

Review of Doctoral Thesis

1. PhD candidate
Josef Frýza / fryza@fme.vutbr.cz
2. Name of PhD programme
Design and Process Engineering
3. Title of PhD thesis
Elastohydrodynamic Film Study under Impact Loading and Lateral Vibrations

4. Principal supervisor
Prof. Ivan Křupka / krupka@fme.vutbr.cz
5. Co-supervisor
Dr. Petr Šperka / sperka@fme.vutbr.cz

6. Reviewer
Dr. Vasilios Bakolas / bakolvsi@schaeffler.com
Schaeffler Technologies AG & Co. KG

7. Overview of the scope of PhD thesis¹
Good
<p>The objectives of the thesis are the investigation of the influence of impact loading and lateral vibrations on the film formation and frictional behaviour of a circular contact. The thesis achieves these objectives by means of experiments on appropriate elementary test rigs using primarily thin film colorimetric interferometry. The researcher manages to understand the basic mechanisms and the key influence parameters behind the film formation under both impact loading and lateral vibrations. A very important finding for the case of impact loading is the distinction between approaching and loading speed and the different mechanisms for which they are responsible. The suggestions regarding the theoretical predictions are welcome but can't be evaluated in depth without more theoretical work that would exceed the scope of this thesis. The investigation of the influence of the lateral vibrations provides insights that are necessary for their further theoretical and experimental investigation. The derivation of approximate functions for the determination of central film thickness is an important first step, which needs to be followed by theoretical work. The findings regarding the frictional behaviour (small impact of the vibrations on friction) are interesting but also limited by the experimental setup.</p>

8. Significance of the topic and clarity of problem statement
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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.



Good

Both topics of this thesis are important in terms of basic research on the field of EHL. The thesis provides insights that could be helpful to researchers in the future, especially those researching the effect of impact loading. Lateral vibrations also pose interesting questions as to which effect they have on a lubricated contact. Having said that though, it is difficult to imagine a variety of real life applications that would directly benefit from the findings of this thesis. The documentation of such applications is something that I missed in this thesis. The topics under investigation were documented clearly and sufficiently. The same goes for the main hypotheses that were tested in this thesis.

9. Knowledge of existing literature

Very good

The thesis includes a comprehensive and exhaustive review of the literature. It is difficult to find some important work that has been left out of this review, since it covers a time span of more than 100 years. There also doesn't seem to be a preference to the work of specific scientific teams, since it includes work printed in several journals and coming from different teams from around the world.

10. Choice of methods and technical soundness

Very good

The candidate approached the problem experimentally. He chose to use basic test rigs where he could control all the influence parameters separately in order to be able to investigate their influence. In the case of the investigation of film formation his choice is correct since his aim was to describe the underlying mechanisms caused by impact loading and lateral vibrations. There is some skepticism regarding the experimental setup for the investigation of the correlation between friction and lateral vibrations, since the conditions of pure sliding are rather unique, but the work is still performed in a sound manner. The candidate takes extra care to eliminate any parasitic factors that could influence his results. The description of his experimental setup and procedures makes it possible for future researchers to replicate and expand his work.

11. Quality, originality and significance of the results

Very good

The high quality of the results can be traced back to the way that they were produced. The experimental work was carried out in a way that ensured that the results would fulfil high quality standards as regards their reproducibility. Throughout the work, the reader can find hints that point to the extra care that was taken so that the results would not be influenced by factors that were not in the scope of the investigation (such as for instance temperature). Even if there is already work that has been published on impact loading both the experimental results as well as their interpretation are original. The work on lateral vibrations is, according to my knowledge, unique in the range that was investigated here. The significance of the results is the big question mark. They provide a firm basis for basic research to be carried out in this field, especially on a theoretical level, but the question remains whether they have even a remote connection to real life problems.

12. Quality of attached papers

Very good



All three papers are of high quality. They are well written, relatively easy to understand and provide a plethora of information and results. They are well structured and their introduction and conclusions sections include an appropriate overview of both the current state of the art as well as the main findings of each paper. The reader of these articles should find it easy to follow and if so desired reproduce the experimental work. Due to the complexity of the subjects, it could be expected that some readers would find it challenging to follow the interpretation of the results that were presented in the papers.

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

Very good

The work presented in this thesis is sound, well defined and well executed. It provides future researchers with a body of work upon which they can build in the research of the EHL phenomena. Among the strengths of thesis one should note the very high quality of the experimental work and results. Another major strength is the presentation of the work in such a manner that it can be reproduced. There are practically no questions that can be asked regarding the procedures and the results that are included in the thesis. Taking into consideration that experimental results are always much more difficult to produce in the framework of a Ph.D. thesis the amount of results presented here is impressive. Of course being an experimental work means that the theoretical part is pushed to the background. The explanation of the results is mostly phenomenological which is perfectly understandable given the nature of the thesis

14. Other comments

[Paper A] Please clarify the concepts of approaching and impact speeds. During the impact experiments you calculate the instantaneous impact load according to the Hertz theory; please explain the reasoning behind your choice and possible errors that could be made. What is the stiffness of the contact during the impact experiments? Is this stiffness value constant? What are its influence factors? Could your experiments be used to determine the damping of such a contact? Please name certain real life applications that are related to the experiments? What is the practical use of the results of the impact experiments? [Paper B] Please name some examples of operating conditions where lateral vibrations can occur in a) bearings and b) gear contacts. Did the lateral vibrations lead to a phase shift between the excitation and the resulting film shape? Why? Why is the central film thickness the correct parameter for the estimation of the film breakdown? [Paper C] Please comment on the advantages and disadvantages of the selected experimental setup and its correspondence to the operating conditions of a contact found in bearings and/or gears. You postulate that the absence of shear thinning and shear heating effects are the results of an anisotropic behaviour of the lubricant. How did you arrive to this conclusion and how did you exclude other possible explanations? [General Questions] Suggest possible theoretical work that should follow your work. Explain possible ways and point out to the remaining work that needs to be done in order for your work to be applied to praxis.

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



16/02/2018			
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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*

Review of Doctoral Thesis

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6. Reviewer
Wassim HABCHI, PhD. / wassim.habchi@lau.edu.lb
Lebanese American University

7. Overview of the scope of PhD thesis¹
Very good
<p>This thesis is focused on the experimental investigation of EHL contact performance under transient conditions that are representative of the actual operation of these contacts within their corresponding machine elements. The work is divided into three main parts. The first and second parts focus on the influence of impact loading and lateral vibrations, respectively, on the film forming capabilities of EHL contacts. In the first part, it is found that approaching speed is crucial to film build-up under pure impact loading. Also, the influence of approaching and loading speeds and lubricant rheology on film formation is quantified. In the second part, it is found that lateral vibrations have a profound impact on EHL film shape. Deviations in film shape with respect to the corresponding steady-state case are quantified, by means of some novel and specifically developed dimensionless numbers. The last part investigates the influence of lateral vibrations on the frictional response of EHL contacts. It is found that frictional response in the lateral direction affects the response in the main entrainment direction, but not vice versa.</p>

8. Significance of the topic and clarity of problem statement
Very good

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.



The EHL literature is submerged with studies on the steady-state response / operation of EHD contacts, even though in reality, these contacts are often subject to transient loading and kinematic conditions. This is because transient EHL is extremely complex to analyse (the steady-state EHL problem is already very complex in nature). The merit of the current thesis is that it tackles this complex topic and it does it with finesse. Not only does it bring some well-needed experimental confirmation of previous observations from the literature but also some new findings are revealed. The problem is clearly stated and its context is well defined. The only minor shortcoming in this reviewer's opinion is that the entire document may benefit from English language corrections as well as some fine tuning of the clarity of presentation (e.g. most figures in the literature review section are not referenced in the text, which makes it harder to the reader to follow-up. The reader is left to guess to which section each figure pertains.)

9. Knowledge of existing literature

Excellent

The thesis starts with an extensive review of the literature on transient EHL contacts. The review section has the same overall structure as the thesis. First, a brief coverage of steady-state EHL literature is provided. Though it is not within the scope of the current thesis, the steady-state case is considered as the starting point towards understanding transient EHL contacts. Then, an extensive and comprehensive literature review is provided, pertaining to the influence of different types of transient effects on the film forming capabilities of EHL contacts. The last part of the literature review section offers a coverage of the influence of lateral vibrations on film formation and the frictional response of EHL contacts. This section is however relatively concise, given that previous studies related to this topic are scarce. But, overall, the literature review section provides a very comprehensive coverage of previous works that are related to the topic of this thesis and rightfully acknowledges the works and contributions of others, with a flair of criticism.

10. Choice of methods and technical soundness

Very good

The thesis tackles the problem of impact loading and lateral vibrations within EHL contacts from an experimental angle. The author uses test rigs that were previously developed at the Institute of Machine and Industrial Design. The accuracy and functionality of these rigs has been well tested over the years (as evidenced by the number and high quality of scientific publications within the author's group, using these same test rigs). The author did however adjust the rigs to provide them with the capability of studying the considered problem of transient EHL contacts, with lateral vibrations.

11. Quality, originality and significance of the results

Very good

The results proposed in this thesis are of high quality. Some of the results re-affirm previous observations in the literature. But some other results provide a well-needed experimental confirmation of previously known theoretical results. Also, other results provide new insight into the topic of film formation within EHL contacts that are subject to impact loading or lateral vibrations as well as the topic of friction generation within EHL contacts that are subject to lateral vibrations. The analysis of the results though, lacks sometimes the consideration of certain aspects that may be influential to the studied problem, e.g. the influence of lubricant compressibility on film build-up within EHL contacts under impact loading has been omitted (this is what is at least reflected in the thesis), even though in this reviewer's opinion it may bring some answers and clarifications to the proposed results. Also, in lateral vibration experiments, low speed conditions have been considered to minimize shear-thinning and thermal effects, but further analytical,



numerical or experimental verification of the absence of these effects would have played a comforting role in asserting the validity of the proposed results and analysis (this may have been done, but it is not clearly stated in the thesis).

12. Quality of attached papers

Very good

Two of the three papers (namely, paper A and paper B) are published in one of the most respected Tribology journals (namely, Tribology International). This in itself speaks highly of the quality of these papers and the corresponding underlying work. The third paper is published in a low-tier Tribology journal (namely, Tribology in Industry). Overall, the three papers reflect the quality of the thesis in terms of both its strengths and weaknesses (as described in sections 7-11).

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

Very good

Overall, this thesis tackles an extremely challenging tribological problem; that of transient EHL contacts, in particular under the influence of impact loading and lateral vibrations. The topic itself has the merit of considering a more realistic contact configuration, that is more representative of the actual operation of EHL contacts within their corresponding machine elements, as compared to the often studied steady-state case. Though parts of the thesis are hard to read (see comments in section 8), it is overall well-written, clear and concise. The thesis provides an excellent comprehensive overview of the literature on the topic; that acknowledges the work of others, with a flair of criticism. Though the analysis lacks sometimes a certain finesse in considering all aspects of the problem at hand so that all raised questions are elucidated / explored (see comments in section 11), it remains overall a sound analysis, given the complexity of the studied problem. The proposed results are novel and interesting and they definitely bring new insight and advances to the scientific knowledge within the field of Tribology, in particular elasto-hydrodynamic lubrication.

14. Other comments

No further comments



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

16/02/2018



**INSTITUTE OF MACHINE
AND INDUSTRIAL DESIGN**



**Faculty of Mechanical Engineering
Brno University of Technology**

- 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
Josef Frýza / fryza@fme.vutbr.cz
2. Name of PhD programme
Design and Process Engineering
3. Title of PhD thesis
Elastohydrodynamic Film Study under Impact Loading and Lateral Vibrations
4. Principal supervisor
Prof. Ivan Křupka / krupka@fme.vutbr.cz
5. Co-supervisor
Dr. Petr Šperka / Petr.Sperka@vut.cz
6. Stays at other institutions (min. 7 days)
none
7. Teaching activities
CAD (3CD) / 78 hours Machine Design – Machine Elements (5KS) / 390 hours Machine Design – Mechanical Drives (6KT) / 234 hours Machine Design – Mechanisms (6KM) / 156 hours Mechanical Design Project (ZKP) / 78 hours Team Project (ZIP) / 52 hours Tribology (ZTR) / 12 hours
8. List of main publications
FRYZA, J., P. SPERKA, I. KRUPKA and M. HARTL. Effects of lateral harmonic vibrations on film thickness in EHL point contacts. <i>Tribology International</i> . 2018, vol. 117, p. 236-249. IF: 2.903 FRYZA, J., P. SPERKA, M. KANETA, I. KRUPKA and M. HARTL. Effects of lubricant rheology and impact speed on EHL film thickness at pure squeeze action. <i>Tribology International</i> . 2017, vol. 106, p. 1-9. IF: 2.903 FRYZA, J., P. SPERKA, I. KRUPKA and M. HARTL. Frictional response of lubricant in EHL contact under transient bi-directional shear loading. <i>Tribology in Industry</i> . 2017, vol. 39, no. 4, p. 506-518. FRYZA, J.; SPERKA, P.; KRUPKA, I.; HARTL, M. Behaviour of EHL Films under Lateral Vibrations. In <i>Book of Proceedings of 56th International Conference of Machine Design Departments</i> . Nitra: Slovak University of Agriculture in Nitra, 2015. p. 349-352.



9. Assessment of the supervision process

Good

The supervision process and the candidate response were standard. The process was based on regular (one-month) meetings and other on-demand discussions with supervisor and specialist. The candidate was adequately prepared and able to respond to the topics discussed. He was able to follow new ideas as well as to reflect critical comments. Written work reports and other documents were prepared in good quality, but sometimes at delayed time. Accomplishment of other duties arising from the PhD, including teaching, leading of student projects and several Bachelor theses was very good. The candidate was active in publishing and attending conferences.

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

Very good

The candidate's work was independent, based on discussion with supervisor and specialist as well as with other professors at the institute. The framework of the PhD thesis was partially directed by basic research grant under the Czech Science Foundation. Individual tasks of research were formulated together with supervisor and specialist. The candidate worked on them independently by conducting experiments, interpreting them and comparing findings with an existing knowledge in a literature. Always he was motivated by himself to go into details and do not finish until the problem is clear. During the work it was necessary to design and develop new devices and modules to accomplish experimental research tasks. The candidate has proven that possess necessary technical skills to create necessary devices. Some of them were made in cooperation with bachelor degree students. In the relevant research topic, he supervised four bachelor thesis. All publications where the candidate is listed as the first author were managed and prepared by him.

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

Very good

The work contributes to the area of elastohydrodynamic lubrication (EHL) under transient conditions, more specifically to the problem of fast normal approaching of contact bodies (impact EHL) and the problem of combined motion with transverse harmonic oscillations. The work dealing with impact EHL focuses on experiments with wide range of lubricants of different rheology comparing experimental results with published model. It contributes to the knowledge of film thickness formation under impact motion. A dependency of a film thickness-loading speed slope on lubricant rheology was found. This research was published in Tribology International, Q1 IF journal targeting the papers with the highest scientific quality. The work in transverse harmonic motion deals with film thickness distribution and friction. Film thickness at a transition from steady rolling with no transverse motion and pure reciprocating motion was described. A master curve allowing prediction of film thickness reduction depending on speed ratio was found. This result was published in Tribology International, Q1 IF journal targeting the papers with the highest scientific quality. The second studied parameter under transverse harmonic motion was two-directional measurement of friction. Several interesting new findings were obtained about rheology of lubricant and its isotropy inside EHL contact. It provides further clues into a growing understanding of fluid film friction in EHL contact. Results were published in Tribology in Industry, journal indexed in Scopus.



12. Other comments

none

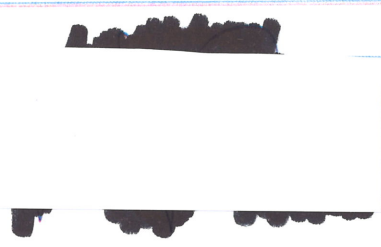
13. Conclusion

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

16. Date and signature

27/02/2018



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