RAIL VEHICLE RESPONSE TO CARBODY EXCITATIONS IMITATING CROSSWIND

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Summary Field tests to measure vehicle response to crosswind are not practicable, which calls for the use of simulations. This study presents results of measured and simulated dynamic responses of a still-standing rail vehicle to defined lateral carbody excitations imitating unsteady crosswind. Responses are evaluated in terms of vehicle suspension deflections, lateral carbody accelerations and vertical wheel-rail forces. Measurements and simulation results in general show good agreement.

INTRODUCTION

Crosswind stability of rail vehicles has been an active research area in recent decades, mostly motivated by accidents, lighter and longer vehicles as well as faster operational speed. The research has resulted in a number of publications, see [1] for example, where the majority is connected to the field of aerodynamics. In addition, crosswind stability is a design criterion for rail vehicles, prescribed by standards and laws, for example [2], where unsteady crosswind is also taken into account. Since repeatable field tests including crosswind, and in particular unsteady crosswind, are not practicable due to safety and economical reasons as well as the unpredictability of gusts in nature, reliable simulation tools and methodologies are necessary to gather information on vehicle dynamics and responses of rail vehicles due to crosswind. However, the simulation models need to be validated. Due to the complexity of rail vehicles and nonlinear components, such as airsprings, for example, the demands on multibody simulation models that are able to simulate the reaction on high wind loads are not clear today.

Previous studies by the authors showed good agreements of measured and simulated vehicle responses at large deflections in the secondary suspension due to quasi-static lateral loads and track irregularities during curve negotiation, but also that unsteady wind loads with short rising times of the gusts represent high impacts on the vehicle [3, 4]. However, vehicle responses to crosswind under defined conditions in open field without disturbing influences from the track, for example, are not easy to determine. Therefore, full-scale experiments are performed in this study, where the carbody of a still-standing rail vehicle is loaded with unsteady lateral loads in order to imitate crosswind loads. The vehicle response is measured and compared with results of multibody simulations.

FULL-SCALE EXPERIMENTS AND MULTIBODY SIMULATIONS

The full-scale experiments are performed using a still-standing single car of an electric multiple unit (EMU). The carbody is loaded laterally by two hydraulic actuators, one situated at each bogie, see Figure 1. This allows for the possibility to introduce both lateral and yaw motions, depending on the steering of the actuators. In order to imitate crosswind, the loads should be applied at a certain height above the track, corresponding to an artificial centre of pressure of aerodynamic loads. However, concentrated loads cannot be introduced to the carbody at such a height without damage. Therefore, auxiliary steel frames are mounted underneath the carbody and used for force transmission from the actuators to the carbody. The applied forces are measured by load cells, located between the actuator cylinder and the auxiliary frame. The vehicle response is measured by recording the lateral displacement between the bogie frames and the carbody, the roll angle between one bogie frame and the carbody and lateral accelerations on the carbody floor above the bogies. In addition, one bogie is situated on scales, recording the vertical wheel-rail forces on both wheelsets of the bogie.

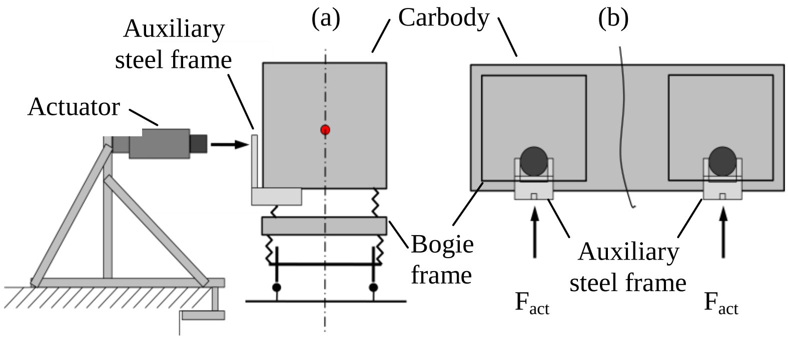

Figure 1: Schematic experimental setup, (a) rear view, (b) top view.

Multibody simulations are performed with the commercial MBS-code SIMPACK [5], using a MBS-model of the EMU used for the full-scale experiments in order to reflect the measured vehicle responses. The model consists of 46 rigid bodies and 124 degrees of freedom. The loads are applied laterally to the modelled auxiliary steel frames, which are connected to the carbody of the model, as time series of the measured forces from the experiments. In order to represent the flexibility of the vertical beam at the auxiliary steel frames used in the experiments, a stiffness is modelled in series to the applied forces. The vehicle response is evaluated through the same quantities as in the experiments.

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VEHICLE RESPONSE TO LATERAL CARBODY LOADS

Two load cases are defined to study the vehicle dynamic response, both represent a certain mean wind that is superposed by a sudden gust. In a *symmetric* load case the carbody is loaded symmetrically by the two actuators. First a certain force level is held to represent a mean wind, then a sudden gust is achieved by tripling the force demand of the actuator within one second. In an *asymmetric* load case the actuators provide different loads causing the carbody to yaw. This scenario is chosen after the "simple artificial gust" used in [4] and shall represent a vehicle passing through a gust with a changing wind yaw angle during mean wind and gust. In this short paper, the focus is on results for the asymmetric load case, presented in Figure 2.

Figure 2a shows relative lateral deflection between bogie frames and the carbody. By comparing the lateral deflections at both bogies, it is seen that a yaw angle is introduced to the carbody. The simulated lateral deflection at bogie 2 is somewhat overestimated compared to the measured one. Figure 2a also illustrates the relative roll angle between bogie 2 and the carbody, showing both measured and simulated overshooting at the beginning of the gust. The measurements include a slightly more high-frequent content compared to the simulations.

In Figure 2b, lateral accelerations on the carbody floor above the bogies are shown. The accelerations above both bogies are almost similar, and a good agreement between measurements and the simulations can be observed.

For the vertical wheel-rail forces in Figure 2c, presented as load transfer between both wheels of a wheelset, an overshooting effect can also be seen, which corresponds to the relative roll angle, compare Figure 2a. Also note that the two wheelsets have almost identical response. Like in Figure 2a and 2b, the simulated responses show some oscillations after the gust-like event, which is less pronounced in the measurements.

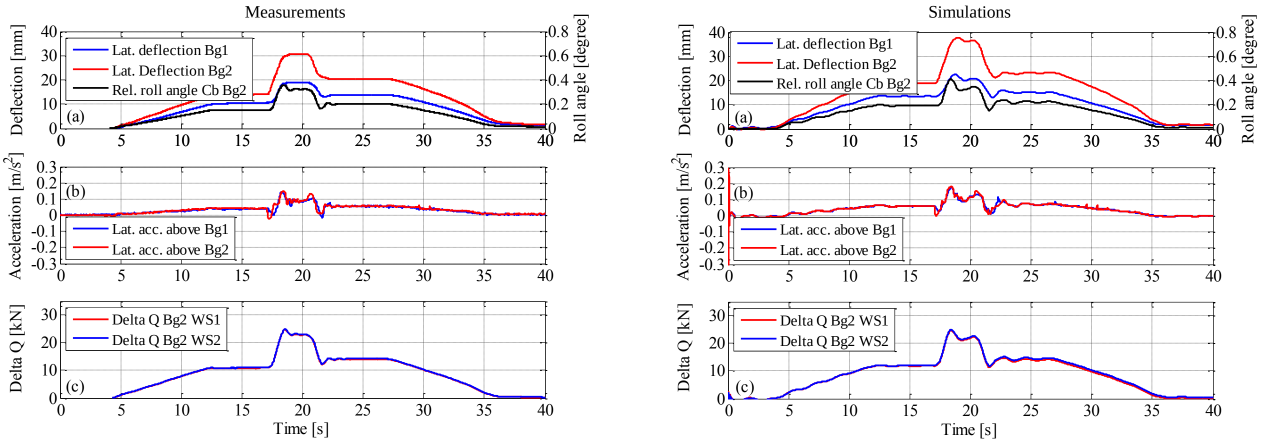

Figure 2: Measured and simulated vehicle responses to asymmetric load case: (a) relative lateral suspension deflections between bogie frames and carbody, relative roll angle between carbody and bogie 2, (b) lateral accelerations on carbody floor above bogies, (c) difference in vertical wheel-rail forces on wheelsets of bogie 2.

CONCLUSIONS

In this study, the dynamic responses of a still-standing rail vehicle due to lateral carbody excitations imitating unsteady crosswind have been investigated by means of full-scale measurements and multibody simulations. The lateral excitations consisted of two load cases, introducing symmetric respectively asymmetric loads to the carbody. The measurements and simulations in general show good agreement, with a smaller overestimation of the response quantities by the simulations. The introduction of a gust-like event in the force application results in a carbody roll response that produces an overshoot in the wheel unloading, which is present in both cases and represents the maximum wheel unloading. The introduction of a yaw angle to the vehicle, in order to represent a wind yaw angle, before and during the gust-like event results in a less pronounced roll response of the carbody, but nevertheless in high load transfer between the wheels of both wheelsets due to the lateral suspension deflection caused by the yaw angle. Airspring levelling, which is not included in the simulation model, influences the vehicle response and should thus be included in the model. In addition, the stiffness and damping in the suspension of the model should be adjusted.

References

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