INSTITUTE OF MACHINE
AND INDUSTRIAL DESIGN

FME

Faculty of Mechanical Engineering
Brno University of Technology

Review of Doctoral Thesis

1. PhD candidate
Ing. Housam Mohammad/ 215325@vutbr.cz
2. Name of PhD programme
Design and Process Engineering (Mechanical Engineering Design)
3. Title of PhD thesis
Experimental Investigation of the Rolling Contact Fatigue Behavior of Toroidal Bearings Using Acoustic Emission

4. Principal supervisor
doc. Ing. Pavel Mazal, CSc. / Pavel.Mazal@vut.cz>
5. Co-supervisor
Ing. Libor Nohál, Ph.D./ xmnohal00@vutbr.cz

6. Reviewer
Univ.-Prof. Dipl.-Ing. Dr. techn. Franz Rauscher / franz.rauscher@tuwien.ac.at
TU Wien

7. Overview of the scope of PhD thesis[1]
Very good
An overview of the scope is given in the summary and in the introduction (Chapter 1). The background and objectives are clearly described in these chapters. In 'Aims of the thesis' (Chapter 4), the tasks set are described. Under 'Scientific questions' (Chapter 4.1), three questions are posed that are to be answered, followed by 'Hypotheses' (Chapter 4.2). The hypotheses are more or less a description of the procedure for answering the questions and the background; clear hypotheses that can be answered with yes or no are not given. All results are summarised in the conclusions (Chapter 7). Overall, the scope of the study is clearly defined, the background is described and the results are summarised.

8. Significance of the topic and clarity of problem statement
Very good
The condition monitoring of wind turbines and, in the context of this task, of the main bearings is an important research topic. The problem of detecting rolling contact fatigue is described in the introduction (Chapter 1) and the state of the art (Chapter 2), where various methods for condition monitoring of this phenomenon are described. The methods that correspond to the state of the art are described and their

[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.

disadvantages are pointed out. For the condition monitoring of rolling bearings with acoustic emission, mainly parameters from the time domain are used. As an extension, the frequency spectrum of the acoustic emission signals with the dominant frequency as the most important parameter is used in this thesis.

9. Knowledge of existing literature

Very good

Within the thesis 72 external references are given. The topics are roller bearings, rolling contact fatigue, condition monitoring, wear monitoring, Acoustic emission, vibration measurement, slow speed bearings, and wind turbines. In the case of acoustic emission measurement (AE), general topic like AE Signal analysis in time as well as in in frequency domain, source location, crack detection, testing, and monitoring as well es more specific topic like Failure detection in roller bearings with AE, and monitoring of slow speed bearings are included. Also, literature form peripheral areas like AE in rocks and sandstone was considered. The literature comes from a large variety of journals, conference proceedings, books etc. and includes older as well as recent publications. The specific topic as well as the background is covered.

10. Choice of methods and technical soundness

Very good

For condition monitoring of Toroidal Roller bearing in wind turbines, acoustic emission measurements for detecting and predicting the initiation of defects was evaluated. For that purpose, a wireless remote condition monitoring system was configured, installed and tested. Special attention given to the ability to do long time measurements on-site. Therefore, operation parameter, parameters from vibration measurement, and some general AE parameters were recorded continuously. In addition, the sampled AE signal was recorded for short time segments. This AE records were analysed afterward in detail. The whole arrangement and evaluation method were tested on a laboratory arrangement. The methods sound appropriate for the chosen duty.

11. Quality, originality and significance of the results

Very good

The traceability of results is assured by describing the measurement procedure. For the interpretation of the results, measurement on a laboratory arrangement was performed. In this case scattered pitting on the inner ring and spalling in the loading zone on the outer ring of the toroidal bearing could be monitored by acoustic emission, vibration, and temperature measurements. Special attention was given to the parameters in the frequency domain. Here the dominant frequency was chosen as parameter extension to previous measurements. The use of frequency-domain parameters is state of the art for acoustic emission testing where transient recorder pages are used for this purpose. The extension here is the special procedure for long time processing with Post processing hit detector.

12. Quality of attached papers

Very good

In chapter 8 "List of publication", five journal papers and three papers from conferences are listed. From the journal papers, two are stated as in progress, and, for the three other papers, a copy of the first page of is included in the theses (a download of the whole papers was possible by the given links), seeing it as the most significant ones: The first one is published in the Springer Book series Lecture Notes in

Mechanical Engineering. The second paper was published in by Taylor&Francis in Nondistructive Testing and Evaluation 2023.The third paper was published in the journal Actuators by MDPI 2022. All three papers have a reviewing process. The first two papers are published by Springer and Taylor&Fracis, which are two traditional publishers with long time good reputation. For the first two papers H. Mohammad is the corresponding author with three other authors. In the third paper, H.Mohammad is one of five authors and, it is stated that the measurement are his contribution. Within the first two papers the contribution of H. Mahammad is not explicitly described, but his position as corresponding author makes, clear that his contribution is the most significant one.

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

Very good

For condition monitoring of Toroidal Roller bearing in wind turbines, a wireless remote condition monitoring system was configured, installed and tested. Special attention given to the ability to do long time measurements on-site. Therefore, operation parameter, parameters from vibration measurement, and some general AE parameters were recorded continuously. In addition, the sampled AE signal was recorded for short time segments. This AE records were analysed afterward in detail. Strengths: The whole arrangement and evaluation method were tested on a laboratory arrangement, long time measurements were done on a wind turbine, and the results were evaluated. Weakness: In comparison to former studies in this field, special attention was given to the frequency spectrum of the acoustic emission signals. Within the results the advantage of these parameters seems to be relatively small. Overall assessment: The performed scientific work, the background, and the basics auf acoustic emission measurement were described within the theses. References to the most important publication of the author are given – the papers are open access and appropriate links are given.

14. Questions and comments

I assume that Mr Mahmammad carried out the essential parts of the research work himself. For me, however, his part and also the parts that existed before his work are not entirely clear. I am also not familiar with the usual grading in Brno, so I am open to other suggestions in the course of the defence.

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

16/09/2024

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*

INSTITUTE OF MACHINE AND INDUSTRIAL DESIGN

FME

Faculty of Mechanical Engineering
Brno University of Technology

Review of Doctoral Thesis

1. PhD candidate

Housam Mohammad / Housam.mohammad@vutbr.cz

2. Name of PhD programme

Programme: Machines and Equipment, Branch: Design and Process Engineering

3. Title of PhD thesis

Experimental Investigation of the Rolling Contact Fatigue Behavior of Toroidal Bearings Using Acoustic Emission

4. Principal supervisor

doc. Ing. Pavel Mazal, CSc. / pavel.mazal@vutbr.cz

5. Co-supervisor

Ing. Libor Nohal, PhD / libor.nohal@zkl.cz

6. Reviewer

Doc.dr. Tomaž Kek / tomaz.kek@fs.uni-lj.si

University of Ljubljana, Faculty of Mechanical Engineering, Aškerčeva 6, 1000 Ljubljana, Slovenia

7. Overview of the scope of PhD thesis[1]

Very good

The objective of this PhD research was to investigate the rolling contact fatigue (RCF) behavior of Toroidal Roller Bearings (TRBs) using acoustic emission (AE) as a primary non-destructive testing technique. The study aimed to explore the potential of frequency-domain analysis, particularly the dominant frequency (DF) of AE hits, for detecting and characterizing defects in TRBs. The research sought to address gaps in existing methodologies by developing new tools, such as DF maps and post-processing hit detectors, and applying these techniques both in laboratory settings and in field conditions, including wind turbines. The research demonstrated that AE, particularly DF analysis, is a more sensitive and reliable method for detecting RCF in TRBs than traditional vibration methods. The introduction of DF maps provided a novel way to visualize and quantify defects, with distinct DF bands correlating with specific defect types and sizes. The successful application of a remote condition monitoring system further validated the practical utility of the approach. This work challenges previous assumptions about AE time-domain parameters and paves the way for future studies incorporating AI to refine defect detection and predictive maintenance strategies.

8. Significance of the topic and clarity of problem statement

[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.

Very good

In his PhD thesis, the candidate focused on three key questions, the first of which related to the connection with the influence of operating parameters in the initiation of RCF cracks at TRBs and other types of bearings. How a quantifiable frequency-domain parameter DF of AE signal, could be used to evaluate or quantify the level of defects on the monitored bearings' raceways and how does the shape of the toroidal rolling element affect the operation parameters of the bearing. Presented scientific questions were the basis for 3 basic hypotheses that the candidate considered in the context of various types of experiments and measurements. Clarity of the problem statement is reflected in the study's focus on improving non-destructive testing (NDT) methods, particularly through the use of acoustic emission (AE) technology. The research identifies a gap in existing methodologies, where time-domain analysis of AE signals has been extensively used, but frequency-domain analysis, especially the dominant frequency (DF) of AE hits, has been underexplored.

9. Knowledge of existing literature

Very good

The student summarized the articles that are related to the topic of the doctoral dissertation and provide a good overview of the current situation in the research field covered in the doctoral thesis. He summarized articles that were published in journals with a high impact factor such as: International Journal of Fatigue, Wear, Tribology International, Renewable Energy, IEEE Transactions on Industrial Informatics, Composites Science and Technology and belong to the field of Q1. He has reviewed also medium impact journals dealing with Tribology, Acoustic emission, Nondestructive Testing and Evaluation and Engineering Failure Analysis that are closely connected to the condition monitoring of toroidal bearing. In his work, the candidate summarized the references that represent the current findings in the field under consideration.

10. Choice of methods and technical soundness

Very good

Candidate investigates the rolling contact fatigue behaviour of toroidal bearings using AE technique. The investigation included laboratory measurements of this type of bearing, as well as measurements in the field where those bearings are installed and are in operation. A wireless remote condition monitoring system was created for the purpose of carrying out measurements at the wind power plant itself. It was necessary to develop appropriate data processing that would enable the analysis of a data-intensive case. The candidate used MATLAB codes to analyse extensive data and introduced a new approach to AE signal analysis in the form of the concept of DF maps. By combining DF maps into a single chart for specific time intervals, he made a connection with the occurrence of defects on the rolling surface of the bearings. The included work represents a demanding experimental performance of measurements, an imaginative analysis of captured AE signals and an implemented system for possible condition monitoring in a real environment, which results in a high level of technical soundness.

11. Quality, originality and significance of the results

Very good

Research work within the framework of the doctoral dissertation helps to solve the real problems of determining the condition of important components of wind power plants on site. The focus on monitoring of toroidal bearings, which is treated very sparingly based on the available literature, represents a significant professional contribution. By developing DF maps and remote monitoring systems, this

research offers a novel approach to detecting and characterizing RCF defects, significantly advancing the field of condition monitoring and predictive maintenance. The introduction of DF maps concept with wireless monitoring system represents a good basis for introducing the method as condition monitoring of bearings at wind power plants.

12. Quality of attached papers

Very good

The candidate has so far published 3 articles in journals with an impact factor. Two articles are focused on condition monitoring of Toroidal Bearings using Acoustic Emission. In addition, two other articles are in the publication phase in well rated journals ("in progress") and are also related to the scope of the doctoral dissertation. The candidate is the first author of two articles and co-author of one article listed in Q2. In addition to five articles in journals with an impact factor, he published three more articles at three international conferences related to the topic. Published papers demonstrate very good quality of the candidate research work, described findings on the acoustic emission signal analysis and basis for on sit bearings condition monitoring and are also related to the set scopes of the PhD thesis.

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

Very good

The significance of this PhD research lies in addressing a critical issue in machinery maintenance: the detection and prediction of rolling contact fatigue (RCF) in bearings, which are essential components in various mechanical systems. Bearings' failure is a leading cause of machine breakdowns, and despite advances in their design and maintenance, early detection of fatigue-related defects remains challenging. This research focuses on Toroidal Roller Bearings (TRBs), which are increasingly used in demanding applications like wind turbines due to their unique ability to handle misalignment and tilting. This work not only addresses one of the vital industrial need but also challenges and expands upon established scientific methods. The candidate introduced novel analysis of acquired AE signals, but there is still enough room for the introduction of different machine learning techniques that can additionally improve monitoring capabilities.

14. Questions and comments

Have you considered introducing feature selection procedures for the selection of the most relevant subset of features of AE signals? What is your insight on the introduction of established machine learning methods in the study? How would the introduction of established machine learning methods affect the diagnostic ability to detect defects on the rolling surfaces of bearings?

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

INSTITUTE OF MACHINE
AND INDUSTRIAL DESIGN

FME

Faculty of Mechanical Engineering
Brno University of Technology

09/09/2024			

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

Vysoké učení technické v Brně
Fakulta strojního inženýrství
Technická 2896/2, 61669 FSI VUT v Brně

Posudek vedoucího dizertační práce

Akademický rok:	**2024/25**
Ústav:	Ústav konstruování
Student(ka):	**Ing. Housam Mohammad**
Doktorský studijní program:	Stroje a zařízení
Studijní obor:	**Konstrukční a procesní inženýrství - K Konstrukční inženýrství**
Vedoucí dizertační práce:	**doc. Ing. Pavel Mazal, CSc.**
Oponent dizertační práce:	2- více oponentů
Datum poslední úpravy:	-999

Název dizertační práce:

Experimental Investigation of the Rolling Contact Fatigue Behaviour of Toroidal Bearings Using Acoustic Emission

Hodnocení dizertační práce:

Kritérium: **Hodnocení A-F dle ECTS**

Celkové hodnocení dizertační práce:

Předloženou dizertační práci doporučuji k obhajobě.
Celkové hodnocení: velmi dobře / B.

Celkové slovní hodnocení:
Assessment of the supervision process

In accordance with the study plan the student passed all required exams in specialized subjects and English by the end of February 2021. This period of the study ended with the state doctoral exam, which Eng. Housam Mohammad successfully passed on 6 December 2021. Specialized doctoral studies were concerned to the development of diagnostics of toroidal bearings using modern methods of non-destructive testing (especially by the acoustic emission method). During the studies, the topic of work and research was focused in more detail on the evaluation of toroidal bearings in the gearbox of a real wind power plant.

Assessment of the candidate's ability to work independently

In the first part of the study, Ing. Housam Mohammad participated in the solution of a number of projects of the Technology Agency of the Czech Republic in the field of bearing diagnostics, which we solved at our workplace. In this part, he was a valid member of our research team. At this time, he also handled several smaller “university” projects, which he handled entirely independently. In the second part of the study, the methodology of bearing testing was verified by the doctoral student at the test stations at the ZKL Research Institute in Brno under the guidance of a specialist supervisor. At the stage of scanning and processing data from the bearings in the real gearboxes of wind power plants, he already worked completely independently. Also, all conclusions in the dissertation are the student's own work.

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

The use of the acoustic emission method for the diagnosis of rolling bearings is gradually becoming a common method among large manufacturers and users, but information on monitoring the condition of toroidal bearings is still very limited. In the case of this dissertation, diagnostics are not limited to laboratory tests, but have been extended to long measurements of bearings in real facilities where they have been installed. A wireless remote

condition monitoring system was developed for this purpose. For a better visual representation of the dominant frequency (DF) representation, the concept of DF maps was introduced and a series of Matlab codes were developed to automate and facilitate its creation. Collecting DF maps into a single chart for specific time intervals and being able to statically analyze them provided an opportunity to quantify defects, which will be a solid foundation for future work. One of the conclusions of this work that contradicts with previous findings in literature, was that AE time-domain parameters, such as RMS, did not completely correspond to the events that were represented by the occurrence of AE hits. In other words, AE time-domain parameters cannot be depended upon solely for condition monitoring (CM) of the bearing. Another output of this work is the successful application of a remote CM system using a VNC server, a 3G internet connection and a PC in the nacelle. This system was motivated by the need for monitoring the long measurements that take days or months in places that are not always accessible. The new monitoring system that is suggested, applied and verified here is an easy-to-apply and easy-to-use method for continuous online monitoring of not just bearings, but any critical asset that requires long time of monitoring.

.....
doc. Ing. Pavel Mazal, CSc.
Vedoucí dizertační práce

V ..... dne 19.09.2024