Modelling approaches to rail track condition analysis

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Various conditions appearing in railway structures along with increasing speeds of operational trains lead to necessity of finding new possibilities for the rail track dynamic behaviour prediction. This process is of importance for designing of new railways, especially for those planned to be built in unfriendly environment, but also when one deals with a need of vibrations and noise reduction. Newly developed or improved track components, such as under sleeper pads, fastening systems, rail dampers and others, need more complex models compared to those described in published literature [1]. In addition, nonlinear properties of these components, and also foundation layers, make solutions more difficult [2]. Therefore, numerical approaches are used most commonly, giving however inefficient tools for extensive parametrical analysis. Still, some important features of these systems can be studied by using analytical modelling and symbolic hybrid semi-analytical approximations [3] which is even more useful when one deals with wide range of dynamically changing physical parameters [4, 5].

The rail track is usually modelled by a system of beams resting on viscoelastic foundation. In recent works, multi-layer systems are used to analyse dynamic behaviour of rail structures [5, 6]. Two-layer structure consisting of one-layer modelling rails and second layer describing sleepers, with appropriately modelled force generated by moving train, was validated by experimental measurements in the case of nonlinear foundation stiffness [6]. Properties of other rail track components can be taken into account by inclusion of additional layers and modification of some assumptions regarding models. These modifications lead to systems difficult to solve by using classical methods. One can mention e.g. a two-layer model based on double-beam system with nonlinear foundation stiffness and nonlinear viscoelastic layer between beams corresponding to the fastening system [7, 8], in addition with included equation responsible for rail dampers. Solution of such systems is possible by application of semi-analytical approximation using wavelet filters combined with Adomian's decomposition applied to nonlinear terms [3, 9-11].

Inclusion of geogrids effect is also possible in this two-dimensional model. In this case, one can assume that stiffness of one of foundation layers changes periodically. Modelling of this layer leads to periodic structure that can be dealt with similarly to the case of random force [12]. The force acting on rail is stochastic among others due to irregularities appearing on rail head rolling surface. Special procedure transferring these imperfections to the force modelling is built and applied in developed previously code. Several models will be presented along with their solutions and computational examples. Also, the method of rail track condition analysis based on energy transfer will be discussed in relation to geosynthetics application [13].

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