Dynamic Analysis of Pantograph-Catenary Interaction in Curved Railway Tracks

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The modern railway system relies on the cost-effectiveness and reliability of electrical traction vehicles where the pantograph–catenary interface, represented in Fig. 1, ensures the supply of energy to power the vehicles motors. Thus, it is of fundamental importance that this supply of energy remains uninterrupted. The catenary, also known as overhead line, is a structure composed by a set of suspended cable wires and supporting elements that run along the railway track. Its mains function is to carry the electric energy which in turn is collected via sliding contact by the pantograph mounted on the vehicles roof tops.

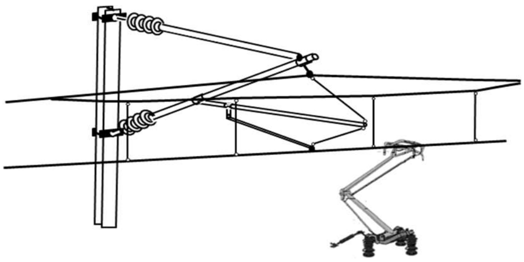

Fig. 1: Representation of railway energy collecting system composed of a catenary and a pantograph.

The contact force developed between the pantograph-catenary interaction is subject to tight requirements in order achieve a reliable and efficient energy collection. Excessively high contact forces avoid contact loss but lead to wear of the contact elements increasing the maintenance periods and risk of failure. On the other hand, operating at a low average contact force may result in contact loss which not only interrupt the energy supply but results in arcing and consequent degradation of the systems components. Moreover, the present need to increase the rail network capacity and its interoperability with other networks put an extra level of demand on these systems where the energy collection remains a limiting factor of the current railway vehicles top speed. Hence, to improve the quality of energy collection, the analysis of the dynamic behaviour of both the pantograph and the catenary as well as their coupling have been object of active research where a number of computer codes for the dynamic analysis of pantograph-catenary interaction have been developed, [1], by several industry and research institutions. These numeric tools have been extensively used not only for research and development purposes but also to aid in virtual homologation and certification. Nevertheless, the simulations until now performed consider exclusively catenaries in straight track rather than considering a more generalised trajectory of the track.

The work here presented purposes an approach for the dynamic analysis of pantograph-catenary interaction in curved tracks. In general, the present computer codes use a finite element based methodology to model the catenary system whereas the pantograph is modelled as a lumped mass system, depicted in Fig. 2 a). Here, the pantograph is modelled after a series of lumped masses interconnected by spring/damper elements where its equations of motion are solved along the catenary finite element solution. Despite its simple topology it represents the dynamic behaviour of a given pantograph with recognised fidelity as its mass, stiffness and damping coefficients are identified through experimental laboratory tests. In this work, due to the more generalized trajectory of the pantograph in curved tracks its formulation needs to be able to handle and provide an absolute spatial definition of the pantograph model. Hence, the pantograph model is here modelled in a three dimensional multibody formulation where also its spatial trajectory in relation to the railway track geometry can be set by a prescribed kinematic motion constraint [2, 3], as represented in Fig. 2 b).

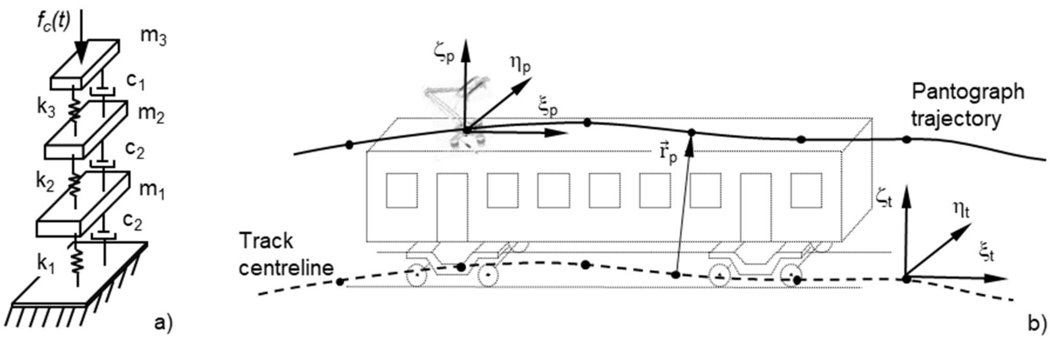

Fig. 2: a) Representation of the pantograph lumped mass multibody model; b)railway energy collecting system composed of a catenary and a pantograph.

Using a multibody formulation, the pantograph can be modelled not only as lumped mass system, [4], but also in a full multibody approach based on design and technical data only [5]. Correspondingly the finite element mesh of the catenary is built according to the considered track geometry. The dynamic analysis of the catenary finite element model is handled by a Newmark family integrator while the multibody pantograph model uses a variable time step and multi-order integrator. To establish the interaction between these models, each with its independent formulation and integration procedure, a co-simulation environment is set, [6]. Here, both codes proceed with their dynamic analysis by sharing state variable data which in turn is used to evaluate the developed contact forces where a penalty formulation is applied.

To demonstrate the proposed approach a set of simulation cases are evaluated for catenary systems on tracks with different radius of curvature and a comparison between the obtained results is presented.

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