Validated Slab Track Models for Railway Vehicle Dynamics

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Modern society demands and environmental factors are putting pressure in the development of new high speed rail networks or on the upgrade of conventional tracks to allow a significant increase in operational speeds and/or load capacity. Such requirements raise scientific and technological challenges that need to be addressed, which include the improvement of numerical tools and experimental techniques to support the design solutions. The dynamic analysis of railway systems involves multidisciplinary problems for which the most recent computer codes for rail applications only allow the study of a particular phenomenon at a time, each with its own mathematical model. By analysing such phenomena independently, it is not possible to capture all the dynamics of the complete railway system and the relevant coupling effects.

The dynamic behaviour of railway vehicles is, in general, analysed using a multibody formulation where the track is generally modelled as a rigid structure considering only the rails. This approach does not represent exactly the reality as the tracks exhibit flexibility [1,2]. Therefore, a methodology that considers all mechanical components of the vehicle, including the details of the suspension elements, and also the specifics of the track, including the stiffness and damping properties of the rails, pads, slab and subgrade, is required to represent realistic railway systems.

The main goal of this work is to develop detailed and reliable three-dimensional slab track models, which include all components of the infrastructure, and study the dynamic behaviour of railway vehicles in such realistic tracks. For this purpose, the physical parameters of the slab track models are identified by comparing the numerical results with experimental tests performed in realistic operation scenarios.

The slab track experimental tests are performed at Heriot-Watt University using the testing facility known as GRAFT II (Geo-Pavement and Railways Accelerated Fatigue Testing), as shown in Fig. 1. It is one of the world's largest purpose-built laboratory test track bed designed to predict the effects of trains on the track and simulate the consequences of decades of operation. It uses hydraulic systems to produce cyclic loads with a combined 120 tonnes of force, which can be configured in different layouts to represent the wheelset loads. Hence, it allows simulating the conditions that the track is subjected to under railway operation and study the behaviour of rail tracks in real life and full-scale conditions for several years of service.

The three-dimensional slab track is modelled here with a Finite Element (FE) formulation using three alternative softwares, ABAQUS, ANSYS and COMSOL, in order to reproduce the same conditions of the experimental tests. The track model, depicted in Fig. 2, is composed by several layers of different materials that include the subgrade, Frost Protection Layer (FLP), Hydraulically Bonded Layer (HBL) Grout Mass (GM), Max Bögl slab, pads and rails. Some parameters of the model are known from the technical specifications of the manufacturers but there are several others which values are uncertain and need to be estimated according with the data available in the literature. Then, these parameters are tuned so that the numerical models produce results that are similar to the ones obtained in the experimental tests [3,4].

Fig. 1: Slab track experimental tests in GRAFT II testing facility at Heriot-Watt University

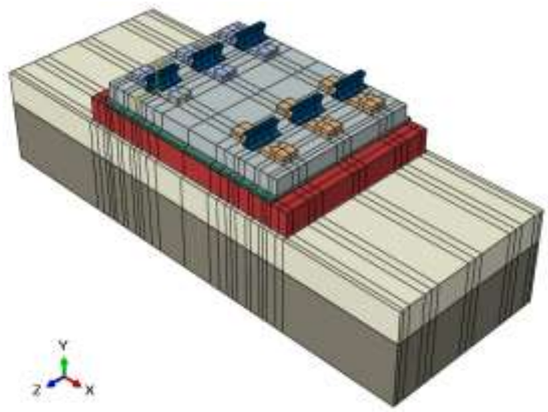

Fig. 2: Slab track model in ABAQUS

The reliable track models are then used for realistic railway studies. For this purpose, the vehicle, modelled with the multibody software SIMPACK, and the validated FE track models are integrated in a common environment and analysed in several operation conditions to demonstrate the developments proposed in this work. In the process, a comparison between the numerical models is presented and the efficiency of the co-simulation between the multibody and FE tools is discussed.

The results are analysed giving special emphasis to the impact of train operations on the infrastructure and, conversely, the damages on vehicles provoked by the track conditions. These topics have a significant economic impact on the vehicles maintenance and also affect the life cycle costs of tracks. Therefore, the work developed here aims to support the development of solutions with technological relevance giving answer to the industry's most recent needs and contributing to improve the competitiveness of the railway transport.

References

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