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STUDY OF THE DERAILMENT POTENTIAL OF RAILWAY VEHICLES SUBJECT TO CYCLIC TOP IRREGULARITIES

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Summary: Railway vehicles are subject to dynamic excitation due to their interaction with the track. However, certain combinations of vehicle design, loading conditions, operational speeds, and track irregularities can amplify specific vibration modes, leading to safety concerns. One critical issue is the cyclic top phenomenon, a periodic longitudinal track irregularity that excites vehicle bounce and pitch modes, potentially causing excessive wheel unloading and derailment. Although historically associated with jointed track sections, cyclic top remains a frequent cause of derailments. Notably, this particular type of longitudinal level track irregularity is not covered by the standards that govern the limits on the vehicle behaviour, nor is there a well-established method for its identification in the literature. This study aims to characterise the vehicle, track, and operational conditions that increase the derailment potential due to cyclic top.

Seemingly, the problem of cyclic top can be addressed by performing the modal analysis of simple, linearised models of railway vehicles. However, railway vehicles in general, and railway freight wagons in particular, often feature suspension designs that involve nonlinear stiffnesses, load-dependent friction damping mechanisms, and local clearances and impacts that motivate a highly nonlinear vehicle behaviour. Therefore, the dynamic analysis of the vehicles in the time domain, using the multibody formulation with a detailed description of the wheel-rail contact is necessary. The derailment risk is assessed using key derailment indicators: the ratio between the lateral and vertical wheel-rail contact forces Y/Q; and the wheel unloading ΔQ/Q0, given by the ratio between the variation of the vertical wheel load relative to the static vertical force ΔQ = Q-Q0 and the static vertical force Q0. A comprehensive set of simulations is performed for two freight vehicles—a two-bogie wagon and a three-bogie articulated wagon—under varying track and operational conditions, with both real and synthetic track data used to model railway track irregularities. Preliminary results suggest that a strategy to minimise the potential for derailment due to cyclic top must be twofold, by ensuring the accurate knowledge and management of both the vehicle loading conditions and the track geometry. Future work will focus on developing a novel algorithm for the geometrical conditions for cyclic top based solely on track irregularity data.

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