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

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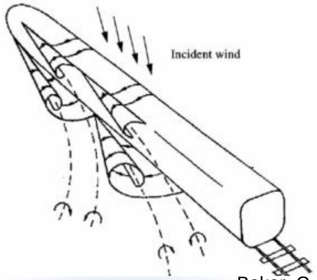
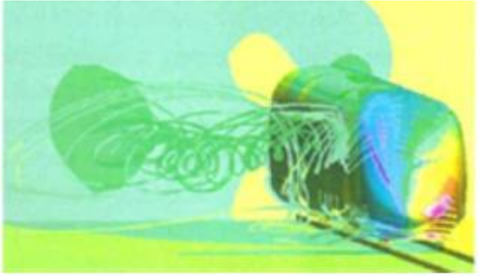
Crosswind stability is a **safety consideration** for the operation of a high-speed train (HST)**:** how stable it is (how likely is it to de-rail) when exposed to crosswind.

This is a greater consideration for light-weight HSTs.

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

can take time to develop, varies over space & time





Baker, C., Cheli, F., Orellano, A., Paradot, N., Proppe, C., Rocchi, D., (2009) Cross-wind effects on road and rail vehicles, Vehicle System Dynamics, 47:8, 983-1022

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

- **Steady**: wind-tunnel experiment with stationary yawed models / steady computer simulations
- **Transient**: moving-model experiments with crosswind / complex transient computer simulations

Clear motivation to:

- **improve understanding** of transient crosswind stability
- potentially develop more **accurate predictions** of a HSTs crosswind stability characteristics.

DLR

Moving-Model Facility

The **moving-model facility** at DLR Göttingen is used to accelerate reduced-scaled models using a hydro-pneumatic catapult mechanism. The models freely move on rails through the test-section and are then decelerated in a tank of polystyrene balls.

- Model speeds of u_t=70m/s
- Scales ~1:25

This facility can be used to assess a HSTs:

- Slipstream
- head & micro pressure-pulse

the future:

- Drag
- **Crosswind stability**

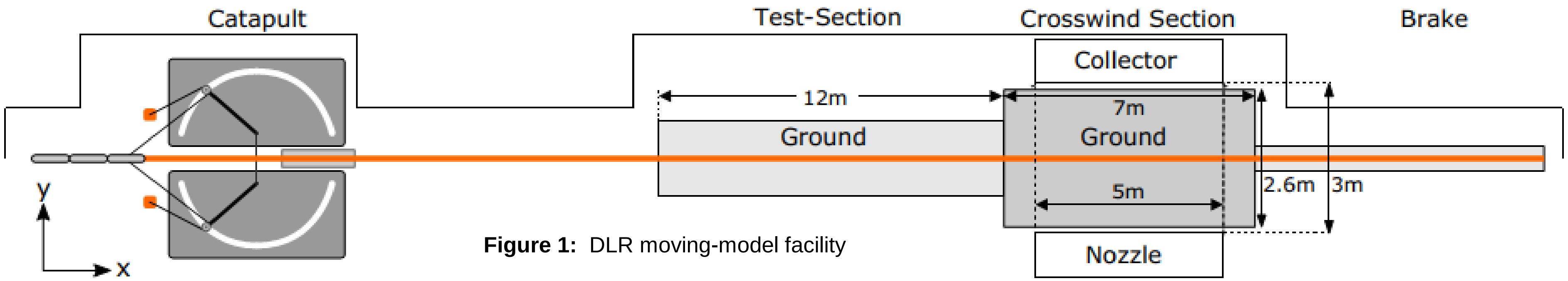


Figure 1: DLR moving-model facility

The **crosswind module** generates side winds with a wind-tunnel which the moving-model passes through

- v_{cw}=10-25m/s (β=0-45º)
- 4 x 30 kW fans.

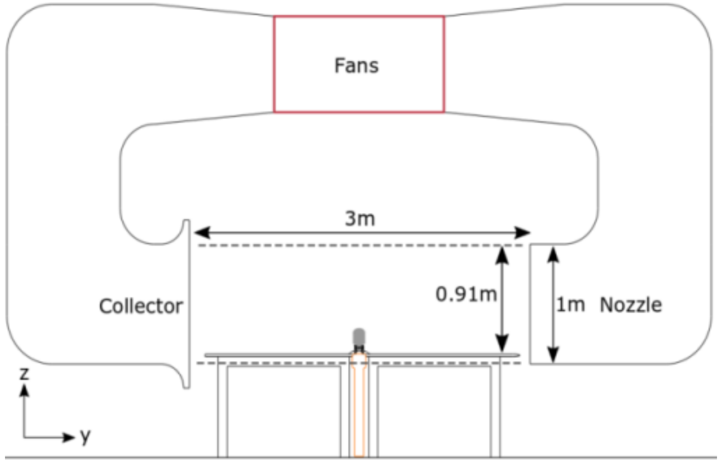


Figure 2: Crosswind modul: wind-tunnel that the moving-model passes through

Experimental model: **ICE3** (Siemens Velaro)

- 1:25th scale
- wheels rotating on rails
- correct ground-vehicle relative motion
- existing crosswind-stability reference data
- CAD geometry available

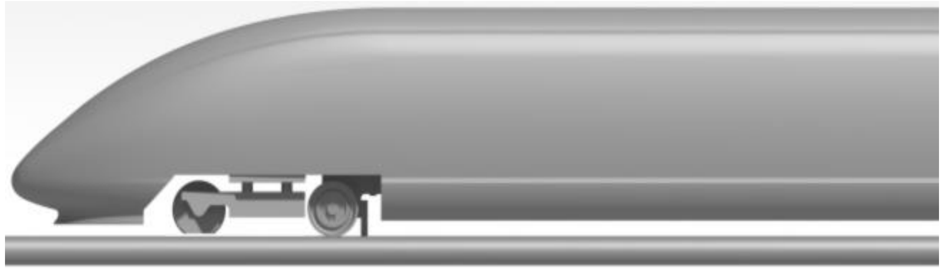


Figure 3: ICE3 HST reference model

On-Board Data Acquisition Functionality

A new system on-board data acquisition (DAQ) was developed to investigate the effect of crosswind on the HST
System **successful functionality of the system** operate under challenging test conditions due to high accelerations (±60g) and vibrations.

DAQ system:

- Teensy*3.6* Micro-controller
- microSD card
- 6x AA batteries
- Signal-noise ratio ~10
- Samples: 3s, @3.5khZ.

a. Surface Pressure Measurement :

- 24 *Freescale* ±7kPa differential-pressure transducers

b. Position/Velocity Measurement:

- Photodiode
- 2 x pairs of LED strips

c. Trigger & Vibration Measurement:

- ±16g *ADXL326* accelerometer

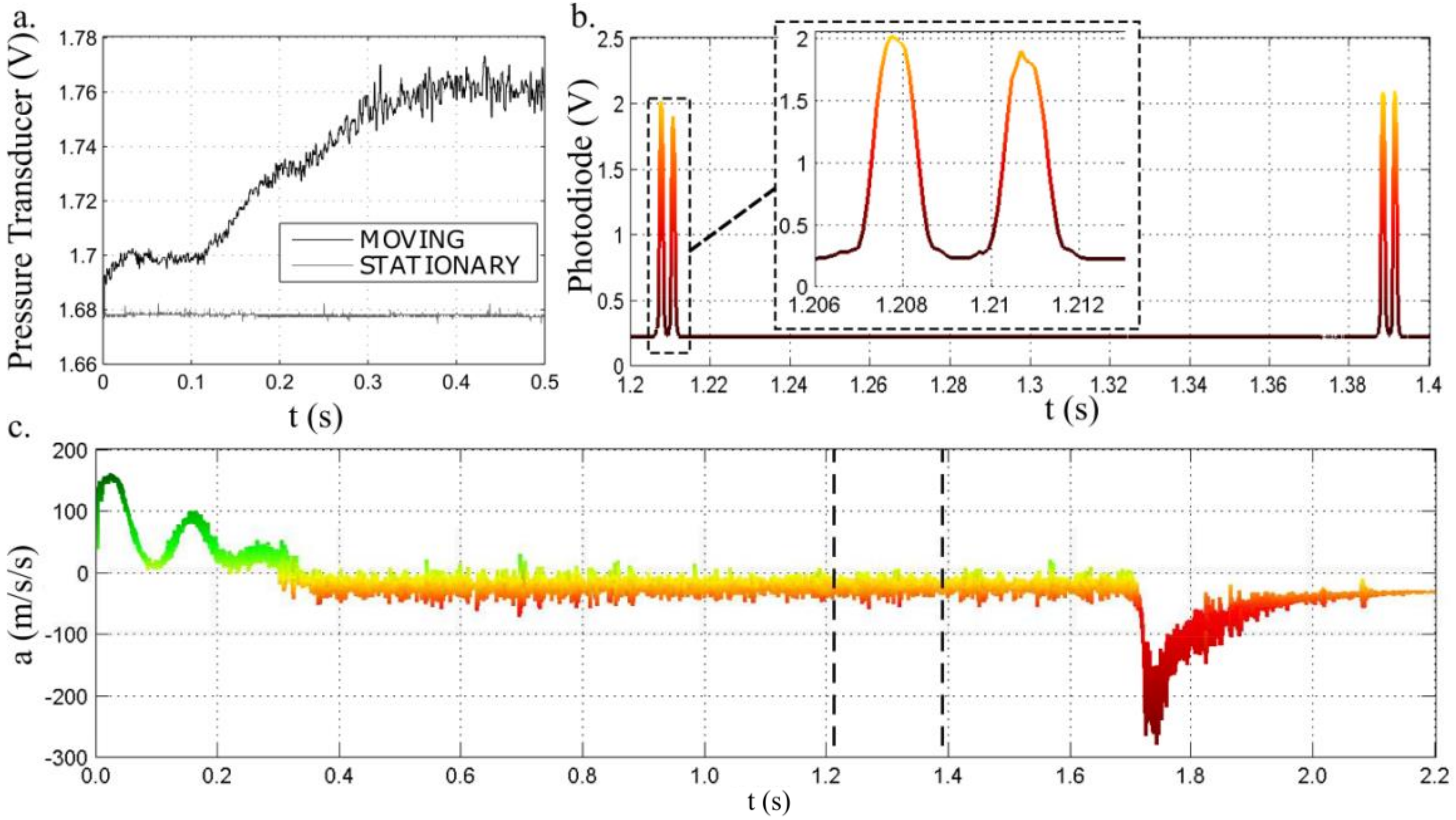


Figure 4: DAQ system functionality a. pressure, b. phototransistor, c. accelerometer

Transient-Pressure Results

Initial measurements during the passage through the crosswind section at the **windward (WW)** and **leeward (LW)** side of the train's nose: Model speed of u_t=32m/s, Crosswind: v_{cw}=18.5m/s, Effective yaw angle of β~30º

During exposure to the crosswind:

- **WW** side increase in pressure of C_P~0.9 quickly (Δt=0.02s)
- **LW** side decreases to C_P~-1.4 at a slower rate (Δt=0.07s).

- Sensitivity to unsteady crosswind modelling indicated
- further investigations planned

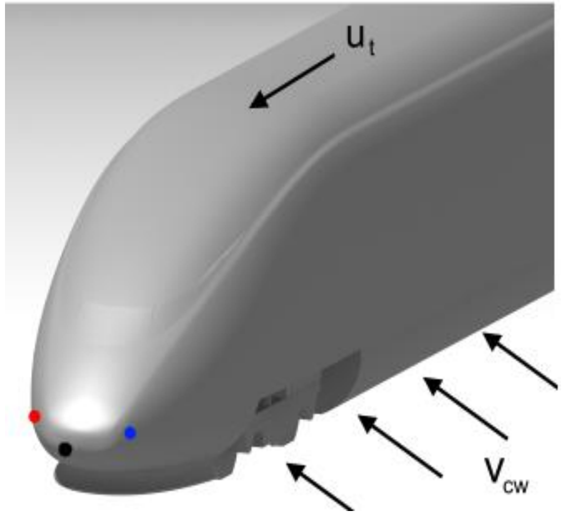


Figure 5: Pressure tap locations

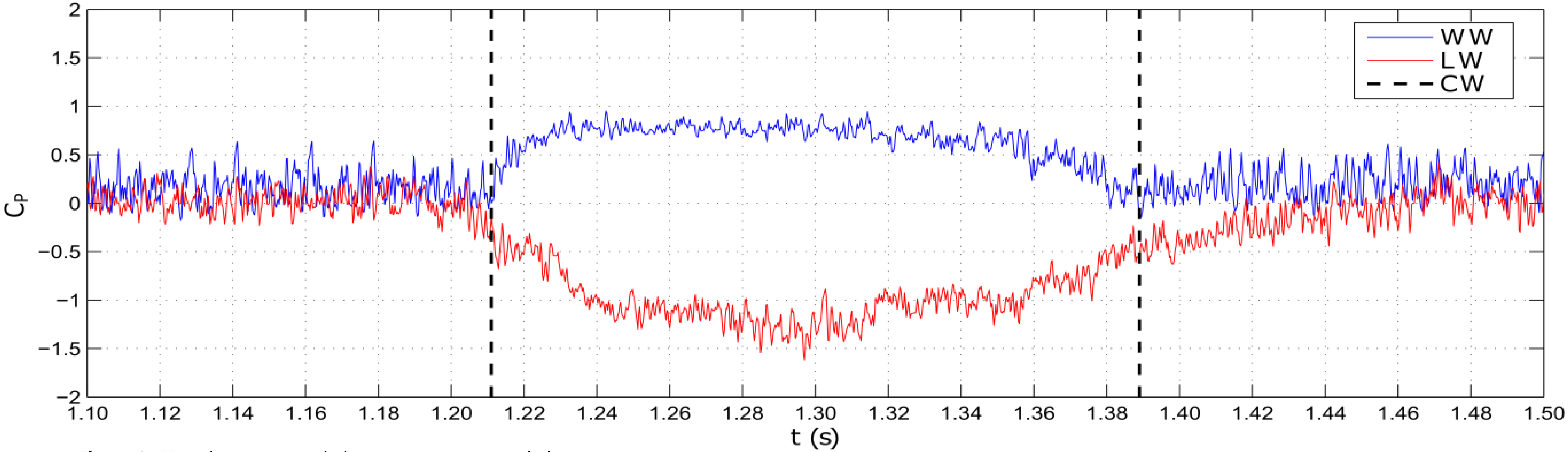


Figure 6: Transient pressure during exposure to crosswind