Séminaire de clôture, Opération de recherches SERRES

# WIND INFLUENCE ON HIGH-SPEED TRAIN ENERGY CONSUMPTIONS

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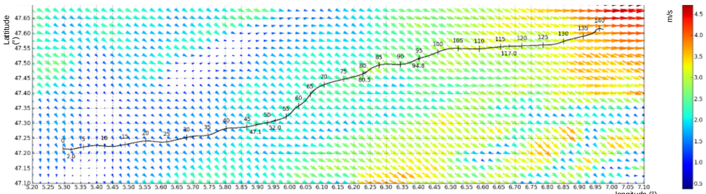
## Introduction

This work aims to determine the level of wind induced aerodynamic forces, compared to the aerodynamic forces due to the train speed (to assess integration in global energy modelling).
Railways, with low rolling resistance, overtake road and air in energy efficiency; high-speed rail transportation lowers this initial advantage [1].
Optimization of rail transportation should involve energy criteria [2].

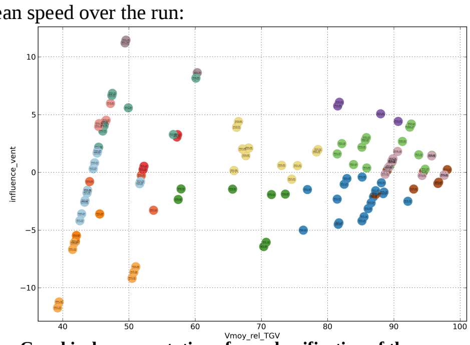
## Methods

*Field determination of atmospheric characteristics:*
- several runs on the Rhine-Rhone high-speed line (electrical power consumptions and infrastructure characteristics known).
- wind speed and direction, pressure and temperature were determined over the whole line (140 km) for the 25 days of tests, with the numerical model AROME [3] from measurements at local weather stations




**Computed wind field around the Rhine-Rhone high-speed line.**

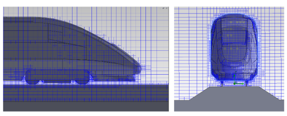
*Run selection: wind range and train speeds*
144 performed runs, various wind speeds/orientations and train speeds.
Classification for the "influence_vent" variable (scalar product of wind and train velocity divided by the train speed) and the "V_moy_rel_TGV" variable, the train mean speed over the run:




**Graphical representation of one classification of the runs set.**

Other classifications: selection of 15 runs (high/low train speed, front/rear wind direction, strong/weak wind).

*High-speed train aerodynamics modeling*
- ALSTOM TGV Duplex
- Navier-Stockes equations, auto-adaptive Cartesian meshes.
- Computed Cx coefficient fits with norm value and [4].
- Computed Cz is 56% lower than the norm value (modeling/ train underside)



$$F=\frac{1}{2}\rho S V^2 C$$

$$M=\frac{1}{2}\rho S L V^2 Cm$$

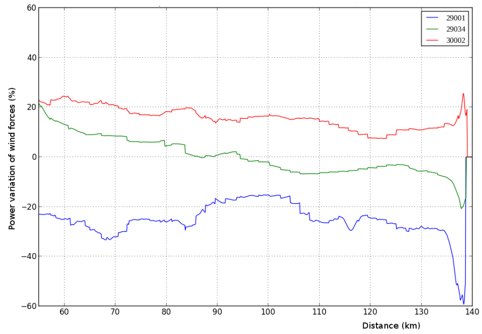
**Left: Auto-adaptive mesh ; Right: Force & momentum (C, Cm)**

→ considered coefficients (see table): combination of literature data on the detailed geometrical model and computed side wind influence (simpl. geom.)

| | Cx | Cy | Cz | Cmx | Cmy | Cmz |
|---|---|---|---|---|---|---|
| Angle de 0° | 1,08 | 0 | 0,08 | 0 | -2,31 | 0 |
| Angle de 5° | 1,20 | 0,69 | 1,72 | -0,47 | -10,94 | 5,82 |

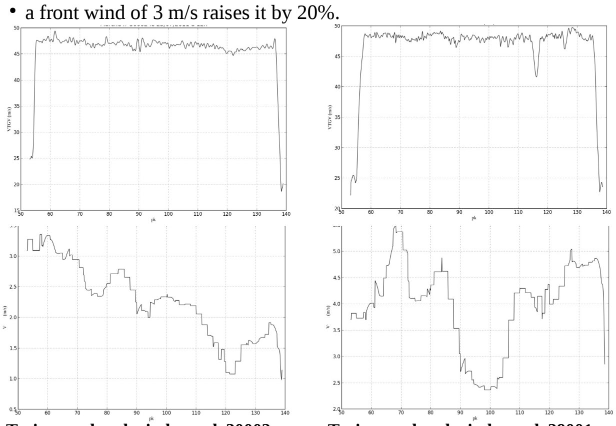
## Results

Particular runs are considered:
* Train travelling at **high speed (~95m/s), weak wind (~2m/s):** green curve "29034", wind influence is of +5% and -5% on power due to aerodynamic forces, resp. on front/rear wind sections of the itinerary (70/85 & 105/115 km).




**Power variation of wind forces for 29001, 29034, 30002 test runs**

* Train travelling at **moderate speed (~47 m/s) for rear and front oriented winds**: resp. blue and red curves "29001", "30002" (see above; speed profiles given below).
→ If considering data around pk=70km:
- a strong rear wind (5.5 m/s) lowers the needed aerodynamic power by 30%, compared to the case without wind.
- a front wind of 3 m/s raises it by 20%.



**Train speed and wind speed, 30002 test run – distance pk (km)** **Train speed and wind speed, 29001 test run**

## Conclusions

* work based on a large set of full-scale experimental data
* reconstitution of the wind field / simulation of aerodynamic forces
→ points out the importance of wind influence on aerodyn. power consumption.

Indeed, for weak wind / high train speed, wind influence reaches 5% of aerodynamic power consumption.
Moreover, with a wind speed about 5,5 m/s and a moderate train speed of 47 m/s, the wind field is accountable of variations on this power as high as 30%.

## Main references

1. Martin, P. (1999).Train performance and simulation. 1999 Winter Simulation Conference Proceedings. IEEE, Phoenix, pp.1287–1294.
2. Smith, R.A., Watson, R., Zhou, J. (2012). Energy and environmental aspects of high-speed rail, CETRA2012, Dubrovnik, Croatia, pp. 35-44.
3. Seity, Y. et al. (2011). The AROME-France convective scale operational model, Mon. Wea. Rev., 139, pp. 976-991.
4. Raghunathan, R.S., Kim, H.-D., Setoguchi, T. (2002). Aerodynamics of high-speed railways train, Pro. in Aerospace Sciences, 38, pp. 469 – 514.