WHEEL PROFILE CONTROL AND MONITORING SYSTEM

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ABSTRACT:

This paper presents a system for monitoring and control the rolling elements in order to improve maintenance and security of railway transport. The dynamic non-contact control system can be installed in depots on any track position. This system allows to measure all important wheel parameters: flange height ($S_h$), flange width ($S_d$), flange gradient ($q_r$), total profile width ($L_r$), wheel rail diameter ($D_r$), profile wear on rolling diameter ($A$). This system operates at low speeds and can be used in depots. The system can be installed at almost any track position with a few modifications. The system allows to identify each individual wheel and record it in the corresponding database.

1. INTRODUCTION

The increase of safe transport and the reducing of the negative effect that railway transportation may have on the environment has been a major objective in the last decades, due to the reversible relation between man and nature, and health and traffic. The dynamic control of the railway wheel profile wear and of defects occurred during exploitation is the more frequently used method within the maintenance activities in the international railways, and represents a development having positive impact on the increase of railway traffic.

Wheel and rail wear is a fundamental problem in the railway field: the change of profile shape deeply affects the dynamic characteristics of railway vehicles such as stability or passenger comfort and, in the worst cases, can cause derailment. It is therefore of great economic relevance to develop a system able to predict the wheel profile evolution due to the wear process since it could be used to effectively evaluate maintenance intervals, to optimize wheel and rail profiles with respect to wear and to optimize the railway vehicle's suspensions with new and worn wheel profiles.

The dynamic control (the control while the vehicle is moving) aim is to detect with high accuracy and frequency the different parameters of the wheels and to use this information in the railway industry.

2. THE IMPORTANCE OF WHEELS GEOMETRY MONITORING PROCESS

Wheels geometry monitoring process is essential to the effective management of the railway industry. Wheels conditions monitoring is also important to the safety of train operation.
Generally, wheels and track geometry monitoring process can provide the following benefits:

- Improving train reliability and reducing the maintenance cost;
- Reduced in the workshop reserves;
- Reduce cost of spares inventories;
- Improved post-incident analysis;
- Facilitate the optimization of the wheel profile.
- Increase the transportation safety.

3. DOMAIN OF APPLICATION

The system for dynamic wheel profile control and monitoring has been designed to be installed along the railway line in depots or other places special arranged. It can be installed along any kind of railway line and it is compatible with any kind of trainset including:

- Locomotives
- Passenger coaches
- Freight wagons

![Example of measurement system installation](image)

4. MEASURED PARAMETERS

The system detects the following parameters:

- Wheel full profile and wear
- Wheel diameters
- Profile specific parameters:
  - Flange height ($S_h$);
  - Flange width ($S_d$);
  - Flange gradient ($q_r$);
  - Total profile width ($L_r$);
  - Profile wear on rolling diameter ($A$).

These parameters are illustrated in figure 2.

![Wheel wear parameters](image)

5. PRINCIPLE OF MEASURING

The method for the measurement of the profile consists in the acquirement of the scanned profile points' coordinates (with two 2D laser scanning systems placed on both sides of the track – figure 3), in the form of Cartesian coordinates within each laser coordinates' system, and turning these coordinates into "profile" Cartesian coordinates. These are the coordinates to be used for the calculation of geometric sizes to be monitored. The rates on the two axes of the laser Cartesian systems are sent in digital
format to PC calculation systems for soft processing, interpretation, playback and storage. The Cartesian coordinates systems are coplanar but rotated and displaced between them. The coordinates systems are described in figure 4.

![Figure 3. The wheel profile scanning](image)

**Figure 3. The wheel profile scanning**

- $\mathbf{X}_1 \mathbf{O}_1 \mathbf{Z}_1$ – the Cartesian coordinates system of the first laser $L_1$;
- $\mathbf{X}_2 \mathbf{O}_2 \mathbf{Z}_2$ – the Cartesian coordinates system of the second laser $L_2$;
- $\mathbf{XOZ}$ – the fixed profile coordinates system;
- $\mathbf{X'O'Z'}$ - the mobile profile coordinates system (connected to the profile in point A and tangent to surface B);

![Figure 4 Coordinates systems](image)

**Figure 4 Coordinates systems**

Change of scanners position determine change of parameters for turning the measured profile from laser Cartesian coordinates in profile coordinates. For this reason the system has a calibration module which is used periodical for determination of
parameters used for to calculate profile coordinate. The data acquired from the two continuous scanning lasers on the profile are mathematically computerized, resulting a single profile which is displayed on the monitor.

Reference profiles can be overlayed measured profiles for interpretation. They are both used for visual comparison and also by some of the calculations.

In addition, any measured profile can be used as the reference for other measurements.

The diameter is measured with the help of a linear laser transducer, with a wide measurement interval which scans an arc of a circle as big as possible, in a $\Delta t$ time interval. This transducer is placed under rolling plane in a 5...10 mm slot cutout in the railtrac. The start and the stop moments are given by two position transducers at a distance $d$ one from the other. May the time Tstart be the time when the measurement is begun, and time Tstop the time when measurement is ended. The duration of the measurement is calculated. The train circulating distance is calculated (knowing the distance $d$ between the measurement START and STOP sensors). $X_iZ_i$ coordinates pairs are built.

Based on the coordinates pairs attained, the circle passing through coordinates $(X_1Z_1),(X_2Z_2),(X_3Z_3)$, is determined, where $(X_2Z_2)$ is the wheel tangency point to the rail (corresponding to the minimum $Z$ value in the line), and $(X_1Z_1)$ and $(X_3Z_3)$ are points situated symmetrically to a possible maximum distance in relation to point $(X_2Z_2)$. Using the equation of the circle defined by three points, the circulation circle radiation/diameter is calculated.

6. SYSTEM CONFIGURATION

The system for dynamic wheel profile control consists in two large parts:

• **The sensor block** placed on the rail (Dynamic profile meter) (figure 5) consisting of:
  - 2 wheel presence sensors
  - 2 laser scanners for scanning the wheel profile, each mounted on one side of the rail
  - laser for scanning one segment of the wheel rolling circle length.
  - mechanic structure for ensemble fixed to the railway.
  - electronic blocks, for supply.

• **The acquisition and processing block** which comprises the calculation system taking over the data provided by the sensors for the purpose of processing and analyzing them.

For this, a performing hardware structure was chosen, with excellent working skills in multitasking regime, and a software application, dedicated to taking over these data, storing, processing and interpreting the results, will be developed, also allowing facilities for the remote transmittal of these results.

The data acquired from the two continuous scanning lasers on the profile are mathematically treated, resulting on a sole acquisition a single profile comprising the parameters of interest measurement points and the display on the PC monitor of the profile restored based on the processed data; a graphic capture on the monitor (screen shot) is described in figure 6.
Figure 5 Dynamic profile meter

a. Dynamic profile meter structure
1. Fixing mechanical structure
2, 6. Wheel presence sensors
3, 4. Profile laser scanners

b. Dynamic profilemeter mounted on the railtrack

Figure 6 Graphic reconstitution of the scanned profile (screen shot)
The system future

- the dynamic measurement of the following parameters: $\text{Sh}$ - profile flange height; $\text{Sd}$ - profile flange width; $\text{q}_R$ - profile flange gradient; $\text{L}$ - profile total width; $\text{D}_R$ - The wheel rolling diameter; $\text{A}$ - Wear on the wheel rolling profile;
- capture, processing, playback, and storage of the checked railway vehicles’ wheels parameters and the transfer of information obtained on informational networks of the automated central data base or of dispatching units with a decisional duty for the provision of the circulating material maintenance and the railway traffic safety.
- the train traveling speed during checking: max. 5 km/h;
- operating temperatures field: -20°C...50°C;
- numerical and graphical display and printing of measurement results;
- adaptability to new types of profiles and wheels;
- decrease power consumption.

Properly controlled profiles for wheels reduce the risk of derailment, minimize the dynamic interaction between vehicle and track and improve passenger comfort.