Numerical modelling of flying ballast phenomenon on high speed lines. Part A: Analysis of the train-track aerodynamic interaction by means of field data and a CFD model

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Ballasted high speed railway lines might eventually experience a phenomenon known as flying ballast (or ballast projection). It consists of ballast particles becoming airborne under the effect of a running train, and may lead to safety and management problems on both the rails and the vehicle [1]. In this regard, the aerodynamic field generated between the track and the rolling stock plays a key role, being able to set in motion the ballast particles under certain circumstances [2]. Such displacements may be either superficial or aerial and derive into new particle projections (*i.e.*, by colliding with nearby particles), thus amplifying the phenomenon.

A considerable amount of scientific research has been carried out in the recent years in order to study the processes involved as well as to propose mitigation measures, concluding that the problem can be addressed either by acting on the vehicle or the track aerodynamics (or on both). In this sense, the present research project aims to develop a new heavy ballast, made out of concrete and other high-density recycled materials, to be less prone to suffer the flying ballast phenomenon. Within this project, the new material has been numerically and physically modelled in order to better know its behaviour, test its efficiency and determine the most convenient design parameters.

The numerical modelling of the new ballast behaviour under the passage of a high speed train has been divided in two clearly differentiated segments: i) the aerodynamic interaction between the track (i.e., ballast, rails and sleepers) and the vehicle, which determines the initiation of motion of the ballast particles; and ii) the mechanical behaviour of the ballast (accounting for its nature as a discrete medium) under the vibrational and aerodynamic excitation induced by the train.

This paper describes a simplified aerodynamic model of the vehicle-track system, which is able to reproduce the air flux generated in the vicinity of the upper ballast layer due to the relative train-track displacement. It is later used to obtain the averaged aerodynamic loading (velocity profile and turbulence) induced on the ballast particles after several train passages, by means of a CFD (computational fluid dynamics) numerical model and field measurements from [3]. Such loads shall be later introduced in a DEM model of the track for the entire flying ballast phenomenon to be modelled [4].

The model is based on the hypothesis that the air flux between the train and the ballast can be assimilated to a developed turbulent Coulette flux [1] with certain added particularities such as: i) periodical variability of the planar distance due to the presence of sleepers and irregular vehicle geometry (*e.g.*, train equipment, car-car connections); and ii) development of a boundary layer starting from the train nose and extending along the nearby region, which moderates the air flux in the first seconds.

For the model calibration and validation, the simplified analytical description of the fluid field is first calculated on a certain point of the track (namely the central point between two sleepers) and the results are compared with real track measurements. Then, the field is calculated on a different point (over a sleeper) by means of the CFD model and also compared with real track measurements for calibration and validation. Finally, once both models have been validated, it is possible to calculate the field on any point of the track by obtaining (via CFD modelling) a correction function of the field in the central point between two sleepers.

References

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