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A probabilistic approach for estimating the behavior of railway tracks

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ABSTRACT

Railway engineering is confronted with problems due to degradation of the rail network that requires important and costly maintenance work. However, because of lack of knowledge on the geometrical and mechanical parameters of the track, it is difficult to optimize maintenance management. In this context, this paper presents a new methodology to analyze the behavior of railway tracks. It combines new diagnostic devices which permit to obtain an important amount of data and thus to make statistics on the geometric and mechanical parameters and a non-intrusive stochastic approach which can be coupled with any mechanical model. Numerical results show the possibilities of this methodology for parametric studies (influence of the distribution and of the correlation of the parameters...). In the future this approach will give important informations to railway managers to optimize maintenance operations.

1. Introduction

In the field of computational mechanics, the necessity of taking into account the uncertainties affecting the mechanical and geometrical parameters of numerical models is today recognized. To satisfy this requirement, a possibility consists in choosing some particular situations corresponding to particular values (extreme values, mean values) of uncertain parameters, then in estimating the mechanical response corresponding to each of these situations, and finally in retaining the most unfavorable situation with regard to a given failure criterion. This strategy, often used in practice, is very debatable because the choice of the most unfavorable situation is made among a family of situations which does not naturally contain all the possible situations. The most rigorous solution consists in fact in using a strategy based on a probabilistic approach [1–8]. In this paper, a strategy of this type is proposed for the probabilistic analysis of the behavior of railway tracks.

Railway engineering is confronted with problems due to degradation of the rail network that requires important and costly maintenance work. Railway damage due to drainage problems, relative settlements or layer degradation and the necessary maintenance interventions create heterogeneities in the mechanical and geometrical characteristics of the different subgrade layers. Upgrading of the track level is thus even more problematic. Due to a lack of knowledge of these heterogeneities and of their possible consequences on the track behavior, it is difficult to provide an optimized maintenance management.

As a result, to describe in a realistic way the mechanical behavior of a railway track under dynamic loads, it is necessary to use a numerical model able to take into account the uncertain nature of some mechanical and geometrical parameters. Several numerical approaches based on the finite elements (FE) method have been developed in the last decades to describe the global or local behavior of railway tracks [9]. To take this random variability into consideration, the natural way is to use a stochastic finite elements (SFE) method [10–20]. It is the solution chosen in this paper, with the aim of analyzing the propagation of uncertainties through the numerical model describing the mechanical behavior of track sections. In this way, different maintenance solutions could be analyzed and compared by railway managers.

This paper is organized as follows. The next section deals with the methodologies of diagnostics used by railway companies. In particular, the new devices used to collect the required mechanical and geometrical data are described. Then, the deterministic FE track model is presented. Section 4 is focused on the probabilistic modeling of the uncertain data and on the choice of the control variables used in the probabilistic approach. The proposed SFE method (based on the stochastic collocation method) is presented in Section 5. Some numerical applications of this method to the railway problem are detailed in Section 6 (influence of the distribution and of the correlations of the parameters, uncertainty propagation), and finally we explain how this approach can be used from a practical point of view by track managers to improve maintenance and draw some conclusions in Section 7.

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