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Experimental and numerical investigations of dual gauge rail tracks

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Abstract

Currently, two types of track gauges are currently in use in the Spanish railway network: the Iberian gauge (1668 mm) and the international gauge (1435 mm). In order to allow the passage of trains with a specific gauge, a dual gauge track was developed in which a third rail is added. With that, this particular track requires an analysis of mechanical behaviour.

In particular, this study focused on dual gauge track response produced by train loads. To accomplish this task, a new 3-D finite element model was developed and validated with in situ measurements. The results obtained may be used to predict the track stiffness and vertical response with respect to different track parameters and characteristics.

Keywords: dual gauge, rail track, finite element, vibrations, test track.

1 Introduction

The traditional gauge of the conventional railway network in Spain is 1,668mm, known as Iberian gauge. However, most railways in Europe use the standard gauge of 1,435 mm. Under these particular conditions and considering the need to link the European Union to the Mediterranean countries by means of efficient transport system, a number of specific solution have been developed in the latest decades.

One possible solution to resolve the problem of different track gauge, which is actually under implementation, is the dual gauge track. This rail track is formed by special concrete sleepers (AM-05) that allow installing three rails: two adjacent outer rails for each gauge, while the single outer rail is common to trains of both gauges, as shown in Figure 1.

Figure 1: Dual gauge track in Spain.

With the implementation of dual gauge track, several problems caused by the break of gauge have been solved. Nevertheless, the introduction of the third rail modifies the classical structure and thus requires an accurate analysis of mechanical phenomena of the track. In fact, the acceptance of speed upgrade is strongly conditioned by the mechanical properties of track behaviour and their stiffness [1].

Nevertheless, few analyses have been conducted on the evolution of mechanical behaviour of dual gauge tracks in terms of stress, displacements and stiffness. Moreover, it is interesting to estimate such mechanical properties based on the records of sensors installed in dual gauge tracks. In this study, the displacements and stress amplitudes under different axle types were analysed by means of finite element model. In order to predict track behaviour, a 3-D finite element (FE) model was formulated. Then, the evolution of deflections under both types of axle loads was compared from the records of accelerometers installed at different locations. Finally, numerical and experimental results were presented to explore the track behaviour under different train loads. Several conclusions have been derived, which is an important step in the study of the dual gauge tracks.

2 Methods

Over the years, numerous studies have been performed on evaluating different aspects on conventional rail tracks. However, the analysis of the stability on dual gauge tracks introduces new configurations that should be taken into account, considering the particular addition of the third rail.

Firstly, a new three-dimensional finite element (FE) model of dual gauge track is proposed, in which various assumptions are made. To approach the problem in a realistic way, a 3D numerical model of the rail track was developed in Ansys. The rail track was simulated with solid elements (hexahedra elements with six degrees of freedom per node) and fasteners were modelled as linear elastic block elements, which are based on experimental investigation [2]. The moment of inertia of the sleeper was matched with the actual sleeper at the rail seat section. Finally, a linear elastic model was chosen for subgrade layers. With that, the unsymmetrical section represented by the addition of the third rail is explicitly taken into account. The length of modeled track is 12 meters witch is equal to 20 sleepers with 0.60 m spacing (Figure 2). All displacements perpendicular to each boundary plane were restrained. Regarding the model loads, they were applied as point loads moving along the track, with each load representing a train axle. With all, the model enables variation in structural layer thickness, rail size, sleeper type and material properties.

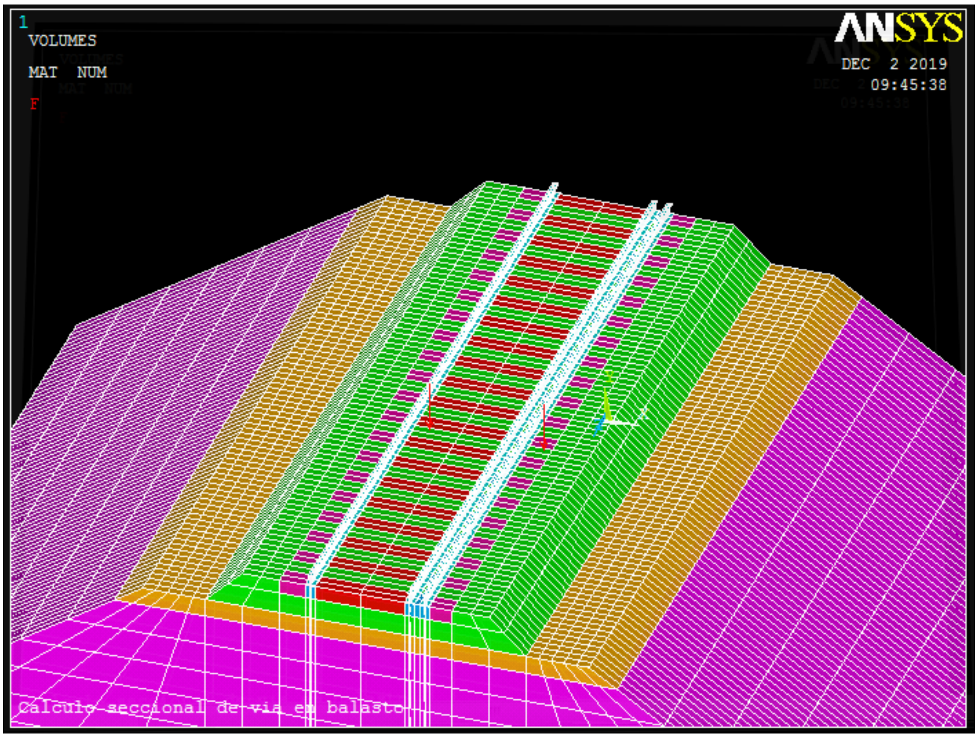

Figure 2. Finite element model.

Secondly, the experimental site selected was located in Massalfasar, Spain, in the line connecting Valencia and Barcelona (Figure 3).

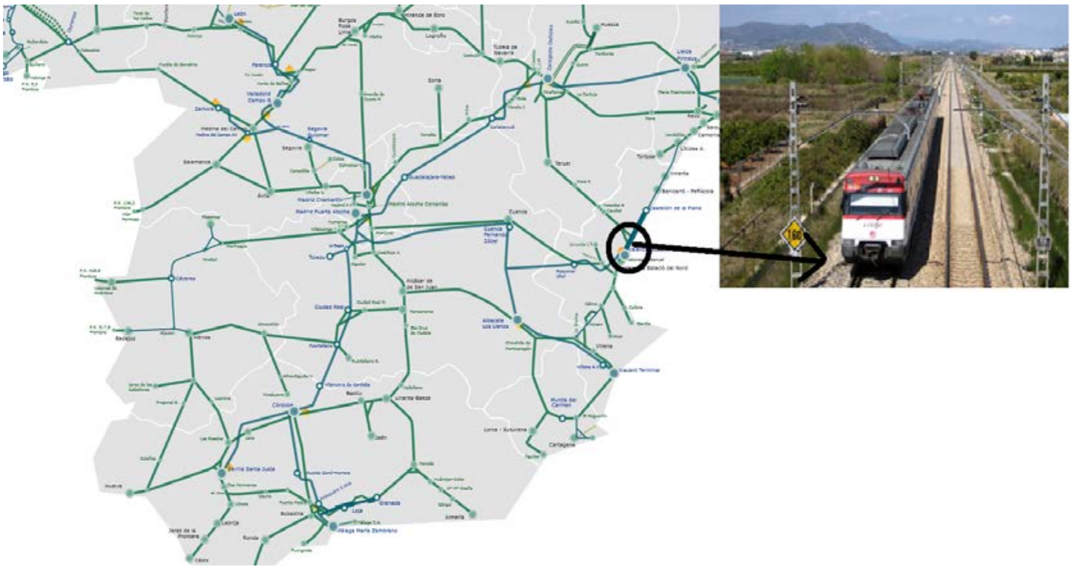

Figure 3. Track site location.

To monitor the track, dynamic sensors such as displacement sensors and accelerometers were installed at two different locations along the experimental site (Figure 4). As indicated in Fig. 3, accelerometers were fixed on the rail base and sleeper surface using a glue in the vertical direction. Displacements sensors were also fixed to rails with clamping jaws. Thus, all sensors were installed under the same track-side and connected to a data logger. Accordingly, displacement and acceleration levels were measured during the passing of vehicles at controlled speed (the speed limit for the track is actually 200 km/h).

Figure 4. Displacement (right) and accelerometers (left) sensors.

With that, measured accelerographs and displacements were compared to modelled ones using part of the available data set, fitting acceleration peaks and average levels so as to calibrate the numerical model.

3 Results

The aforementioned approach and developed finite element model were applied to different train loads. Thus, the traffic load was modelled over a time step evaluated as elapsed time. After the calibration, the numerical simulation results and experimental results for the different train loads have a good consistency.

As shown in Figure 5, vertical deflections of the analysis results on rails are in good agreement with those obtained on the test track. The calculation predicted the settlements well, which indicates that the proposed method is a useful tool for analyse dual gauge track behaviour. Figure 6 shows that the numerical model not only predicts vertical displacements but also predicts vertical accelerations along the sleeper. Figure 6 represents the frequency spectrum based on measured data from field test. Results shows that vertical accelerations at rails welds was found to have high-frequency vibrations between 400 to 1200 Hz.

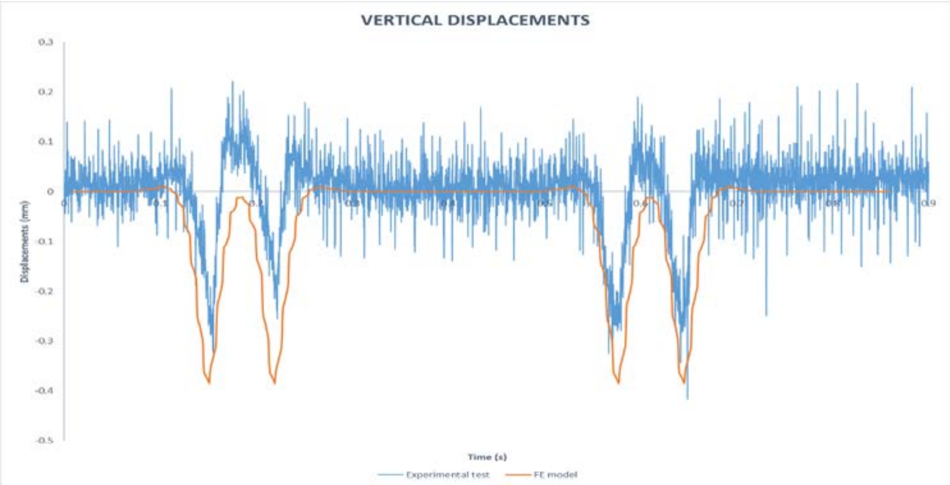

Figure 5. Vertical deflections of FEM and test.

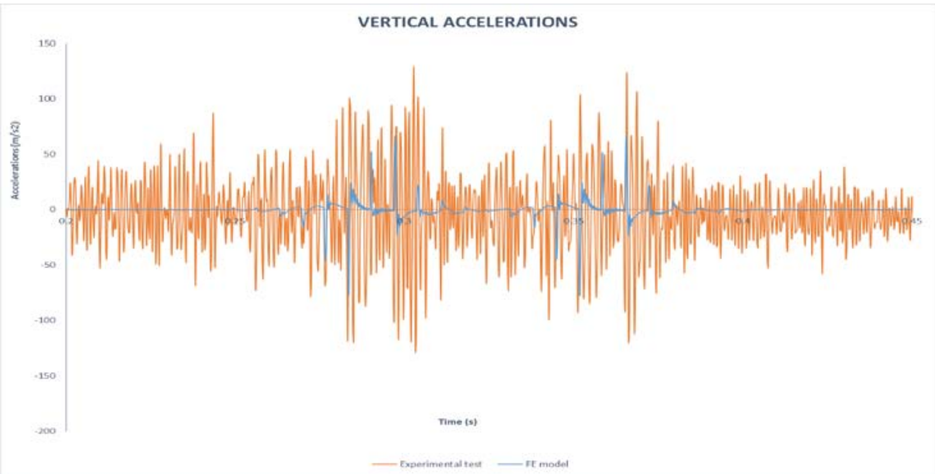

Figure 6. Vertical accelerations of FEM and test.

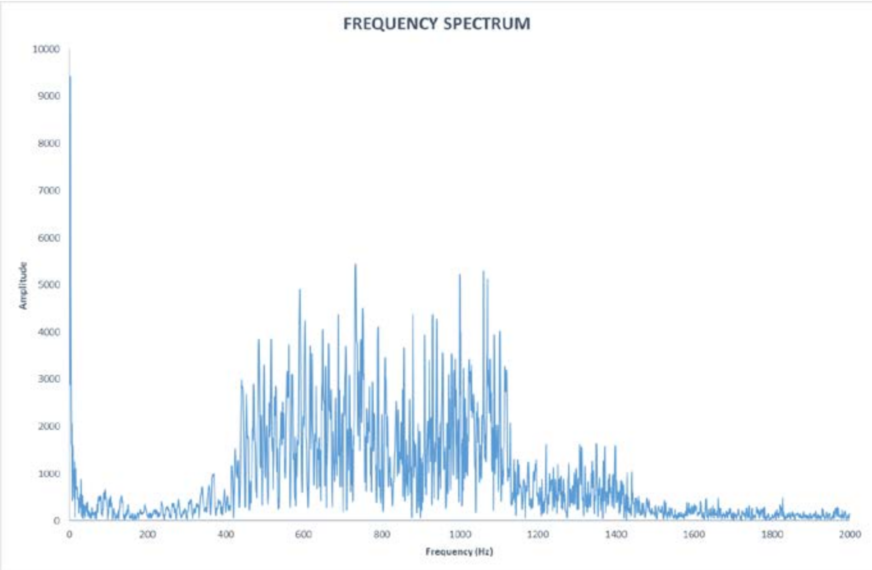

Figure 7. Frequency spectrum from vertical accelerations.

With the previous results, the finite element model was employed to investigate the effect of the third rail in the rail track substructure, and led to the discovery that the distribution of vertical stress and deformations on soils layers (ballast and subballast) is not symmetrical, as in conventional rail tracks, due to the introduction of the third rail (Figure 7.). In particular, stresses resulting from applied loads are concentrated under the common rail. Those results provide a more comprehensive view of dual gauge track response in terms of track settlement pattern of the sub grade.

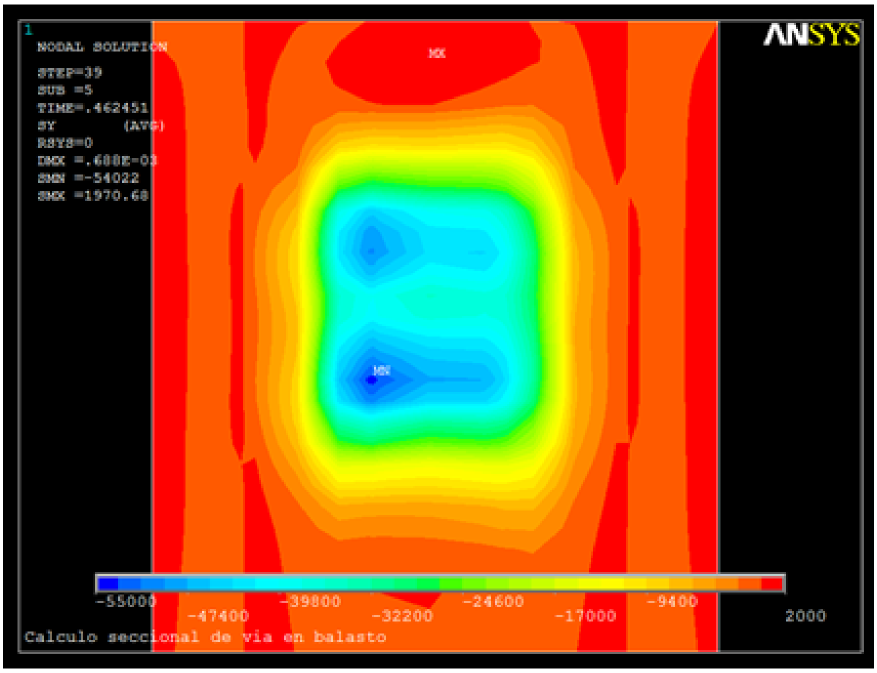

Figure 8. Vertical deflections in subbalast layer.

In conclusion, the numerical model and the test results show a good consistency. This indicates that the model assumptions can be applied, but large-scale test can provide more detailed conclusions and safety considerations.

4 Conclusions and Contributions

The Government of Spain is currently upgrading the existing Iberian gauge rail track to dual gauge in the Mediterranean arch until a new rail freight line is built. In case of mixed corridors such as the Mediterranean corridor (connects the south-western Mediterranean region of Spain with the Ukrainian border with Hungary), the demands for dynamic load carrying capacity and track smoothness increase simultaneously.

The main objective of this study was to create a three dimensional rail track model, in which the stress-strain response of different track components could be evaluated realistically. The created model is based on finite element method using Ansys software, which offers an efficient and cost-effective simulation methods for designers and engineers.

The proposed model considers the 3D traffic load transfer mechanism, the magnitude and the position of traffic load applications, multi-layer ground conditions, and the strength and compression characteristics of the soil layers. The model was applied to analyse a long test section near Massalfasar station, in Valencia (Spain).

From the results, it shows that the proposed model can be used for calibrating the design of dual gauge tracks and useful in maintenance procedures. The analysis also revealed the unsymmetrical response of the soil layers due to load transmission between track components. From this perspective, the optimization of track design can provide a solution that resists the loads required while at the same time improving the of life-cycle costs. Hence, there is a great need for a model which enables designing the load-carrying capacity of a dual gauge track structure as a whole and simultaneously evaluates the stress and/or strain levels of each track component.

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