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Automatic detection of flats on the rolling stock wheels

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ABSTRACT

Purpose: The goal of this work was increasing safety of tram, metro and trams operation.
Design/methodology/approach: The accelerometers were fixed directly to the rail to provide the system with the best defect signal quality. Analysis of the acoustic signals collected using microphones proved that too much of the background noise limited their usefulness.
Findings: It has been proven that all wheel geometry defects can be reliably detected and classified according to the experimentally established defect categories.
Research limitations/implications: Exact measurements of the wheel defect geometry may be possible only after collecting huge signals time series along with the wheel measurements taken with other methods to reveal the relationships between them. This goal is hard to achieve, as the system performs already very well, and such experiments would be very costly and time consuming.
Practical implications: Integrated wheel geometrical data collected from the wheel ovality, flat spots, and build-up detection system along with the wheel profile information have eliminated all derailments due to faulty wheel geometry.
Originality/value: The system presented is the first wheel monitoring application in Poland, its unique feature is that it can be used at low speeds, like those allowed in depots.
Keywords: Wheel geometry; Wheel flats; Build-up; Wheel profile; Wheel reprofiling; Safety of tram operation

1. Introduction

Wheels of the railway rolling stock are never round. They have always shape errors. Their out-of-roundness causes additional dynamic load to the track, is a source of the increased noise, and may even result in damaging the rails. Wheel/rail rolling noise, dominating on straight track is produced by the changing loads generated in the wheel/rail contact zone by roughness on the running surfaces of the wheel and rail. Another cause for the noise may be the wrong wheel shape, called polygonisation, and sometimes wheel flats.

Controlling the noise resulting from the mating surfaces roughness alone at the source calls for reducing this roughness or changing the interaction between wheel and rail in the contact zone, to reduce the interaction forces. The approaches include, smoothing of wheels and rails, properly treaded wheels, wheel profile modifications to suit adapt them to the actual rail profile, and the use of greases [1].

The development of roughness on surfaces of wheels and rails is influenced by wheel/rail dynamics as well as wear phenomena. Rail roughness value grows with the presence of multiple wheels on the rail. Overlaying of frequencies of vibrations caused by interaction of the particular wheels with the waviness of the rail leads to roughness growth at frequencies associated with peaks in the contact force that have a particular phase angle relative to the roughness excitation [2].

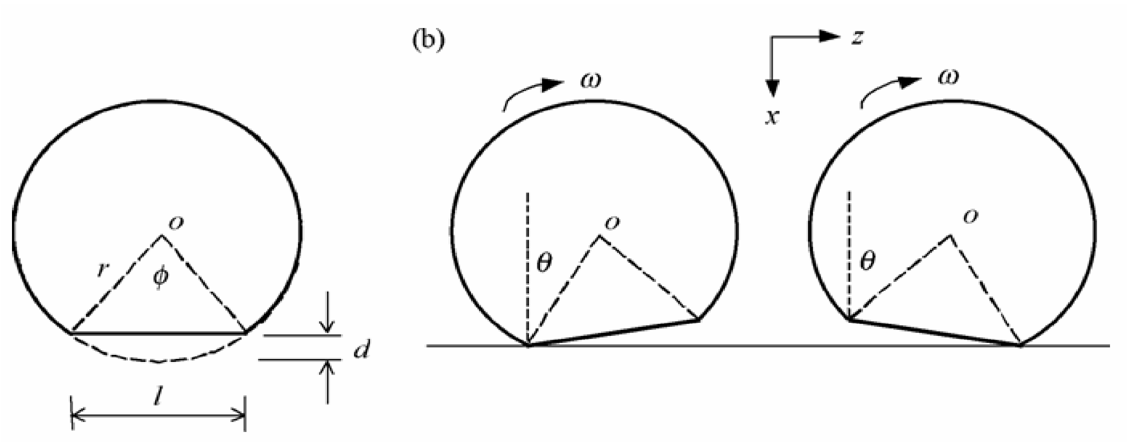

Fig. 1 Schema of the wheel flats interaction with track [1]

Another wear mechanism is especially serious in case of wheel flats whose effect is not only the increased rolling noise level. Wheel flats develop usually when the brakes are applied to a railway wheel. Locking the wheel results in its sliding along the rail. Usually the cause for that may be bad condition of brakes, which may be poorly adjusted, defective or frozen. Another cause may be poor adhesion at the wheel/rail interface, sometimes reduced to nil, for example due to leaves on the rail head or wrong cant of the rails in the track. In this case the wheel/rail contact takes place along a very narrow path, making breaking nearly impossible, so the wheel slides on the rail head. This sliding causes serious wear of the part of the wheel that is in contact with the rail, leading to its deformation by development of a 'wheel flat'. Such flat spaces on the wagon wheel may be typically 50 mm long but can be as big as more than 100 mm long [1,3].

Discontinuities on the rotating wheels produce big impact loads between the wheel and track (Fig.1). As a consequence, a periodic impact noise is produced, when the faulty wheel edges hammer the rail head, in addition to the usual rolling noise, which is more random in character. The dynamic forces generated by wheel flats, which may have big amplitudes, may result in damage to the track, like fatigue cracks in the rails or sleepers.

Moreover, the detrimental wheel surface structure changes take also place. They heat up to high temperatures during sliding, and later cool rapidly down, which leads to development of brittle martensite within the steel beneath the wheel flat. Therefore, damage to the wheel can occur, by cracking and spalling, which lead to the additional loss of relatively large pieces of metal [4,5].

Wheel shape errors feature a serious issue when safe and efficient train operation is considered. In order to improve the efficiency of railway transportation, Chinese Railways, for instance, has decided to raise the speed of trains on the existing railway main lines. It was found that raising train speeds on the existing railway lines increases the dynamic effects of vehicles on tracks, especially in the turnout areas, in the welded rail joints, and in the sections of bridge-subgrade connections. The occurrence of wheel flats becomes more general after raising train speeds. All wheel flats traversing the track add to the premature use of all the above mentioned specific locations in the track. Unfortunately the peak of dynamic effects of wheel flats on tracks occurs in the speed range from 140 to 160 km/h, which is just the range of line speeds for passenger trains after raising their speed [6]. This detrimental effect of wheel flats on rolling stock operation safety is also true for metro and trams, albeit their operating speeds are much lower [7]. In practice, a rounded flat will differ in geometry from the idealised case considered here. Rolling stock owners take countermeasures, including stricter maintenance standards for the high-speed railways, but also tram and metro monitor carefully wear rate of their wheels and carry out careful planning of their re-profiling and correcting their out-of-roundness. To this end stationary monitoring systems and portable instruments are needed as data source, as well as diagnostic databases for analysis of the wheel data [8].

2. Rolling stock wheels monitoring system

The system was designed for storing information about profile and diameter of wheels and flat spaces and build up on their tread surface (Fig.2). The system makes it possible to define the required information about cars, logging the distance covered by each wheel and visualisation of their wear over time as well as their repairs, inclusive generation of the wheel wear reports. The system can integrate all measurement data collected by many units of a transport company. Measurement results of wheel geometry obtained with the portable gauges and with other methods are archived in a database, with the powerful graphical user interface. Moreover, information about boogie measurements and other car service operations defined by the system user are also saved. System database makes it possible to print wheel wear reports according to the user selected criteria, e.g., presenting

- wheel, bogie, and cars lists sorted according to:
- wheel flange height value
- wheel flange width value
- wheel diameter values
- differences of wheel flange widths in a bogie
- differences of wheel diameters in an axle
- tread surface condition, including:

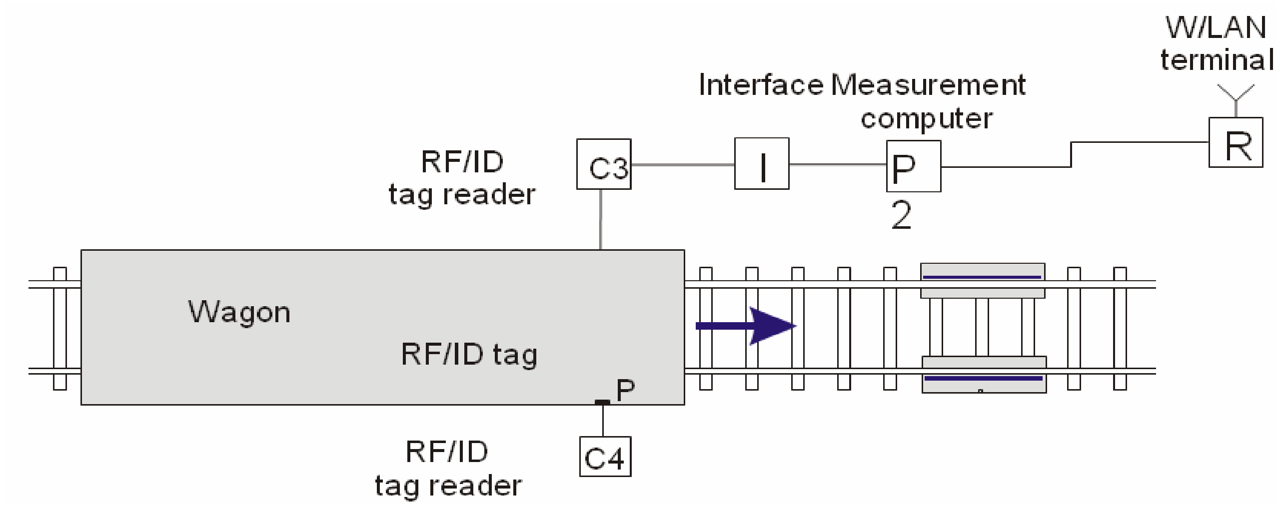

Fig. 2. Wheel monitoring system

Fig. 3. General view of the system - tram version

3. System operation

The presented system was designed for detecting the flats on wheels while the train passes the measurement system with speed of 10-30 km/h (Fig.3). It is composed of multiple accelerometers installed on both rails over 3 m length. The sensors are installed within the rugged covers protecting them from damage. In practice, due to continued running of the wheel after formation of the flat, the profile becomes rounded at the corners of the flat, whereas the central part will remain unchanged.

The overall length of the rounded flat, will be greater than that for a new flat of the same depth. The measurement signals are sent to the measurement computer housed in a cabinet close to the system. The measurement software processes the signals from the sensors and classifies wheels into one of the four wheel flats sizes. Wheel flats exceeding 60 mm are tagged as needing “repair", whereas three other subranges refer to the following levels: “warning” (45 mm), "observation", and “good”.

Measurement results are sent by a wireless LAN to the system operator computer, where information about the wheel flats is reported and their location in the train is specified. The measurement system was installed at the entry to the depot, which makes it possible to monitor all trains.

Each wagon is described in the database and all technological operations for each wheel are recorded, like turning, reprofiling, etc.(Fig.4). Exemplary logged wheel service operations include**:**

- Removing flats and out of roundness
- Turning the bogie
- Measuring wheel profile and diameter
- Measurement of buildup and wheel flats
- Reprofiling of wheel on the underfloor wheel lathe
    - current list of defects
    - list of cars with no actual measurements
    - car condition report
    - train condition report

The proven system deployment effects are as follows:

- Effective derailment prevention
- Reduction of the allowed wheel diameter differences
- Reduction of noise level in urban areas
- Replacement of wheels and bogies

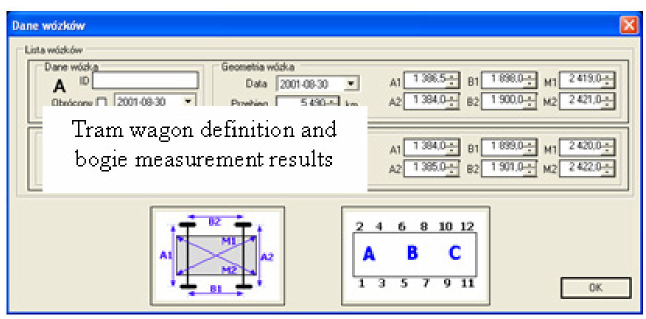

Fig. 4. Example of wagon and bogie definition

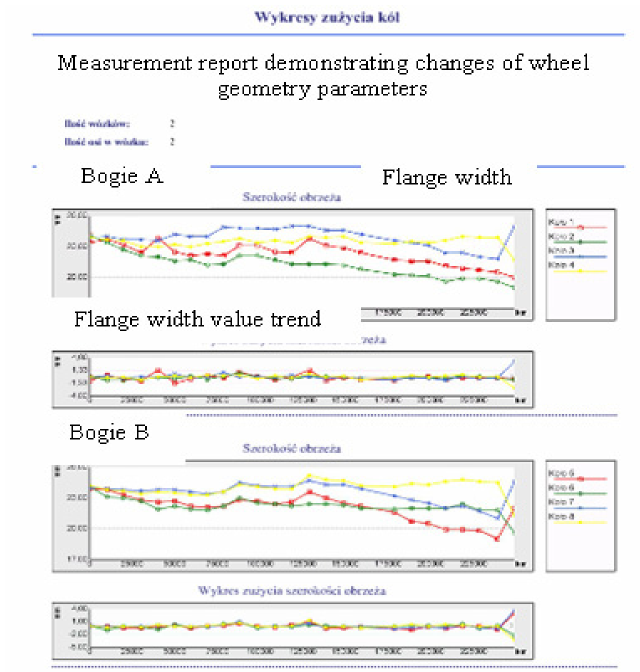

Fig. 5. Exemplary wheel wear report for a wagon

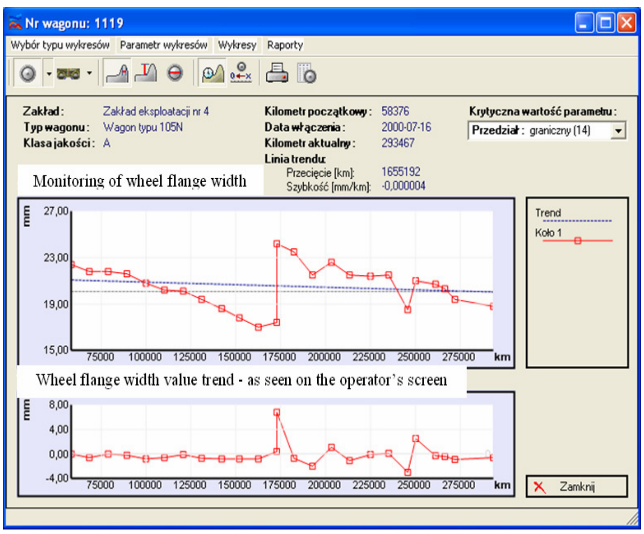

Fig. 6. Exemplary change of wheel geometry in service with visible changes after reprofiling

4. Summary

In order to predict the consequent noise radiation, the wheel/rail interaction force is transformed into the frequency domain.

As the train speed increases, the force spectrum and consequently the noise radiation, contains greater amplitudes at high frequencies and the overall noise level due to wheel flat excitation increases with the train.. This differs from rolling noise due to roughness excitation. The noise from flats of depth 1 mm and 2 mm exceeds that due to typical roughness on tread-braked wheels and good quality track for all tram and train speeds; however the low speeds pose more problems with the reliable signal processing. As the wheel load increases, the noise from wheel flats increases. In contrast, the rolling noise due to roughness is relatively insensitive to wheel load.

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