INSTITUTE OF **MACHINE**
AND **INDUSTRIAL DESIGN**

FME

Faculty of Mechanical Engineering
Brno University of Technology

Review of Doctoral Thesis

1. PhD candidate
Ing. Martin Valena/ Martin.Valena@vut.cz
2. Name of PhD programme
Design and Process Engineering (Mechanical Engineering Design)
3. Title of PhD thesis
Performance Evaluation of Products for Rail Head

4. Principal supervisor
prof. Ing. Martin Hartl, Ph.D. / Martin.Hartl@vut.cz
5. Co-supervisor
Ing. Radovan Galas, Ph.D. / Radovan.Galas@vut.cz

6. Reviewer
Dipl.-Ing. Dr.techn. Alexander Meierhofer / Alexander.Meierhofer@v2c2.at
Virtual Vehicle Research Center

7. Overview of the scope of PhD thesis[1]
Very good
It was made very clear, how the three phases are meant to close the research gap that currently exists within the literature. The steps are logically sound, to first start of with laboratory tests and trying to find a way to standardize them in order to generate a type of benchmark. Later, the results from the lab tests were transferred to the field before being finally tested there. To achieve these goals, several types of equipment had to be developed and were described to a satisfying degree within the thesis. While this all was impressive, it was not always easy to distinguish between the contributions of the phd-candidate and others. Also, I wished a few of the results shown in the papers were also discussed in detail in the thesis itself since they should be the focus and not the tools used to achieve these results.

8. Significance of the topic and clarity of problem statement
Excellent
After a very intensive and in-depth discussion of the available literature, the findings were discussed and a research gap was found. I agree with the necessity to close this gap. To this end, a plan consisting of three phases was clearly laid out in the thesis. It consists of Lab-to-Lab testing, then Lab-to-Field scaling and lastly field measurements. The goal of each phase was described and from these were requirements

[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.

derived for each phase and broken down into sub-problems. This was all well documented with papers relating to each phase and describing the work. The overall goal presented in the thesis was to use this plan to answer four scientific questions. With each question, a hypothesis was formulated which was to be proven within the rest of this work. So, in summary, I agree that the topic is very relevant and I could very well follow the problem statement and the ideas on how to solve the issues to close the research gap.

9. Knowledge of existing literature

Excellent

The thesis gives a very detailed overview regarding friction management products, their categorization into four different main groups and their use. These artificially introduced wheel-rail contact contaminants mix with already naturally occurring particles like different types of iron oxides and change the frictional behaviour. Next, all types of laboratory tests regarding third body layers in the wheel-rail contact are discussed and presented in great detail, be it their influence on the coefficient of adhesion/traction, carry-on mechanisms the influence of the composition or the effect on squeal noise. Also, the results of field measurements were discussed and the usage of portable tribometers in the literature. All these investigations were analysed before specifying the research gap. This shows to me that the author did a very thorough analysis on the existing literature, for which a very great knowledge of it is a necessity.

10. Choice of methods and technical soundness

Very good

In my opinion, the choice of methods was clearly motivated by the literature research, the state of the art and the research gap. There were three stages defined, lab-to-lab, lab-to-field and field tests. The steps were described in detail and multiple tools had to be developed in order to perform the set tasks. These tools are also adequately described and their advantages as well as their disadvantages mentioned. Especially the BUT tribometer was discussed in its own separate paper and is, as I think, of great relevance for future research into investigations of the coefficient of adhesion on real rails in the field. However, since most of the attached papers had multiple authors and cover a wide range of investigations, the actual contribution of the phd candidate was not always easily discernible.

11. Quality, originality and significance of the results

Excellent

The presented ideas are of high quality and very novel to me. First, there is the standardization of ball on disc tribometer tests. I feel like this is a very important task and cannot be understated since there are a lot of such tests reported in the literature, but they are all performed differently. It is very hard to really compare the results and thus know how different friction modifiers or third-body-layers actually perform. The second paper focuses on the BUT tribometer and this device is also something that the railway industry is lacking. The state-of-the-art tribometer are not reliable and, as such, this newly developed device will be of great help in the future. This allows to really compare friction modifiers and their properties in the field as well as their influence on noise. Especially this last investigation was very interesting and will hopefully be the basis for a much wider and more thorough investigation in the future.

12. Quality of attached papers

Very good

There were four papers attached to the thesis. The first one focused on a newly developed standard for pin on disc tribometers. This is a very important step to compare measurements from different authors in the future. The paper was of high quality if a little hard to understand sometimes and quite complicated in parts. The second paper was focused on the development and results of the BUT tribometer, which is a very useful device that will come in handy in future investigations. The paper presents itself clearly and the results are of high quality. The third paper is again one focused on benchmarking and standardization. It investigates closely the properties of friction modifiers. The last paper is a very interesting one since it discusses the influence of Coefficient of Traction on squeal noise and even covers weather related influences like temperature and humidity. This was also very well written with very good results. The only downside was the small data base, which leads me to hope for a wider and more thorough study in the future.

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

Very good

This thesis covers first a very well documented literature research, clearly identifies the resulting research gap and tries to solve it by introducing research questions and hypothesis. These are then tested by a three-phase plan, where lab-to-lab tests, lab-to-field tests and finally field tests were performed. The accompanying four papers describe work behind the thesis in great detail and range over a wide array of topics: standardization of pin on disc tribometer tests, the development and the application of the BUT tribometer (a very useful device for future work), development of a Contact Simulator and its use in measuring friction modifier properties, as well as using the BUT tribometer in field tests and investigates the influence of the coefficient of traction on noise. Overall, the quality of the thesis and the papers is excellent, it shows a lot of possibilities for the developed test devices. There are just two things that I think are weaknesses of the thesis: first, it is not always obvious what the main contribution of the phd candiate to the papers was and, second, the thesis itself focuses more on the tools to gather data than presenting the results of the studies themselves.

14. Questions and 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

Date: 22.11.2024

Please note

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Review of Doctoral Thesis

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Ing. Radovan Galas, Ph.D. / Radovan.Galas@vut.cz

6. Reviewer
Dr Ben White / bwhite2@sheffield.ac.uk
The University of Sheffield

7. Overview of the scope of PhD thesis[1]
Very good
Justification for evaluation: 100 – 200 words. The title, "performance evaluation of products for railhead" is covered by multi-phase laboratory to field methodologies using top-of-rail (water based) friction modifiers and top-of-rail (oil based) lubricants. Problems with previous test methods have been highlighted and a new test rig has been designed to aid evaluation of these TOR products, using methods that are more representative of the real wheel/rail contact. Improvements in some aspects upon previous friction measuring devices have been made. This work, as well as the two new devices that have been developed (contact simulator and tribometer) will be valuable for both academia and the rail industry. The aims of this thesis have been met and the novel work carried out here provides an excellent platform for further testing, using the described methodology in field environments to optimise TOR product usage and improve operational wheel/rail performance.

8. Significance of the topic and clarity of problem statement
Excellent
Justification for evaluation: 100 – 200 words. The topic, evaluation top-of-rail friction management products, is valuable for the current rail industry. Evaluation and therefore optimisation of these products

[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.

has been difficult. This is due to a number of reasons, such as the small amounts of TOR product applied, the variability of wheel/rail contact and environmental conditions in the field and also due to the lack of friction measuring technology that closely simulated the wheel/rail contact. Improvements to the evaluation and optimisation of these products could lead to performance benefits such as reduced noise, energy consumption, extension of wheel/rail lifespan and reduction in carbon. TOR product suppliers can improve their formulations and application methods can be improved.

9. Knowledge of existing literature

Very good

Justification for evaluation: 100 – 200 words. A "state of the art" analysis has been carried out, covering the benefits of using TOR products and the problems with current methods to evaluate them. This includes information about the difficulties comparing between the laboratory and the field. TOR product effects that are frequently observed on MTM/twin disc small scale contacts may not be as prevalent/applicable in operational situations, such as over-lubrication. Different types of friction measurement methods are compared and the importance of a test rig that can be used in the laboratory and the field, a robust methodology to use this rig to evaluate different TOR products was described.

10. Choice of methods and technical soundness

Very good

Justification for evaluation: 100 – 200 words. Small scale laboratory test rigs such as MTM are well established methods to determine product properties, but have limitations of a very small and cyclic contacts, as well as TOR product applications and third body effects. The author acknowledges this and develops a portable tribometer to provide more representative data to the real wheel/rail contact. The design of tribometer and a comparison of operation in comparison to other tribometers available at the time of writing has been carried out. The methodologies required to collect and interpret friction data from the laboratory and field (where possible) have been thoroughly assessed.

11. Quality, originality and significance of the results

Excellent

Justification for evaluation: 100 – 200 words. This work provides a significant increase in the knowledge of top-of-rail friction management products. The author highlighted the lack of suitable portable tribometers and designed a novel measurement method. This has improvements on previous devices and will be of significant benefit to both academia and the rail industry. The originality of the contact simulator is also relevant, which provides a mechanism to simulate wheel passes without requiring expensive and complex full scale test facilities or wheel passes. This provides a a novel approach to the problem of run-in procedures and TOR product dispersal in the laboratory. The results are clearly displayed in high quality, peer reviewed journals.

12. Quality of attached papers

Excellent

Justification for evaluation: 100 – 200 words Together, the set of four paper provide a useful guide to evaluating TOR product properties the laboratory, including a field case study. The carry down and retentivity of products is of particular interest to friction management suppliers and infrastructure operators

at the moment. The authors comparison of the tribometer results compared to small scale mini-traction machine and twin disc highlights that the risk of friction being too low due to product over-application is less severe in the field than may have been previously expected from small scale laboratory results. This is important information for TOR product suppliers and users in the rail industry. In future, field trials using real vehicle passes (rather than the contact simulator) and realistic TOR product applications (either on-board or wayside) would provide valuable information for optimising TOR product application.

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

Excellent

Justification for evaluation: 100 – 200 words. A thoroughly researched thesis containing excellent and novel contributions to the field of wheel/rail friction management. The steps required to assess the performance of TOR products, including scaling results between the lab and the field have been clearly described. Novel features include both the design and use of a new tribometer as well as the contact simulator the simulate wheel passes, essential for run-in procedures and TOR product dispersal. An improvement could be a more detailed discussion on the field application of these top-of-rail products in real application situations and the benefits of this. Further field trials would be useful with these wayside or on-board applications, but I acknowledge that getting track access can be very complex or expensive. This is noted in "next steps" at the end of the thesis but an approach/framework could be described, even if the field investigation could not be carried out. Further discussion could be made on how the results of this work can be used to improve operational wheel/rail performance. For instance a further understanding of carry down, retentivity and noise suppression could influence both TOR product application and the resultant effects on the wheel/rail contact.

14. Questions and comments

1) Bearing steel has been chosen for the tribometer measuring wheel. Is this due to availability or to improve durability of the wheel? What is the surface finish/roughness of the wheel and is does it change throughout usage? Have you thought about the effects of this on the resultant friction coefficient? 2) the run-in wheel/rail friction increased by a large amount compared to the "clean" rail. Why do you think this is? 3) How do you think this TOR evaluation approach can be used to improve friction management in the wheel/rail interface? 4) The tribometer wheel is cleaned between measurements. How do you think the results for the field approach would differ if the tribometer wheel was not cleaned. Would this be more representative of the real wheel/rail contact? 5) In my experience the application of TOR product can vary laterally as well as longitudinally across the rail surface. Have you thought of any procedures that could be carried out to "map" out this product coverage? 6) In the paper titled "A benchmarking methodology for top-of-rail products: Carry distance and retentivity", the same amount (80 ul) was used for both the TOR-L and TOR-FM. Operational application amounts from each manufacture differ in the field, could the testing be adapted to include this?

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

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24/11/2024	

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

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Brno University of Technology

Principal supervisor's final report on the PhD study

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Martin Valena / Martin.Valena@vut.cz
2. Name of PhD programme
Design and Process Engineering
3. Title of PhD thesis
Performance evaluation of products for rail head

4. Principal supervisor
prof. Ing. Martin Hartl, Ph.D. / Martin.Hartl@vut.cz
5. Co-supervisor
Ing. Radovan Galas, Ph.D. / Radovan.Galas@vut.cz

6. Stays at other institutions (min. 7 days)
Loram Finland Oy / Finland / 31/08/2021 / 30/09/2021

7. Teaching activities
CAD (3CD) / 234 hours Design and CAD (4KC) / 208 hours Design and CAD (CKC) / 104 hours Team project (ZIP) / 39 hours Aventics – Pneumobil Racing (0ZP) / 39 hours Engineering Project (ZKR) / 26 hours Pneumobil Racing (0ZR) / 13 hours

8. List of main publications
GALAS R, SKURKA S, VALENA M, KVARDA D, OMASTA M, DING H, et al. A benchmarking methodology for top-of-rail products. Tribol Int 2023; 189: 108910. https://doi.org/10.1016/j.triboint.2023.108910. [IF = 6.1] VALENA M, OMASTA M, KVARDA D, GALAS R, KRUPKA I, HARTL M. An approach for the creep-curve assessment using a new rail tribometer. Tribol Int 2024; 191: 109153. https://doi.org/10.1016/j.triboint.2023.109153. [IF = 6.1]

GALAS R, VALENA M, JORDÁN T, KVARDA D, OMASTA M, SKURKA S, et al. A benchmarking methodology for top-of-rail products: carry distance and retentivity. Tribol Int 2024: 197: 109810. https://doi.org/10.1016/j.triboint.2024.109810.
[IF = 6.1]
VALENA M, OMASTA M, KLAPKA M, GALAS R, NAVRATIL V, KRUPKA I, HARTL M. Case Study: Correlations Between Curve Squeal, Weather Conditions, and Traction in a Tram Loop. Tribology in Industry (manuscript)
[CiteScore = 2.8]

9. Assessment of the supervision process

Good

Communication with the doctoral student occurred through regular monthly meetings. The student consistently arrived well-prepared, presenting updates on his progress and proposing ideas for future work. After discussions with his supervisor and co-supervisor, the student suggested a plan for the next steps, which he then carried out independently, demonstrating a strong level of autonomy in his research. However, I would expect better time management from the student. His poor planning resulted in delays in writing his thesis, and one of his articles should have been submitted for review earlier (it is currently under revision).

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

Very good

The PhD student demonstrated a strong ability to work independently. From the beginning of his studies, he participated in several research projects, where he was a valuable team member. He performed his teaching duties exceptionally well, which was reflected in the positive feedback from students. The student also proved his capability to lead student projects and supervise bachelor's theses. Additionally, he demonstrated the ability to formulate hypotheses related to his research and test them through experiments he designed himself. Based on these experiments, he formulated conclusions and made recommendations for future work. During his studies, he participated in a one-month internship as part of the European H2020 project.

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

Very good

The thesis focused on developing a multi-phase methodology for assessing top-of-rail products used in rail transportation to reduce noise and wear. The student made significant contributions to each part of this methodology. I consider the development of a unique tribometer for evaluating the coefficient of traction to be particularly important. Due to its innovative design, the device can be used both in the laboratory and for field measurements, which the student utilized for testing in both settings. In the case of laboratory studies, a two-phase testing approach for top-of-rail products was proposed to minimize the number of experiments necessary on the track. In a field study, the student assessed the development of the coefficient of traction on a selected tram line and compared it with meteorological data and data from a noise module for detecting squeal noise. The doctoral thesis includes three articles published in the prestigious journal Tribology International (Q1), with the student being the first author of one of these publications. Additionally, the student is the first author of a fourth publication, which is currently under review. I consider all of these results to be relevant and beneficial to the field of wheel/rail tribology.

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	
Date: 21-08-2024	

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