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DEVELOPMENT OF DEVICES FOR MAINTENANCE OF RAILWAY VEHICLES

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Abstract. *Maintenance in railway industry is important for proper functioning of the railway system. Therefore, some measures are introduced for diagnosing the possible problems on time and to prevent or reduce the risk of failures and breakdowns. Most important among these are inspections of the railway system individual subsystems. The product development process from an idea to the final product is important for developing new products or improving existing ones by using newest technology solutions. It can increase quality and speed of inspection especially with the principles of IoT. This paper presents an innovative solution for easier maintenance of railway vehicles.*

Key words: *Maintenance, Railway, Vehicle, Wheel, Inspection.*

1. INTRODUCTION

Control inspections are an integral part of the regular maintenance of railway vehicles and they are carried periodically with the aim of determining the condition of the vehicle and its components and acting preventively in order to prevent or postpone failures.

The periodic inspection of a railway vehicle is a set of works on a railway vehicle that are carried out after a certain number of kilometers traveled or the expiration of a certain period of use of the railway vehicle. According to the established description of the works and the appropriate technological procedure, the periodic inspection includes checking the general condition of the vehicle and its systems, devices, assemblies and parts, replacing or replenishing lubricants or other consumables, as well as eliminating defects on the railway vehicle.

With the development of new technologies and with their wider use there is a need to implement them in IoT systems in order to process data more conveniently.

This paper presents how new technologies can help with inspection of railway vehicles in such a manner so that they can improve safety and reduce operating costs of a railway vehicle.

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1.1 Maintenance of railway vehicles

The rulebook on the maintenance of railway vehicles defines the general principles of maintenance of railway vehicles. Every country that has a railway service has one. In general, those rulebooks are similar, and the rules can be applied to the whole railway system. According to the rulebook on maintenance of railway vehicles, regular maintenance, which is carried periodically and planned and scheduled in advance, includes:

- Control,
- Service inspections of the tracting (trailing?) stock,
- Periodic inspections,
- Regular repairs,
- Washing and cleaning,
- Disinfection and pest control. [1]

The parts of railway vehicles that are important for the safe operation of railway traffic, as prescribed in this rulebook, are:

- brake devices and their parts (brakes);
- wheelset;
- buffing and draw gear;
- bogie;
- frame;
- suspension;
- lighting devices and sirens;
- driver safety devices;
- the locomotive part of the radio-dispatching device;
- locomotive part of the auto-stop device;
- speedometer and recording devices;
- pressure vessels;
- device for automatic door closing of motor trains and passenger cars;
- high-voltage electrical devices and protective earthing. [1]

The person in charge of maintenance creates and maintains a maintenance file for each vehicle in their charge. The preparation of the maintenance file is based on the initial technical documentation, which is prepared by the manufacturer of the railway vehicle and which is attached to the request for issuing a license for the railway vehicle use.

The owner of the railway vehicle submits complete and correct technical documentation to the person in charge of maintenance.

1.2 Maintenance of axle assemblies

The correctness of the axle assemblies is checked when checking the correctness of the railway vehicle during operation and as part of regular maintenance. When checking the railway vehicle correctness during exploitation, the following are visually checked:

- wheel rim wear;
- wheel tire wear;
- wear of the rolling surface and its eventual damage;
- rigidity of the wheel rims;
- existence of possible damage to the wheel plate, wheel band and wheel rim;
- existence of possible places of thermal overload of the wheel.

During periodic inspections, in addition to the above, the profile is also measured.

1.3 Maintenance of the suspension and suspension elements

Maintenance of the suspension and suspension elements is carried out in such a way as to ensure the necessary relative movements between the connected parts.

The suspension and suspension elements are maintained at every periodic inspection, and in doing so, it is checked whether there are: cracks, mechanical damage, pinching, wear, damage to the protective elements against dust and other mechanical impurities, and whether the distance between the suspension parts is within the prescribed limits.

2. Overview of Modern Measuring Devices

In order to achieve more efficient maintenance, numerous detection systems have been developed that can be installed on the vehicle or placed near the track in order to determine potential failures during the exploitation of the vehicle and plan interventions in the period when the vehicle is out of traffic. This was made possible by modern diagnostic systems such as optical cameras, thermal imaging cameras, laser measuring systems, etc.

To assess the condition of the wheels and their life span, it is important to control the condition of the rolling surface of the wheel, the profile of the wheel rim, as well as the stress and cracks of the wheel.

In order to make control inspections in depots more successful and to be completed for a shorter time, specific diagnostic systems were developed. The main goal is to use these devices to ensure efficient diagnosis of defects, i.e. faulty parts, and spend less time on that.

Examples of such devices are shown in Figs. 1, 2. They are made by the Goldschmidt company.

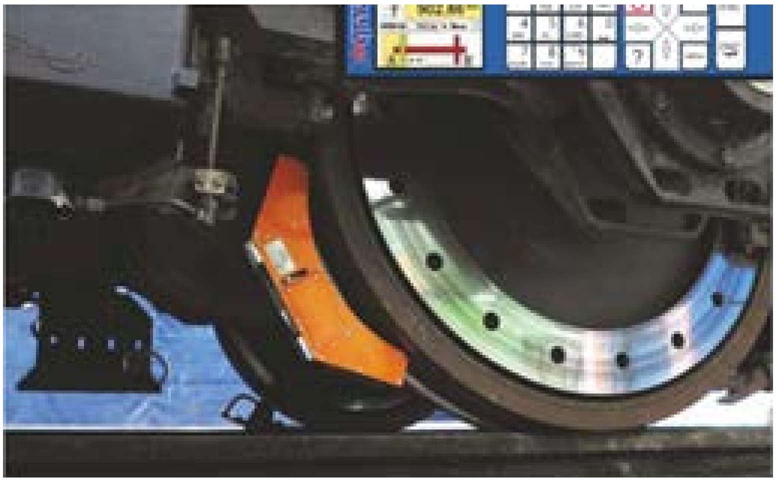

Fig. 1 Measuring the wheel diameter at three points [2]

Fig. 2 Measuring the geometric parameters of the wheel rim [3]

3. Improvement of control inspections

3.1 Laser device for the wheel profile control

The profile of the wheel rim determined by the standard UIC 510-2 allows the vehicle to move on rails and has the greatest impact on the safety of movement, the smoothness of the vehicle ride, the wear of wheels and rails, etc. During the daily movement of the vehicle on the rails, wear, tear and other changes occur on the tread surface of the wheel. If a visual inspection reveals damages that could threaten the geometric characteristics, the wheel rim profile is measured, namely: rim height, rim thickness and rim sharpness. The sharpness of the wheel rim is measured with a special device, called a universal qR meter presented in Fig. 3, [4, 5].

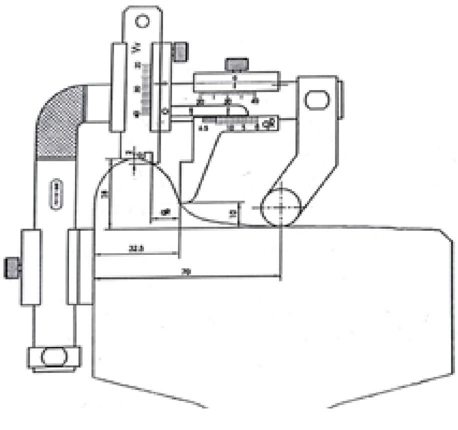

Fig. 3 Universal qR measuring device [4]

However, determining the qR measure is also possible with a laser device. By scanning the profile of the wheel rim by using the laser profilometer, the points of the wheel rim profile coordinates are obtained, Fig. 4. By processing the obtained data, a standard qR measure is obtained for the scanned rim of the wheel.

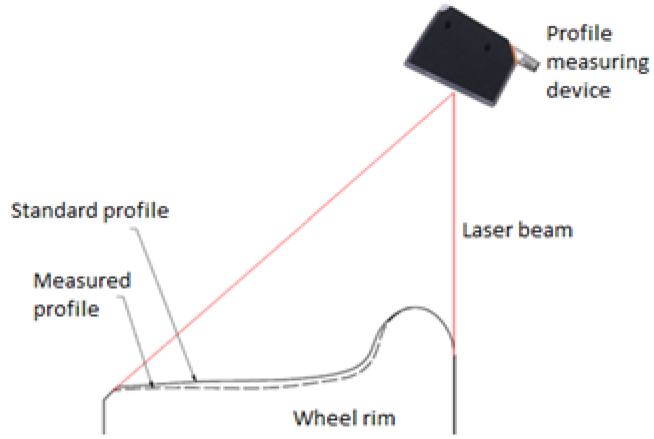

Fig. 4 Scanning the profile of the wheel rim

Obtaining the qR measure based on the scanned points of the wheel rim profile is presented below. For the sake of easier comparison of the results, the coordinate system is set as when measuring with a universal qR meter, Fig. 5.

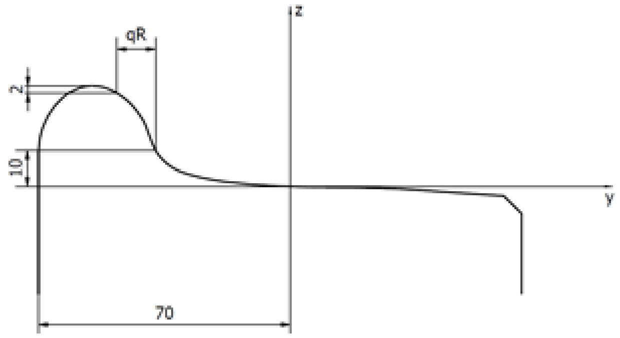

Fig. 5 Obtaining a qR measurement using a laser profilometer

The center of the y-z coordinate system is placed 70 mm from the outer edge of the wheel rim, on the surface of the wheel. By lowering by 2 mm in the z direction from the highest point and reading the corresponding y coordinate for that displacement, the first point reading of the qR measurement is obtained. By moving 10 mm lower in the z direction and finding the corresponding y coordinate on the rim profile, a second point for reading the qR measurement is obtained. The absolute difference of the y coordinates of those two points is the required qR measure, Fig. 5.

In order for the wheel rim to be correct for exploitation, the qR measurement of the wheel rim should be greater than 6.5 mm, while the outer surface of the rim must not have ridges higher than 2 mm, and the surface of the rim covered by the qR measurement must not have sharp edges and channels. [4]

Based on the research of laser devices for measuring the distance of machine components, the concept of a device for measuring the qR measurement of the wheel rim was determined.

The basic component of the device is the IFM OPD 100 laser. In addition to the laser device, there should be an IO link inside the device that enables communication between the laser and the adequate hardware, which will contain the appropriate software for data processing. This hardware device - an Arduino or Raspberry Pi device, must be equipped with Wi-Fi in order to have a wireless connection with the computer where the data would be stored and processed. The device must also have a power source for proper operation of the components and to achieve proper autonomy in operation as well as easy charging.

Inside the housing, Fig. 6, there should be neodymium magnets at the appropriate position and distance to facilitate the positioning of the device on the wheel. The housing must be positioned in such a way that when approached from the side, the housing is positioned and the correct main function of the product is enabled, which is that the laser emits the beam at an appropriate angle suitable for further processing. Also, the magnets should allow easy removal of the product by pulling it away from the wheel.

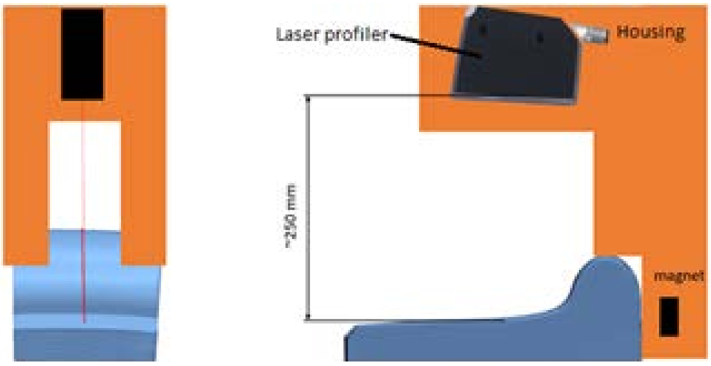

Fig. 6 Sketch of a prototype device for measuring the profile of a railway wheel

3.2. Measuring the diameter of a wheel on a vehicle

Railway vehicles have steel wheels, which roll on a steel track (rails) and wear out during operation. That wear is uneven and can change the profile of the wheel rim, as well as the diameter of the wheel. After a certain period of exploitation, when certain parameters of the wheel geometry reach minimum values, it is necessary to process the rim of the wheel. As part of the constant monitoring of railway vehicles, the profile of the wheel rim is checked, but it is also necessary to periodically check the diameters of the wheels. Discrepancies in the diameter of the wheels on one axle can cause additional slippage and accelerated wear and can endanger the stability of the vehicle's movement and traffic safety.

Wheel diameter measurements with a standard on-site gauge can be performed when the axle assembly is detached from the vehicle, i.e. base, which is most often done when the rail vehicle is being overhauled. However, measuring the wheel diameter when the vehicle is completely assembled is not possible with standard gauges due to lack of access. That is why the wheel diameter is measured in three points.

The device for measuring the diameter of a wheel in three points works on the principle of obtaining coordinates for three points located on the wheel itself. The coordinate system itself and its position is not so crucial for obtaining the diameter, but accuracy is required when measuring. Small deviations when measuring the positions of these points can cause large deviations in the final measured diameter. Therefore, the design of the device would be such as to introduce fewest initial errors possible. This would be achieved by fixing two points on the device itself and their exact positions would be known, while the third point would have a change in one direction, while it would be fixed in the other. That change of position needs to be determined by a high-precision displacement sensor. Such a device would give good enough results in measuring the diameter itself, for the measurement error lower than 3%.

The following is a description of the mathematical model for measuring the diameter of a wheel at three points. If there are three points located on the circle diameter (x_1, y_1), (x_2, y_2), and (x_3, y_3) and the function of the circle given in an explicit form:

$$x^2 + y^2 + 2gx + 2fy + c = 0 \tag{1}$$

Each of these coordinates must satisfy the circle function given in Eq. (1). By substituting the coordinates (x_1, y_1), (x_2, y_2), and (x_3, y_3) in the equation of the circle, three equations are obtained that are solved to obtain the constants g, f, c. From the obtained constants, the diameter of the circle is found as:

$$d = 2 \cdot \sqrt{g^2 + f^2 - c} \tag{2}$$

Considering the presented mathematical model of determining the circle diameter in three points, the concept of the device was established. The device for measuring the diameter of the wheel would be a unique unit that would measure and process the obtained data, display the obtained results and save them. The device is designed around a high-precision displacement sensor with accompanying electronics. A microcontroller (Raspberry Pi) with a touch screen that would process data and save it, as well as a power source (battery). The equipment would be installed in the device housing, to ensure safe and accurate use of the device. A concept sketch of the device is shown in Fig. 7.

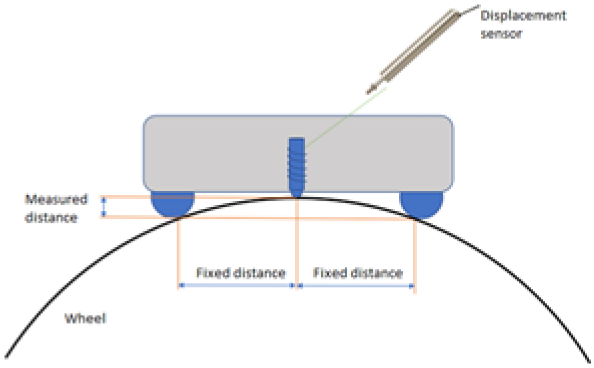

Fig. 7 Sketch of a wheel diameter measuring device

4. Conclusion

This paper presented solutions for easier inspection and maintenance of a railway vehicle. These solutions can be implemented on already existing systems and improve them. All data measured can be stored on a cloud and accessed over the Internet from anywhere in the world. In that manner these presented technologies can be easily implemented in Industry 4.0 with the aim to help with control inspections of a railway vehicle. By implementing these technologies in Industry 4.0 we can expect that safety and reliability of rail vehicles will improve. With easier inspections of certain components, inspectors will save time for inspection, and that time can be used inspecting more critical components of a rail vehicle.

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