STUDY ON THE PANTOGRAPH CHARACTERISTICS AFFECTING THE OVERHEAD CONTACT SYSTEM FOR HIGH SPEED TRAINS

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Summary In general the electrical energy is provided to the trainsets by the pantograph-catenary contact. The study of this system is of great interest as it contributes to decrease the number of incidents and the maintenance and interoperability development costs. In this work, a validated computational tool is used to study the pantograph-catenary interaction. For this purpose, several pantograph parameters are varied and the contact force results and the catenary uplift are analysed. The results are evaluated according to the European standards and allow assessing the pantograph parameters whose properties are more important for the performance of the overhead contact system.

INTRODUCTION

The pantograph-catenary system is still the most reliable form of collecting electric energy for running trains. Nevertheless, the interaction between the moving rolling stock and the overhead contact line is one of the factors that limits the operating speed of railway vehicles and, consequently, is one of the research priorities in the railway community. From the mechanical point of view, the most important feature of the pantograph-catenary system consists in the quality of the contact between the contact wire(s) of the catenary and the contact strips of the pantograph. Therefore, the study of this system requires not only the correct modelling of the catenary and of the pantograph, but also a suitable contact model to describe the interaction between them. In this work, a validated computational tool is used to study the pantograph-catenary interaction. The software is composed by two modules, the Finite Element (FE) one is used to describe the catenary and the Multibody (MB) module is applied to represent the pantograph. As the FE and the MB codes use different time integration algorithms, a co-simulation procedure that allows the communication between the modules using shared computer memory and suitable contact force models, is implemented [1-3].

The work presented here aims at enhancing the understanding of the pantograph-catenary interaction phenomena by identifying the key parameters, associated to the pantograph, that affect the contact forces and the catenary uplift. A multibody formulation is used to model the pantograph and the catenary is modelled with a linear finite element methodology. By using a co-simulation procedure the dynamics of the pantograph is effectively coupled with that of the catenary, representing the complete system interaction. The numerical simulations performed here involve varying several pantograph key parameters and compare the results against the ones obtained with the nominal (reference) case. The parameters to be varied are the: i) Mass of the pantograph head (-2 kg, -1 kg and +1 kg) that correspond to the wear of the contact strip and to the modifications required for the pantograph to run in other catenaries; ii) Springs of the pantograph head: (-50% and +100%), which correspond to factors related to operation conditions, maintenance and material degradation, and; iii) Lower damper of the pantograph: (-50% and +100%), corresponding to factors related to usage in service, degradation and lack of maintenance. The analyses are carried out for a high speed train running at 300 km/h. The influence of the modelling parameters on the pantograph-catenary interaction is assessed according to the European standards [4,5]. In this regard, the characteristics of the contact forces, the values of the catenary uplift and the loss of contact events are studied with detail.

PANTOGRAPH-CATENARY ANALYSIS METHODOLOGY

The pantograph considered in this work is the Faiveley CX pantograph, shown in Figure 1, which is used in the French high speed trains. By performing laboratory tests, it is possible to represent the dynamic behaviour of the CX pantograph by the so-called lumped mass model, represented in Figure 1. The mass, stiffness and damping properties of the lumped mass model are obtained experimentally in such a way that its frequency response matches the one of the real pantograph. The pantograph is modelled here using a multibody formulation.

Catenaries are complex periodical structures, such as those presented in Figure 1. Examples of typical structural elements involved in the catenary model are the contact, stitch and messenger wires, droppers and registration arms. The contact wire is the responsible for the contact between catenary and pantograph and, therefore, is the element that provides electrical power. The contact wire is characterized by a small cross-section compared to its length and built in a material with good electrical conductivity and fine mechanical properties such as copper or steel alloys. The messenger wire prevents excessive sag caused by the contact wire weight. Both of these wires are connected by vertical, tensile force elements called droppers. The motion of the catenary is characterized by small rotations and deformations in which the only nonlinear effect is the slacking of the droppers. Therefore, catenaries are typically modelled by using linear finite elements.

The structure of the communication between the multibody and finite element codes is performed based on the shared force information. The compatibility between the two integration algorithms imposes that the state variables of the two subsystems are readily available during the integration time but also that a reliable prediction of the contact forces is also available at any given time step. The key of the synchronization procedure between the codes is the time

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integration, which must be such that it is ensured the correct dynamic analysis of the pantograph-catenary system, including the loss and regain of contact.

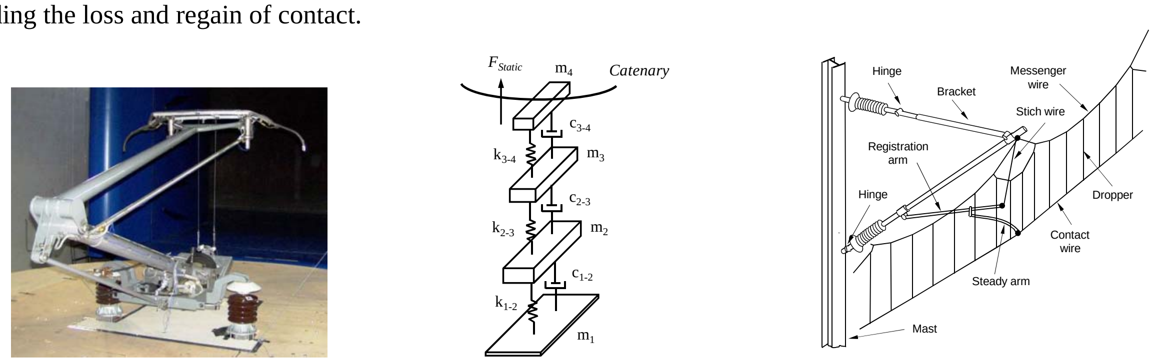

Figure 1: Faiveley CX pantograph; Lumped mass model of CX pantograph; SNCF 25 kV LN2 catenary

PRELIMINARY RESULTS

The pantograph-catenary interaction is studied here in order to assess on how the contact quality is sensitive to the variation of several pantograph components. The methodology adopted consists of changing each parameter at one time and of comparing the results with respect to those of the reference model. The studies are performed for high speed trains running at 300 km/h on a straight track with 1.2 km length.

In order to analyse how the variation of the pantograph head mass influences the pantograph-catenary interaction, the mass of the pantograph head is varied and the results are compared with respect to the ones of the nominal case. The variations considered are -2 kg (6.5 kg), -1 kg (7.5 kg) and +1 kg (9.5 kg), being the nominal value 8.5 kg.

The contact force statistical parameters for the CX-LN2 pair, considering the variations of the pantograph head mass, are depicted in Figure 2. The results show that the increase of the pantograph head mass tends to raise the value of the maximum contact force. In addition, it is observed that the standard deviation increases, deteriorating the contact conditions, and the probability of contact losses grows as a consequence of the lower statistical minima.

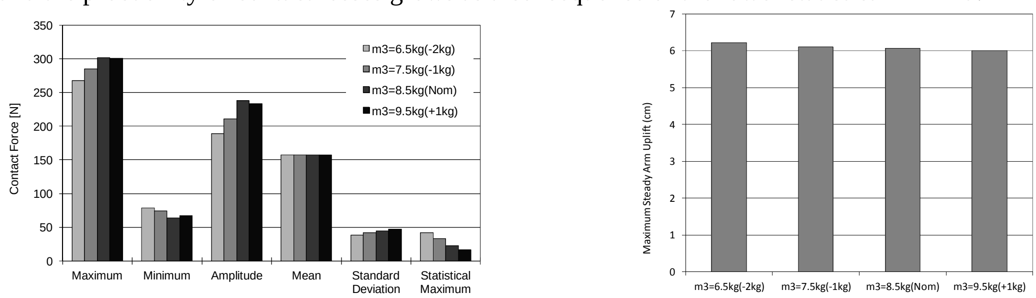

Figure 2: Variation of the pantograph head mass: Statistical parameters; Maximum catenary uplift

Another important parameter that is used to assess the performance of the pantograph-catenary interaction is the catenary uplift. It represents the vertical displacement of the catenary induced by the running pantograph. The maximum values allowed for the catenary uplift depend on the characteristics of the overhead contact system and are defined by the infrastructure managers. For the French LN2 catenary, the maximum value allowed for the contact wire uplift at the supports is 10 cm. The results obtained, depicted in Figure 2, show that the catenary uplift is nearly non-sensitive to the variation of the pantograph head mass. Furthermore, it is observed that the values registered in all studies are quite below the maximum catenary uplift value set by the infrastructure manager.

CONCLUSIONS

The preliminary results obtained show that the increase of the pantograph head mass tends to increase the standard deviation of the contact force, deteriorating the contact conditions, and the probability of contact losses grows as a consequence of the lower statistical minima. The studies of the vertical displacement of the catenary induced by the pantograph show that the values registered are below the maximum catenary uplift set by the infrastructure manager to allow the trainset operation.

References

[1] Ambrósio, J., Pombo, J., Rauter, F. and Pereira, M., "A Memory Based Communication in the Co-Simulation of Multibody and Finite Element Codes for Pantograph-Catenary Interaction Simulation", *Multibody Dynamics*, (Bottasso C.L., Ed.), Springer, Dordrecht, The Netherlands, pp. 211-231, 2008.

[2] Rauter, F., Pombo, J., Ambrósio, J. and Pereira, M., "Multibody Modeling of Pantographs for Catenary-Pantograph Interaction", *IUTAM Symposium on Multiscale Problems in Multibody System Contacts*, (P. Eberhard, (Ed.)), Springer, Dordrecht, The Netherlands, pp. 205-226, 2007.

[3] Rauter, F., Pombo, J., Ambrósio, J., Pereira, M., Bobillot, A. and Chalansonnet, J., "Contact Model for the Pantograph-Catenary Interaction", *JSME International Journal of System Design and Dynamics*, **1**, No. 3, pp. 447-457, 2007.

[4] EN 50318, "Railway applications - Current collection systems - Validation of simulation of the dynamic interaction between pantograph and overhead contact line", 2002.

[5] EN 50367, "Railway applications - Current collection systems - Technical criteria for the interaction between pantograph and overhead line", 2006.