Approaches to control of railway vehicles in motion by predictive maintenance techniques

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Abstract. The ambition of specialists from the Bulgarian Academy of Sciences, the Technical University of Sofia and T. Kableshkov University of Transport to develop a scientific approach to prevent emergency events in transport requires electronic devices for continuous monitoring on railway vehicles in motion. The study presented in this paper was carried out in order to propose a methodology for identification of the number of vehicle and examine the temperature changes occurring in zones important in terms of their operational security and located in the undercarriage and brake systems. An attempt was made to implement the country's commitments, stipulated in international agreements, to develop an adequate approach for implementation of the monitoring system components increasing the transport process safety and efficiency. Conditions created for the study and analysis of information from a real experiment in MATLAB environment have been determined by the capabilities of specific devices. The comparative analysis of data from two different devices was conducted to identify their strengths, weaknesses and areas of application. The rating made by importance of thermography in current and planned repairs was based on the current technical condition of the rolling stock of the Bulgarian railways.

Keywords: technical condition, diagnostics, railway vehicles, thermography, laser scanning

1. Introduction

The aim of this paper is to develop a diagnostic methodology with comparative analysis of the data from temperature measuring with railway vehicles systems [1]. Using laser scanning, it is possible to make fast and efficient identification of the railway vehicles registration numbers. For the practical performance of this task the TU equipment, including Infrared thermograph for non-contact measurement by marking laser with a measuring range -40^{O}C ÷ 220^{O}C (Fig 1.) as well as Smart Lab equipment i.e. Thermo Camera FLIR 640 (Fig 2.) and Hand-held color 3D laser scanner Handyscan 3D VIUscanCreaform (Fig 3.).

Fig 1. Infrared thermograph

Fig 2.Thermo camera FLIR

Fig 3. Laser scanner CREAFORM

2. Motivation

In order to make railway transport safer, faster and more efficient, maintenance managers should have reliable methodology [2] to prevent any high risk of incidents. The research and tests of railway vehicles are determined in accordance with regulation documents including DIRECTIVE 2001/14/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL/ 26 February 2001 on the allocation of railway infrastructure capacity and levying the charges for railway infrastructure access and safety certification EN 14363:2005 – Railway applications/ Testing for acceptance of running characteristics of railway vehicles/ Testing of running behavior and stationary tests.

The predictive maintenance techniques are designed to assess the technical conditions of mechanical systems in order to define when to perform maintenance. This approach leads to cost savings for routine or time-based preventive maintenance [3]. The aim of predictive maintenance is to make appropriate scheduling of repairs and prevent unexpected failures of systems. Knowing which system needs maintenance, repairs can be planned in a better way (providing spare parts, experts, etc.) thus transforming ‘unplanned stops’ into shorter and fewer ‘planned stops’ that will increase system availability. The potential advantages include also increased safety and life expectancy of systems, optimization of spare parts supply, etc. Thanks to monitoring on significant parameters such as temperature of important elements (Fig.4), it is possible to examine the actual condition of the railway vehicles.

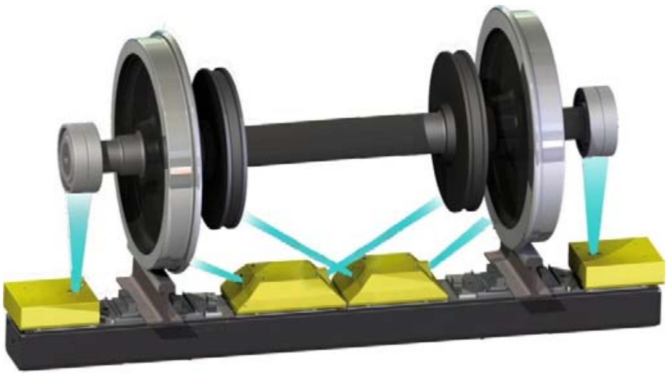

Fig 4.Temperature observation of a railway vehicle axle and its braking parts

Measuring can help to perform predictive maintenance and avoid typical faults as hot boxes, wheel flats [4], etc. (Fig.5, 6).

Fig 5. A flat spot occurred while the vehicle wheel set is dragging along the rail

Fig 6. Overheated railway vehicle axle box (Hotbox)

3. Comparative analysis of equipment used for field research

Smart Lab and the VTU equipment are used to record the results of monitoring on the bearing and breaking surfaces. Pursuing high accuracy of the result, from the diagnostic point of view it is necessary to assess whether the measured temperature exceeds the preset/selected threshold (e.g. if the axle bearing unit temperature is higher than 120^{O}C, it generates malfunction). The laser scanner can be used to give information about the numerical registration code of railway vehicles. Based on the data acquired through these three devices, it is possible to make complex comparison and draw conclusions related to an approach that leads from instrumentality to methodology. The results are presented in MATLAB environment for better visualization and perception.

For filters and transfer Functions are used MATLAB-filter functions and other Signal Processing Toolbox functions [5], e.g. the z-transform Y(z) of a discrete-time filter's output y(n), who is related to the z-transform X(z) of the input by:

$$Y(z) = H(z)X(z) = \frac{b(1)+b(2)z^{-1}+\ldots+b(n+1)z^{-n}}{a(1)+a(2)z^{-1}+\ldots+a(m+1)z^{-m}}X(z)$$

where H(z) is the filter's transfer function. Here, the constants b(i) and a(i) are the filter coefficients and the order of the filter is the maximum of n and m.
Our Signal processing is based on the mathematical foundation of filtering - convolution [6]. The MATLAB convolution function performs standard one-dimensional convolution, convolving one vector with another:

$$y(k) = \sum^{\infty} h(l)x(k-l)$$

4. Conclusions and future work

The comparative analysis in this paper could help us gain better results in railway system diagnostics of thermal loaded contact surfaces and ensure greater stability with technical operation. To evaluate the technical condition of railway systems, predictive maintenance techniques for nondestructive testing such as thermography and laser scanning are used. A new approach in this area is to utilize the measurements of railway systems using Smart Lab equipment to improve diagnostics process. With applying the VTU equipment it is possible to identify the defect of the railway system while Smart Lab equipment can help acquire more reliable data for in-depth diagnostics and future fault characteristics. The Laser scanner enables us to identify and connect the information according to each vehicle and data for subsequent archiving. Based on this diagnostics, it is possible to reduce operating and maintenance costs. It can result in high performance service management and give educational or training opportunity for scientists working at this area.

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