Test Set for Measuring Railway Weight under Condition of Movement

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Abstract – **The subject of the paper is the methodology for railway weight measuring under condition of moving. A smart strength sensor for measuring the wheel load is applied. Specific measurement channel for wheel static load determining is used as a test set for dynamic measuring. Collected data of wheel load is analysed and a proper algorithm is offered.**

Keywords – **Railway weigh, Dynamic load, Force sensor, Analog data treating.**

I. INTRODUCTION

Measuring carriage weight is an important process for railway transport in two aspects. First of all, the measuring allows to determine the dead or full load of railway carriages and to avoid the overcharging as well. Secondly, the measuring permits to know the distribution of the load among the wheels.

The difference of the wheel loads changes the process of the railway carriage interaction with the railroad. Moreover, this difference changes also the parameters of the above-spring construction dynamic part. As a consequence: the reaction of the vehicle mechanical system is increased; the limitation in the cohesion of the drive and brake forces is lowered; the intensity of wheel wearing-out is increased; the wheel axle directing ability is decreased; and the reliability of some important elements of the vehicle running part is decreased.

The measurement of the wheel load can be realised by special static test set, but it requires an individual measurement unit for each carriage wheel. Another way of carriage weight measuring is to use just two measurement units and to complete measurement process under condition of carriage moving.

The presented in the paper investigation aims to collect a practical data from measuring of vehicle weights under condition of movement and to offer a suitable method for data treating and calculating the load of each passing wheel.

To perform the carriage weight measuring under condition of movement, we used existing equipment for static load measuring of railway carriage wheels [1]. It consists of a specific measurement channel and a computer based data acquisition system. This equipment is used primary for locomotive spring system adjustment. The measurement channel is a typical railway channel with force measurement devices placed under each locomotive wheel. That allows the load of all the railway vehicle wheels to be measured at one and the same time. The number of measurement devices is 12 (for a 6-axles locomotive).

Each measurement device is an immovable sensor being part of railway [2]. It is built on a peace of standard rail type P49 with length of 1140 mm. On milled pads in the niche area of the peace of rail are mounted two full bridge of strain gauges [3, 4]. The distance between the bridges is 700 mm.

II. EXPERIMENT EQUIPMENT

To complete the experiment, we engage just two interface placed measurement devices, that form a measurement couple for the load of two wheels, belonging to a single axle. The first couple of measurement devices, that is suited at the beginning of the channel is chosen.

Each measurement device is a smart force sensor provided with embedded microcontroller. The force sensor is connected through industrial network (standard RS485) to the central computer. The experiment was planed preliminary. We completed the needed software for the smart force sensor and for the central computer as well. We decided the experiment to be completed by the following technology:

1. The central computer sends a command for starting the process of measuring. The force sensor measures periodically forces applied to both strain gauge bridges and stores them into an internal buffer (data segment – RAM). The measurement continues until the buffer is filled or a command for stopping the measuring is received from the central computer.
2. The railway carriage passes upon the force sensor and the measuring of the wheel load is being performing in progress.
3. After the measuring, the stored data is downloaded from the force sensor and is saved in a file at the central computer.
4. Off-line, the saved information is processed and analyzed and a technology for the individual wheel load determining is specified.

The preparation of the experiment includes creation of specific software:

1. Experimental software for the smart sensor: software designed for periodic measuring of voltage values generated by strain gauge bridges and storing the data into an internal buffer; software for the command interpreter completed with commands for starting the measuring, stopping the measuring and sending the collected data; software for loading the data on the central computer.

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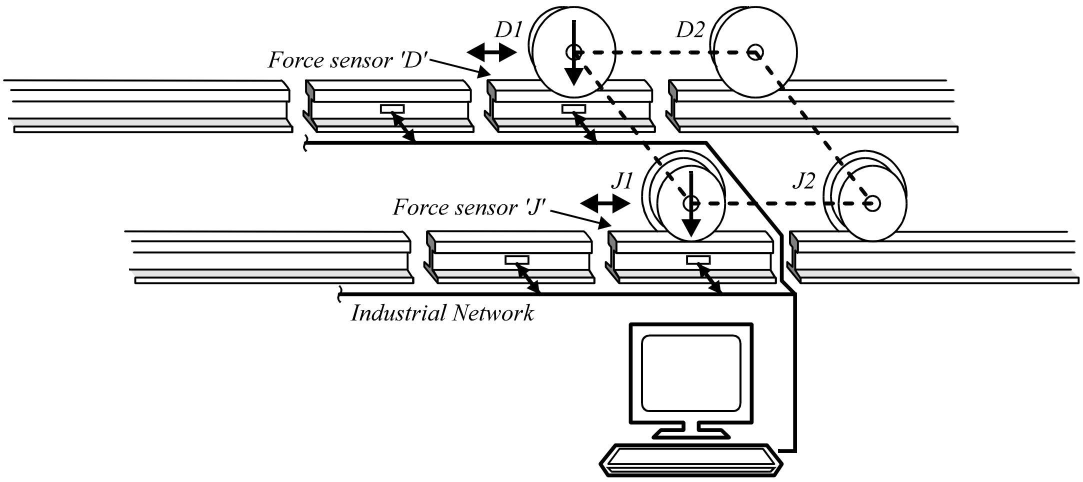

Fig. 1. Experimental test set for measuring wheel load under condition of movement.

2. Experimental software for the central computer: adding to the command interpreter commands for starting the measuring, stopping the measuring and receiving the data collected by the force sensor; software for saving data into a file with MS EXCEL compatible format.

The created experimental software was laboratory tested. The experiment was performed on the 21 of February in Locomotive Shed Ltd. in Sofia, Bulgaria. The experimental software was loaded on the used force sensors. The central computer was loaded with specialized software for testing and demonstration.

A locomotive (Series 46) passed with low speed upon the used force sensors (named ‘D’ and ‘J’). When the locomotive was passing, the digital signals of the wheel load from the two wheel-axles were recorded. The movement was firstly directed from right to left and after that reversed from left to right. The recorded data is sent to the central computer, stored into a file and later – processed and analyzed with MS Excel.

III. Results

Two different sampling rates were applied for analog-to-digital (AD) conversion. They are the minimal and the maximal allowed frequency of sampling for the embedded in the force sensors AD Converter. The analysis of the sampled data with the maximal frequency said that it is unusable, due to the low number of samples in so-called active measurement zone of the force sensors. The recorded data at the maximal sampling rate is suitable for analysis. The records are shown in fig. 3. The sequence of forms correspond to the wheel load movement D1 and D2 (left movement) and D2 and D1 (right movement) from the first picture. The sequence of forms in the second picture is analogous to the first, but for the sensor ‘J’ –wheel load J1 and J2 (left movement) and J2 and J1 (right movement).

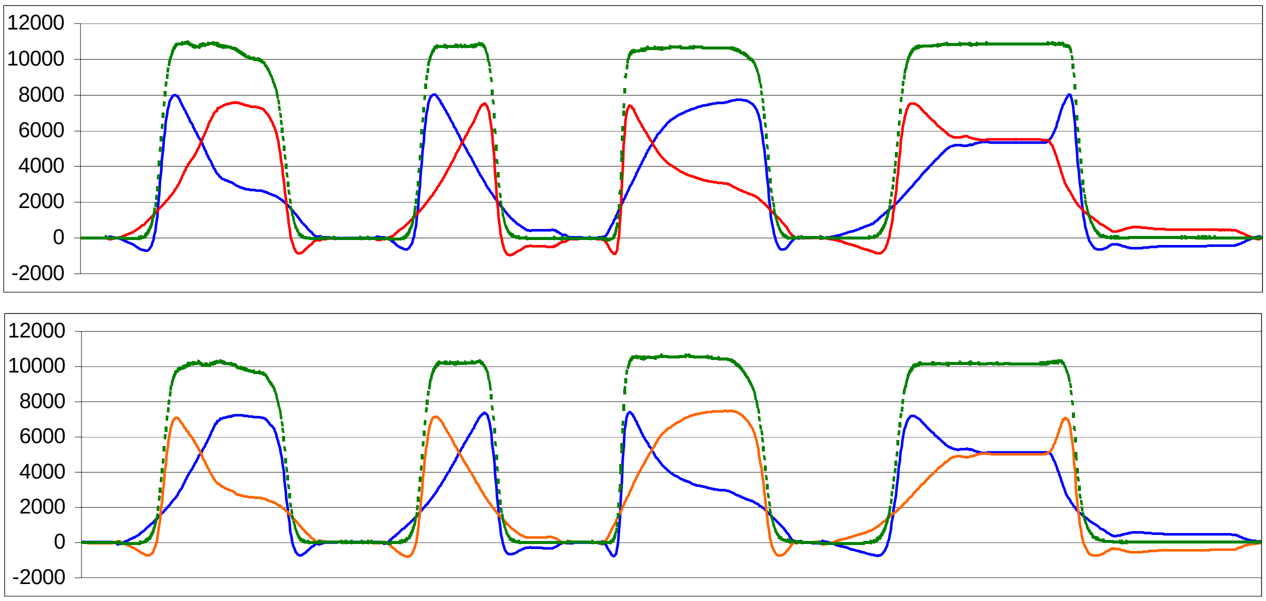

Fig. 2. Primary data sampled by force sensors D (first picture) and J (second picture). Y dimensions are displayed in kg.

Except the recorded signals from the couple of strain gauge bridges, in pictures on figure 2 is shown full passed weights. The full weight is calculated as a sum of signals from one couple strain gauge.

IV. ALGORITHM FOR WEEL LOAD ESTIMATING

A specific algorithm for processing the collected data is created. It aims to localise the zone of proportionality [5]. In this zone the calculated value of the force (weight) does not depend on its applied point. Its place is experimentally determined of ±250 mm according the centre of the force sensor.

The determination is done by detecting the value of the signal, corresponding to 90% of the maximum of the signal from strain gauge bridges (fig. 3). The next figures demonstrate the different stages of the algorithm, visualizing the results of the signals from wheel D2, moving leftward.

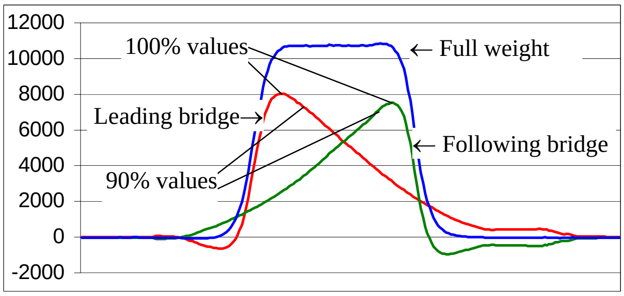

Fig. 3. Primary signal for D2 wheel (left movement).

This algorithm is one directional, i.e. it processes the signals in the same sequence as they arrive. It is impossible to know 90% of the maximal value of the following strain gauge bridge, because the maximum value is situated later in time. Thus it is accepted that the both 90% values are approximately equal, so this one, which is calculated first, is used for both of the bridges.

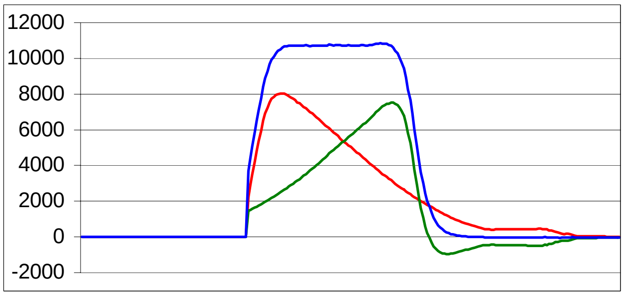

Fig. 4. Omitting samples below 2000 kg threshold.

The realization of the algorithm is made by a state machine with 5 stages:

1. The accounts of both of the bridges are being kept clear, until the leading one indicates value lesser than the given level. For the aims of the experiment, this level is set to 2000 kg, which is approximately 20% of the maximal weight, something that can be expected. Results are shown on fig. 4.

2. The maximal value of the signal in the leading bridge is being searched, and till the moment it is determined, the accounts of both bridges are being kept clear. When the maximal value is determined, it is calculated 90% of its value. The result is shown on fig. 5.

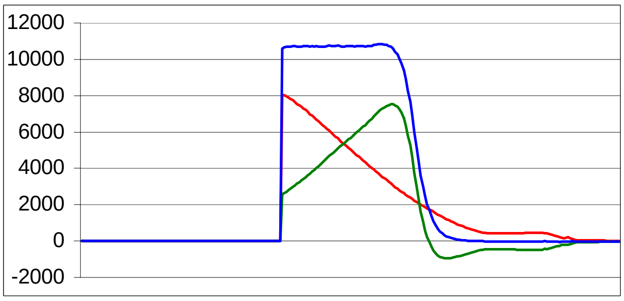

Fig. 5. Omitting samples before maximum in the left bridge.

3. The first account from the leading bridge which is lesser than the preliminary calculated 90% value of the maximum, is being searched. The accounts of both of the bridges are cleared. The result is shown on fig. 6.

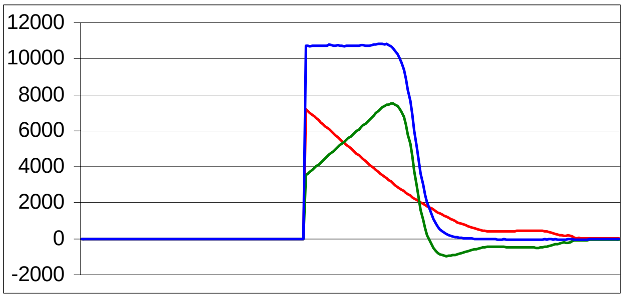

Fig. 6. Omitting samples above the 90% values in the left bridge.

4. The first account from the following bridge which exceeds the preliminary calculated 90% value of the maximum, is being searched. The accounts taken till that moment are being averaged and the result represents the passed load.

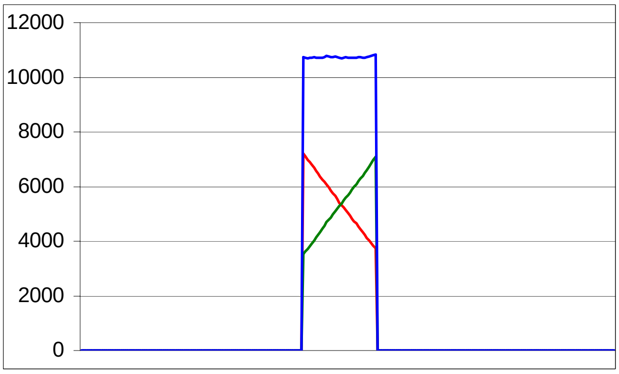

Fig. 7. Omitting samples after the 90% value in the right bridge.

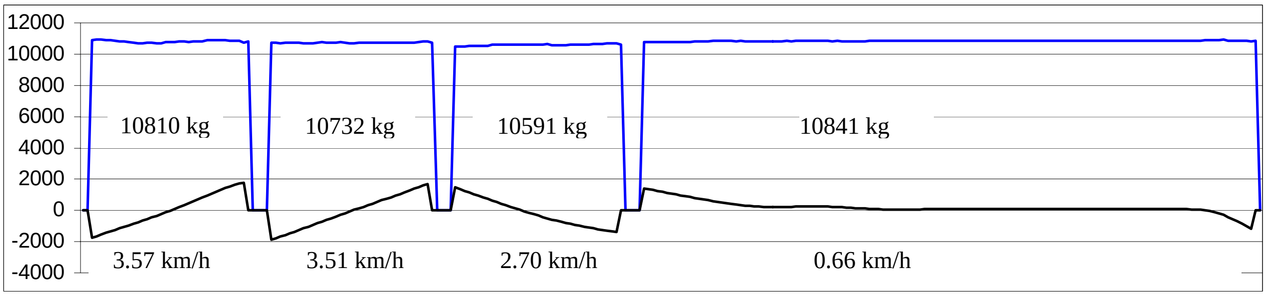

Fig. 8. Final results after completing the offered algorithm.

The algorithm ends with calculating the average load of the wheels for the determined sections.

5. The first account from the followed bridge which is lesser than the preliminary given measurement level (2000 kg), is being searched. The accounts of both of the bridges are cleared.

6. The procedure starts again from stage 1 and the accounts of both of the bridges are being kept clear until new measurement level is reached or the buffer ends. The result is shown on fig. 8.

The two graphics from the figures correspond to the total weight of the passed load (sum of the data from the bridges) and the speed of the load passing over the sensor, respectively.

By comparison of the data for the movement of one and the same wheel in both directions, a difference in the registered total weight is noted. This diversion for wheel D1 is –0,28 %, while for wheel D2 it is +1,31 %.

There is no explanation for this difference for now. Probably it appears due to an aperture error of the ADC or to the force sensor inertia. We intend to continue the research and the experiments in order to eliminate or compensate the discrepancy found.

V. Conclusion

An experiment has been planned for sampling and taking data from smart strength-sensor under condition of weight moving, for the purposes of the railway transport. An existing test set has been used for determining the static loading of locomotive wheels, which comprises the same sensors. The experiment used data from only two of all sensors.

Experimental software for the smart sensor and the central computer has been developed.

The experiment has been made as the data obtained by the two strain gauge bridges has been saved in a file.

On the basis of the data-file analysis has been developed an experimental algorithm for determination each wheel load in progress.

In addition the algorithm determines the speed of the load passing upon the sensor.

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