VIBRATION OF THE TRAIN/TRACK SYSTEM WITH TWO TYPES OF SLEEPERS

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Summary The conventional and reinforced railway track is composed of two infinite rails separated from the sleepers by visco-elastic pads. There are numerous assumptions leading to different simplifications in railway track modeling. Two-dimensional periodic model of the track consists of two parallel infinite Timoshenko beams (rails) coupled with the visco-elastic foundation (or equally spaced sleepers). Nowadays the interest of engineers is focused on the Y-shaped sleepers. The fundamental qualitative difference between the track with classic or Y sleepers is related to local longitudinal symmetric or antymetric features of railway track. The sleeper spacing influences the periodicity of elastic foundation coefficient, mass density (rotational inertia) and shear effective rigidity. The track with classical concrete sleepers is influenced stronger by rotational inertia and shear deflections than the track with Y sleepers. The increase of elastic wave velocity in track with Y sleepers and more uniform load distribution will be proved by the analysis and simulations. The analytical and numerical analysis allows us to evaluate the track properties in a range of moderate and high train speed. However, the correct approach is not simple, since the structure of the track interacts with wheels, wheelsets and vehicles, depending on the complexity of the analysis. We can notice the amplitude growth in selected velocity ranges.

The conventional and reinforced railway track is composed of two infinite rails mounted to the sleepers by means of the fastening with pads. There are various assumptions leading to the different simplification in railway track modelling. The two-dimensional periodic model of track consists of two parallel infinite Timoshenko beams (rails) coupled by visco-elastic foundation (or equally spaced sleepers). The qualitative difference in track modelling with classic or “Y sleepers” is related to local longitudinal symmetric or antymetric features of railway track. The dynamic analysis of the above track models as periodic structures can be based on Floquet’s theorem. The Timoshenko beam model on an elastic or visco-elastic foundation can also be used to describe the vertical or lateral track motion. In such a case sleeper spacing influences the periodicity of elastic foundation coefficient, mass density (rotational inertia) and shear effective rigidity. The track with classic concrete sleepers is influenced much more by rotational inertia and shear deflections as the track with “Y sleepers”. The increase of elastic wave velocity in track with “Y sleepers” and more uniform load distribution will be proved in analysis and simulations.

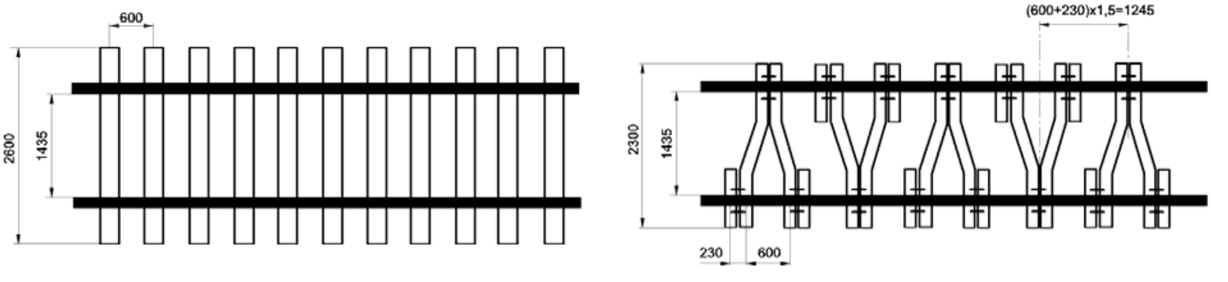

Fig. 1. Classic track (left) and reinforced track with “Y” sleepers (right)

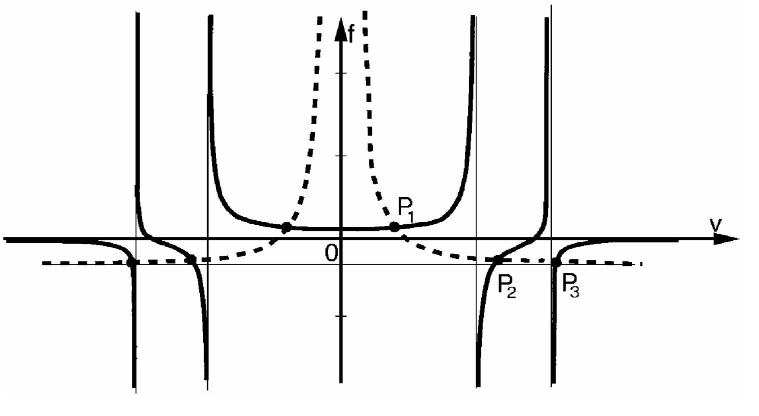

Fig. 2. Wave velocities in conventional track for the case when both rails vibrate “out of phase” and rails – sleepers vibrate “in phase”.

In the case shown in Fig. 2 the minimum speed of elastic waves in the track *v* is determined by point P_1. The value of the speed is smaller as half of share wave velocity. The determination of the velocities of elastic waves (P_1, P_2, P_3) in the track make it possible to estimate maximal speed of the train. The response of the track subjected to moving and oscillating wheelset [1, 2] or boogie is possible in an analytical way by using Floquet's technique similar as in ref. [3]. The numerical analysis of the track response carried out by the space-time finite element method [4, 5] will be presented in the second part of the study.

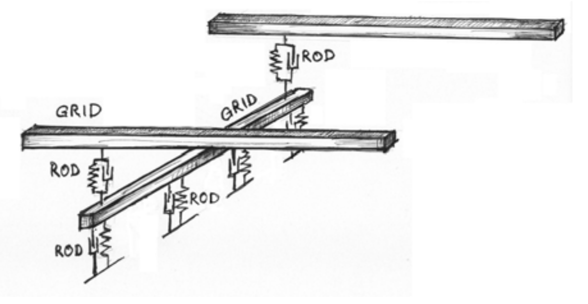

Fig. 3. Model of the track used in computational analysis

Numerical track model was composed of grid and bar finite elements (Fig. 3). Both rails and sleepers were modelled as a grid separated by visco-elastic pads modelled by bar elements. The Winkler type foundation was modelled by visco-elastic springs. The total length of the track was 20 m. Both ends were fixed. Significant damping allowed us to reduce the influence of boundary conditions.

The vehicle was built as a mass and spring 3-dimensional systems combined with frame elements.

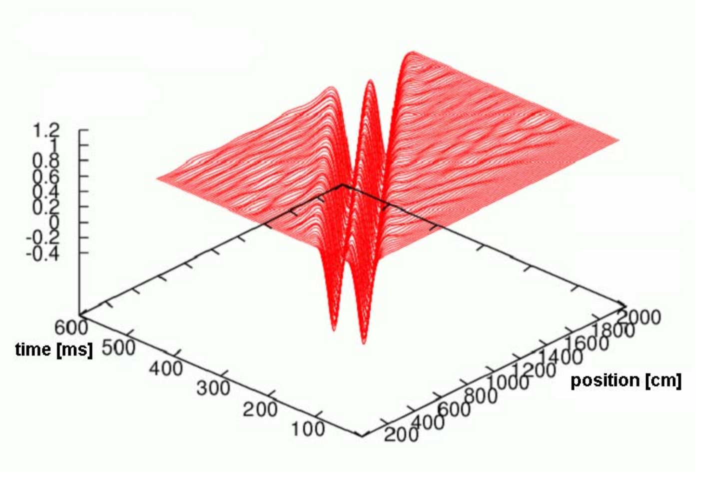

Fig. 4. Vertical displacements of a track obtained in the time-space domain.

The vehicle and the track represented by systems of algebraic equations were solved independently by a direct method. The coupling was ensured by iterations. In practice 3-6 iterations per time step provided sufficient precision. We can say that in spite of simplicity of the approach the results obtained were highly satisfactory.

The selection of parameters of the classic and Y-type sleeper track for various speed ranges enabled us to investigate vibrations of the system and formulate conclusions for proper engineering design.

Advantages of Y-type sleepers are significant for practical use. They are characteristic of lower amplitude level and in the same way lower acoustic emission. The wear (for example corrugations) is decreased since the contact force does not oscillate as much as in the case of the classical track.

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