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VIBRATIONS DUE TO THE PASSAGE OF A RAILWAY VEHICLE ON STRAIGHT AND CURVED TRACKS

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Abstract

The paper presents the results of vibration measurements on line of railway during passages of a train at a constant speed. The measurements have been performed on a railway track at straight and curve sections as well as and inside the train on the floor. The experimental results exhibited higher amplitudes of vibrations on the curve of the track than on its straight segments. The lateral slip in rail/wheel contact zone is considered as a possible reason of such a phenomenon.

Keywords: railway vibrations, dynamic train-track interaction, ground borne vibrations, moving load.

Introduction

There is an increasing interest in the scientific world in the issue of ground borne vibrations from railway tracks, and in the vibration control by means of the track structure modification [1]. A wide range of different track and train structures is available, characteristic of different levels of performance. A train generates vibrations which are transmitted through the track to the ground, resulting in vibration and re-radiation noise in nearby building. The amplitude of vibrations depends on several factors, such as roughness of wheels and rails, dynamic properties of a train, a vehicle speed, characteristics of a railway track, a soil damping and a propagation of waves thought the soil [2, 3, 4].

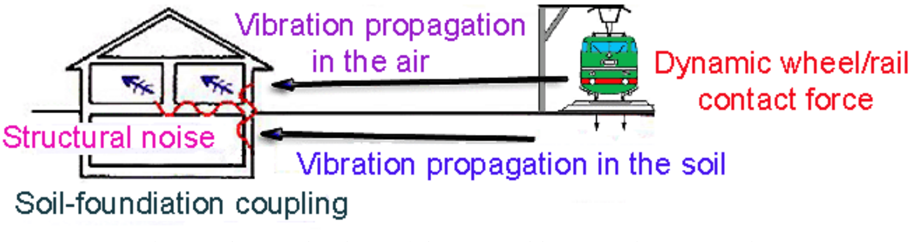

Fig. 1. The mechanism of the ground borne noise generation .

The main objective of the paper is to present results of experimental measurements of vibrations within the train and on the sleeper at straight and curve segments of track and to compare experimental data with numerical simulation results. The paper is focused on the influence of the lateral slip in rail/wheel contact zone on the generation of vibrations and a noise [5].

1. Measurement system

Our measurement system can be divided into two subsystems. The first one allows us to measure vibrations on the railway track, the second one can measure vibrations on the floor inside the train car-body. The external measurement system included: two-axis vibration transducer, geophone, infrared gate system, analog-digital converter of 12 bit/20kHz and data acquisition computer (Fig. 2). The two-axial accelerometer and geophone were fixed in the middle of railway sleeper (Fig. 3). The sensors were connected with the data acquisition computer through the A/D converter. The measurement was initialized and stopped when the infrared gate system gave an impulse to the converter. The first infrared gate switched on the converter when the train arrived at the measuring area while the second gate stopped measurements when the train was leaving this area.

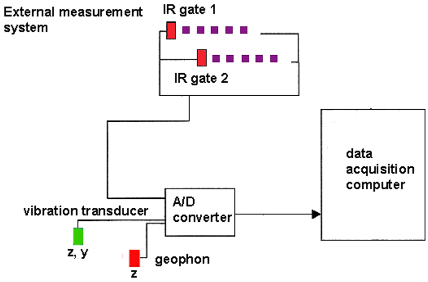

Fig. 2. Scheme of measurement system.

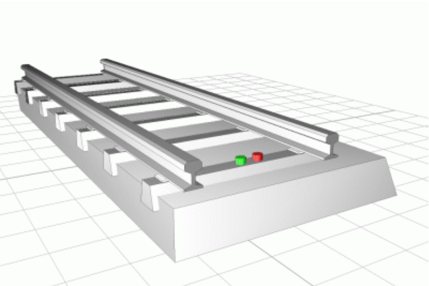

Fig. 3. Sensors placed on a railroad.

The second measuring system included two one-axis transducers and the mobile A/D converter of 12bit/10kHz. The converter contained data acquisition system (Fig. 4). The transducers was fixed to a steel bar in vertical and horizontal direction. The steel bar was placed on the train floor (Fig. 5).

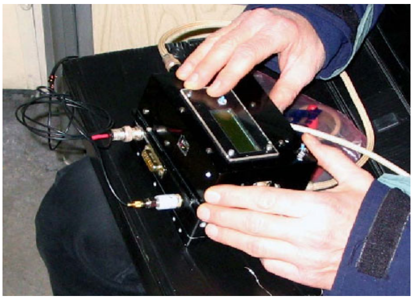

Fig. 4. Mobile converter with self data acquisition system.

Fig. 5. Vibration transducers placed on the train floor.

The average speed of the train has been estimated from two sources. The first one was a portable GPS module located in the train. The infrared system was the second source of information. The infrared gates measured time between the passage of the first and the last wheelset. The time interval and the distance between both axles allowed us to estimate the train speed.

2. Characteristic of the rolling stock

The investigated train of type EN 71-100 consisted of four coaches (Fig. 6). Each coach had two bogies with two wheelsets. Two final coaches had motor bogies while two middle coaches had trailer bogies. The length of motor car was 20.70 m, while the length of the trailer cars was 21.57 m. The total length of the train was 85 m. The distance between axles on the bogie was 2.70 m. The dead weight of the trailer car was 34 T whereas of the motor car was 57 T. The total mass of the train was 182 T. The traction and trailer wheels were of monobloc type and had a diameter of about 0.94 m and 1.00 m, respectively.

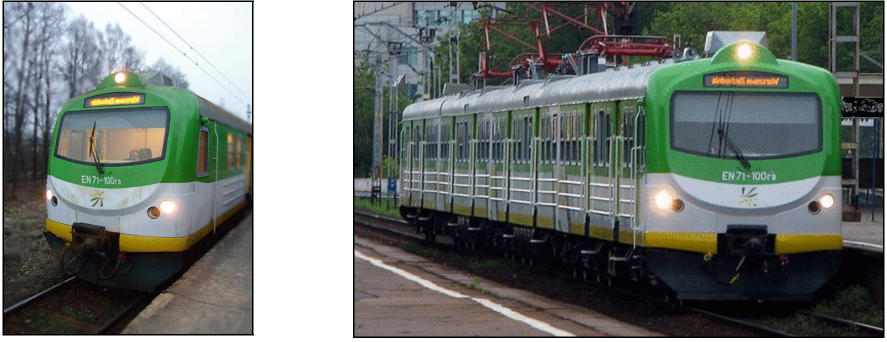

Fig. 6. Investigated train of type EN71-100.

3. Experimental results

The vibration measurements were performed during rush hours (10 am ÷ 16 pm) for 10 passages of EN 71-100 type trains on straight and curve test segments of a track and in the train in the same places. The radius of the curvature of the tested track segment was about 1000 m. The average speed of the railway vehicle was equal to 58 km/h on the curve segment of the track and the average speed of the train was equal to 61 km/h on the straight segment. The vertical and horizontal accelerations and vertical velocity were measured by two-axial accelerometer and one-axial geophone (Fig. 3).

Vibrations were analyzed in terms of accelerations, velocities or displacements as a function of time and frequency. The displacements were obtained by double integration of acceleration results. Displacements were checked by integrated velocity results obtained by measurements by the geophone.

Comparison of experimental results demonstrated higher amplitudes of vibrations generated on curves of the track than on straight segments (Fig. 7, 9). Measurements on curves exhibited eight characteristic predominant groups of vibrations (Fig. 7). These groups confirmed the passage of respective wheelsets of bogies by the point of measurement. In Fig. 8 the spectral analysis of experimental results of vibration are

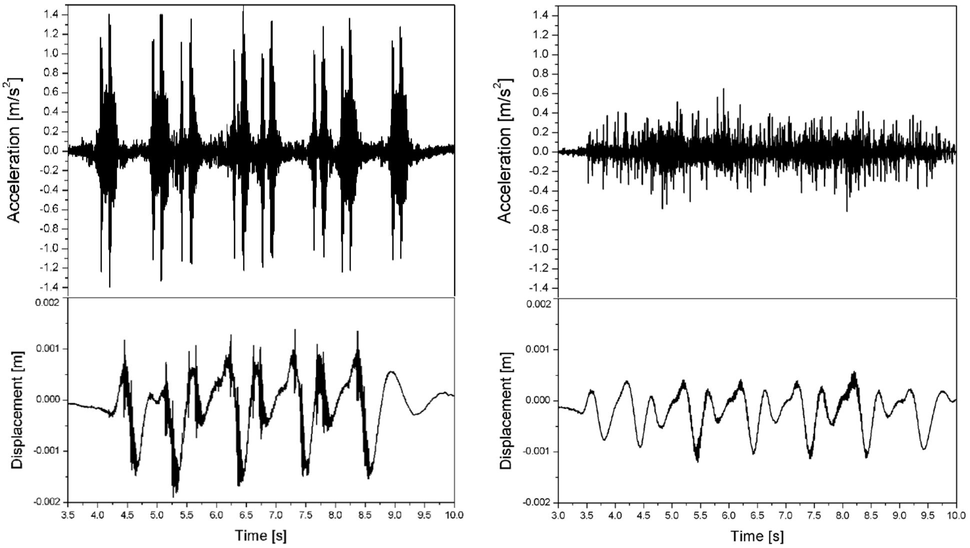

Fig. 7. Time history of the vertical accelerations and displacements measured on the sleeper: curve segment (left), straight segment of a track (right).

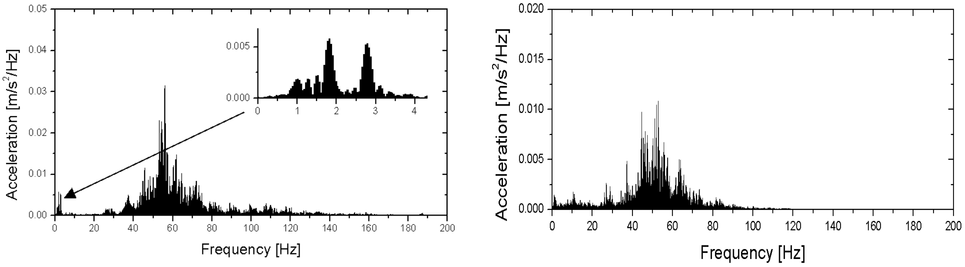

Fig. 8. Spectra of vertical accelerations measured on the sleeper: curve segment of a track (left), straight segment of a track (right).

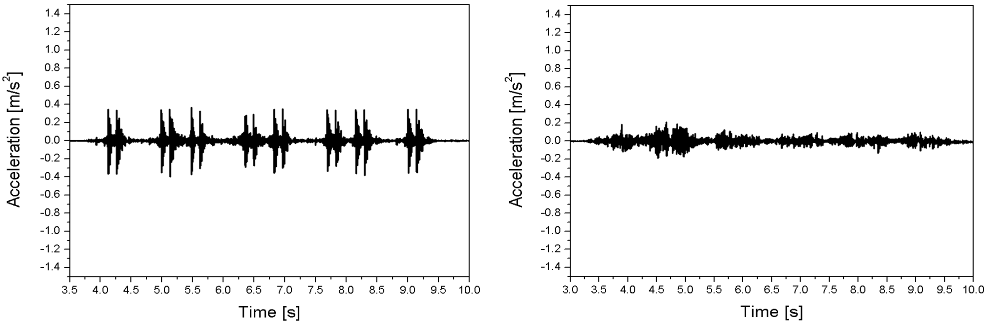

Fig. 9. Time history of lateral accelerations measured on the sleeper: curve segment of track (left), straight segment of track (right).

depicted. Frequencies from ranges 1÷2 Hz and 40÷80 Hz on the curve segment of the track can be noticed whereas on the straight the respective frequency is equal to 30÷75 Hz. The predominant frequency on the curve and straight segments of track is equal to 53 Hz and 58 Hz, respectively.

Fig. 10 shows the time history of vertical and horizontal vibration measured inside a car body on the floor for a period of time corresponding to the passage of approximately one train length. The measurements were performed during the passage in the place of investigation on the track. The comparison of the graphs in Fig. 10 exhibits higher intensity of horizontal vibrations (in transversal direction) for the curve segment than for the straight segment. Moreover, in this case we have about 2 times higher amplitude. Differences in amplitudes of vibration in the vertical direction are significantly lower than in the transversal direction.

Fig. 11. shows the spectra of vertical and horizontal acceleration measured inside a car body. It can be noticed that vibrations with higher range frequencies occur on the straight track than on the curve segments. The spectral analysis of vibrations (Fig. 11) shows the frequencies of ranges 2÷60 Hz and 300÷600 Hz on the curve segment whereas on the straight segment the frequency was 500÷700 Hz for transversal direction and 400÷750 Hz for vertical direction. The predominant frequency on the curve and straight segments is equal to 43, 400, 700 Hz and 52, 83, 550, 630 Hz, respectively.

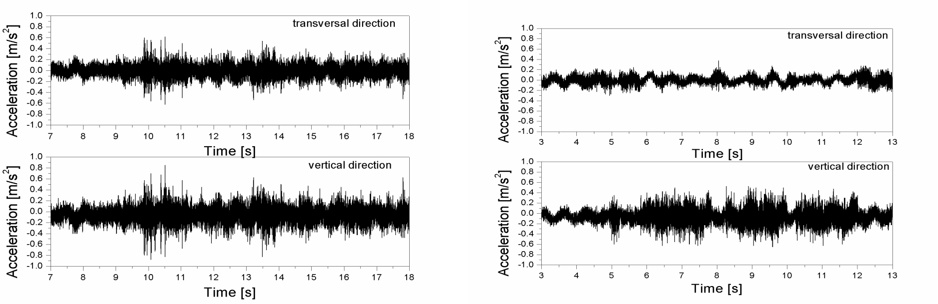

Fig. 10. Time history of vertical and horizontal acceleration measured inside car body on the floor: curve segment of track (left), straight segment of track (right).

4. Numerical results

Intensive numerical modelling of vibrations generated by a travelling vehicle was performed by the space-time finite element models. It was the only method which allowed us to analyze the moving mass problem. In classical approaches the track was subjected to a moving system of massless forces. The wave phenomena could not be considered with a sufficient accuracy in higher ranges of a speed. In reality the moving wheel or wheelset considered as an inertial point is bound with the track or simply with the rail. It significantly influences the dynamic response of the trail-track system. This problem, however, will not be considered in the present paper.

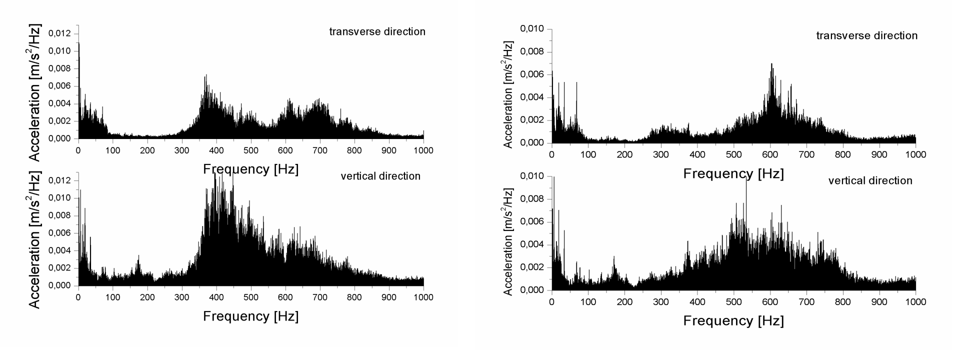

Fig. 11. Spectra of vertical and horizontal acceleration measured inside a car body on the floor: curve segment of track (left) and straight segment of track (right).

5. Conclusions

Higher vibrations on curves can be resulted from the wear of railway track which was caused by centrifugal forces influenced by the passages of the train, deformations of wheels, wheelsets and rails, different linear velocity of wheels on curves and rotary oscillations of wheelsets. Plane of the wheel skewed to the direction of the rolling resulted in lateral slip in rail/wheel contact zone. The rail/wheel system oscillates and generates noise.

In the future the experimental data presented here as well as results of measurements in the Metro tunnel will be used for validation of numerical prediction models, being under development. Model development, calibration and validation will benefit from the available data set. In further stage of the project the obtained models of vibration source and models of soil will be applied to describe vibration propagation through the soil to the buildings in the environment.

References

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