Influence of Lateral Flexibility in Rail Pantograph-Catenary on Contact Performance

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EXTENDED ABSTRACT

1 Introduction

Railway catenary systems, also known as overhead equipment, play a crucial role in providing power to trains as they travel on tracks. Recent advancements in technology have enabled researchers to use advanced computational methods, such as finite element analysis and computational fluid dynamics, to simulate and understand how the catenary system behaves under different loading and environmental conditions. Pantograph, that makes contact with the catenary and transfers power to the train, is modeled using either a lumped mass model or a multi-body model [1]. The latter approach allows for a more accurate representation of the pantograph's dynamics, but it comes with the added complexity of requiring co-simulation frameworks [2]. To simplify the modeling process, a lumped mass model is often used, but this approach is limited to modeling vertical dynamics of pantograph as per EN50318:2018. But real-world scenarios can cause lateral deflection due to various factors such as friction on the contact strip, pantograph lateral flexibility, and catenary lateral elasticity. Additionally, wind loads and uneven wear on the contact strip can also contribute to the lateral deflection of the catenary. The simulation of accurate modeling of lateral dynamics helps to understand the behavior and identify potential areas for improvement in the design of the pantograph and catenary system.

2 Methodology

A 3D finite element method is used to represent the catenary elements: Contact wire, Messenger wire and dropper wires as beam elements and its supports as spring-mass or spring-damper systems. In the case of pantograph, a lumped mass model is used. In accordance with the EN50318:2018, the vertical lumped mass modes (p_1, p_2, p_3) have have been extracted. An additional degree-of-freedom (p_4) is introduced to model pantograph lateral flexibility, which is shown in Figure 1. The equivalent lumped mass parameters (k_4, m_4 and c_4) for p_4 are to be tuned from the experimental FRF data.

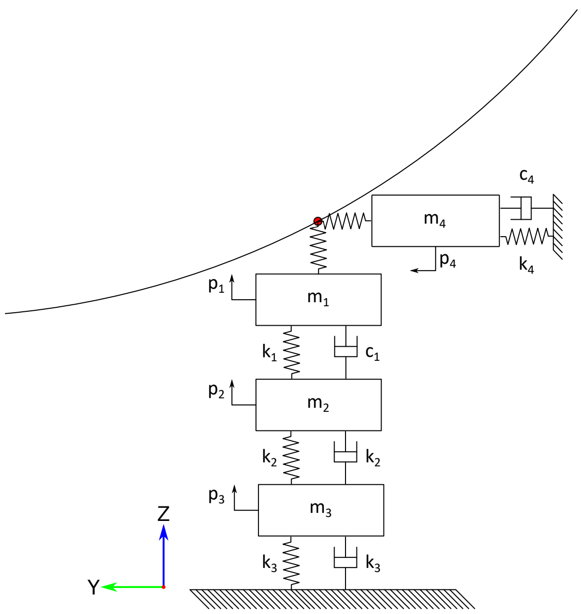


Figure 1: A lumped mass representation of a pantograph

Penalty method is used to model the interaction [2]. At time $t = 0$, initial contact is established until the desired contact force is achieved. For further dynamic iterations, Newmark implicit integration scheme is used to integrate the dynamic equations of motion as shown in Figure 2

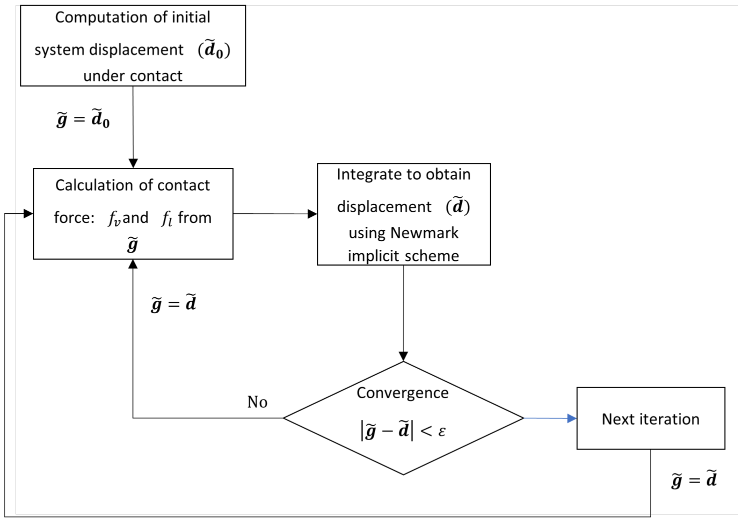
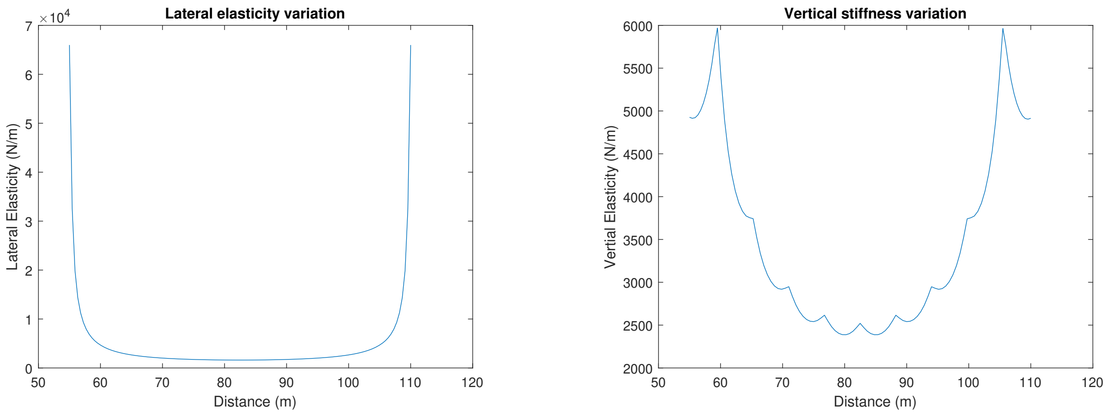


Figure 2: Flowchart showing numerical integration of PC system

The variation in elasticity along a catenary span has a crucial impact on fluctuations in contact force. The vertical elasticity (Figure 3b) results have been validated with benchmark results [3-4]. As shown Figure 3a, there is a significant fluctuation in lateral elasticity with a maximum of 65E+3 and a minimum of 1.6E+3, making it essential to take these fluctuations into account during pantograph-catenary interaction design.



(a) Lateral elasticity

(b) Vertical elasticity

Figure 3: Elastic variation of catenary

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References

[1] Antunes, Pedro, et al. "A new methodology to study the pantograph–catenary dynamics in curved railway tracks." Vehicle System Dynamics (2019).

[2] Ambrósio, Jorge, et al. "A memory based communication in the co-simulation of multibody and finite element codes for pantograph-catenary interaction simulation." Multibody Dynamics: Computational Methods and Applications (2009): 231-252.

[3] Bruni, Stefano, et al. "The results of the pantograph–catenary interaction benchmark." Vehicle System Dynamics 53.3 (2015): 412-435.

[4] EN50318, Railway applications. Current collection systems. Validation of simulation of the dynamic interaction between pantograph and overhead contact line, 2018.