Mitteilung

Fachgruppe: Aerodynamik bodengebundener Fahrzeuge

Investigating extreme crosswind-stability of vehicles on bridges: applying a moving-model and side wind-tunnel methodology with full-scale validation

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A multi-disciplinary approach – combining wind engineering and vehicle aerodynamics – is being developed for investigations into the stability of vehicles operating in extreme cross-wind conditions. In this case, heavy vehicles travelling over a 56m high bridge across a Norwegian fjord that could encounter wind gusts of up to 40m/s. Potential changes to the climate and weather conditions could result in increased occurrence of extreme wind events, in addition to ever increasing road usage and infrastructure development. Crosswind exposure and vehicle-infrastructure interaction are inherently transient, non-statistically stationary aerodynamic events that require novel scaled experimental methodologies and full-scale measurements for realistic, representative aerodynamic investigations.

In this work, a new configuration of the moving-model facility in DLR Göttingen is presented. Originally intended for high-speed-train and tunnel interaction, the test-section has been modified to include a 1:15 scale model of the Lysefjord Bridge, and a generic truck model within the side-wind tunnel jet (Fig. 1). Previous work on passenger automotive-vehicle crosswind-stability over flat-ground in the facility [1] has identified transient characteristics (not able to be modelled in traditional, quasi-steady wind-tunnel experiments), as well as agreeable validation with full-scale measurements in BMW Aschheim side-wind facility [1]. Here, the scaled moving-model experiments are validated against novel full-scale measurements taken by the University of Stavanger on the Lysefjord bridge, where surface pressure and ultrasonic anemometers measure real-world aerodynamic characteristics [2-5]. The scaled moving-model wind-tunnel area will be tuned in an attempt to represent the oncoming and local flow (magnitude, turbulence intensity and length-scales, frequency spectra and gust profiles) experienced by the bridge (and to which the vehicle is exposed to), as well as their effects: transient surface pressure on the bridge. Additional, real-world validation is planned, with measurements on an operational truck loaded with the DLR FR8-LAB – a measurement equipped shipping container [6]. Transient pressures and inferred global forces can be compared to measurements made on-board the scaled moving-model truck in the experiments.

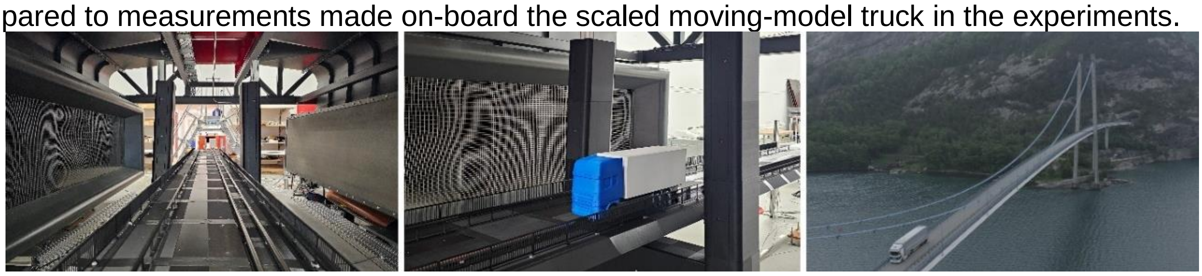

Figure 1: Left : Wind-tunnel setup:1 :15 model of Lysefjord bridge, towers, railing and (center) generic truck, and (right) the real Lysefjord bridge in Norway.

Surface-pressure measurements on the 1:15 scale moving-model (MM) results at 10m/s wind velocity (Reynolds number, based on bridge width, $Re_W=5.5x10^5$) show reasonable comparison to the full-scale (FS) bridge from a 1 hour sample with moderate winds of 10m/s ($Re_W=8.2x10^6$). These results are presented as vectors of normalized pressure, C_P, in Figure 2. A difference is the pressure on the lower windward surface, which is C_P~0.5 for MM and C_P~-0.4 for FS. This is proposed to be due to the minor angle of attack in the natural wind. The real bridge also exhibits wider variability due to natural wind fluctuations; to explore this, different windowed-averages and filters were applied. The fluctuating pressure and velocity characteristics: standard deviation, transient signals and spectra have also been compared.

The transient surface pressure experienced by the bridge during crosswind exposure and as the moving vehicle (20m/s, $Re_W=2.3x10^5$, where a full-scale truck at 50km/h ~$Re_W=2.4x10^6$) passes over the pressure measurement-position is presented in Figure 3. With C_P calculated using the vehicle speed, wind speed and resultant, ($C_{P,V}$, $C_{P,W}$ & $C_{P,R}$). The moving vehicle generates a clear high pressure, then low pressure and then flucutations in its wake; clearly visible with no crosswind (Fig 3a). During crosswind, the pressure at the windward (B1), leeward (B12) and upper surface (B15) exhibit different characteristics (Fig 3b). The bridge during crosswind and vehicle passing exhibit signs of both (Fig. 3c), however, not with simple superposition, indicating complex interaction. Transient pressures on the moving-truck (Fig. 4) show clear the acceleration of the model, complex, unsteady interaction with the crosswind (t=1.3-1.5s), as well as local effects of the bridges vertical towers (t=1.4s).

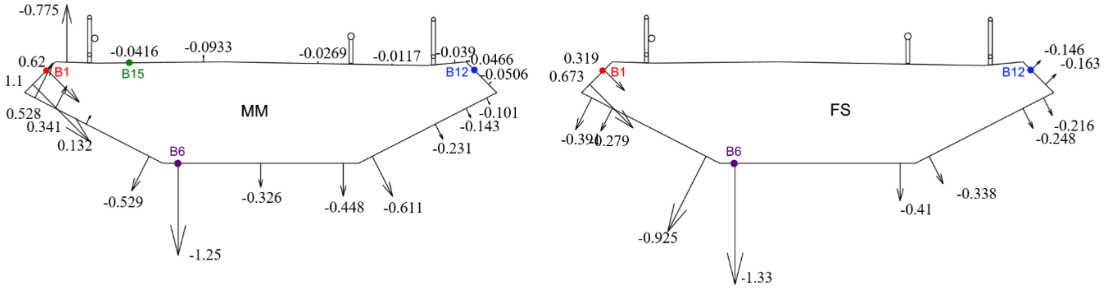

Figure 2: Average pressure (C_P) on moving-model-bridge MM, and full-scale-bridge (FS).

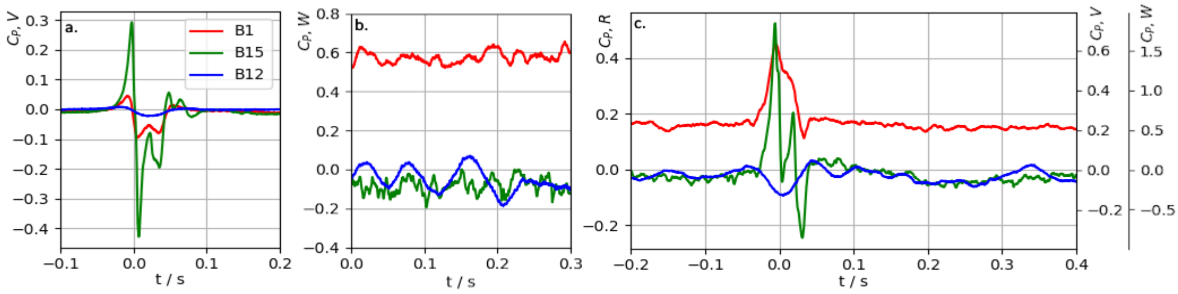

Figure 3: Transient surface-pressure from the bridge with a. a moving vehicle (20m/s, $Re_W=2.3x10^5$) with no crosswind, b. during crosswind (12m/s), and c. moving vehicle (20m/s) with crosswind (12m/s).

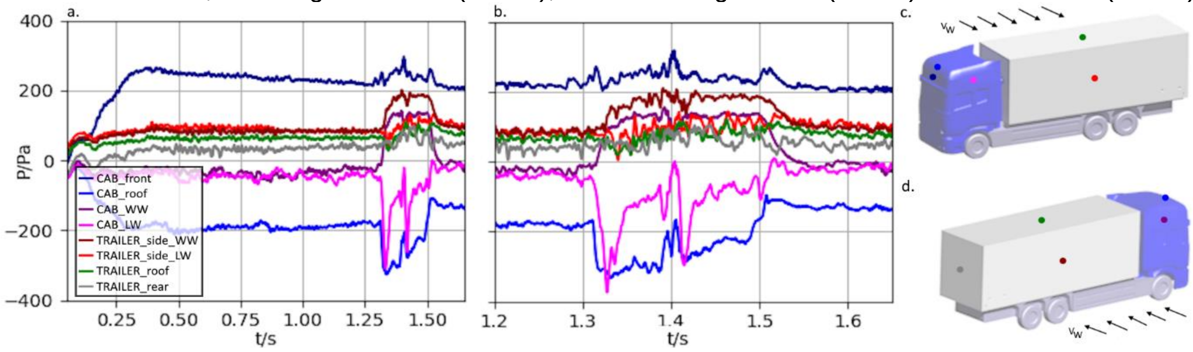

Figure 4: Transient surface-pressure on the moving truck (27m/s) during a. the entire run, b. crosswind (V_W = 10m/s) section, at c. leeward (LW) and d. windward (WW) locations.

This work demonstrates the functionality of the novel methodology with encouraging comparison to full scale results. Future work is planned for further optimisation, and additional variability (e.g. turbulence, yaw/pitch of oncoming flow) and subsequent optimization and assessment of bridge geometry and infrastructure effects such as towers, as well as engineering solutions like wind fences, and safety operational guidelines.

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