Mitteilung

Fachgruppe: Aerodynamik bodengebundener Fahrzeuge

Investigation of the Tunnel Passage of Coupled Trains

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The aerodynamic drag experienced by trains in tunnels is significantly higher than in open space. This applies in particular to new single-track, twin-tube tunnels with a relatively narrow cross-section. A special situation arises when two trains pass through a tunnel relatively close together, as is the case with virtually coupled trains. This raises the question of how the aerodynamic resistance of the two train sections compares with that of directly coupled train sections or a uniform single train of the same length.

In the first step, the aerodynamic drag caused by the coupling point between two train sections during tunnel travel will be analyzed in more detail. The tests are carried on a 1:25 scale ICE3 model in the Tunnel Simulation Facility Göttingen (TSG). In this facility, the train models are accelerated using a catapult and then travel along a rail track through a model tunnel due to inertia.

Figure 1: Left: Coupling point of the original ICE3. Right: Model of a coupled ICE3 at the entrance of the model tunnel in the TSG facility.

Figure 1 (left) shows a photograph of the ICE3 coupling point. On the right-hand side, the test model is shown at the entrance of the model tunnel. The model has a length of about 2.5 m (62.5 m in full scale). It consists of two carriages, with the ICE3 coupling point reproduced between them. The head of the model has a generic geometry. The rear complies with the shape of an ICE3 head. Converted to full scale, the model tunnel has a cross-sectional area of 44 m² and a length of 400 m. The relatively small cross-sectional area corresponds approximately to the new Koramltunnel in Austria, which is due to open in 2026.

Pressure sensors are installed at several locations in the side wall of the tunnel. In addition, there are light barriers in front of and behind the tunnel to determine the speed of the model. The model also incorporates a data acquisition unit and various sensors. The surface pressure and the pressure drop across the coupling point are measured onboard. The position of the model is simultaneously recorded by an optical sensor.

Parallel to the measurements, the passage of the train model through the tunnel is simulated numerically using a quasi-one-dimensional model of both the flow and the pressure waves in the tunnel. This model requires empirical parameters to describe friction losses. These parameters are adjusted so that at a position of 3 m in the model tunnel (75 m in full scale) the calculated and measured variations in wall pressure match as closely as possible. The calculation model is calibrated against the wall pressure at this point.

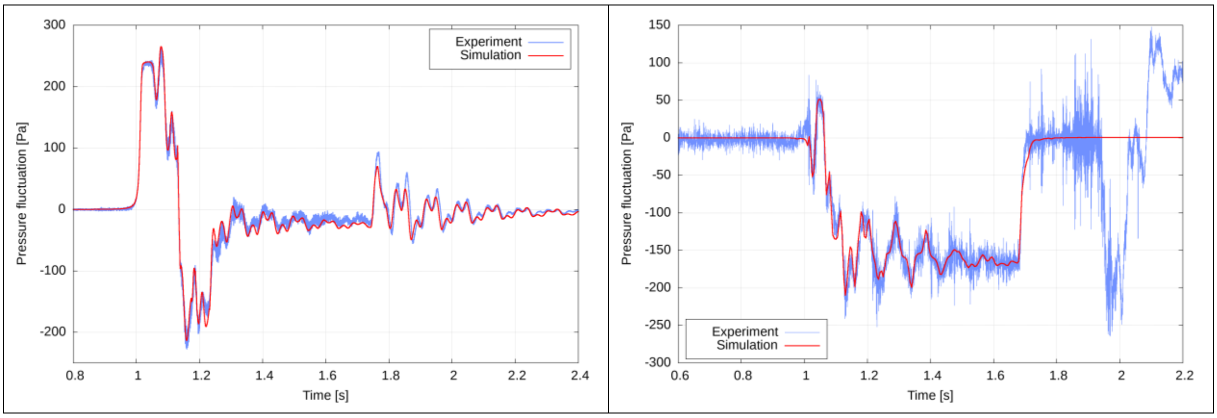

Figure 2: Left: Measured and calculated pressure at the tunnel wall, 3 m inside the model tunnel. Right: Measured and calculated pressure at the side of the first carriage of the model train (approx. 0.4 m behind the nose).

Figure 2 (left) shows a comparison of the pressure curve measured at the 3 m point (75 m full scale) with the calculated curve. The right side of Figure 2 shows the pressure at the outer wall of the first carriage. The model speed is 23 m/s. The nose enters the tunnel at about t = 1 s. The tail leaves the tunnel at t = 1.75 s. The figures show a good agreement between the calculated results and the measured data. It should be noted that the calculation was calibrated against the measured curve on the left-hand side of Figure 2 only. The good agreement between the curves on the right-hand side of Figure 2 demonstrates that the numerical method accurately captures pressure fluctuations throughout the tunnel, not just at the calibration point. Of course, quasi-one-dimensional modeling cannot describe all effects. For example, the noise in the measurement data in the curve on the right-hand side of Figure 2 is caused by the turbulent boundary layer on the outer skin of the train model. Turbulence effects are not included in the calculation model. At around t = 1.8 s, the train model smashes into a bed of polystyrene beads and decelerates. This leads to strong fluctuations in the measured surface pressure, which of course are not present in the calculations.

The calibrated calculation model can now be used to determine the additional resistance caused by the coupling point compared to a single uniform train. In terms of resistance, the directly coupled train can then also be compared with configurations in which two train sections are not directly coupled, but travel through the tunnel at a relatively close distance (virtual coupling).