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Optimisation of railway vehicle performance using virtual tests in running dynamics

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Abstract

Acceptable running characteristics of a railway vehicle are essential for a safe and economic operation of a railway system. The assessment of running characteristics applies not only to newly developed vehicles but also to vehicles which have had relevant design modifications. The work presented in this paper concerns the use of virtual tests to assess running characteristics of a modified regional train. The method employed is based on the European standard EN14363:2018.

The aim of this work is to prove quickly the advantages of using a new innovative hydraulic bushing of primary suspension to replace the original bushing for an existing regional train in France. To achieve our objective, 3 main tasks are performed. Firstly, a numerical model is built and validated based on the annex T of the standard EN14363:2018, using initial on-track measurements. Then, this validated model is used during the design phase to obtain a set of optimal characteristics for the hydraulic bushing. Those data are proposed to our supplier for the manufacture. Finally, the model is used again to simulate the running behaviour of the train equipped with real characteristics of hydraulic bushings on different types of track (tangent and curved tracks).

This work proves a good level of safety with a potential reduction of 40% of wear and energy consumption in certain curves of the train equipped with hydraulic bushings.

Thank to our study, 30 new innovative hydraulic bushings are manufactured and installed in 3 commercial trains in 2022 for at least two years of test. A regular monitoring of wear of the wheel will be carried out. It is expected to observe a

reduction of the Life-Cycle Costs (LCC). If this is confirmed by test, the whole fleet of this type of train could be equipped with these hydraulic bushings.

Keywords: virtual tests, running dynamics, hydraulic bushings, vehicle performance.

1 Introduction

Acceptable running characteristics of a railway vehicle are essential for a safe and economic operation of railway system. The assessment of running characteristics applies not only to newly developed vehicles but also to vehicles which have had relevant design modifications. In Europe, nowadays, this assessment is based on the homologation process defined in the standard EN14363 [1]. The last version in 2018 of this standard requires on-track tests and/or numerical simulations, hereafter called virtual tests. The use of virtual tests can help to reduce the Life-Cycle Costs (LCC) of a vehicle. Virtual tests also provide the possibility to analyse safety-critical situations without risks.

The work presented in this paper concerns the use of virtual tests to assess running characteristics of a modified regional train. In the modified train, the original bushings of primary suspension are replaced by new innovative hydraulic bushings. The aim of using hydraulic bushing is to reduce wear of wheel and rail in curves while ensuring a stable behaviour in straight lines [2, 3].

The results of virtual tests are analysed in order to compare the behaviour of the modified train with the original one. Different quantities for stability, running safety and track loading in tangent tracks and different curves are investigated. This work helps to prove a good level of safety with a potential reduction of wear and energy consumption. The new innovative hydraulic bushings are installed in some commercial trains in 2022 for at least two years of test.

2 Methods

In this paper, firstly, a description of the numerical model of the original train is presented. This model is built using the multi-body dynamics software SIMPACK of Dassault Systemes [4]. The validation of this model is based on the method 2 of the annex T of the standard EN14363:2018 [5, 6, 7], and consist in a comparison between simulations and initial on-track measurements of the original train. For this validation exercise, a total of 16 track sections including 4 sections from each of the 4 test zones (tangent track, large radius curves, small radius curves and very small radius curves) are taken randomly from available data. Measured track irregularities and nominal wheel rail profiles are used. A special tool has been developed using the software MATLAB in order to facilitate the validation exercise. The validated numerical model of the original train is obtained by doing an optimization of the wheel rail friction coefficients.

In the second step, the new innovative hydraulic bushing is modelled. The frequency and amplitude dependence of the stiffness is considered. The parameters of this sub-

model are identified by using experimental data obtained with common lab tests on the component.

Finally, the numerical model with the new innovative hydraulic bushings is used to simulate the running behaviour of the modified train on 4 selected test zones. The stability of the train in tangent track is verified by calculating the lateral acceleration of the bogie frame for different speeds. The wheel-rail contact forces and the energy dissipation in the contact area of each wheel-rail pair are analysed when the train runs on curved tracks. The results obtained with modified train are compared with those of the original train.

3 Results

The numerical model of the original train is successfully validated based on the method 2 of the annex T of the standard EN14363:2018. This validated model is then employed for two phases of the project: design phase and "validation" phase.

During the design phase, a Design of Experience (DOE) is defined for the characteristics of the hydraulic bushings. Numerical simulations are performed to verify the stability of the train in tangent track and the wheel-rail contact forces in curved tracks. Thank to those simulations, a set of optimal parameters for the hydraulic bushing is obtained and proposed to our supplier for the manufacture.

The "validation" phase is performed after the manufacture of the bushing. This phase is necessary because of the gap between the theorical optimal characteristics and the real ones obtained with the manufacture process. During this validation phase, two studies are carried out. The first one is similar to the one of the design phase with the same types of simulation. The results obtained confirms a potential reduction of up to 40% of wear and energy consumption in certain curves of the train with the real hydraulic bushings. The second study concerns simulations of the running behaviour of the modified train on more than 100 track sections from the 4 test zones (tangent track and curved tracks) to verify the compliance with the standard EN14363. This work proves a good level of safety of the modified train.

4 Conclusions and Contributions

The work presented in this paper concerns the use of virtual tests to assess running characteristics of a modified regional train. The method employed is based on the European standard EN14363:2018. This work is carried out within the framework of the Work Packages 5 and 7 of the project PIVOT-2 of Shift2Rail programme.

The aim of this work is to prove quickly the advantages of using a new innovative hydraulic bushing of primary suspension to replace the original bushing for an existing regional train in France. To achieve our objective, 3 main tasks are performed. Firstly, a numerical model is built and validated based on the annex T of the standard EN14363:2018, using initial on-track measurements. Then, this validated model is used during the design phase to obtain a set of optimal characteristics for the hydraulic

bushing. Those data are proposed to our supplier for the manufacture. Finally, the model is used again to simulate the running behaviour of the train equipped with real characteristics of hydraulic bushings on different types of track (tangent and curved tracks).

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Thank to our study, 30 new innovative hydraulic bushings are manufactured and installed in 3 commercial trains in 2022 for at least two years of test. A regular monitoring of wear of the wheel will be carried out. It is expected to observe a reduction of the Life-Cycle Costs (LCC). If this is confirmed by test, the whole fleet of this type of train could be equipped with these hydraulic bushings.

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