature. The few pieces of information that are not provided in them include, for example, the type and manufacturer of utilized measurement sensors (especially for pressure and displacement measurements) and the exact positions of their installation (for displacement sensors).

13. Overall assessment, strengths and weaknesses (based upon the above evaluation categories 8–12)

Very good

The overall assessment of the reviewed dissertation is very good. The paper contains original research results on methods to increase the efficiency and operational safety of large hydrostatic bearings. The obtained results are interesting and valuable, especially for designers of bearing systems of this type and scientists involved in bearing engineering. The strengths of the work include: a) a comprehensive review of the existing state of knowledge, b) using a variety of experimental and theoretical techniques to solve a problem, c) very reliably conducted and documented original numerical and experimental studies on near



real-world objects and d) unique experimental results with predefined assembly errors. This type of experimental study conducted under static and linear sliding conditions at low speeds during HS operation was previously unknown in the literature. The few weaknesses of the work, which do not affect the high rating of its content, include the following: the relatively low accuracy of the used measurement sensors to measure values of the parameters and the lack of information about the utilized type of sensors, or the unverified assumption of the lack of deformation of the bearing elements when interpreting the experimental results of the impact of assembly errors on the performance of the system. The overall high evaluation of the dissertation is also confirmed by the fact, that all obtained results have been published in peer-reviewed international scientific journals.

14. Questions and comments

The following are questions and comments that arose during the analysis of the proposed methods and the obtained research results. They are mainly of minor importance and are supplementary and informative. They are as follows:

1. The obtained geometry of the HS bearing pad using the new two-parameter optimization method according to Figure 14 from page 64 of the thesis has a cylindrical hydrostatic pocket that (as can be seen from the posted dimensions) is tangent to both symmetry planes of the segment ($D = 35.32$ mm, $t = 17.66$ mm, $D = 2xt$). Is this pad geometry possible to manufacture? Is it reasonable, to introduce an additional limitation of the optimization method as the minimum thickness of the passage between pad lands?
2. Do the optimal segment geometry results obtained by the proposed new optimization method suggest that the most favorable solution for the analyzed segment is a system close to a single hydrostatic pocket with a square shape located centrally?
3. Experimental verification of the optimal geometry from the one-parameter and two-parameter methods would be a very interesting complement to the results obtained through theoretical analyses. Would it be possible to carry it out on the test stand you possess? What would be the expected results of such research based on theoretical analyses?
4. The use of interpolation of the results obtained from the optimization method did not change the location of the optimal point. In addition, an analysis of the result in Figure 13 (page 64 of the thesis) shows that there is quite a large group of solutions with similar energy requirements (the Plato area around the indicated optimal point), which perhaps for other practical reasons (e.g., the ability to compensate pad misalignment) could be considered as valuable. Is this statement true?
5. In the case of numerical computational analysis, it is good practice to show the details of the developed computational grid, which is missing in the dissertation. In addition, it is worth considering in the future a different way of presenting the results of calculations than contour plots, such as plots of the variation of a selected parameter (pressure, flow velocity) as a function of the length of the diagonal segment. This would make it easier to compare results with each other.
6. What was the type of measurement sensor used to monitor oil pressure and relative displacement of components and their measurement range?
7. Positions of the sensors are not given precisely, especially for proximity sensors. According to Fig. 14 (on page 77 of the dissertation), it seems, they are positioned relatively far from the pad edge. It makes direct interpretation of the results of oil film thickness difficult without further processing. It would be better (more precise for distance measurements) to place the sensors as close as possible to the pad edge. The reason for placing the distance sensors away from the bearing pad was not discussed in the dissertation. Was that a possibility of oil contamination of the proximity sensor?
8. In addition, when planning future studies, one could also consider placing pressure measuring points at locations other than the hydrostatic pockets (selected points on the sliding surface).
9. In the dissertation content, the assumption of non-deformability (without confirmation) of the components of the bearing system was made to interpret the experimental results of the impact of component assembly errors of the bearing system. Has it been verified by any methods (computational,



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experimental)? Alternatively, when verifying this assumption, did it take into account the design of the support of the bearing pads and the slider, which may affect the rigidity of the system?
10. What was the typical accuracy (tolerance) of the predefined assembly and position errors of the bearing and slider components?

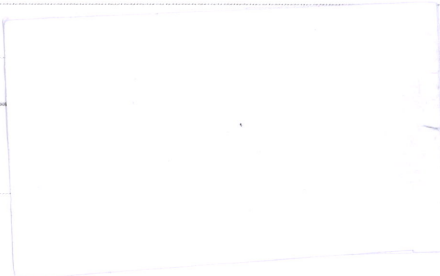
15. Conclusion

PhD thesis is an independent scientific work that presents a novel solution to a significant problem in the research area and demonstrates the candidate's ability to conduct independent research.

YES

16. Date and signature

25/03/2024



Please note

- A. Evaluate categories 7 to 13 using the following scale: unacceptable, acceptable, satisfactory, good, very good, excellent. The qualification of 'excellent' should only be given for a PhD Thesis in the top 3% of the research in your field of expertise.
- B. E-mail the completed form to: Klara.Javorcekova@vut.cz



Principal supervisor's final report on the PhD study

1. PhD candidate
Ing. Michal Michalec / michal.michalec@vut.cz
2. Name of PhD programme
Machines and Equipment (D4Z-P - P2302) / Design and Process Engineering
3. Title of PhD thesis
Performance and safety improvement of large-scale hydrostatic bearings
4. Principal supervisor
doc. Ing. Petr Svoboda, Ph.D. / petr.svoboda@vut.cz
5. Co-supervisor
Ing. Petr Šperka, Ph.D. / petr.sperka@vut.cz
6. Stays at other institutions (min. 7 days)
26/06/2023 – 10/07/2023 University POLITEHNICA of Bucharest, Romania, 04/01/2023 – 30/01/2023 University of Maribor, Slovenia, 12/01/2022 – 22/05/2022 Auburn University, USA, 22/08/2021 – 12/09/2021 INSA Lyon, France 03/06/2021 – 30/06/2021 TU Wien, Austria
7. Teaching activities
2023 ZRS Project Management 2023 1K Engineering Drawing Fundamentals 2023 1K-A Engineering Drawing Fundamentals 2022 ZKR Research and Development Project 2022 ZRS Project Management 2022 0ZP Aventics Pneumobil Racing 2022 1K Engineering Drawing Fundamentals 2021 ZKR Research and Development Project 2021 ZRS Project Management 2021 1K Engineering Drawing Fundamentals 2020 ZKR Research and Development Project 2020 0ZR Pneumobil Racing 2020 1K Engineering Drawing Fundamentals 2020 2K Engineering Drawing 2020 3CD CAD 2019 ZIP Mechanical_Design_Project 2019 1K Engineering Drawing Fundamentals 2019 2K Engineering Drawing 2019 3CD CAD



8. List of main publications

Publications related to the thesis topic:

MICHALEC, M., P. SVOBODA, I. KŘUPKA, M. HARTL. A Review of the Design and Optimization of Large-scale Hydrostatic Bearing Systems. *Engineering Science and Technology, an International Journal*, 2021, vol. 24, issue 4, s. 936-958. ISSN: 2215-0986. [IF = 5.7]

MICHALEC, M., V. POLNICKÝ, J. FOLTÝN, P. SVOBODA, P. ŠPERKA, J. HURNÍK. The prediction of large-scale hydrostatic bearing pad misalignment error and its compensation using compliant support. *Precision engineering*. Elsevier, 2022, vol. 75, 67-79. doi:10.1016/j.precisioneng.2022.01.011 [IF = 3.6]

MICHALEC, M., J. HURNÍK, J. FOLTÝN, P. SVOBODA. Contactless measurement of hydrostatic bearing lubricating film using optical point tracking method. *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, 2022, vol. 237, issue 1, 1-9. <https://doi.org/10.1177/13506501221108138>. [IF = 2.0]

MICHALEC, M., T. DRYML, D. JAVORSKÝ, L. SNOPEK, M. ČUPR, J. FOLTÝN, P. SVOBODA. Assembly error tolerance estimation for largescale hydrostatic bearing segmented sliders under static and low speed conditions. *Machines*. MDPI, 2023, vol. 11, p.14. doi:10.3390/machines11111025 [IF = 2.6]

MICHALEC, M., M. ONDRA, M. SVOBODA, J. CHMELÍK, P. ZEMAN, P. SVOBODA, R. L. JACKSON. A novel geometry optimization approach for multi-recess hydrostatic bearing pad operating in static and low-speed conditions using CFD simulation. *Tribology Letters*. Elsevier, 2023, vol. 71, issue 52, p.14. doi:10.1016/j.precisioneng.2022.01.011 [IF = 3.2]

Other publications:

MICHALEC, M., P. SVOBODA, I. KŘUPKA, M. HARTL. Tribological behaviour of smart fluids influenced by magnetic and electric field – A review. *Tribology in Industry*, 2018, vol. 40, issue 4, pp. 515-528. ISSN: 0354-8996. [Citescore = 2.6]

MICHALEC, M., P. SVOBODA, I. KRUPKA, M. HARTL a A. VENCL. Investigation of the tribological performance of ionic liquids in nonconformal EHL contacts under electric field activation. *Friction*, 2020, 8(5), 982-994. ISSN 2223-7690. Available from: doi:10.1007/s40544-019-0342-y [IF = 7.4]

VENCL, A., M. KANDEVA, E. ZADOROZHNYA, P. SVOBODA, **M. MICHALEC**, A. MILIVOJEVIĆ a U. TRDAN. Studies on structural, mechanical and erosive wear properties of ZA-27 alloy-based micronanocomposites. *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications*, 2021. <https://doi.org/10.1177/1464420721994870>. [IF = 2.5]

ČERNÁK, M., **M. MICHALEC**, M. VALENA, M. RANUŠA. Inlet shape optimization of pneumobil engine pneumatic cylinder using CFD analysis. *Journal of Physics: Conference Series 1935. Journal of Physics: Conference Series*, 2021. ISBN: 1742-6588. [Citescore = 0.7]



9. Assessment of the supervision process

Very good

The supervision process followed the pre-set rules for PhD study. The process was based meetings and on-demand discussions with supervisor, co-supervisor and colleagues from a Hydrostatic Research Group. The candidate was always well prepared to discuss the issue of the dissertation including reflection of critical comments. The final PhD thesis and research papers were prepared in time and in sufficient quality. The output of the dissertation was three main research papers supplemented by a review article about the state of the art. The review is based on 209 references including original research articles, reviews and books on topic of HS lubrication and large-scale HSB. The teaching activities of candidate were focused especially on tutorials of courses of Engineering Drawing, Research and Development Project, Aventics Pneumobil Racing and CAD. The candidate attended three international conferences where he presented partial results of his research: 76th STLE Annual Meeting, Orlando, FL, USA; 7th World Tribology Congress 2022, Lyon, France and 9th International Tribology Conference 2023, Fukuoka, Japan.

10. Assessment of the candidate's ability to work independently

Very good

The candidate worked independently, based on the discussion with me and my colleagues from the lab and other experts from universities and companies in the field of mechanical engineering. I would like to highlight his cooperation with foreign experts in the field of HSL: prof. Robert Jackson from Auburn University (USA), prof. Michel Fillon (University of Poitiers), Dr. Michal Wodtke (Gdansk University of Technology) and prof. Traian Cicone (Universitae Politehnica Bucharest). The candidate independently designed a methodology of experiments based on the state of the art, performed experiments, and, according to the results analyses, he formulated conclusions. All the publications, where candidate is listed as the main author, were prepared by himself. The candidate also supervised five bachelor theses, one diploma thesis and significantly participated in the other research projects of our small Hydrostatic Research Group with Bosch Rexroth company.

11. Assessment of the contribution that the research makes to knowledge in the field

Very good

The PhD thesis is composed from three main research papers in the journals with impact factor (Tribology letters, Precision engineering and Machines) supplemented by an own review article about the state of the art (Engineering Science and Technology, an International Journal) based on 209 references. However, the candidate is also author and co-author of other publications in the field of tribology, namely three publications in journals with impact factor and two in journals in Scopus database. He also participated in applied research outcomes (two utility models and two functional samples). The main scientific output of this thesis is a novel multi-recess pad shape optimization method of HSB based on CFD. For the first time, assembly errors of segmented sliders were assessed and experimentally investigated under static and low-speed conditions. As part of the work, it was suggested experimental-based methodology for HSB compliant support and compared with rigid support. These findings are missing in current methodologies for the design of HSB. This work helps to find answers to some of the questions regarding the HSB design. I believe that the obtained scientific findings will suite the future development of HSB for better design and energy saving.

12. Other comments

none



13. Conclusion
PhD thesis is an independent scientific work that presents a novel solution to a significant problem in the research area and demonstrates the candidate's ability to conduct independent research.
YES

14. Date and signature	
08/01/2024	

Please note

- A. Evaluate categories 9 to 11 using the following scale: unacceptable, acceptable, satisfactory, good, very good, excellent.
- B. In each category 9 to 11 explain reasons for evaluation using between 100–200 words.
- C. E-mail the completed form to: Klara.Javorcekova@vut.cz