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EXPERIMENTAL INVESTIGATION OF THE VEHICLE–GROUND INTERACTION – EXPERIMENT PREPARATION AND PRELIMINARY RESULTS

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Abstract

Interaction of the moving vehicle and the ground represents the actual engineering, environmental and economic problem. Due to the complexity of the problem, a combination of the experimental measurement and the computational simulation to understand the interaction mechanism is the most beneficial approach. Results of the in-situ observation serve as an input for the numerical analysis and also as a background for the calibration of the model. Presented paper brings the summary of the experiment preparation and preliminary results which are necessary for further analyses and numerical models. Computational simulations will be helpful for understanding the vehicle–ground interaction when inputs will be verified by the experimental way at known boundary conditions.

Keywords:

Accelerometers;
Experiment;
Vehicle–ground interaction;
Vehicle T 815;
Velocity.

1 Introduction

Pavements are usually loaded by the dynamic forces of the moving vehicles. Beside the static component of the force, additional dynamic effect of the mutual interaction of the vehicle–ground is presented. The source of these dynamic effects lies in the irregularities of the pavement surface and the following response of the vehicle to this excitation. The actual load amplitude is the variable of time and frequency domain.

The best approach to describe this phenomenon is to combine experimental and computational methods. The analysis of the transport communications loaded especially by the heavy traffic needs an approach using both experimental and computational way because of complexity of the problem when certain inputs cannot be defined without in-situ measurement [1, 2, 3, 4].

The results of the theoretical solution of the dynamic response of the system vehicle–ground should be verified by the experimental measurement due to the complexity of the vehicle–ground dynamic system. The purpose of the experiment was to determine the additional input data for the numerical simulation that cannot be derived by the analytical way. This paper presents the preparation and the realization of the experimental observation of the vehicle movement on the experimental track using several types of equipment to obtain relevant inputs for the numerical study.

2 Experimental track

The aim of the experimental measurement of the dynamic effects of the vehicle movement on the track was to evaluate the selected quantities such as vehicle velocity and acceleration on the ground and at the vehicle depending on the various vehicle velocities. Processing of the output signals in the time and frequency way was another part of the effort. The results later served as background for the computational simulations. Because the interaction between vehicle and the ground is realized through the contact surfaces of the tyres, shape and dimension of these surfaces were also measured.

Experimental section of the track was situated on the asphalt concrete pavement with observation length of 50 m. The velocity of the test vehicle was constant within this section.

Experiment involved the observation of the 10 passes of the test vehicle with recording of the selected quantities such as vehicle velocity and accelerations in the selected observation points. The vehicle trajectory was identical for each pass. Every run was recorded by the camera for further analyses.

Total 5 sensors (accelerometers) were used to monitor the vehicle–ground response during the test. Three of the sensors (with designation BK1, BK2 a BK3) were situated on the vehicle – on the front axle, rear axle and in the cargo space of the vehicle (Figs. 1 and 2).

Two sensors (with designation BK4 a BK5) were installed on the steel stripes attached to the pavement surface within the test section (Figs. 1 and 2). Sensors BK4 and BK5 served as control points for catching of the vehicle arrival and departure in the test track. Check of the overall velocity can be then made with known distance of the vehicle run.

Laser scanner was used to determine the profile of the pavement surface, especially in the footprint line of the tyres. Unevenness is one of the largest sources of the kinematic excitation in the system vehicle–ground and this phenomenon will be important part of the further computational analysis [5, 6, 7, 8, 9].

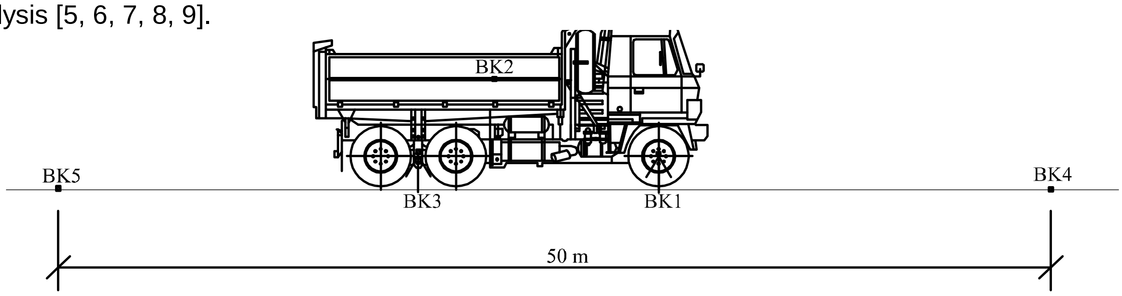

Fig. 1: Position of the accelerometers.

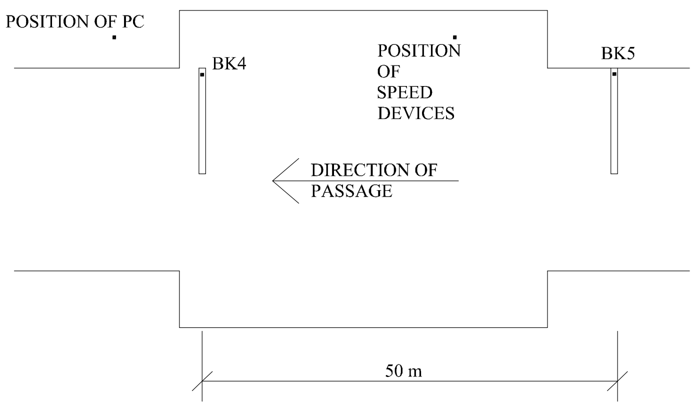

Fig. 2: Situation of the experimental track and the accelerometers on the pavement.

Wi-Fi antennas were used to transfer the data from the accelerometers to the computer for further processing. The sensor identification was realized via channel assignment so the signal evaluation was straightforward. The signals were processed using the software DIADEM and evaluated in the software MATLAB.

3 Test vehicle and equipment

The real vehicle was selected to simulate the ground response to the moving load. Usually, half-part models of the vehicle are widely used for the numerical modelling. Because both 2D (half-part model) and 3D numerical modelling will be the part of the further research, utilization of the real vehicle is very suitable.

To measure the acceleration and vehicle velocity, appropriate equipment was assembled as will be mentioned below.

3.1 Test vehicle

The heavy truck Tatra 815 was used as a test vehicle that represents a typical 6-wheel lorry with the double rear axle and with the cargo space. Basic technical parameters are noted below:

- type of the vehicle T-815 S1,
- kerb weight 11 300 kg,
- payload weight 10 700 kg,
- total weight 22 000 kg,
- maximum speed 80 km$\cdot$h^{-1}.

The vehicle accelerated to the desired final speed outside the test track so the velocity was constant at the first contact at the accelerometer BK5. The velocity stayed constant along the 50 m test section up to the accelerometer BK4. The velocity was measured using 3 types of equipment:

- Bushnell Speedster speed gun,
- statistical radar Sierzega SR4 (stationary radar),
- evaluation of the record of the accelerometers installed on the pavement.

The vehicle velocity within the test track varied from 10 to 36 km$\cdot$h^{-1}.

3.2 Bushnell Speedster

The speed gun was used to simple and quick evaluation of the actual vehicle speed (Fig. 3). Original purpose of this equipment was to measure the speed of the sports cars. The principle lies in the utilization of the Doppler Effect. The range of measurement is from 16 to 322 km$\cdot$h^{-1}. Maximal target distance is 457 m with the accuracy ± 2 km$\cdot$h^{-1}. This apparatus has no PC connection and the results are only displayed on the screen, [10].

Fig. 3: Buschnell Speedster speed gun, [10].

3.3 Statistical radar Sierzega SR4

For exact determination of the vehicle velocity, the statistical radar Sierzaga SR 4 was utilized (Fig. 4). This apparatus was developed for creation of the record of the statistical quantities of the observed section for the measurement interval from 8 to 255 km$\cdot$h^{-1}. The accuracy reaches ± 3 % according to the technical parameters of the manufacturer, [11].

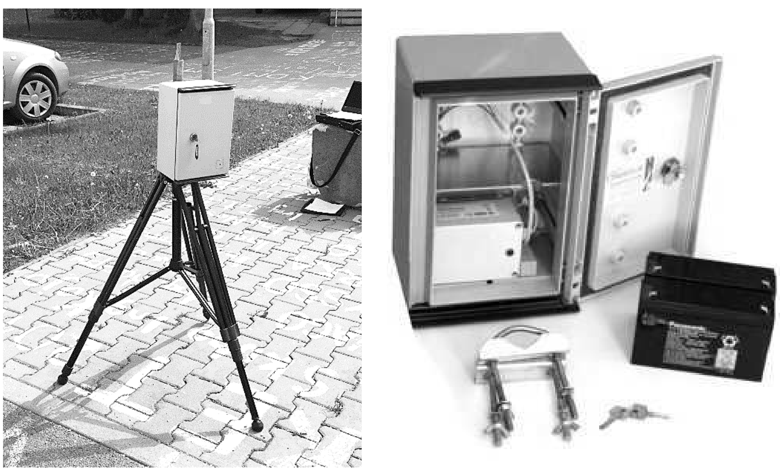

Fig. 4: Statistical radar Sierzega SR4, [11].

3.4 Laser scanner

Laser scanner Leica ScanStation C10 (LS) is compact pulse laser scanner which contains laser scanner system together with biaxial compensator, internal accumulator, control unit with touch screen, integrated hard disc, automatic video camera, high definition camera, and electronic plummet. Apparatus disposes of full field of view (360° × 270°). The range of the station is up to 300 m at reflectivity of 90 % and scan speed 50 000 points/s. Positional scanning accuracy is up to 6 mm with distance accuracy up to 4 mm, [12].

3.5 Piezoelectric accelerometer

Piezoelectric accelerometers BK 4508 B 002 were used to measure the accelerations induced by the vehicle pass (Fig. 5). The range of measurement is ± 70 $m \cdot s^{-2}$ and the frequency range is 0.4 Hz - 8 kHz. This frequency range was sufficient for our purposes. Designation and the constants of the accelerometers are in Table 1, [13].

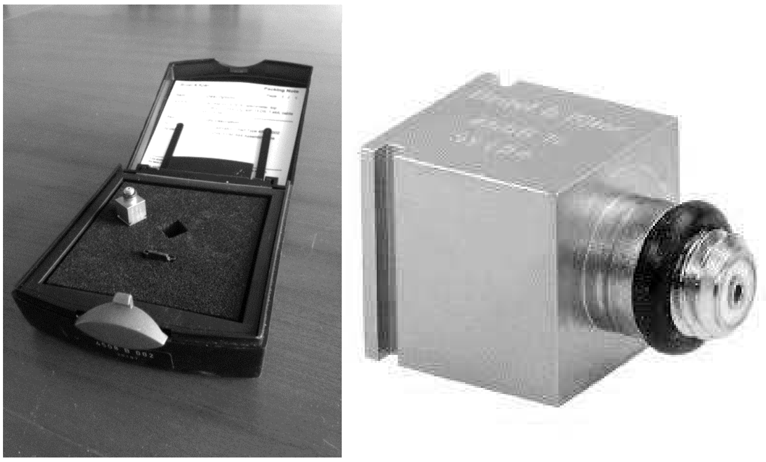

Fig. 5: Piezoelectric accelerometer BK 4508 B 002, [13].

Table 1: Designation and constants of the accelerators, [13].

Designation of the accelerator	**Constant** $\mathbf{mV/m \cdot s^{-2}}$	**Constant mV/g**
BK 1	99.56	976.4
BK 2	101.5	995.3
BK 3	100.8	988.5
BK 4	100.9	989.6
BK 5	103.7	1017

3.6 Measuring scheme

Measuring configuration consisted of the accelerometers, A/D transducers, Wi-Fi antennas, Wi-Fi signal receiver and PC with software (Fig. 6). This configuration allows wireless collection of the data from accelerators in real time.

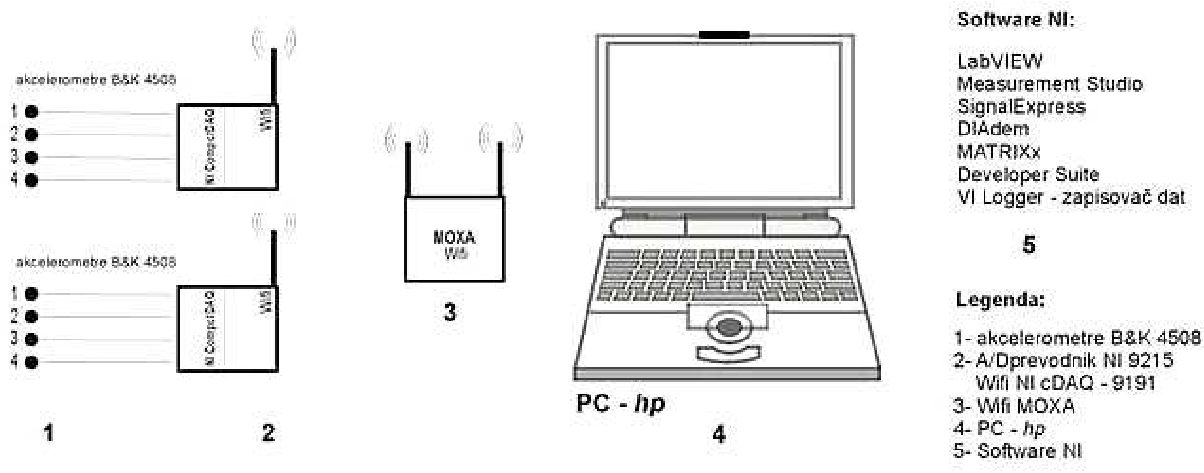

Fig. 6: Scheme of the measuring and the evaluation line.

4 Results of measurement

In the first step, velocity of the vehicle was analysed. The velocity was determined using three types of equipment – Bushnell Speedster speed gun, statistical radar Sierzega SR4 and the data from the accelerometers BK5 a BK4. Obtained results are presented in Table 2. These results will be later used as a background for the numerical simulation of the vehicle pass.

Table 2: Vehicle velocities in particular runs.

No. of run	**Bushnell Speedster [km·h^{-1}]**	**Statistical radar SIERZEGA SR4 [km·h^{-1}]**	**Accelerometers [km·h^{-1}]**
1.	22	23	-
2.	27	25	24.335
3.	26	28	26.837
4.	-	-	7.613
5.	11	11	11.163
6.	16	13	14.714
7.	23	22	22.018
8.	31	33	31.796
9.	14	13	13.584
10.	34	35	33.758

Point clouds obtained from the laser scanning were analysed to compile the pavement profile in two lines in distance 1.98 m under the truck tyres.

Appropriate coarseness of the finite element mesh, especially at the tyre–pavement contact, is necessary for accurate describing of the mutual interaction of the vehicle–ground system. In this case, step size was selected 0.3 m considering footprint dimensions of the vehicle tyre. Excessive amount of the elements causes larger calculation time without significant increase of the output accuracy. Track profiles under both left and right tyre lines are plotted in Fig. 7. Profiles will be used as a basis for the excitation sources to the vehicle self-weight in the numerical models.

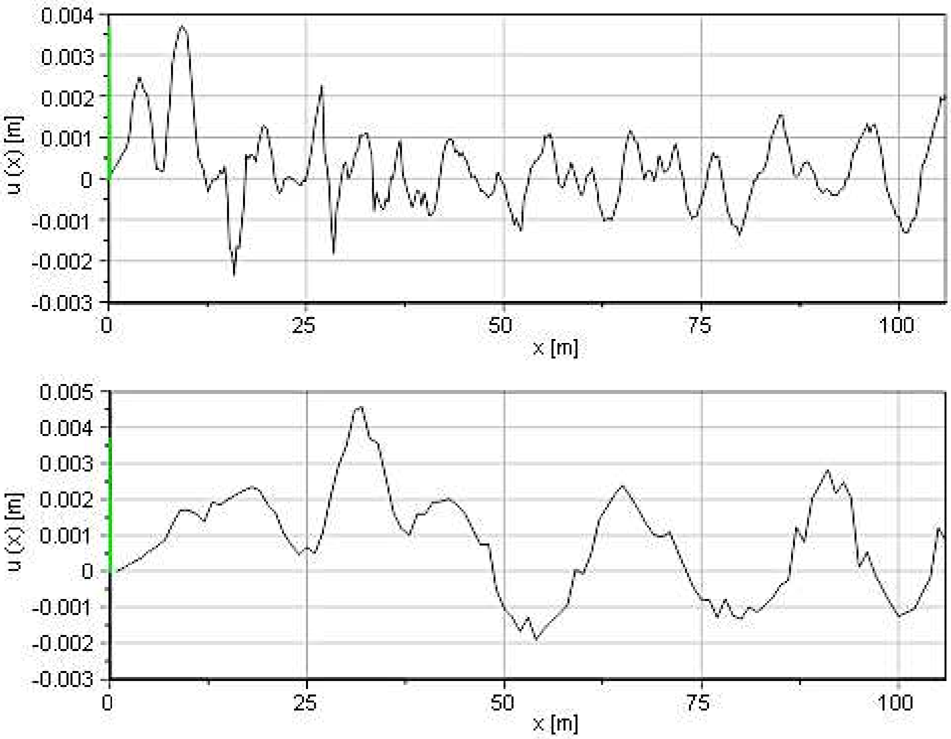

Fig. 7: Scanned profile of the test track under the tyre lines, left tyre line (above), right tyre line (below).

5 Conclusions

Obtained data will be used as a background for further analyses and numerical modelling of the vehicle runs. Each run will be simulated using computational models what allows us to better describe the vehicle–ground interaction at known boundary conditions.

First step will be aimed at the “cleaning” of the data records to exclude the noise signals that are necessarily present due to the complexity of the experimental runs. Processed data contain inputs for numerical model such as response of the vehicle and the ground observed at control points.

Calibration of the model and calculation of required values is then possible. In dependence on the tyre position within the test track calculated contact forces vary as a result of the unevenness of the pavement and dynamic characteristics of the car. The variation of the contact forces together with the stress state analysis of the pavement structure will be the topic of further investigation.

Acknowledgement

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