



## PREVENTIVE MAINTENANCE IN RAILWAY VEHICLES USING NEW TECHNOLOGIES

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**Abstract** – Preventive maintenance is essential for the safe and efficient operation of railway vehicles. This paper introduces a laser scanner system developed to measure critical wheel profile parameters, including the qR value (wheel profile conformity index), flange height (Sh), and flange thickness (Sd). These parameters are crucial for monitoring wheel wear and ensuring proper wheel-rail interaction. The laser scanning system provides real-time, high-precision measurements, enabling early detection of wear patterns that could lead to failures if left unaddressed. This non-contact, automated technology integrates seamlessly into existing maintenance workflows, reducing human error and enhancing decision-making capabilities. Maintenance teams can use the data to plan predictive interventions, reducing downtime, extending the life of both wheels and rails, and minimizing maintenance costs. The system has been tested in operational environments, demonstrating its effectiveness in improving the reliability and safety of railway vehicles. By offering a more efficient approach to wheel monitoring, this technology contributes to the future of predictive maintenance in the railway industry.

**Keywords** – preventive maintenance, railway vehicle, wheel profile, inspection, flange.

### 1. INTRODUCTION

The condition of railway vehicle wheels is a key factor in ensuring safety and operational reliability. According to the Regulation on the Maintenance of Railway Vehicles issued by the Serbian Railways Directorate [1], regular preventive maintenance is essential to reduce the risk of wear-related failures and ensure the longevity of railway components. While traditional manual inspections are common practice, they are often time-consuming and prone to human error [2]. As railway systems evolve, the need for advanced inspection technologies has become evident. Tools like the Goldschmidt WM3 Wheel Measurement System [3] and Graw's Electronic Wheel Wear Caliper [4] offer non-contact, high-precision measurements, significantly improving the accuracy of wheel condition assessments.

Key parameters such as qR (wheel profile conformity), flange height (Sh), and flange thickness (Sd) are critical for ensuring safe wheel-rail

interaction [5]. As highlighted in Maintenance of Railway Vehicles by Stamenković [6], the implementation of modern technologies in the maintenance process enables railway operators to detect early signs of wear, allowing for timely intervention and reducing the likelihood of critical failures. By adopting predictive maintenance strategies, which leverage real-time data from laser scanning and other advanced condition-monitoring systems, railway operators can optimize maintenance schedules and minimize downtime [7][8].

This paper presents a novel laser scanning system designed to further improve the precision of railway vehicle wheel inspections. It builds on prior studies that demonstrate the effectiveness of automated measurement systems in reducing human error and streamlining maintenance procedures [9]. The proposed system offers a comprehensive solution for continuous wheel monitoring, enhancing both safety and operational efficiency across the railway industry. By integrating appropriate software, preventive

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maintenance of rolling stock can be achieved. This would provide operators with more flexibility to organize better-planned wheel rim replacements. While operators have data on the number of kilometers a wheel has run, the terrain configuration and rail conditions have a greater impact on wheel rim wear. Therefore, incorporating wheel rim measurement with overhead software would be a valuable step forward.

**2. MODERN MEASURING DEVICES**

To enhance the efficiency of railway vehicle maintenance, a variety of advanced detection systems have been developed. These systems can be either installed directly on the vehicle or positioned along the track, allowing for real-time identification of potential failures during the vehicle's operation. By leveraging these technologies, maintenance teams can plan necessary interventions during scheduled downtime, minimizing disruption to service. Modern diagnostic tools such as optical cameras, thermal imaging cameras, and laser measurement systems have played a key role in enabling this proactive approach. [10]

Assessing the condition and lifespan of railway wheels requires close monitoring of critical factors, including the state of the rolling surface, the profile of the wheel rim, and the detection of stress or cracks in the wheel structure. [6]

Advanced diagnostic systems have been developed specifically for use in depots, where control inspections can be conducted more efficiently and completed in a significantly shorter time. The primary objective of these systems is to provide rapid and accurate diagnoses of defects, allowing maintenance teams to identify faulty components with minimal inspection time, thus improving overall maintenance productivity. Such devices can be seen in Figs. 1 & 2.



Fig. 1. Device for measuring wheel rim parameters [4]

Laser for distance measuring, that is the key technology parameter, has always some mistake during the measurement and this is the well know thing. Company Elag designed more sophisticated solution that gives more accurate by integrating laser that is moving during the measurement and always have same position to wheel flange.



Fig. 2. Device for measuring wheel rim made by company Elag

**3. WHEEL PARAMETERS MEASURING DEVICES**

The wheel rim profile, as defined by UIC 510-2 standards, plays a critical role in enabling the vehicle to move safely on rails. It directly influences key factors such as vehicle stability, ride smoothness, and the rate of wear on both wheels and rails. Over time, as the vehicle operates on the rails, the tread surface of the wheel is subjected to wear and deformation. If a visual inspection identifies damage that could compromise the geometric properties of the wheel, precise measurements of the rim profile are necessary. The differences between the standard wheel rim profile and the damaged profile are shown in figure 3.

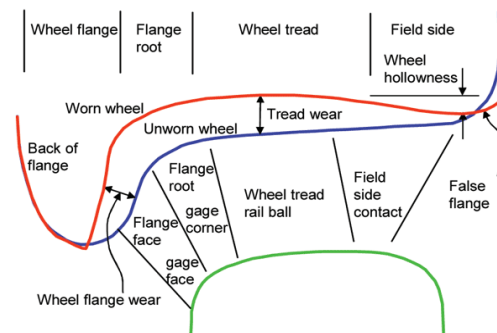


Fig. 3. Difference between unworn and worn wheel

**3.1. Universal qR measuring device**

The universal qR measuring device (see Fig. 4) is commonly used to obtain critical parameters of the wheel rim, such as rim height, thickness, and sharpness. While this analog device is widely relied upon in the railway industry, it does come with certain limitations. One of the primary concerns is that the device depends on manual readings and data entry by operators, which introduces the potential for human error. These errors can occur during both the measurement process and the manual input of data, leading to inaccuracies that may compromise the quality of the inspection. Additionally, the reliance on human operators increases the time needed for inspections, particularly when precision is crucial. This highlights the need for more automated, digital

solutions that can reduce human involvement, improve accuracy, and streamline the entire measurement process.

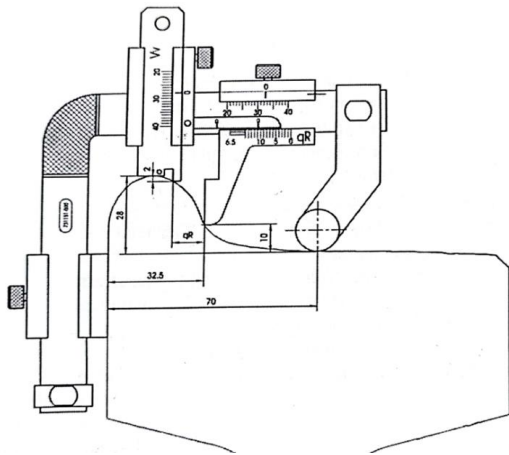


Fig. 4. Universal qR measuring device [6]

### 3.2. Non-contact laser wheel profile measuring device

On the other hand, key wheel rim parameters can also be determined using a laser device, which provides non-contact, high-precision measurements. Unlike traditional methods, laser profilometers scan the entire profile of the wheel rim, capturing the exact coordinates of multiple points along the rim's surface. These data points are then processed to generate accurate measurements of critical parameters such as rim height, thickness, and sharpness. This method not only eliminates the risk of human error but also offers significantly higher accuracy and repeatability. By automating the process, laser devices can provide real-time data that allow for more efficient and reliable assessments of wheel condition, ensuring the safety and longevity of the vehicle. Developed device was tested in real life scenarios, wheel rim was scanned and wheel profile parameters were obtained with it (see Figure 5).



Fig. 5. Wheel rim profile scanning

This device scans nearly the entire width of the wheel rim, providing significantly more detailed information about the condition of the wheel profile compared to traditional measuring tools. Unlike

conventional devices, which may only capture specific points or sections of the rim, the laser system generates a complete profile line. This comprehensive data offers a far more accurate and thorough insight into the wheel's condition, enabling better assessments and more informed maintenance decisions. By capturing the full profile, the device allows for a clearer understanding of wear patterns and potential issues, ultimately leading to improved safety and efficiency in railway operations.

The collected data is then processed, with the measured wheel profile displayed alongside the reference wheel profile for comparison. This side-by-side visualization allows for an easy and accurate assessment of any deviations or wear in the wheel rim. In addition to the visual comparison, key parameters such as qR measurement, flange height (Sh), and flange thickness (Sd) are also displayed, providing crucial insights into the overall condition of the wheel. The output generated by the device offers a comprehensive overview of the wheel's status, as shown in Figure 6.

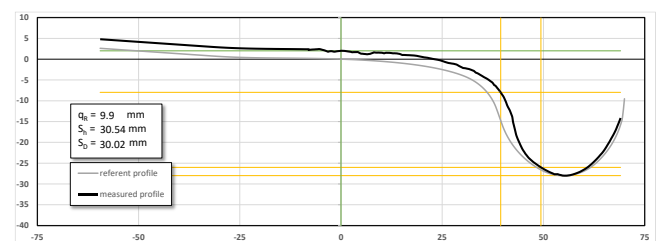


Fig. 6. Example of measured wheel profile

### 3.3. Comparing of two methods

Both the traditional and advanced laser-based methods for measuring the wheel rim profile are effective, but each comes with its own set of advantages and disadvantages. The traditional measuring device, for instance, is highly portable and simple to use. It doesn't rely on batteries, external hardware, or software, which makes it easy to operate in a variety of settings. However, as previously mentioned, the traditional method has some drawbacks, such as the potential for human error during data collection and manual input, as well as the time-consuming nature of the process.

On the other hand, the laser measuring device offers several key advantages, particularly in terms of accuracy and efficiency. This device provides instant, precise measurements without requiring additional manual steps, making the process straightforward and reducing the chance of operator error. The device is secured to the wheel using strong neodymium magnets, ensuring stability during the scanning process. Once positioned, the operator simply presses a button to initiate the scan. The device then scans the entire wheel rim profile, displaying the data immediately for the operator to review. The operator

can then decide whether to save the data to the corresponding wheel of the railway vehicle or dismiss the measurement, providing flexibility and control in the inspection process.

Despite its many advantages, the laser measuring device does have some limitations that should be considered. One of the primary drawbacks is that it requires additional hardware beyond the scanning tool itself. This includes a portable suitcase containing essential components such as batteries to power the device, a touch screen for displaying real-time information, and a Raspberry Pi microcontroller to process the collected data. Additionally, the system features several knobs and switches for ease of use, as well as the scanning head equipped with an IoT device that facilitates data transmission to the microcontroller. While these components enhance the device's capabilities, they also introduce a level of complexity and require more preparation and maintenance than the traditional method. The fully assembled laser measuring device, stored in its portable case along with all the essential components for wheel rim measurement can be seen in Figure 7.



Fig. 7. Laser measuring device housed in its portable suitcase for wheel rim inspection

#### 4. CONCLUSION

This paper has presented a comprehensive solution for enhancing the inspection and maintenance processes of railway vehicles. The proposed solution can be seamlessly integrated into existing maintenance systems, offering a significant improvement in both efficiency and accuracy. By utilizing advanced technologies, such as laser scanning and automated measurement systems, the inspection process becomes more streamlined, reducing the reliance on manual labor and minimizing human error.

One of the key advantages of the system is its ability to store measured data on cloud-based platforms, enabling remote access and real-time monitoring from anywhere in the world. This cloud

integration aligns perfectly with the principles of Industry 4.0, where digitalization, data exchange, and automation are essential for improving operational efficiency. The ease with which this technology can be implemented into Industry 4.0 frameworks ensures that railway operators can optimize maintenance schedules, reduce downtime, and make data-driven decisions that improve the overall performance of the railway system.

Furthermore, the adoption of this technology will significantly enhance the safety and reliability of railway vehicles. By facilitating faster and more accurate inspections, maintenance teams can focus their attention on the most critical components, prioritizing those that pose the greatest risk to operational safety. As a result, the risk of unexpected failures will be reduced, and the lifespan of both the wheels and the entire vehicle will be extended. In conclusion, the integration of these technologies into the maintenance workflow represents a pivotal step forward in ensuring the future sustainability and reliability of railway transport.

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