Moving-Model Analysis of the Transient Crosswind Stability of High-Speed Trains

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Crosswind Stability is a safety consideration for the operation of a HST**:** it is how stable the train is (how likely is it to de-rail) when exposed to crosswind.

Train + crosswind → 3D flow field → asymmetric pressure distribution → forces / moments

can take time to develop & varies over space and time

Potentially, a **difference in predicted forces & moments** exists between a steady or transient interaction between the train and the crosswind.

- **Steady**: the entire vehicle experiences a constant, steady crosswind
  Modelled in wind-tunnel experiments with stationary yawed models / steady computer simulations
- **Transient**: the vehicle gradually experiences a transient crosswind
  Modelled in moving-model experiments with crosswind / complex transient computer simulations

There is therefore clear motivation to **improve understanding** of transient crosswind-stability of HSTs, which could potentially result in more **accurate predictions** of a HSTs crosswind stability characteristics.

An **On-Board Data Acquisition** was developed to measure **time-resolved surface pressure** on the moving-model to investigate the effect of crosswind on the HST. This system consisted of: a *Teensy 3.6* Micro-controller, microSD card, 24 *Freescale* ±7kPa differential-pressure transducers (Fig 4a), phototransistor (Fig 4b) measuring LEDs in the track, and an accelerometer (Fig 4c). These initial results demonstrate the **successful functionality of the system** with acceptable operation quality (14bit, 3.5kHz, noise~10) under challenging test conditions due to high accelerations and vibrations.

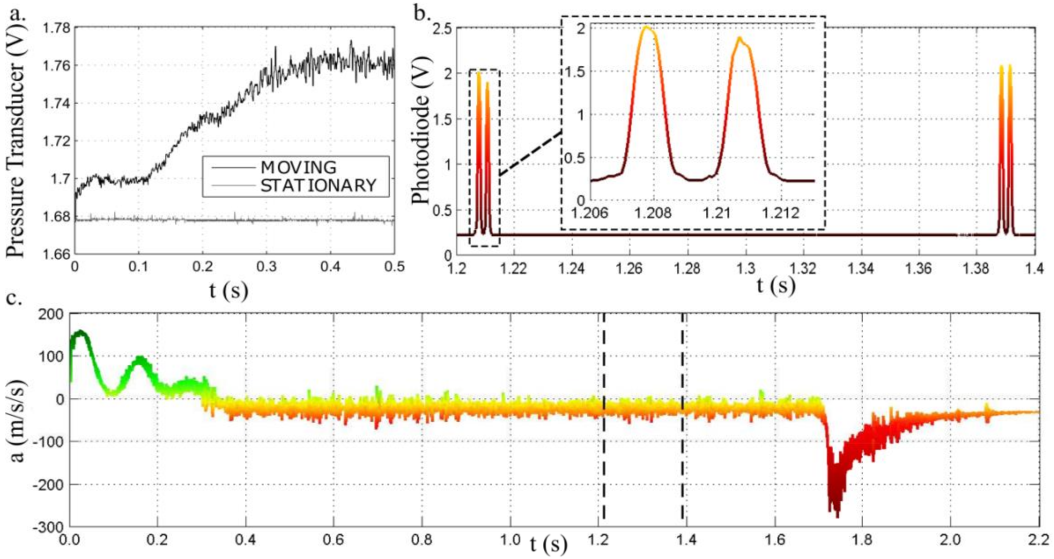

Figure 4: DAQ system functionality: a. pressure, b. phototransistor, c. accelerometer

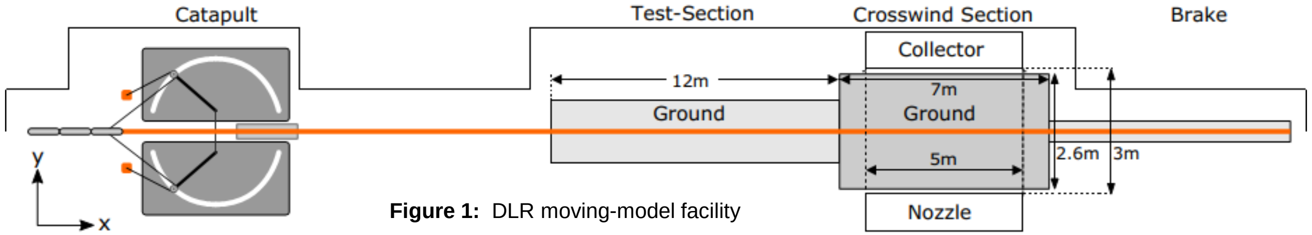

Figure 1: DLR moving-model facility

The **Moving-Model Facility** at DLR Göttingen is used to accelerate reduced-scaled models using a hydro-pneumatic catapult mechanism up to speeds of u_t=70m/s. The models freely move on rails through the test-section and are then decelerated in a tank of polystyrene balls. This facility can be used to assess a HSTs **slipstream, head & micro pressure-pulse** and ultimately in the future, **drag** and **crosswind**.

A **1:25th scale ICE3** (Siemens Velaro) moving-model was used with wheels rotating on rails, modelling the correct ground-vehicle relative motion. This model has existing crosswind-stability reference data and CAD geometry available.

The **Crosswind Module** generates side winds with a wind-tunnel which has 4 , 30 kW fans. The moving-model passes through v_{cw}=10-25m/s (β=0-45º) wind experiencing a transient, unsteady exposure to the crosswind.

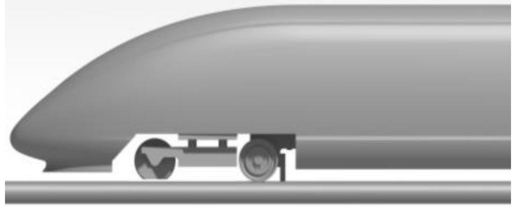

Figure 2: ICE3 HST reference model

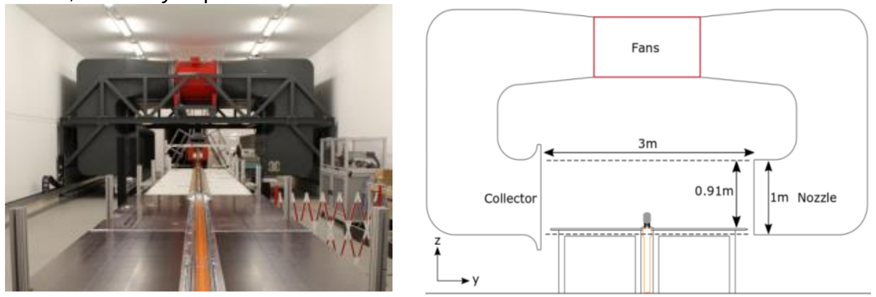

Figure 3: Crosswind module - wind-tunnel that the moving-model passes through

Transient-Pressure Results from initial measurements during the passage through the crosswind section at the **windward (WW)** and **leeward (LW)** side (illustrated in Fig. 5) of the train's nose are presented in Fig. 6; with a model speed of u_t=32m/s, and crosswind (90º to moving-model path) of v_{cw}=18.5m/s (effective yaw angle of β~30º). During exposure to the crosswind, the **WW** side quickly (Δt=0.02s) exhibits an increase in pressure of C_P~0.9 as expected. In contrast, the pressure at the **LW** side decreases to C_P~-1.4 also as expected, but at a slower rate (Δt=0.07s). These initial results indicate **sensitivity to unsteady crosswind** modelling which will be further investigated.

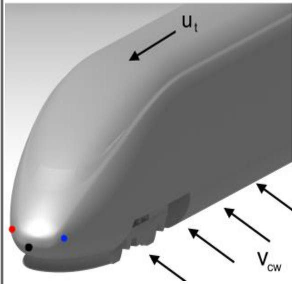

Figure 5: Pressure tap locations

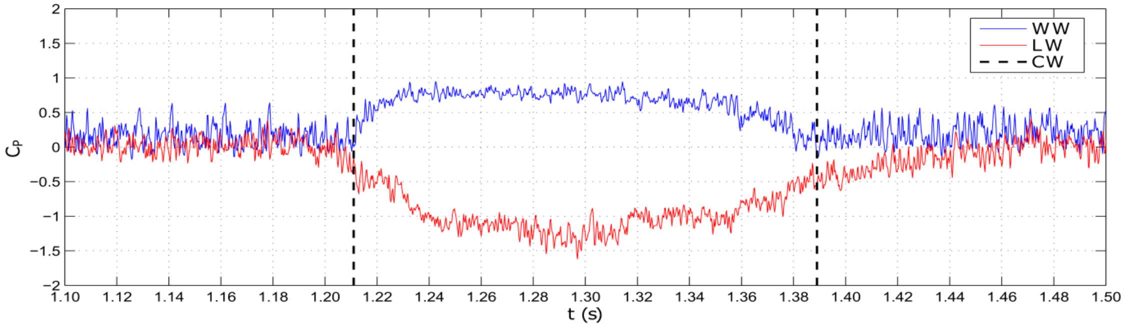

Figure 6: Transient pressure during exposure to crosswind

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