Assessment of the short and long term behaviour of the track at a railway transition zone

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1 Introduction

The railway experience in conventional and high speed lines shows that when track characteristics change abruptly, namely between embankment and bridge or underpass transitions, the degradation of the track is faster. These zones require frequent maintenance operations to restore the geometrical quality of the track.

The work presented intended to contribute to the understanding of the short and long term dynamic behaviour of railway transition zones using finite element numerical models. The train-track dynamic interaction was included in the models by means of contact elements applied to the wheel-rail interface. Contact elements were also used to simulate the sleeper-ballast contact so that the hanging sleeper phenomenon can be analysed.

The track permanent deformation is considered using a methodology developed to simulate the deformed track profile evolution that results from the railway traffic. Based on an iterative procedure, this tool allows the numerical model to take into consideration the permanent deformations, which are estimated through laws that depend on the number of loading cycles and the stress state the materials are subjected to.

2 Track model and vehicle-track contact

The track model used in this work consists of a two-dimensional model where the rail is modelled through Euler-Bernoulli beam elements with equivalent characteristics to the stiffness and to the mass of the UIC60 rail. The rail pads are represented by spring-dashpot assemblies. The rest of the track components are 4-nodes finite elements in plane stress that enable width definition. Contact elements were incorporated in the sleeper-ballast interface. The track section considered corresponds to a complete track structure.

The 2D model was statically and dynamically calibrated using a 3D finite element model with geometric and mechanical characteristics similar to those of the two-dimensional model. The results obtained with both models were compared and similar results were obtained in several parameters (Alves Ribeiro, 2012). The vehicle model is composed by a concentrated mass that represents the mass of the wheel-axle (M), and a spring (K_H) simulating the stiffness of the wheel-rail contact.

3 Methodology for long term simulation

The methodology proposed to simulate the permanent settlement of the track due to railway traffic consists of an iterative process through the articulation between the ANSYS software and MATLAB program (Alves Ribeiro, 2012). The numerical models are defined in ANSYS where the dynamic analyses of the vehicle-track system are carried out, as well as all the pre- and post-processing of the results. MATLAB program performs the reading of the results of the dynamic analyses, the application of the deformation laws and the determination of the permanent deformation of the track that is then introduced in the numerical model. Figure 1 shows a schematic representation of this methodology.

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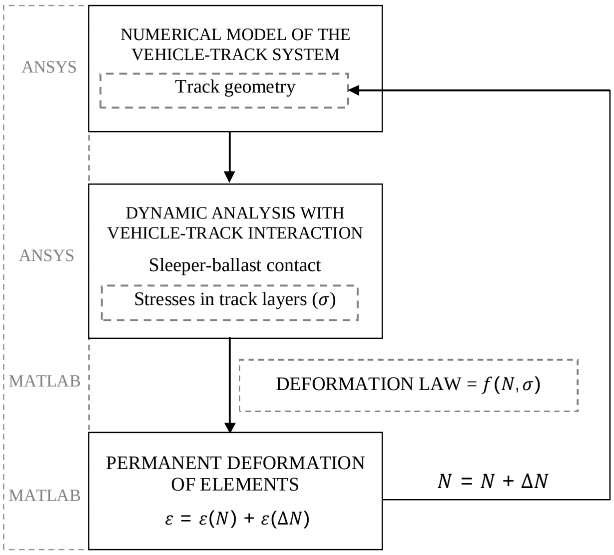

Figure 1: Iterative procedure for the simulation of the permanent deformation of the track.

To do this simulation procedure it is important to model the track layers using finite elements that enable the accurate simulation of the stress state of the track. After the dynamic analysis it is possible to calculate the principal stresses over time for each finite element and with that the permanent deformation in each finite element is determined in MATLAB, and then it is stored and provided to the ANSYS program to be imposed on each finite element, in the next iteration. This way the geometry of the track is automatically changed. It is important to point out that in this methodology it is easy to incorporate any deformation law, since it depends on the stress state and the number of cycles. In this case it was considered ORE law (1970) to estimate the ballast permanent deformation and the law proposed by Gidel et al (2001) in the other track layers.

Since the passage of only one train axle causes a very small permanent deformation, the simulation process is not performed cycle to cycle but in a set of cycles (ΔN), assuming that the stress state of the track layers remains constant in each set of cycles.

4 Conclusions

1. Permanent deformation is higher when the deviatoric stress of the elements increase;
2. The base of the sleepers do not follow the deformation of the track layers – gap appearance;
3. The ballast layer permanent deformation dominates the track deformation;
4. The dynamic effects obtained on the transition zone when permanent deformation is considered are considerably higher than those obtained when only the stiffness variation is considered.
5. This methodology can easily be applied to predict the long term behaviour of the track in other zones.

5 References

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