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Comparing train running safety using longitudinal train dynamics and multibody simulations

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Most of the railway lines in European countries are electrified, which makes railway transportation more eco-friendly when compared to road transportation. Nonetheless, while increasing running speeds and hauled loads could improve the attractiveness and competitiveness of the railway system for freight transportation, this brings several con-cerns in terms of running safety. It is well known from the literature that due to the delays in the air brake system, longitudinal compressive forces (LCFs) are generated between consecutive vehicles during braking operations, with possible generation of lateral force components that increase the risk of derailment during curve negotiation.
The IRS40421 [1] defines a statistical method to assess the safety of new freight trains based on the values of LCFs, which can be obtained from longitudinal train dynamics (LTD) simulations. The latter consider a train as a system of lumped masses, each one with a single degree of freedom (DOF) along the track curvilinear abscissa. On the other hand, the EN14363 standard [2] defines different safety indexes that derive from the lat-eral and vertical wheel-rail contact forces, which can be calculated from multibody (MB) simulations of individual vehicles/small groups of vehicles.
The objective of the present paper is to assess the running safety of trains during air brake operations on curved track sections with the two methods, comparing the results and investigating whether the IRS40421 is indeed more conservative.
To achieve the objectives of the work, a computational framework is built to simulate the running dynamics during stop braking operations characterized by a high derailment risk. All simulations consider a reference train with a head locomotive trailing 40 wagons. In the train composition, all wagons have the same length (18 m) and axle-load (22.5 ton), except for the 3 wagons in the middle. The axle-load of the wagons in the middle trio are changed so that the middle wagon is always the lightest in the composition: on this light wagon, the highest derailment risk occurs. The main simulation parameters are sampled via a Latin hypercube sampling (LHS), to test a wide range of possible configuration of the space of the input parameters.
For each configuration, a preliminary LTD simulation is run using a dedicated ver-sion of the TrainDy code developed at the Tor Vergata University, which is the reference code approved by the UIC for the LTD calculation with classic air brake system. The out-puts of the TrainDy LTD simulation include the position and speed evolution of each wagon in the train as well as the values of the in-train forces. Therefore, with these values, it is possible to calculate the LCFs and compare them with the permissible values, thus assessing the running safety according to the prescriptions of the IRS 40421.
After running the TrainDy simulation, for each configuration, an MB simulation is run for the wagons in the central trio. The MB model of the wagon trio is built starting from a well-established model of the Y25 bogie, developed by the railway research group from Politecnico di Torino in past activities and implemented in SIMPACK. The results of each MB simulation include the safety indexes defined by the EN14363 standard on all wheels of the middle wagon of the trio. These include the derailment ratio, the unloading ratio and the sum of the guiding forces. Therefore, it is possible to compare these values against the limits defined in the EN14363 standard and identify the running safety of the middle wagon with higher accuracy, based on the values of the wheel-rail contact forces.
The results obtained for all input configurations are grouped into the following main categories, where Positive/Negative means that the train is considered safe/unsafe and the first word is for the IRS4041, while the second refers to the EN14363:
1. Positive-Positive.
2. Positive-Negative.
3. Negative-Positive.
4. Negative-Negative.

The results show that in most cases, the two methods are in good agreement (either condition 1 or 4 is obtained), while the number of discrepancies is limited. Please note that condition 2 is the most undesirable, as the method in the IRS40421 is conceived to be more conservative with respect to EN14363.

Work is still needed to investigate whether the criteria of IRS40421 should be modi-fied to ensure higher safety levels, as cases falling into category 2 are undesired.

References

1. IRS 40421:2021. Rules for the consist and braking of international freight trains: new IRS 40421.
2. EN 14363:2016. Railway applications - Testing and Simulation for the acceptance of running characteristics of railway vehicles - Running Behaviour and stationary tests.

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Classifica Sessioni: Progettazione Meccanica

Classificazione della track: Progettazione Meccanica