

Faculty of Mechanical Engineering
Brno University of Technology

Review of Doctoral Thesis

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| 1. PhD candidate |
| Kazumi Sakai / Kazumi.Sakai@vutbr.cz |
| 2. Name of PhD programme |
| Design and Process Engineering |
| 3. Title of PhD thesis |
| Study of correlation between grease film formations and mechanical losses on various surfaces |

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| 4. Principal supervisor |
| Prof. Ivan Krupka / krupka@fme.vutbr.cz |
| 5. Co-supervisor |
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| 6. Reviewer |
| Dr David Gonçalves / degoncalves@inegi.up.pt |
| INEGI - INSTITUTE OF SCIENCE AND INNOVATION IN MECHANICAL AND INDUSTRIAL ENGINEERING |

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| 7. Overview of the scope of PhD thesis¹ |
| Good |
| <p>The candidate proposes to find the relationship between the grease formulation and the tribological behaviour, in what concerns rolling bearing friction torque. With the work performed for this thesis, the author also aims to understand the correlation between the grease formulation and its rheological parameters, mainly yield stress and viscosity. The ability to form a lubricant film and the ability of the grease of adapting to different surface conditions was also the main focus of the candidate. In order to fulfil these objectives, the applicant performed rheological measurements of the tested greases, analysed their thickener structure, performed film thickness and traction measurements in ball-on-disk devices and has performed full rolling bearing tests in a dedicated test rig. The candidate correlated the behaviours observed in rolling bearings tests with the film thickness measurements and, based on the results obtained from rheology and electronic microscopy, tried to identify which grease property correlated better. Although some of the conclusions are open to discussion, the candidate performed an interesting analysis, clearly explaining, in his understanding, the behaviours which he observed experimentally. The author attributed the different film thickness and rolling bearing torque observed at high and low speeds, to the breakdown of the thickener material into smaller elements. This behaviour was also used to explain the different flow patterns found at the downstream of the contact. Since the tested greases are formulated with the same base oil, the differences between greases were attributed to the different</p> |

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.



chemical characteristics (polarity) of their thickeners but also its rheological properties (yield stress and apparent viscosity).

8. Significance of the topic and clarity of problem statement

Good

Grease lubrication has a very small share of the lubricants' market when compared to oil. However, millions of rolling bearings are used worldwide and the vast majority of them are actually grease lubricated. Furthermore, as stated by the candidate in the introductory chapter, the mechanisms which rule grease lubrication are far from being understood, hence the significance of this study. Friction in mechanical components constitutes up to 40% of the total power loss of a mechanical system and the rolling bearings can be one of the major contributors to this friction loss. Therefore, any study which contributes to the understanding of grease lubrication in rolling bearings can greatly contribute to the development of energy-efficient products. Besides, the number of publications related to grease lubrication and/or related to rolling bearings friction torque are very small, which makes the candidate's work a valuable contributor to the research field. The applicant presented an interesting introduction to the research topic and also a well-founded literature review which allowed him to clearly identify his work's objectives and the problem statement.

9. Knowledge of existing literature

Good

The candidate presents a very comprehensive chapter on the state of the art regarding grease lubrication, showing a very good knowledge on the most recent investigations and contributors to the research field. Although I would have liked to see the literature review presented in a different order, the candidate covers all the major topics from rheology of the greases, thickener structure and chemistry, EHL film thickness, surface texturing, grease behaviour in rolling bearings and rolling bearings friction torque. However, I was expecting to see a more detailed section on grease rheology (which could justify the choice of the methods used later on) and on the grease friction behaviour, which is very important when analysing the rolling bearing friction torque.

10. Choice of methods and technical soundness

Good

The main results reported in the candidate's work are obtained from simple ball-on-disk and full rolling bearing tests. It is necessary to first understand the grease lubrication mechanisms in simple ball-on-disk tests in order to understand the full rolling bearing tests, which the candidate did successfully. The ball-on-disk tests are very important because they allow to evaluate the grease behaviour in a more controlled environment, allowing to measure film thickness or friction with all parameters set constant and only changing one variable at time. These results can then be extrapolated to contacts that are more complex and more difficult to understand. The full rolling bearing tests are also of utmost importance because they represent the main-application of grease lubrication. In this type of tests, it is not possible to control the slide-to-roll ratio and grease replenishment, and the successive-over rolling can also affect the results. However, some of the operating conditions were not well justified and their presentation was sometimes confusing. The author performed tests with Li thickened greases which are the most used greases and have the largest share in the market.

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| 11. Quality, originality and significance of the results |
| Good |
| <p>The candidate presents a very large amount of experimental work, which is the base of the scientific method. These experimental results were measured in different equipment in order to answer the hypothesis stated in the aim of the thesis. These results are of good quality and those results related to the film thickness of grease-lubricated contacts in the presence of surface indentations are particularly original and never seen before. Grease lubrication is far more complex than oil lubrication, grease can be particularly chaotic and the deviations of the measurements can be very high due to the amount of variables involved (grease spreading, sample homogeneity, temperature and humidity deviations, etc). Therefore, performing experimental work with greases can be very difficult and sometimes frustrating, but it is very important to make a large experimental work to have statistical background. The results found by the author come to confirm and validate the results of other authors while shedding light on some behaviours, which are new and difficult to attribute to a single parameter or grease characteristic. The results are very significant, although their analysis could have been more thorough. The presentation and analysis of the results of film thickness in the presence of surface indentations could particularly be improved.</p> |
| 12. Quality of attached papers |
| Satisfactory |
| <p>The candidate presents 5 papers in international journals and 7 papers in conferences. However, only 2 from the 5 papers in international journals are directly related to this PhD thesis. Regarding the conference papers, the candidate has participated in some important conferences in the tribology field (NORDTRIB, ECOTRIB, ITC and STLE) where the work developed during this thesis was presented.</p> |
| 13. Overall assessment, strengths and weaknesses (based upon the above evaluation categories 8–12) |
| Good |
| <p>The candidate has performed a well-founded, solid work. The document is well organized in general, despite the English being poor. The main strengths of the thesis are the large amount of experimental work performed with a difficult product - lubricating grease - and the correct choice of methods to evaluate the hypotheses. The main weaknesses are the lack of justification of testing conditions and the poor analysis of some of the results. Still, the conclusions found are interesting and valuable for the tribology research field.</p> |
| 14. Other comments |
| <p>The written English needs revision.</p> |
| 15. Conclusion |
| <p>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.</p> |
| YES |



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| 16. Date and signature | |
| 12/06/2018 | David Emanuel Rimentel Gajdner |

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