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Development and Validation of a Multibody Pantograph Model for Realistic Current Collection Studies

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EXTENDED ABSTRACT

1 Introduction

Rail electrification makes use of the interaction between the pantograph and the catenary to provide power to railway vehicles. Advanced computational tools are used to help understanding the complex physical phenomena associated to this interaction and to find the best design solutions for reliable rail operations. Numerical analyses can de-risk and decrease the costs of electrification projects by reducing the need for expensive on-track testing to ensure good current collection compatibility. In this work, a detailed pantograph Multibody (MB) model is developed and tested in a virtual laboratory. The MB methodology frequently requires fine tuning of the modelling parameters to address eventual uncertainties associated to the properties of the suspension elements and/or linking components. The virtual laboratory enables to adjust these modelling parameters so that the frequency response of the pantograph MB model matches the experimental results gathered in a test bench. The state-of-the-art solution for pantograph-catenary interaction dynamics includes the use of MB models as it is a fully three-dimensional formulation, allowing to study the current collection performance on each individual contact strip and account for the pantograph head roll and pitch movements. Therefore, the model validation procedure proposed here is essential to increase the confidence in these MB models and the accuracy of the dynamic analyses outputs.

In the following, the pantograph modelling methodology is described. Then, the virtual laboratory is presented, together with the MB pantograph model validation methodology. Finally, conclusions are presented to highlight the benefits of the approach proposed here.

2 Pantograph Multibody Model

The pantograph considered here is the Wabtec/Brecknell Willis HSX. The MB model is composed of 9 bodies, 9 joints, 6 spring-damper elements, 1 actuator and 4 bumpstops [1]. The base of the pantograph is rigidly fixed to the carbody roof. The lower arm, represented by a rigid body, is constrained to the base through a revolute joint, allowing the pitch motion that is controlled by the pneumatic actuator. The lower link and the base are assembled with a spherical joint.

In the pantograph knuckle a chain attaches the lower link to the upper arm. The chain is modelled as a spring-damper element. Moreover, a revolute joint is used to constraint the relative motion between the lower and upper arms, allowing pitch motion only. The connection between the lower arm and the upper link is assured by a spherical joint instead of a revolute joint to avoid constraint redundancy.

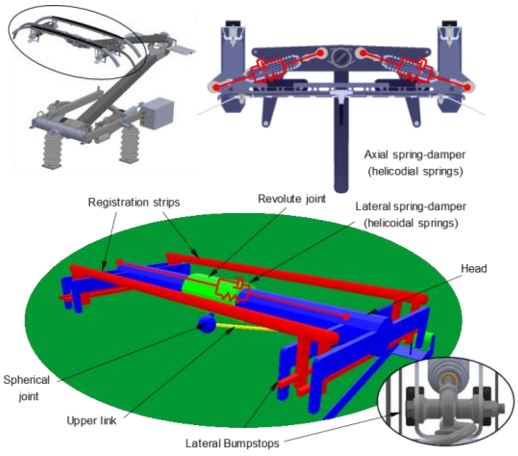

Figure 1: HSX MB pantograph model

A revolute joint is used to represent the constraint between the head of the pantograph and the upper arm, allowing the pitch motion, as shown in Figure 1. A spherical joint attaches the upper link to the head. The contact strips are rigidly fixed in a frame, which is represented by one rigid body that is supported by 4 inclined springs that constrain mainly their vertical and roll motions with respect to the pantograph head. Additionally, a lateral spring-damper element is used to represent the transverse stiffness due to the shear effect of the helicoidal springs. The transverse relative motion between the head and the contact strips is limited by lateral bumpstops as shown in Figure 1, which are modelled as nonlinear force elements that develop a resistive force when the element deformation exceeds the gap of the bumpstop.

3 MB Model Validation

The experimental data that is used here to validate the HSX multibody model is obtained from tests performed at Deutsche Bahn (DB) test bench. The full-scale experiments include several tests in which the pantograph head is excited with vertical sinusoidal imposed displacements of varying frequencies and amplitudes. The measured data enables the characterization of the pantograph dynamics defined in the frequency domain. The measured data is post-processed to produce relevant transfer functions for the identification of the pantograph Lumped Mass (LM) model.

One sensible manner to assess the accuracy and validate the MB model is to subject it to the same excitation profile experienced by the HSX pantograph at DB test bench and compare the results. For this purpose, a virtual lab is developed to replicate the HSX experimental conditions, i.e., the head of the numerical model is excited (vertically and laterally) with the same characteristics of the experimental campaign. The accuracy parameter (Q) is used to evaluate the accuracy of MB model in representing the HSX pantograph. This indicator compares the Frequency Response Function (FRF) of numerical and experimental results as defined in the standards [2,3].

The results presented in Figure 2 demonstrate that the HSX MB pantograph model presents values of 99% accuracy when compared to the pantograph dynamic response in the DB test bench in both full range of frequencies [0.2, 22] Hz and low-frequency range [0.5, 5] Hz [1]. This level of accuracy is the same that the LM pantograph model identified by DB exhibits when compared to the experimental tests.

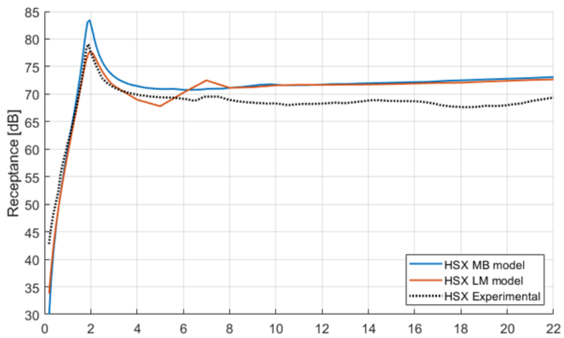

Figure 2: FRF of LM, MB and Experimental Tests

4 Conclusions and Future Developments

This work presents a modelling methodology to create the MB model of a pantograph. The model is adjusted to address the uncertainties associated to the properties of the suspension elements and linking components. A virtual laboratory is used to validate the MB model by comparing its frequency response with the experimental results gathered in a test bench. In this validation exercise, 99% of accuracy is obtained, giving confidence on the MB methodology used here to represent the pantograph. Future work includes computational fluid dynamic studies on the pantograph components in realistic operations conditions and the inclusion of such aerodynamic loads on the pantograph for realistic air flow conditions.

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References

[1] Rebelo J, Santos J, Magalhães H, Antunes P, Pombo J, Mishra R, et al. Contact Wire Heights at Level Crossings - WP3: Pantograph-OCL Dynamic Studies on Level Crossings/Gradients Considering Aerodynamic Effects. Technical Report RSSB (COF-UOH-49): 2022.
[2] EN 50317:2012. Railway Applications - Current Collection Systems - Requirements for and Validation of Measurements of the Dynamic Interaction between Pantograph and Overhead Contact Line 2012.
[3] EN 50318:2018. Railway Applications - Current Collection Systems - Validation of Simulation of the Dynamic Interaction Between Pantograph and Overhead Contact Line 2018.