Monitoring of Railway Traffic as a Part of Integrated SHM System

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ABSTRACT

In the last years one can observe an increasing interest in structural health monitoring (SHM) from Polish Railways. There are several hundreds of steel truss bridges of various spans and similar topologies in Polish railway infrastructure. One of them, located over a canal in Nieporęt near Warsaw with span of 40m became an object of investigation and implementation of an integrated SHM system.

The system consists of two components – weigh in motion (WIM) part for identification of train load and SHM part for assessing the bridge state. The WIM module supplies load data required for SHM inverse analyses, however it can operate as an independent system for monitoring of railway traffic providing information about axle loads and rolling stock identification.

Many in-situ installations of SHM systems suffer from a troublesome and time-consuming way of data acquisition via standard cables. In order to facilitate data collection related with this way of acquisition, an alternative solution of wireless transmission of the measured data from the field to analysis centre is proposed. Two aspects of wireless transmission are considered – short range (in the vicinity of the bridge) and far range (from the bridge to the centre of analysis).

This paper takes up the practical issue of design and implementation of the integrated SHM system for truss steel railway bridge with a special insight into the monitoring of railway traffic.

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INTRODUCTION

In the last years, one can observe an increasing interest in structural health monitoring (SHM) from Polish Railways. In Polish infrastructure, there are several hundreds of truss steel bridges of various spans and similar topologies. One of them, spanning a canal in Nieporęt near Warsaw is the object of investigation presented in this article.

The steel railway bridge has a span of 40m and is 8m high. The layout of the bridge is typical, therefore possible transfer of the system developed for the selected structure should be very straightforward.

The bridge, depicted in Fig. 1, carries just one centrally located railway track and is not subjected to heavy traffic.

Figure 1. Investigated bridge.

The load from the track is transferred by two main double T-shaped stringers through a system of transversal floor beams to the two main truss girders. The girders are connected at the top and bottom chord by lateral bracings. The boundary conditions at the foundations of the bridge are: pinned and rolling support.

The program of monitoring of the bridge includes two major issues. First, monitoring of structural health and its potential degradation due to e.g. corrosion is planned. Second, monitoring of railway car mass and speed is of interest to the owner of the infrastructure. The monitoring will be performed using piezoelectric strain sensors.

CONCEPT OF THE INTEGRATED SYSTEM

The patent-pending [1] integrated system, depicted in Fig. 2, consists of two parts corresponding to the Weigh in Motion (WIM) and Structural Health Monitoring (SHM) subsystems.

The WIM part is supposed to identify dynamic load exerted on rail by passing trains. This load will provide input for the SHM system, mounted on the bridge. The role of the SHM system is to collect dynamic responses of the structure. These responses confronted with a calibrated numerical model of the bridge should enable identification of possible structural damage. The general methodology for solving the problem is presented in [2].

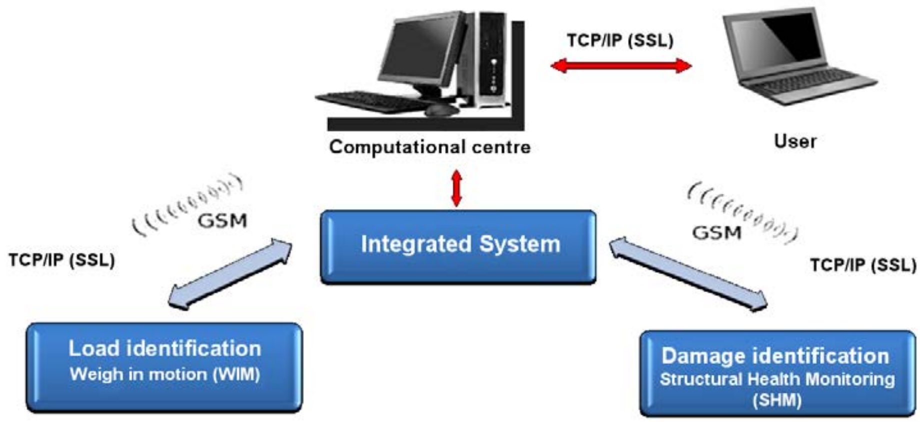


Figure 2. Scheme of the integrated system.

The WIM module does not only supply load data required for SHM inverse analyses, but also operates as an independent system for monitoring of railway traffic, providing information about axle loads and rolling stock identification.

Due to numerical complexity of the applied algorithms, data processing takes place in a remote computational centre, to which necessary numerical data is sent by means of long-range, GSM-based wireless transmission. Post-processed results are available to users through SQL-based web applications.

SYSTEM IMPLEMENTATION

The detailed layout of the WIM and SHM parts of the integrated system is shown in Figs. 3 and 6. Each part of the system works independently in the sense of data collection and transfer. The only link between the two parts is provided by activating sensors, connected to the WIM system, which should remotely initiate the acquisition of data in the SHM system.

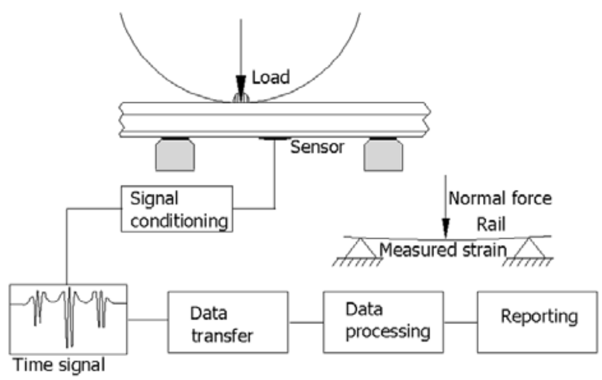


Figure 3. WIM subsystem.

The both subsystems utilize piezoelectric sensors for strain measurements. Piezoelectric sensors are less laborious at the stage of mounting compared to strain gauges and less expensive in terms of driving electronics compared to optical fibres. Both PZT and PFC (Fig. 4) sensors were successfully applied during investigations on the truss bridge. Results were compared against alternative methods of stress and strain measurements (e.g. strain gauges, ultrasonic system) showing good accuracy [3].

Figure 4. WIM piezoelectric PFC sensor.

In order to improve the accuracy and increase the reliability of the railway traffic monitoring, the WIM system uses minimum four sensors. It is important, that the sensors are mounted in a secure way due to the risk of devastation. The proposed solution does not require any special preparation of the railway track and sleepers. Installation of sensors is quick and does not require any closures of the railway line.

During the passage of a train, electrical signal generated from the piezoelectric sensors is subjected to analogue conditioning and after A/D sampling is stored in the memory of the controller. Data transfer to the processing centre begins as soon as the signal acquisition has been completed. However, it can be suspended in the case of subsequent triggering. Results obtained during field tests of the WIM subsystem are presented in Fig.5.

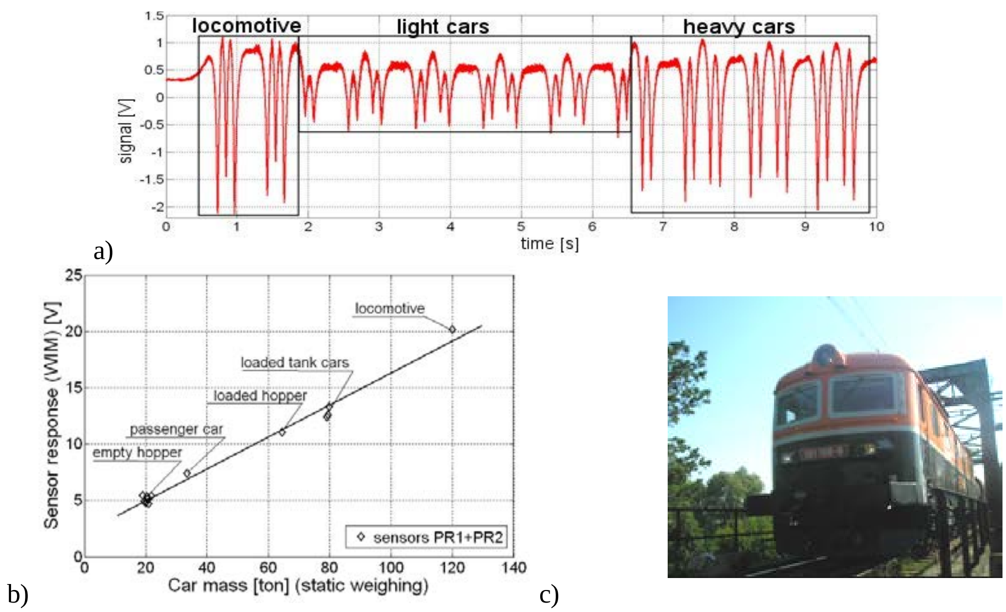


Figure 5. Results of mass identification from the WIM subsystem.

Fig. 5a depicts a time evolution of a signal generated by a cargo train. Fig. 5b shows good accuracy of identification of mass of a train (Fig. 5c), which was previously statically weighed.

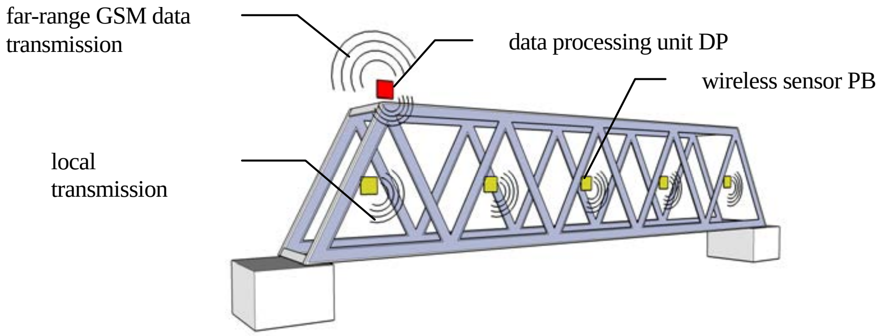


Figure 6. SHM piezoelectric sensor.

In the SHM subsystem, which is schematically presented in Fig.6, two levels of wireless transmission are implemented [4]. The first level is a local, short-range transmission between the main data processing unit (DP) and the piezoelectric smart sensors mounted on the bridge (PB) and equipped with transceivers. The PB units are based on piezoelectric strain sensors and their electronic part is magnetically mounted to the steel structure of the bridge (Fig. 7).

First, the PBs receive a signal from the DP (triggered by the WIM system) to start collecting data from a passing train. Next, they transmit the data back to the DP as soon as the train has left the bridge. Once the data from the system have been acquired, an independent far-range GSM-based transmission starts.

The tasks of the PB and DP units are: collection of analogue signals from the measurement, conversion of signals to digital format, signal compression and transfer to a remote computing centre for analysis. A block diagram of the wireless sensor PB and its implementation in the form of a printed circuit board (PCB) are presented in Fig.8.

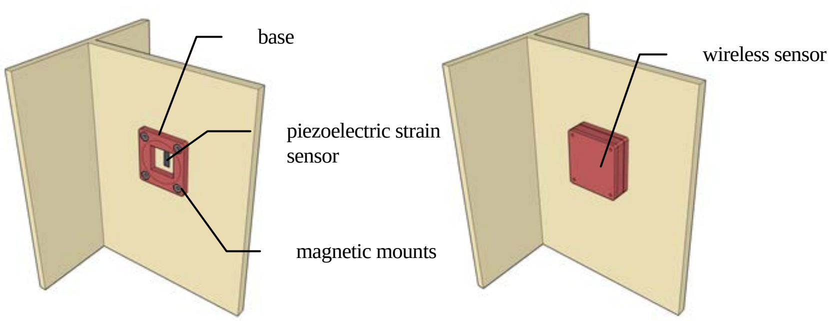


Figure 7. Mounting of wireless SHM sensor.

The experimental measurements for a passage of the 120-ton ET-22 locomotive were confronted with numerical models developed for the bridge and the rail-sleeper-ground interaction. Fig. 9 depicts a comparison of experimental and numerical responses in a selected measurement point on the structure of the bridge. Generally, a good conformity can be observed although the numerical model tends to disregard high frequency components evidently present in experimental curves. Unfortunately, the adopted simplified skeletal model of the bridge is not able to reflect the real behavior of the bridge in such details.

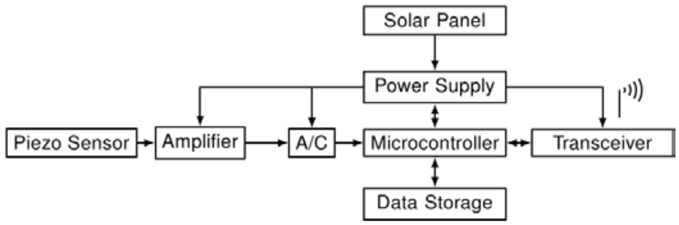
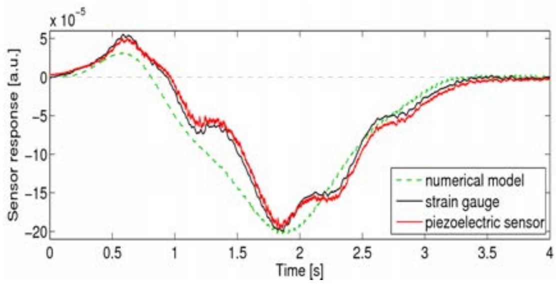


Figure 8. Wireless sensor: block diagram and PCB implementation.

CONCLUSIONS

The paper presents selected aspects related to the design and implementation of an integrated SHM system for a truss steel railway bridge. The system utlizes piezoelectric sensors for strain measurements and customized hardware for wireless data acquisition and processing. Thoughtfully designed for the railway infrastructure, it is supposed to monitor traffic (WIM) and condition of truss bridges (SHM).



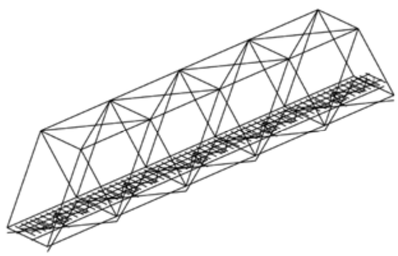


Figure 9. Comparison of numerical and experimental results at selected point.

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