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REVIEW OF THE DOCTORAL DISSERTATION prepared by Yohanis Dabesa Jelila, MSc entitled "Method of Assessing the Condition of Wheels of Wheelsets of Railcar During Railroad Drive"

1. Basis for preparing the review

The formal basis for the preparation of the review is:

- Resolution No. 44/2024 of the Scientific Council for Civil Engineering, Geodesy and Transport of the Silesian University of Technology, dated May 23rd, 2024, on the appointment of the subject doctoral dissertation reviewers,
- Letter No. RDILGT.512.2.2024 from the Scientific Council for Civil Engineering, Geodesy and Transport of the Silesian University of Technology Chairman Marcin Staniek, PhD, DSc, Professor of the Silesian University of Technology, dated June 14th, 2024, requesting this review.

2. The subject of the review

The subject of this review is the doctoral dissertation of Yohanis Dabesa Jelila, MSc, entitled "Method of Assessing the Condition of Wheels of Wheelsets of Railcar During Railroad Drive". The dissertation was prepared after the training at the Joint Doctoral School of the Silesian University of Technology and is the basis for applying for the Doctor of Philosophy degree in the Civil Engineering, Geodesy and Transport science discipline. The dissertation's supervisor is Wiesław Pamuła, PhD, DSc, Professor of the Silesian University of Technology, and the co-supervisor is Adam Mańka, PhD, both from the Faculty of Transport and Aviation Engineering of the Silesian University of Technology.

3. Evaluation of the structure (layout and content) of the dissertation

The reviewed dissertation consists of two main parts. The first part is on pages marked with Roman numerals (22 pages). It includes a summary of the dissertation in English and Polish, a list of figures and tables, and a list of symbols and abbreviations. The second part is on pages marked with Arabic numerals (119 pages) and contains the central part of the dissertation. This part comprises six chapters, a bibliography and one appendix containing MATLAB scripts used to conduct the research described in the dissertation.

The **first chapter** (12 pages) introduces the research problem and comprises five subchapters. As a part of outlining the background of the research (the first subchapter), the Author pointed out typical faults that can occur in the wheels of railway vehicles, as well as their impact on driving and the degradation of infrastructure and superstructure. He also discussed methods for monitoring and diagnosing the condition of vehicle wheels. The Author then presented the research's motivations (the second subchapter). He noted that urban tram networks, compared to railway networks, may contribute to a greater extent to damage to vehicle wheels due to the different geometric parameters of the infrastructure, which is why it was chosen for analysis. In the next part of the dissertation, the Doctoral Student identified the problem to be solved, which he presented in the form of the research question and adopted two research hypotheses (the third subchapter). He identified the objectives of the dissertation and four specific objectives (the fourth subchapter). The last subchapter is a description of the dissertation's layout. The chapter layout is correct and raises no objections from a scientific point of view. The content in the individual subchapters is logically connected. The Doctoral Student has justified the reason for taking up the problem. I believe the research question and the research hypotheses are appropriate (I discussed them in greater detail in section 4.2 of the review). The objective of the thesis is correct and seems achievable. The content of the chapter correctly defines the problem of the dissertation.

The **second chapter** (47 pages) is a comprehensive review of the literature relating to the research problem and consists of six subchapters. The first subchapter deals with monitoring the condition of railway vehicle wheels. In it, the Doctoral Student discusses the techniques and methods that have so far been used in the issue mentioned above. He points out that a significant group are methods based on data processing. The second subchapter is devoted to monitoring the condition of railway wheels using vibration measurement. Because the occurrence of a defect in the wheel causes a change in vibration characteristics, it is possible to use this phenomenon for diagnostics. It can be conducted in three ways. The first is to analyse signals in the time domain (the third subchapter). The Doctoral Student presented typical measures that can be used for analysis. The second way is to analyse signals in the frequency domain (the fourth subchapter). To do this, it is necessary to transform the signal into a form that will allow analysis. The recommended tool is the Fourier transform, which is ineffective for analysing non-stationary signals. However, the third way is to analyse signals in the time-

frequency domain (the fifth subchapter), making studying non-stationary signals possible. Here, the Doctoral Student presents tools that can be used for diagnostics. Among them, he highlights the wavelet packet transform (WPT), which in the MODWPT version he used for the research conducted in the reviewed dissertation. The sixth subchapter is a comparison of time-frequency methods. The chapter layout is correct and raises no objections from a scientific point of view. The content in the individual subchapters is logically connected. It is worth emphasising that each cited publication has been duly analysed and characterised. Thus, the literature review was prepared reasonably. On the other hand, the chapter's volume is too large for the others. The Doctoral Student's research workshop on the search for past achievements in a given research area deserves to be pointed out.

The **third chapter** (20 pages) describes the Author's method for evaluating the condition of wheels using the MODWPT procedure for signal transformation, which consists of four subchapters. The Doctoral Student presented the assumptions for the Author's method (the first subchapter), which consists of three components: data acquisition using MEMS sensors, processing the measured signals using the MODWPT transformation, and evaluating the obtained waveforms for wheel faults. He also discussed the conditions for MEMS accelerometers, which he used for data acquisition (the second subchapter). He analysed the sensors available on the market and selected one that would be best for the research. The Doctoral Student then discussed the research tool in the form of the MODWPT signal transformation method (the third subchapter). The mathematical formalism of the method was presented. The last subchapter deals with analysing signal anomalies at wheel fault locations. The Doctoral Student presented a simplified optimisation task and then determined the mother wavelet, data sample size and decomposition level based on the analyses. The chapter layout is correct and raises no objections from a scientific point of view. The content in the individual subchapters is logically connected. The Doctoral Student developed the Author's method and assumptions, which were validated in the work described in the fourth chapter. I have included my remarks about the chapter's content in section 5 of this review.

The **fourth chapter** (13 pages) is a validation of the Author's method for evaluating the condition of wheels on accurate data and consists of four subchapters. The Doctoral Student presented a block diagram of the Author's method validation procedure. Then, he characterised the research area, and the accelerometer used (the first subchapter). In addition, he presented the method and results of filtering the sensor data (the second subchapter). The Author also presented the energy values of the signals obtained using the MODWPT transformation during tram test rides at the depot (the third subchapter). MATLAB program was used to perform this stage of the research. In the last subchapter, the Author presented the wheel condition evaluation results obtained using the Author's developed method. The chapter layout is correct and raises no objections from a scientific point of view. The content in the individual subchapters is logically connected.

This chapter confirms the research hypotheses defined on page 10 of the dissertation and, together with the fifth chapter, answers the research question posed on page 9 of the dissertation. I have included my remarks about the chapter's content in section 5 of this review.

The **fifth chapter** (4 pages) is a consideration of the accelerometer used. The Doctoral Student discussed installation, energy balance, radio transmission, and durability issues. In my opinion, the Author of the dissertation omitted several problems in the description that were relevant to the dissertation's research. I have included my remarks about the chapter's content in section 5 of this review. This chapter and the fourth chapter answer the research question on page 9 of the dissertation.

The **sixth chapter** (4 pages) is a summary and conclusions resulting from the research in the dissertation. The Doctoral Student has successfully verified the research hypotheses. He presented findings and directions for further study. The chapter layout is correct and raises no objections from a scientific point of view.

Summing up, the structure of the dissertation is correct. The Author begins his considerations by introducing the research problem, then formulates the research question and adopts two research hypotheses. He also presents the main objective of the dissertation and the specific objectives. He further summarises the state of the English-language literature, Polish and foreign authors, and confirms the research gap in the analysed area. He developed a research method consisting of three scientific steps and validated it with accurate data. As a result of the considerations conducted, the Doctoral Student answers the formulated research question and proves the research hypotheses. The main objective of the dissertation and the specific objectives have been achieved. The structure of the doctoral dissertation presented for review as a scientific dissertation does not raise my objections.

4. Evaluation of the merits of the dissertation

4.1. Evaluation of the dissertation subject selection

The research subject of the dissertation submitted for review was the infrastructure of urban tram networks and superstructures in the form of tram vehicles. Attention was focused on the tram wheels and their contact with the rail (wheel-rail contact). It should be noted that the indicated elements are among the important ones in ensuring a safe and comfortable ride. Therefore, conducting research concerning the abovementioned elements is reasonable, as this will allow us to maintain the highest possible degree of safety for traffic and people.

Many faults can occur in the wheels of rail vehicles. These faults, which negatively affect driving comfort and safety, can cause infrastructure and superstructure degradation. It

sometimes involves high repair costs for components damaged or destroyed by defective wheels. It is, therefore, essential to look for methods that will allow early detection of a fault in this component of a tram vehicle, thus reducing the potential costs associated with the damage caused by the fault. It affects the cost of diagnosis, which should be kept to a minimum.

Urban tram networks, relative to railway networks, are more likely to cause damage to vehicle wheels due to the different geometric parameters of the infrastructure (including smaller radii of curves, intersections of tram tracks in one level or other construction of turnouts). Damage to a tram wheel causing a traffic stop generates significant organisational chaos in a selected part of the city or the entire city. In addition, due to the limited number of rolling stock, taking a vehicle out of service for an extended period can cause disruptions to the timetable. Therefore, it is reasonable to look for methods that will minimise the probability of disruption to the scheduled traffic organisation.

Current diagnostic methods are based mainly on visual and auditory inspection by a human - operator, whose experience determines the interpretation of test results. Detection of a fault is possible only when it is visible or audible. It is reasonable to look for methods that will support the work of an experienced human-operator and allow detection of the fault before it becomes detectable. It will reduce the time spent on searching for defects. In addition, the cost of repairing the faults can be significantly reduced, benefiting the vehicle owner.

The Doctoral Student addresses the issues mentioned above in his dissertation in line with the latest research in this area. Hence, in conclusion, I think that taking up the research issue by the Doctoral Student is justified. It should be emphasised that the problems addressed by the Doctoral Student have a scientific dimension and are part of current research trends, and also an utilitarian dimension. Any activities related to ensuring the highest possible level of safety in passenger transport should be considered desirable. In addition, searching for methods that will not generate high costs is most needed in an era of rising operating costs for vehicle owners. The Doctoral Student, therefore, fits well with current research needs in this area.

4.2. Evaluation of the objective, thesis, and method of solving the identified problem

Based on the conducted analyses, the Doctoral Student identified the problem to be solved in the dissertation, which he presented in the form of the research question (quote, page 9):

In what way MEMS-based acceleration sensors can be applied to assess the condition of wheels of wheelsets of railcars during railroad drive?

In my opinion, the Doctoral Student formulated the research question correctly, in a clear and unobjectionable manner from a scientific point of view. It leads to identifying a method of using MEMS accelerometers to measure vibrations and then transforming the obtained signals using the MODWPT method and interpreting the results. It is presented in the Author's method of assessing the condition of wheels. The answer to the question is presented in the content of the fourth and fifth chapters of the reviewed dissertation.

The Doctoral Student formulated two research hypotheses (quote, page 10):

The analysis of the vibration signals or image with a 0-500Hz limited frequency spectrum of the railways during a railroad drive enables the assessment of the fault condition of wheels. The energy of vibration signals in characteristic frequency bands during a railroad drive indicates the condition of wheels.

In my opinion, the presented research hypotheses were formulated correctly by the Author of the dissertation in a straightforward manner and are not objectionable from a scientific point of view. They have been confirmed by validating the Author's method of assessing the condition of wheels using accurate data and presented in the content of the fourth chapter of the dissertation.

The objective of the dissertation is (quote, page 11):

to develop and validate a method for assessing the condition of wheels of railcars using vibration analysis during railroad drives operation.

The Doctoral Student further identified four specific objectives (quote, page 11):

- *Propose a way of identification of irregularities of the vibration frequency spectrum.*
- *Determine the characteristic frequency bands of vibrations significant for describing the condition of wheels.*
- *Propose measures for collecting vibration data during railroad drives with the minimum resources possible.*
- *Develop an implementation of the vibration data analysis that will facilitate wheel-rail maintenance workshop operations.*

In my opinion, the formulated main objective and the specific objectives have been defined correctly by the Doctoral Student and are not objectionable from a scientific point of view. I think that the objective of the dissertation, described in this way, is essential from both a scientific and a utilitarian point of view. The Author of the dissertation has defined that he is looking for a method to assess the condition of wheels, which will then be validated on actual data. It was achieved and demonstrated in the third and fourth chapters of the dissertation. For the method to obtain the right results, the Doctoral Student proposed a way to identify irregularities in the spectrum, defined characteristic frequency bands, proposed a way to collect data and developed an implementation of signal analysis using the MATLAB tool. Thus, the specific objectives have been achieved.

4.3. Substantive evaluation of the dissertation

The analysis of the dissertation's content indicates that the Doctoral Student undertook a difficult task, which he defined in the objective of the dissertation, i.e. the development of a method for assessing the condition of vehicle wheels using vibration analysis during driving and its validation on accurate data. In this context, I think the most essential part of the dissertation is chapters 3 - 5, in which the Author of the dissertation presents the model, empirical research, and verification of the proposed approach.

The validation of the method on accurate data should be highly rated. It was conducted on the ground (in a tram depot using vehicles with damaged and undamaged wheels) using a prototype measuring device and data acquisition system. The empirical studies became the basis for calibrating the Author's method and, consequently, for realising the specific objectives set by the Doctoral Student (among others, for establishing the frequency bands for describing the condition of the wheels).

In my opinion, the dissertation provided for review is the Author's original approach to a method of assessing the condition of vehicle wheels using vibration analysis during passing, which uses MEMS accelerometers, the transformation of the obtained signals using the MODWPT procedure and recommendations for assessing the vibration energy indicative of wheel damage. The calibration of the method using empirical studies adds value to the dissertation.

As the main achievements of the Doctoral Student, I can point to:

- the development of a method for assessing the condition of vehicle wheels using vibration analysis during passing,
- validation of the method on data from real traffic conditions,
- identification of characteristic vibration frequency bands relevant to the description of wheel condition,
- development of recommendations for an accelerometer that can be used for wheel condition assessment (e.g., for installation, energy balance, radio transmission, and durability issues).

It should be highlighted that the Doctoral Student has demonstrated the ability to introduce the research problem adequately in the dissertation. Using literature items, he outlined the background of the research and clearly indicated the reasons for undertaking the topic.

The Author chose the research methods competently and adequately in terms of the form of the input data. Data analysis was performed with due care on an adequate research sample. The method was calibrated based on a large population of input data (measurement data from real traffic conditions for damaged and undamaged wheels). The analysis of the results and the conclusions that were reached do not cause any concerns for me.

I conclude that the problems undertaken in the dissertation and the way of solving the presented research problem demonstrate good substantive preparation of the Doctoral Student, his scientific maturity, and his ability to conduct scientific research independently. The discussed issues confirm the good preparation of the Author to solve the problem.

In conclusion, I think the discussed construction of the reviewed doctoral dissertation, the method of implementation of the empirical research and the form of the conducted analysis, including the adopted research methodology, are appropriate for this type of thesis. The Author of the dissertation has demonstrated general theoretical knowledge, good knowledge of the research subject and mastery of the experimental methods used in the scientific discipline of Civil Engineering, Geodesy and Transport.

4.4. Evaluation of the bibliography

The bibliography consists of 107 items. These are English-language items. Their authors come from both Polish and foreign scientific centres. In the literature, there are fundamental positions relating to the topic of the dissertation, which date from before the year 2000, while the majority of the literature items are from the last two decades, which proves that the Doctoral Student has taken into account the latest scientific trends relating to the topic of the dissertation. It enhances the substantive value of the dissertation.

4.5. Evaluation of the editorial correctness of the dissertation

The Doctoral Student has tried to ensure that the reviewed dissertation is clear regarding editing. The language used in the dissertation is correct. The illustrative material used is correct and enriches the content covered in the dissertation. The Author of the dissertation did not avoid some editorial shortcomings, which are present in almost every work. Using the LaTeX editor to write the dissertation, which causes many writing problems, should be underlined.

5. Remarks on the dissertation

While reading the dissertation, the following remarks came to my mind. I would ask the Doctoral Student to refer to some of them (underlined) during the dissertation defence.

- The abstract in Polish should include a translation of the most essential elements of the dissertation from English. The Doctoral Student has translated the research question and the research hypotheses. However, there is no translation of the dissertation objectives. The translation made by the reviewer may not fully reflect the Author's ideas.

- Regarding figures and tables, the Doctoral Student does not indicate the sources of photographs and data. In my opinion, all the elements mentioned above are the Doctoral Student's work. In future, I would suggest adding information about the source.
- Mathematical symbols in formulas should be written according to international standards, mainly ISO 80000-2:2019: Quantities and units. Part 2: Mathematics. As an example of another source for correct notation, please refer to https://en.wikipedia.org/wiki/Glossary_of_mathematical_symbols.
- Subchapter 3.1, p. 62, Fig. 3.1 – In my opinion, the dissertation lacks a presentation of the algorithm of the method using a block diagram, which would describe the operations in successive steps and with a relatively high degree of accuracy.
- Next to mathematical formulas, the units in which the values are expressed should be included.
- Subchapter 3.4, pp. 72 and 73, formulas (3.7), (3.8) and (3.9) – The Doctoral Student indicates that the formulas mentioned are objective functions, which are an indicator for evaluating the quality of the solution in an optimisation task. The notation lacks information as to which extreme of the function is sought.
- Chapter 4, p. 80 – in the first sentence, the Doctoral Student wrote that the method was validated at the main depot of the Tramwaje Śląskie S.A. Which depot is he referring to? I would ask for an answer to this question during the defence of the dissertation.
- Subsection 4.1, p. 83 – The Doctoral Student presented a zoom of the installed sensor on the rail in Figure 4.2. In my opinion, the dissertation lacks the presentation of a photo of the testing ground so that a section of the rail (track system) before and after the sensor installation site can be seen. It would allow an assessment of the extent to which factors such as the condition of the rail, the distance from the rail connection point, the need for vehicle braking or the distance from the turnout, among others, may affect the occurrence of additional vibrations interfering with the result. I would guess that this is due to critical infrastructure protection issues. I fully understand this issue.
- Chapter 5 – In this chapter, the Doctoral Student has included a consideration of the prototype acceleration sensor solution used for the dissertation. In the first chapter, on page 4, the Author mentions that the developed method is costless. The dissertation lacked, for me, a calculation of the approximate value of the costs associated with the method (including the cost of the sensor, the cost of the necessary electricity, the cost of human labour, etc.). I would ask that the Doctoral Student provide an approximate value of the costs associated with his proposed solution during the dissertation defence.
- Chapter 5 – The Doctoral Student has discussed issues related to the advantages and limitations of the proposed solution. In my opinion, there is a lack of information (recommendations) in the dissertation regarding the organisation of the depot's work from the point of view of traffic management in relation to taking measurements. There is also a lack of recommendations concerning the location of the accelerometer from

the point of view of the technique of conducting traffic through the depot. I would ask the Doctoral Student to comment on the issues mentioned above during the dissertation defence.

- Chapter 5 – based on the readings, the question arises - does the proposed method, particularly the installation of the sensor, result in a possible violation of any of the regulations concerning the safety of vehicle operation (legal acts, normative acts)? I would ask the Doctoral Student to comment on the issues mentioned above during the dissertation defence.
- Bibliography – the Doctoral Student made bibliographic descriptions using the same style but took a different approach to authors' names. I would suggest that in future the description should be standardised.

6. Summative evaluation

6.1. Evaluation of the Doctoral Student's theoretical knowledge

The dissertation presented for review allows me to assess that the Doctoral Student applying for the Doctor of Philosophy degree in the discipline of Civil Engineering, Geodesy, and Transport has general theoretical knowledge of the research area. Based on the considerations in the doctoral dissertation, I can conclude that the proposed solution to the scientific problem is theoretically grounded. As an example, I can point to the assumptions made by the Author of the dissertation about the identification of the mother wavelet, the data sample size, and the decomposition level, among others. These have proved to be accurate and have been confirmed in empirical studies.

6.2. Evaluation of the Doctoral Student's ability to conduct scientific work independently

The doctoral dissertation presented for review allows me to assess that the Doctoral Student applying for the Doctor of Philosophy degree in the discipline of Civil Engineering, Geodesy, and Transport demonstrates the ability to conduct scientific work independently. The problems are taken up, and the way of solving the problem, in my opinion, shows a proficient level of this skill. It should be emphasised that the language of the work is scientifically mature. The arguments provided by the Author in the dissertation are factual and adequate. The layout of the dissertation is thoughtful and refined. Furthermore, it is noteworthy that the Doctoral Student has published three co-authored articles in high-impact scientific journals, where the review process is very demanding. It has enhanced the Author's ability to conduct scientific work independently.

6.3. Evaluation of the originality of the solution to the scientific problem

In my opinion, the dissertation presented for review represents an original solution to a scientific problem in developing an author's method for assessing the condition of vehicle wheels using vibration analysis during passage. As mentioned by the Doctoral Student at the conclusion of the literature review, there are many publications related to wheel condition monitoring. However, no publications describe the use of MEMS accelerometers and the MODWPT signal transformation method for the issue above. In addition, my literature review did not identify any researchers who had discussed the scientific problem. It should be noted that the Doctoral Student has published three co-authored articles in high-impact journals and has presented five times at scientific conferences combined with the publication of a paper. Thus, various researchers, including reviewers of scientific articles, have confronted the developed method and its implementation. In my opinion, this confirms the originality of the solution to the scientific problem.

7. Conclusion

I think the comments and reservations in the review do not reduce the reviewed doctoral dissertation's substantive scientific and application value. It represents an original solution to a scientific problem by the Author, which I have positively evaluated in the earlier points of the review. I conclude that the scope of the dissertation falls within the research area of the scientific discipline of Civil Engineering, Geodesy and Transport.

I conclude that the reviewed doctoral dissertation prepared by Yohanis Dabesa Jelila, MSc, entitled "Method of Assessing the Condition of Wheels of Wheelsets of Railcar During Railroad Drive", written under the supervision of Wiesław Pamuła, PhD, DSc, Professor of the Silesian University of Technology and Adam Mańka, PhD **fulfils the conditions** specified in Article 187 of the Act of July 20th 2018 The Law on Higher Education and Science **and may be the basis** for awarding the Author with a Doctor of Philosophy degree in the field of engineering and technology in the discipline Civil Engineering, Geodesy and Transport.

In connection with the above, I apply to the Scientific Council for Civil Engineering, Geodesy and Transport of the Silesian University of Technology for admission to the dissertation defence.

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