Full-scale experimental study on the new Italian high-speed train aerodynamics: on board and trackside measurements

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Abstract: A full-scale experimental campaign has been carried out in order to assess the aerodynamic features of the new high speed trains ETR1000-V300Zefiro. Through experimental runs up to 300 km/h various aspects have been investigated, both in the open air and inside tunnels. With the idea to create a rich and organized database of experimental data to validate numerical codes more than 100 pressure sensors were put on the train surface and trackside. In this work the results coming from the analysis of this double set up are showed and compared.

Keywords: High speed train, aerodynamics, full-scale measurements, pressure taps.

1 Experimental set-up

In order to evaluate the aerodynamic features of the new high speed trains ETR1000-V300Zefiro one of the first convoys has been equipped with surface pressure sensors. Besides the homologation process required by the international standards ([1][2]), additional measurements have been performed for investigation purposes to assess the aerodynamic performances of the train. The main purposes of the whole experimental campaign were the study, by means of full-scale measurements, of the main aerodynamic issues that are of concern in the design and operation of modern trains ([5]). In particular, the following aspects have been investigated: the head pressure pulses, the slipstream effects, the maximum pressure variations in tunnels (train-tunnel pressure signature and pressure comfort), the pressure field that surrounds the head and the tail and the roof around the pantograph region.

The test train has been equipped on almost every coach and in many different positions with more than 100 sensors that have been installed and distributed along the train, inside and outside, including leading and trailing car, pantograph area, undercar body, bogie skirts and train lateral and top surfaces. The majority of sensors are pressure sensors, for the measurement of the pressure around atmospheric pressure values, but also several differential pressure sensors have been placed in some particular locations, in order to measure net pressure loads on surfaces, and some temperature and moisture sensors were used for assessing ambient conditions.

On the other hand, the pressure and velocity field that surrounds the train has been measured also trackside, using absolute pressure sensors and ultrasonic anemometers. Thanks to this double setup it was possible to measure the same phenomena from two different reference systems: the first placed on board while the second placed trackside. Finally, in order to try to correlate the two sets of measurements in different situations, the experimental tests have been performed both in the open air and in tunnel.

1.1 On board

As one the final goal of the research was to study the pressure field that surrounds the train probably the best solutions would be to drill holes in the train surface to obtain pressure taps as in the case of wind-tunnel tests ([3][4]); unfortunately this was not possible, therefore we had to adopt an alternative solution. Two fairings (visible in Figure 1) have been designed in order to solve this issue: one is used to house the pressure taps and tube that brings the pressure from the train surface to the pressure transducer (about 8mm in height), the other, placed in a higher position, is used to house the pressure transducer (about 25mm in height). Both the fairings are held in position using sailing boat adhesive tissue in order to avoid unwanted detachments and guarantee a good durability with sun and wind pressure. Using this solution, it was possible to measure the pressure distribution along the train and the pressure fields around the head, the tail and the pantograph region as visible in Figure 2.

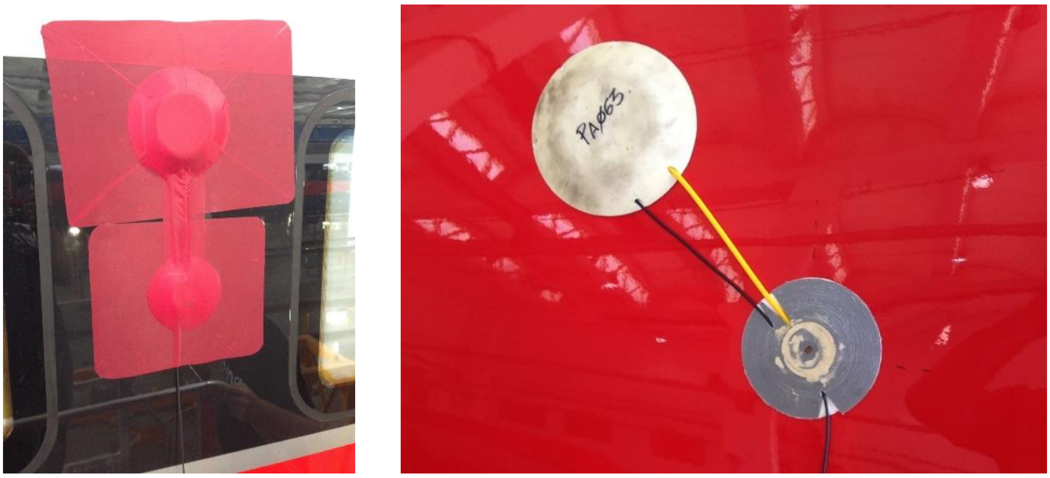

Figure 1: Two views of the fairings covering the pressure tap and the sensor with and without the adhesive tissue.

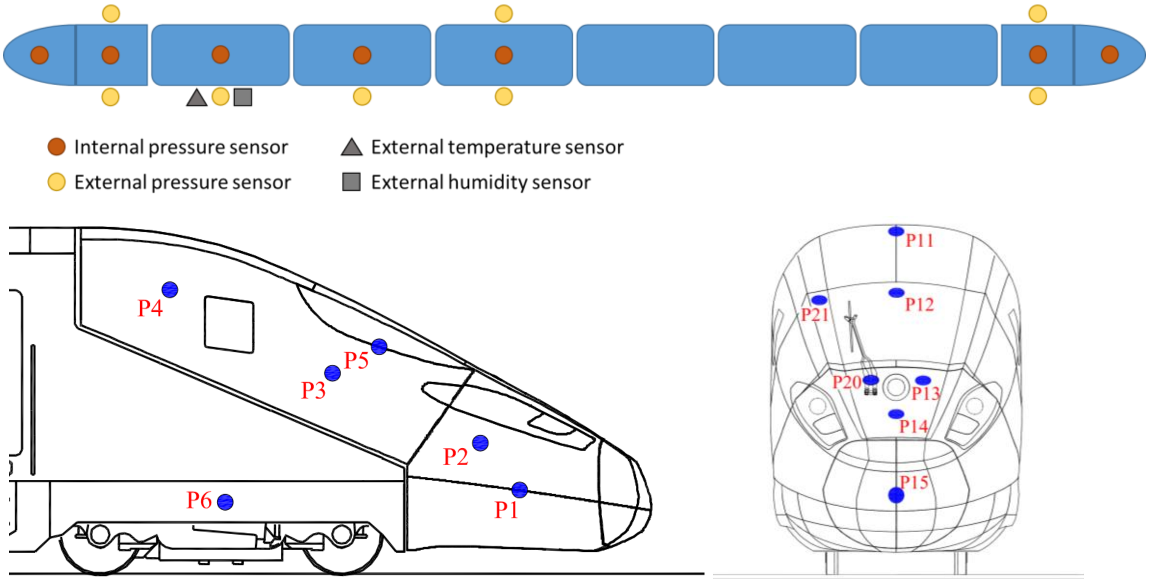

Figure 2: Schematic visualisations of some pressure taps position along the train surface and on the train head.

1.2 Trackside

During the tests runs of the train various quantities were measured also trackside such as the environmental conditions (wind speed, temperature, humidity and absolute pressure), the air speed and the pressure at different heights and distances from the top of rail. This was done both in open air and inside the tunnels so that it gave us the possibility to study the head pressure pulses and the slipstream effects on the one hand while the train-tunnel pressure signature on the other.

Figure 3: Instrumentation installed trackside: pitot rake, pressure taps and sonic anemometer.

2 Results

Several standard analyses can be conducted analysing the pressure data recorded, depending on the objective of interest: pressure comfort, overpressures in tunnel, slipstream, pressure pulse, etc. On the other hand, one of the most interesting aspects of the presented experimental campaign is the opportunity to have synchronous data on board and trackside: this allows to study the correlation between the wake generates by the slipstream and the pressure distribution on the train tail or also, in a tunnel, between the pressures measured on board and trackside.
After all, one of the central aspects of this research was to create a rich and organized database of experimental data usable in the future to compare with.
For this purpose, the experimental campaign for example has led to have:

- in open air and in tunnel, pressure distributions on the train surface and in boundary layer in order to obtain pressure coefficients for the validation of CFD numerical codes or usable for comparisons with the results coming from wind tunnel tests on scaled models;
- pressure time evolutions inside the tunnels generated by the interaction between train

and tunnel in order to validate and calibrate the one-dimensional numerical codes or CFD simulations;

- in tunnel, pressure loads on the train surface and pressure variations inside the train to evaluate the pressure tightness and the resulting pressure comfort.

In Figure 4 some of these results are presented. On the left it is possible to visualise the pressure distributions around the pantograph area in the two running directions. Whereas, on the right side of the figure, the time evolution of the pressure generated by the interaction between train and tunnel is showed. The same phenomenon has been recorded by pressure sensors placed inside the tunnel at different positions (figure on the top) and by five pressure sensors placed on the lateral surface of the train (figure on the bottom).

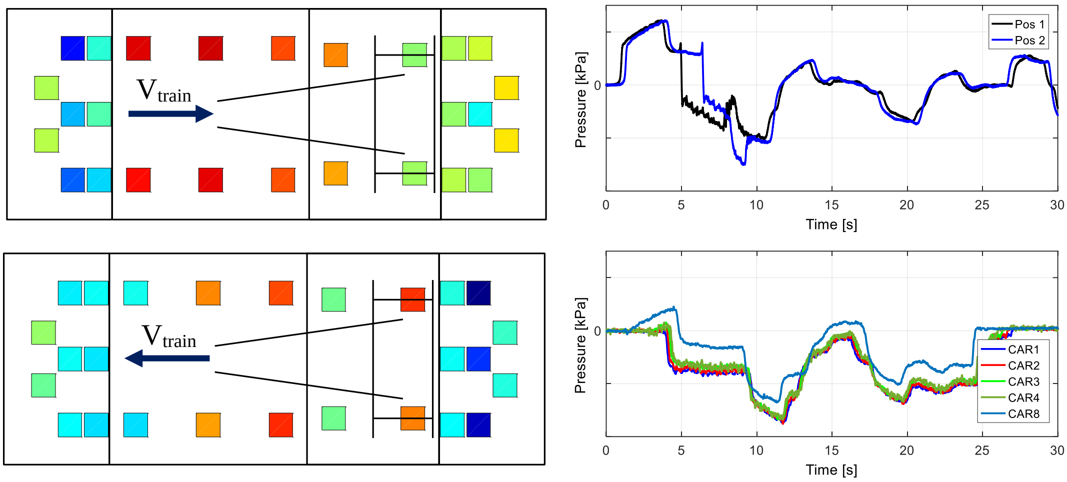

Figure 4: Some examples of the experimental data acquired: pressure distribution around the pantograph area on the left and pressure time evolution inside a tunnel.

3 Acknowledgements

The authors are grateful to Bombardier Transportation and, in particular, to Mikael Sima and Luca Barbone for the worthwhile discussions and for helpful support during and after the whole test campaign.

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