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## REVIEW

### of the doctoral dissertation of Mr. Yohanis Dabesy Jelili „Method of assessing the condition of wheels of wheelsets of railcar during railroad drive”

The basis for the preparation of the review was letter No. RDILGT.0211.44.2024 - Resolution 44/2024 of the Discipline Councils Civil Engineering, Geodesy And Transport of the Silesian University of Technology, dated 23 May 2024.

The review consists of 11 relevant points for the assessment of the dissertation described in 9 numbered pages.

#### 1. Basic information

The author of the dissertation: „*Method of assessing the condition of wheels of wheelsets of railcar during railroad drive*” is Mr. Yohanis Dabesy Jelili, PhD student at Silesian University of Technology, and scientific supervisor of the dissertation is Professor D.Sc. Eng. Wiesław Pamuła and scientific co-supervisor Adam Mańka PhD Eng. The dissertation was completed and submitted for review in June 2024.

Reliability, testing and diagnostics of rail vehicle wheelsets are areas of vital importance to the safety and efficiency of rail transportation. The safety of movement of rail vehicles requires a continuous diagnostic process and assessment of the technical condition of the rail vehicle. This applies to both elements of the rail vehicle and the track surface. Analysis of the technical condition of rail vehicles is a process that includes, among others, collecting and analyzing data collected during technical inspections and diagnostic tests. An important element of diagnostic tests is the analysis of the technical condition of rail vehicle components, which can also be performed during non-invasive tests. Such research allows not only to identify potentially dangerous elements but also to forecast time parameters related to operation. Railway wheel set diagnostics is therefore a key element in maintaining the safety

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and efficiency of rail transport. Wheel sets of rail vehicles are not only elements connecting the vehicle with the track, but also a factor influencing the movement resistance and wheel wear. Damage to the wheels of rail vehicles can lead to serious breakdowns and catastrophic consequences. An uneven distribution of stress around the wheel circumference can, for example, lead to abnormal wear. Wheels of rail vehicles are elements that not only affect the safety of movement but also the driving comfort and stability of the rail vehicle. Diagnostic processes therefore allow for early detection of emerging defects and irregularities. It is also necessary to mention here factors caused by improper functioning of rail vehicles, such as noise or vibrations generated while driving.

Modern methods of wheel set diagnostics for rail vehicles make it possible to assess the technical condition of a wheel by, among other things, analyzing vibrations or monitoring the condition of wheels in real time. Therefore, it is extremely important to use diagnostic methods that reliably and effectively allow to ensure a high level of safety minimizing the risk of failures and accidents. The use of modern diagnostic techniques also optimizes the maintenance costs of rolling stock and increases the safety of its use.

The doctoral dissertation presents a study at the diagnosis the condition of tram vehicle wheels using micro-electromechanical systems (MEMS)-based accelerometer sensors that record rail vibrations during the passage of a rail vehicle over the measurement system placed on the manoeuvring track in the tram depot. The study analyses sensor signals in the time-frequency domain to assess the condition of wheels during railroad drives.

## **2. Assessment of the composition of the doctoral dissertation and its content**

The doctoral dissertation presented for review „Method of assessing the condition of wheels of wheelsets of railcar during railroad drive” has got 142 pages. It consists of six main chapters, including subsections and a summary. Additionally, the dissertation contains a bibliography and supplements. The content of the dissertation is consistent with the title. The chapters of the dissertation constitute a logical whole and used chronology does not raise more doubts.

The subject of the doctoral thesis undertaken by the doctoral student in relation to the author's publications to date is a continuation of his research and scientific interests. The work presents a method for assessing the condition of wagon wheels while driving.

The analysis of the doctoral dissertation submitted for evaluation allows to conclude that as part of the doctoral thesis, the doctoral student:

- formulated the research problem,
- conducted a literature review,



- indicated the aim, scope and thesis of the dissertation,
- conducted an analysis of the current state of knowledge and identified research gaps in the field of rail vehicle wheel diagnostics,
- used a mathematical apparatus and applied this apparatus to analyze wheel fault condition,
- developed the concept of a method of assessing the wheelsets of rail vehicles,
- implemented the author's solution in a programmable controller based at MEMS sensors,
- carried out verification of the method proposed in the thesis using an experimental setup.

The author set as the goal of the study the development and validation of a method for assessing the condition of railroad tramway wheels using vibration analysis during operation. According to the author of the dissertation, the study aims to establish the relationship between vibration patterns and wheel damage states, enabling a scientific and reliable assessment of the condition of railcar wheels. In order to achieve the set research task, the author of the dissertation identified specific objectives:

- proposed a way of identification of irregularities of the vibration frequency spectrum,
- determined the characteristic frequency bands of vibrations significant for describing the condition of wheels,
- proposed measures for collecting vibration data during railroad drives with the minimum resources possible,
- developed a method for analyzing vibration data that will facilitate the work of the technical staff involved in the maintenance of rail vehicles.

In the first chapter of the doctoral dissertation, the author introduced the topic of the dissertation and briefly presented an analysis of damage to rail vehicle wheels. When making a preliminary description, he referred to the works of authors dealing with similar research issues. The doctoral student introduced to the methods for detecting damage to rail vehicle wheels. Concluding the brief introduction, he noted that time-frequency analysis techniques have proven to be a promising approach to train wheel damage diagnosis, providing a more comprehensive and effective way of analyzing and interpreting signals collected from train wheels. In the next step, he presented the motivation for the research undertaken on the issue of detecting damage to rail vehicle wheels. At this stage, the doctoral student indicated that there was a need for diagnostics of railway means of transport in the tram depot. The doctoral student described and defined the research problem specified as: *in what way MEMS-based acceleration sensors can be applied to assess the condition of wheels of wheelsets of railcars during railroad drive?* In this chapter, he indicated the assumptions and goals of the work.



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In the second chapter of the dissertation, the author provided a description of methods for assessing the condition of wheels of rail vehicles. In this chapter, the author analyzed the state of knowledge, citing numerous works. The doctoral student presented issues related to vibration-based monitoring and damage diagnosis. Based on a well-prepared mathematical apparatus, he presented techniques used in vibration analysis. These methods make it possible to isolate the characteristic features of the signals collected by the sensors. This chapter was dominated by issues such as:

- Vibration-based condition monitoring.
- Time-domain analysis of vibration signals.
- Frequency-domain analysis.
- Time-frequency analysis of vibrations signals (e.d. Short-time Fourier transform; Wavelet transform - continuous and discrete; Hilbert-Huang transform).

Chapter two abounds with academic-level mathematics supplemented by characterisations that illustratively complement the description very well. The chapter ends with the issue of time-frequency methods comparison.

The third chapter of the dissertation presents a method for evaluating the condition of railroad car wheels while on the track. The doctoral student indicated limitations regarding the use of MEMS sensors and presented assumptions for further considerations. The author assumed that wheel condition irregularities cause disturbances in the frequency spectrum of recorded accelerations, and these irregularities can be used to obtain information about the wheel condition. He pointed out that the properties of MODWPT can be used to analyze the collected measurement data, which will allow for effective interpretation of vibration signals to detect potential damage. In this chapter, the author presented detailed information about the MODWPT algorithm for analyzing the condition of wheel fault signals. In order to conduct a comprehensive analysis, he proposed three stages of work: data collection, data processing (with MODWPT), analysis of coefficients of MODWPT. The chapter was filled with numerous drawings, patterns and references to literature. The author discussed variants of the proposed method.

After introducing the proposed method, which was presented in the third chapter, the fourth chapter validates the proposed method. The author conducted research at the main tram depot of Tramwaje Śląskie, S.A. He presented a brief description of the measurement site - infrastructure and measurement system. To collect measurement data, the author used a prototype recording device based on a 3-axis MEMS accelerometer sensor. The author presented and discussed the results of the tests, which were carried out in two sessions, each with 10 test drives. The author recorded and analyzed the vibration energy of selected tram



vehicles in order to identify differences in vibration energy resulting from the normal and faulty states. The results of his work are presented in graphical and tabular form. He indicated the minimum and maximum values of the results obtained, which allowed for the selection of good and defective wheels. The research results presented in chapter four indicated that the increase in wheel damage generates higher weighted difference values and higher vibration energy values.

In the fifth chapter, the author presented the functional assumptions of the control and measurement system which described in the fourth chapter (Fig. 4.2). The author presented the possibility of using a system based on radio transmission and its own power supply system. The author presented a solution that optimizes energy consumption in relation to the achieved data transmission range. The solution presented makes it possible to bypass integration into the track infrastructure at the tram depot and to located the measurement system anywhere. This chapter is the shortest chapter of the dissertation.

The dissertation ends with a summary (chapter six) in which the doctoral student referred to the achieved results. Additionally, at the end of the work there is an attachment in the form of MATLAB code.

### **3. Assessment of the literature used**

The bibliographic index contains 107 items. The bibliographic index does not include 3 journal articles and 5 co-authored articles by the doctoral student, which are included in the separate list shown on pages XIII and XIV.

It is noteworthy that all of the author's papers are part of the topic undertaken in the dissertation. The indicated works are from 2021-2023, including 4 publications from 2021, 2 publications from 2022, and 2 publications from 2023. The doctoral student's publications should be considered new.

The selection of literature used should be considered correct. Among the 106 references, 38 are studies that are 5 years old or less. The total number of bibliographic items not older than 10 years is 62, which constitutes more than 50% of the entire list. The number of bibliographic items should be considered sufficient.

### **4. Assessment of the purpose of the work**

The author pointed out that there is a need to introduce effective systems ensuring wheel diagnostics of rail vehicles. The author of the dissertation proposed a diagnostic system based on a three-axis MEMS sensor mounted under the railway track and used to record vibrations



of road wheels. To achieve the objective of the dissertation, the author identified sub-objectives, which were:

- analysis of existing solutions related to testing the condition of wheels of rail vehicles,
- based on the MODWPT transformationa testing algorithm was developed,
- assumptions were made for carrying out the tests and the appropriate frequency range was indicated as a measure of the technical condition of the rail vehicle wheel,
- validation of the method was carried out during test runs of trams on the depot's maneuvering tracks. An acceleration sensor prototype based on a 3-axis accelerometer using MEMS technology was used,
- the possibilities of using the developed method to detect wheel defects of rail vehicles while driving was indicated.

The implementation of partial tasks and the research method used in the work allow us to conclude that the aim of the work has been achieved.

#### **5. Assessment of the applied research methods**

The doctoral student used a well-known environment for performing engineering and scientific calculations, Matlab, to carry out the analyses. In the area of the doctoral dissertation, the selection of software should be considered as correct. In terms of theoretical research methods, it should be noted that the doctoral student identified, described and compared time-frequency methods based on mathematical apparatus, including:

- STFT - Short-Time Fourier Transform
- CWT - Continuous Wavelet Transform
- DWT - Discrete Wavelet Transform
- WPT - Wavelet Packets Transform
- EMD - Empirical Mode Decomposition
- HHT - Hiltert Haung Transform
- MODWPT - Maximal Overlap Discrete Wavelet Packet Transform

This allowed for a proposal MODWPT signal processing technique as a good method for processing the acquired acceleration signals. He developed a prototype of the device and scientifically justified the proposed method.



## 6. Assessment of research results

Based on the research method used and the proposed prototype of an accelerometer sensor based on MEMS technology measuring rail vibrations during the passage of a tram, the doctoral student demonstrated that the solution used allows for the implementation of tasks related to the diagnosis of tram wheels, indicating potentially dangerous tram wheels.

## 7. Implementation of research results

The prototype system for assessing the condition of tram wheels presented in the doctoral dissertation was installed in the tram depot of Tramwaje Śląskie S.A. This made it possible to carry out the research necessary to write a doctoral dissertation. The obtained results allow us to conclude that the presented prototype can be an element of the depot's trackside infrastructure, contributing to the quick and selective diagnosis of tram wheels.

## 8. Notes for work

The doctoral dissertation was written in an understandable language, although there are places that require re-reading the text. The dissertation submitted for evaluation contains incomprehensible page numbering. The dissertation begins with Roman numbering, where after number XXII the page numbers are changed to decimal numbers and the dissertation begins with number "1".

On pages XIII - XIV, the doctoral student presents his studies - list of publications, but it is difficult to find references to them in the doctoral dissertation.

The author of the dissertation does not refer to the bibliographic list in the form of numbered references, which makes the analysis of the text difficult. The electronic version of the dissertation has references to studies by other authors along with links to the list, but in the case of a printed study, this forces the reviewer to look for references in the bibliographic list.

In the reviewer's opinion, chapter five is unnecessarily separated, and the information contained therein could be a perfect complement to chapter four, in which the doctoral student presented a prototype of a control and measurement device. On the other hand, the dissertation lacked an introduction to the Matlab environment. The appendix of the dissertation clearly indicates that such an environment was used.

The dissertation did not clearly indicate which of the drawings or diagrams are the author's. The lack of attribution of such information may indicate that the entire graphic content of the dissertation is the author of the doctoral student.

The description contained in the work does not indicate whether the prototype of the device (Fig. 4.2) is the author's own or was created as a result of the team's work.



After reading the dissertation, the reviewer would like to ask the following question:

- Is the prototype of the device shown in Fig. 4.2 original or the result of the research team's development? If it was developed jointly by a team, what was the participation of the PhD student in the creation of the measurement system?
- On page 81 of the dissertation, the doctoral student writes that in the range 420Hz to 422 Hz this frequency clearly determines the condition of wheels within which fault conditions experienced. Where does this frequency range come from? The resolution used in the drawings in the doctoral dissertation does not allow for such a precise reading. Please explain.
- In what outdoor conditions were the measurement tasks carried out and what can, for example, temperatures below freezing can affect the obtained measurement results?
- What effect can the technology used to make the trackbed have on the measurement results? (vibration analysis)
- The dissertation presents the measurement results from two sessions. According to PhD student is there a reference threshold (DW, energy) above which potentially wheel damage can be considered?

### **9. Assessment of the originality of the work**

Despite the comments indicated in the review, it should be considered that the doctoral dissertation submitted for review is an original work. The doctoral student presented his own concept of a method for assessing the condition of wheels of a railway wagon while driving. The developed prototype vibration recording device containing a MEMS accelerator sensor system is an original idea.

### **10. Assessment of the doctoral student's knowledge and preparation for research independence**

In his dissertation, the doctoral student demonstrated that he had research and analytical skills enabling the implementation of scientific and research tasks. The doctoral student also demonstrated experience in conducting research in real conditions. This experience was presented in chapter four of the doctoral dissertation. The doctoral student's knowledge allowed him to prepare a prototype of a device enabling the assessment of the condition of tram wheels.





## 11. Conclusions

After reading the doctoral dissertation of Mr. Yohanis Dabesy Jelili titled "Method of assessing the condition of wheels of wheelsets of railcar during railroad drive", the reviewer states that the doctoral dissertation is a contribution to the development of safe rail transport. The choice of the topic is accurate and current. The practical importance of the topic discussed should also be emphasized. Reservations and comments do not in any way diminish the positive assessment, but are only intended to serve as a guide in improving the research, cognitive and writing skills of the doctoral student. The doctoral student demonstrated theoretical knowledge on a given topic and the ability to use tools to carry out experimental tasks.

In conclusion, the doctoral dissertation of Mr. Yohanis Dabesy Jelili is a thematically coherent study and presents the issues of wheel diagnostics of rail vehicles in an original and creative manner. I conclude that the dissertation meets the requirements of the Act of Law of 20 July 2018 – The Law on Higher Education and Science. I am requesting that Mr. Yohanis Dabesy Jelili be allowed to publicly defend his doctoral dissertation.

*Yours faithfully*

