INSTITUTE OF MACHINE AND INDUSTRIAL DESIGN

FME

Faculty of Mechanical Engineering
Brno University of Technology

Review of Doctoral Thesis

1. PhD candidate
Ing. Šimon Skurka / Simon.Skurka@vut.cz
2. Name of PhD programme
Design and Process Engineering
3. Title of PhD thesis
The effect of contamination of friction modification in the wheel-rail contact

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

6. Reviewer
Angelo Mazzù, PhD / angelo.mazzu@unibs.it
University of Brescia

7. Overview of the scope of PhD thesis[1]
Excellent
The scope of the thesis was presented by means of three scientific questions with hypothetic answers, to be confirmed or not by the experiments. This is a very clear and innovative way to present the objectives and the results, giving the reader a conceptual key to understand the evolution of the research. The state of the art, the needed knowledge and the gap between them are described very clearly. The final comparison between the answers to the scientific questions initially hypothesized and what emerged from the experiments is a very honest and effective way to express the advancements in the knowledge achieved with the research.

8. Significance of the topic and clarity of problem statement
Very good
The problem of TOR lubricants and FM contamination in real use is very relevant, because all real applications are subjected to such issues, which can have severe consequences such as collisions between trains. However, in the literature, whereas wide research has been done on the performances of TOR products, the knowledge on the effect of contamination of those products is insufficient. As highlighted in the previous point, in the thesis the relevance of this problem is presented in a very clear

[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.

way, by showing the consequence on the real life in terms of accidents. The correlation between the accidents and the TOR products contamination is presented in a convincing way by means of the analysis of the daily occurrence of accidents due to low adhesion.

9. Knowledge of existing literature
Very good
The thesis is supported by a wide literature cited by the author, showing he deeply studied the state of the art and is aware of the achieved knowledge in the world. The author also made an analysis of the results of a literature search on a well-recognized database. He showed that, whereas a wide literature is available on the most general problem, as far as the investigated topic is more precisely specified, the number of publications is reduced to a few papers. This procedure allows someway quantifying the level of knowledge achieved in the world on the studied issue and focusing on the most relevant ones to address the research.

10. Choice of methods and technical soundness
Very good
A relevant effort was spent to set up a testing methodology able to provide reliable and repeatable results. In particular, the testing procedure was elaborated with much care, identifying a sequence of phases to exclude the effect of all uncontrollable factors that depend on the specimen machining, transient phenomena, and casual laboratory conditions. The testing equipment appears reliable, as well as the measurement devices. All experimental parameters, included the way of applying and dosing the TOR products and the contaminants, were carefully controlled. The only choice that could give origin to some concern is the use of materials unsuitable for railway applications in some experiments.

11. Quality, originality and significance of the results
Very good
The results lay on an experimental procedure that assures reliability and repeatability. They are organised and elaborated in a clear way that highlights their relevance. The diagrams with the CoT obtained in the tests are enriched with colour bands and comments helping their interpretation. In particular, I appreciated the OLF diagrams and the overall performance maps, which immediately give an idea of the concept: I think this is an innovative and effective way to present the practical consequences of the findings. The originality of the results is a consequence of the originality of the research topic, which approached a field not satisfactorily studied in the literature. Their relevance is given by the operational guidance that can be drawn from the experimental findings, well highlighted in the conclusions.

12. Quality of attached papers
Excellent
Some of the attached papers are taken from some of the best-ranking journals in the field of tribology, subjected to a very severe selection; the last paper is taken from the proceedings of one of the most prestigious international conferences on railway tribology. The research team is international, including authors from the Chinese academic institution with the highest ranking on railway research. All papers are clear and rich in data, which are presented in an effective way and a deeply discussed. All papers include a rich list of references that help consolidating the validity of the methods and results presented. The number of papers produced during the doctorate is remarkable as well.

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13. Overall assessment, strengths and weaknesses (based upon the above evaluation categories 8–12)
Very good
Overall, the thesis is considered a high-quality piece of work. The main points of strength are: 1) the relevance of the investigated issue in the railway industry, given the severe potential consequences of TOR products contaminations; 2) the originality of the research, as a very low number of studies has been done worldwide on the investigated topic; 3) the solidity of the experimental methodology, which was deeply studied to provide reliable results; 4) the significance and clarity of the results, which can provide indications in the choice of TOR products in operation. The main weak point was well highlighted by the author: it is the gap from the size scale of the ball-on-disc and disc-on-disc test benches to the real application. Further work must be done to confirm the answers to the three scientific questions in the real world.

14. Questions and comments
Further questions and comments will be the object of the final discussion.

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	
30/05/2026	

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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Review of Doctoral Thesis

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6. Reviewer
Dr. Martin Evans / M.D.Evans@hud.ac.uk
University of Huddersfield

7. Overview of the scope of PhD thesis[1]
Very good
The thesis abstract provides a clear and succinct summary of the thesis objectives and main findings. The abstract includes an introduction to the topic of top of rail friction management, a brief description of the research gap and experimental methods used, finishing with some key findings which clearly add to the state of the art. The thesis introduction (chapter 1) provides further detail on the importance of friction management and the relevance of this work. Chapter 3 takes the results of the comprehensive literature review, clearly demonstrating the presence of a significant research gap, and defining how this work will address this gap, through the definition and testing of five hypothesis. Chapters 4 and 5 clearly define the aims and layout of the thesis, 7.9 evaluates the outcomes of the hypothesis and Chapter 8 concludes the thesis competently. Overall, these sections provide a very good indication of the experimental work, results and discussion detailed in Chapters 6, 7 and the 5 published papers accompanying the thesis.

[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 work investigates a significant gap in existing research, clearly demonstrated by the literature search detailed in Chapter 3 and the comprehensive literature review provided in Chapter 2. The problem statement is well defined in Chapter 3 using clear scientific questions and hypotheses, with associated thesis aims provided in Chapter 4.

From my own experience, the author is correct to conclude there is very little research on the effect of contaminants on top of rail friction management products (or indeed flange/gauge corner lubricants), with much of the existing work focusing on the effect of products in isolation, in an otherwise clean, dry interface. The author is also correct to conclude this is a significant oversight worthy of further investigation, since the wheel / rail interface is an open system and contamination from water and oxides (as assessed by this work) would be commonplace.

9. Knowledge of existing literature

Very good

Chapters 2 and 3 provide a very good study of the state of the art, and identification of a gap in existing research, which is subsequently addressed by this work.

I personally disagree with the definition of some terminology, but that does not detract from the quality of this work presented. I encourage the author to align with the terminology defined in the recently published PD CEN/TS 15427-2-2:2023 (superseding PD CEN/TS 15427-2-2:2021 which is referenced in this work). In this latest version, the definition for the term 'coefficient of adhesion' has been dropped, and water-based, oil-based and hybrid TOR products are all considered to be 'friction modifiers' – I think this is focusing on the intended function rather than the composition. Terminology is discussed further in the comments.

Otherwise, the thesis shows extensive knowledge of the state of the art, presented in a clear and structured fashion, highly relevant to the work presented.

10. Choice of methods and technical soundness

Very good

I have reservations about the use of the MTM machine, particularly the test procedure defined in PD CEN/TS 15427-2-2:2023 (and PD CEN/TS 15427-2-2:2021). The use of the MTM in this work gives me no reason for concern, and its limitations are acknowledged by the author. The methodology proposed in Article 2 also addresses many of my concerns with the procedure specified in PD CEN/TS 15427-2-2:2023.

The author also uses other equipment such as a twin-disc machine, climate chambers and other instruments for tribological measurements – all appear to be sound choices, well utilised. The

methodologies described appear well justified, adapting proven approaches to assess the behaviour of contaminated TOR products.

11. Quality, originality and significance of the results

Very good

Article 1 investigates the effect of water contamination on the performance of TOR products, investigating potential mechanisms behind the changes in behaviour. This work appears to be good quality, novel and significant, addressing a significant gap in existing material.

Article 2 develops a novel benchmarking process for TOR products, defining novel "over-lubrication factor", "performance map" and "performance categories" assessing the performance of TOR produce in terms of their propensity to over-lubricate and their "retentivity". Other works have assessed "retentivity" in the past, although this typically applies to gauge corner / flange lubricants, which different performance metrics – this is the most robust method I've seen for top-of-rail products.

Article 3 uses the methodology developed in Article 2 to assess the performance of two oil-based TOR products under the influence of water (in dew conditions). The results may explain why "low adhesion" issues can occur when oil-based TOR products are used in dew conditions.

Article 4 competently investigates the effect of TOR products on RCF growth and wear, particularly in the presence of water and oxides – much of which has never been investigated before.

Article 5 investigates an interesting phenomena identified in Article 4, investigating possible mechanisms for oxides influencing the growth of RCF cracks. I've not seen any similar work previously.

12. Quality of attached papers

Very good

As noted in the "Quality, originality and significance of the results" evaluation justification, the five articles presented with this thesis are of good quality and significantly advance the state of the art.

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

Very good

I believe this work represents a very strong contribution to the state of the art around top of rail friction management products, considering both frictional behaviour and the effect on RCF (and wear) under contaminated conditions. I only hesitate to rate as excellent as I don't believe I have a complete enough appreciation of the state of the art to consider whether this work would be considered in the top 3% of work in this field. I suspect it would be.

Novel aspects include:

- The consideration of water and oxides as contaminants affecting the behaviour / performance of top of rail friction management products.
- The development of a novel methodology for evaluating the performance of top of rail friction management products, considering both the "retentivity" of the products and their potential to "over-lubricate".

The only weakness noted relates the use of some terminology I disagree with, although this in no way detracts from the validity or scientific value of the work.

14. Questions and comments

Terminology throughout the thesis (and attached articles):
Please note – my criticisms in terminology in no way detract from the scientific value of the work presented.

- Whilst the term "adhesion" is commonly used in reference to braking in the rail industry, it has an entirely different meaning in tribological science. Whilst I do use the terms "low adhesion", "adhesion" and "COA" when discussing in an industrial context, I think it's use should be discouraged in a scientific (and particularly tribological) context. It's also worth noting the term "coefficient of adhesion" has been removed between the 2021 and 2023 versions of PD CEN/TS 15427-2-2.

- As noted in your thesis, the term "coefficient of traction" (COT) is dependent on creepage, as confirmed by the definition in PD CEN/TS 15427-2-2:2023 "ratio of the tangential force at the wheel-rail interface and the force at this interface acting perpendicular to the surface of the rail". Nowhere in this definition states that the traction forces are limited by the available coefficient of friction – and the COT would reduce to zero at zero creepage. There are many instances in this thesis where I believe you are referring to what I would call the "limiting COT", "available COT" or simply "coefficient of friction" (COF).
For example, there are multiple occasions where "friction levels" are referred to alongside the term COT.

- Considering my note above, I recognise that the definition of "coefficient of friction" (COF) given in PD CEN/TS 15427-2-2:2023 also doesn't specify limiting frictional forces, however, I think COF is widely accepted to be referring to limiting frictional forces rather than actual frictional forces.
For reference, the PD CEN/TS 15427-2-2:2023 definition is given as "relationship between the friction force of the wheel and the wheel load on the rail independent of the direction".

- If the term "coefficient of adhesion" (COA) is going to be used, I think this is equivalent to the "COF" or "limiting COT", not simply "COT".

- Richard Stock et al (LB Foster) defined the term TOR lubricants in their 2016 paper (whilst I was a PhD student sponsored by LB Foster). At the time, TOR friction management products were not well established, and LB Foster were marketing a water-based TOR product (KelTrack), whilst others were releasing oil-based TOR products. It could be argued that LB Foster were trying to discredit oil-based TOR products, very possibly with some merit (as shown by your work)!

- Since oil-based products are now well established, I believe they should all be referred to as "oil-based friction modifiers", alongside "water-based" and "hybrid" or "emulsion-based" friction modifiers.
Stock et. al note themselves that "A lubricant shows a clear functional differentiation compared to an FM as it is aiming at reducing the friction to a minimum" – this is not the intended function of so called "TOR lubricants". Indeed, your methodology is testing the ability of these products to NOT perform a lubricating

function!

- Supporting the above argument, PD CEN/TS 15427-2-2:2023 defines "liquid top of rail material" as "oil, water or emulsion-based friction modifiers" – note, this has been updated since the 2021 issue.

- Essentially, I suggest the terms are used in PD CEN/TS 15427-2-2:2023 are adopted, noting that many have been updated since PD CEN/TS 15427-2-2:2021, reflecting current accepted usage.

Referring to your Benchmarking methodology (article 2):

- Over-lubrication is a problem because it could represent a safety risk in braking (and affects performance in traction). Is there a over-lubrication factor level you would consider to be "too bad", i.e. detrimental to safety in braking or performance in traction?

- Currently the quartiles Q1 to Q4 are essentially based on the best-known performing product at any given time (in terms of "I"). This means that a product could be demoted if a better performing product comes along. Would it be worth trying to establish permanent boundaries for the classification, and have you thought about how this could be achieved?

- Ignoring contaminants for the moment, over-application concerns me as a potential cause of "low adhesion". Would it be sensible to consider an excessive application dosage for any given product, to ensure it doesn't cause over-lubrication, even if too much material is applied?

- I find it interesting that the 12mL "dry FM" performed badly in terms of retentivity "I", with only the highest dosage of "wet FM" achieving higher than Q4. Does this suggest that "drying" FM products do not function satisfactorily once "dry"? This would rather limit their usefulness!
Do we perhaps need to consider higher dosages for water-based friction modifiers?

- This methodology considers liquid top-of rail products. Do you have any thoughts on an equivalent assessment for solid-stick products? Would "over-lubrication" be less of a concern?

Referring to the performance of oil-based TOR products in dew conditions (Article 3):

- I'd be interested to see how "TORL B" performs under the 100% RH, cooled sample conditions – although I imagine the 8 conditions performed required considerable effort!

- I'd have liked to see how these results compare to a water-based TOR product under the same conditions – although I imagine this would be a very significant increase in scope, so I understand why this work wasn't undertaken.

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	
29/05/2026	

Please note

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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:	**2025/26**
Ústav:	Ústav konstruování
Student(ka):	**Ing. Šimon Skurka**
Doktorský studijní program:	Konstrukční a procesní inženýrství
Studijní obor:	**bez specializace**
Vedoucí dizertační práce:	**prof. Ing. Martin Hartl, Ph.D.**
Oponent dizertační práce:	2- více oponentů
Datum poslední úpravy:	-999

Název dizertační práce:

Vliv kontaminace na modifikaci tření v kontaktu kola a kolejnice

Hodnocení dizertační práce:

Kritérium: **Hodnocení A-F dle ECTS**

Celkové hodnocení dizertační práce:

Předloženou dizertační práci doporučuji k obhajobě.
Celkové hodnocení: .

Celkové slovní hodnocení:

The candidate started his PhD studies in 2021 and from the beginning showed a clear interest in defining a structured study plan covering individual research steps, expected publication outputs and an international internship. The plan was followed successfully throughout the study and most modifications represented positive developments, such as completing additional research stays beyond the original plan. The candidate approached his work actively and responsibly. Communication was frequent and productive. He regularly proposed his own ideas, interpretations and directions for further work. Overall, the candidate demonstrated a high level of commitment and responsibility throughout the PhD study.

The candidate demonstrated a high level of independence throughout the PhD study. He proposed experimental approaches, prepared testing procedures and performed experiments independently. The evaluation of results and preparation of scientific manuscripts required only limited supervision. His very good English skills significantly accelerated manuscript preparation and simplified both internal and external review processes. He was also able to present the obtained results at leading international conferences and discuss them with experts from academia and industry. Besides activities directly related to the dissertation, the candidate actively participated in several research projects. Some of these projects were closely related to the thesis topic, while others addressed different tribological problems. The candidate was also significantly involved in the development of a testing methodology for top-of-rail products. This methodology is currently routinely used within the research group, not only for internal research activities but also in cooperation with industrial partners. Through these activities, the candidate demonstrated a high level of responsibility, technical competence and the ability to work independently.

The thesis addresses an important knowledge gap related to the performance of top-of-rail products under contaminated conditions. Although these products have been used in railway practice for many years, their interaction with environmental contaminants has not been systematically studied. The candidate focused on the influence of contamination, particularly water, on the frictional performance of top-of-rail products, as well as the effects of contamination on wear and rolling contact fatigue. The research activities at Brno University of Technology focused on frictional performance, while wear and rolling contact fatigue were studied during his stays

at Southwest Jiaotong University, where he broadened his expertise in wheel-rail tribology. Based on the results of the thesis, general recommendations for the application and operation of top-of-rail products under different contamination conditions were proposed. The candidate also contributed to the development of testing methodologies that are currently used for the evaluation of top-of-rail products. The results of the thesis were published in three first-author journal papers and one co-authored paper. The papers were published in leading tribology journals, including Wear, Tribology International and Tribology Letters. My only comment regarding the presented work is that part of the results could have been further validated under field conditions or using a full-scale testing approach. Nevertheless, the overall scientific contribution of the thesis is significant and the obtained findings have both scientific and practical relevance.

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.

.....
prof. Ing. Martin Hartl, Ph.D.
Vedoucí dizertační práce

V ..... dne 05.06.2026