Understanding Steady and Unsteady Aerodynamic Crosswind Effects on Rail Vehicles

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Background and Project Aim

The effect of crosswinds is one of the most critical problems connected to the train safety and stability. The combination between the vehicle movement and the action of a transversal turbulent wind, indeed, generates a complex and highly unsteady flowfield around the train, determining on it the arising of a series of fluctuating aerodynamic forces and moments. The interaction of these loads with the dynamics of the vehicle can cause different stability issues and, in particularly severe cases, even determine the train derailment or overturning, therefore compromising the passengers’ safety.

The assessment of the rail-transport safety risk in crosswinds currently relies on a variety of stability analyses, all based on a numerical-experimental methodology, in which both the vehicle dynamics and the natural wind are modelled numerically. The aerodynamic features of the train, instead, needed to calculate the wind loads, depend on the vehicle geometry and as such are often provided by wind tunnel tests on static scale models, in the form of dimensionless coefficients.

Despite being a well-established technique, due to the impossibility of reproducing the vehicle movement, these type of experiments do not exactly replicate the case of a travelling train at full scale. On one side the simulation of the different wind-vehicle relative angles (yaw angle) is fulfilled rotating the model on its vertical axis. Nevertheless, neither the train-ground relative movement, nor the direction of the wind in respect to the ground is correctly recreated. Therefore, an unrealistic representation of the flow in the train underbody region is inevitably provided, and consequently a margin of approximation affects the measured values for the aerodynamic loads, as well as the correspondent coefficients.

The aim of this research, in conjunction with the AeroTRAIN project (WP3.4), is to assess the impact of the vehicle-ground relative motion simulation on the rail vehicles crosswind aerodynamic loads. To that end, an experimental investigation on scale models in crosswind conditions will be carried out in the TRAIN (Transient Railway Aerodynamics Investigation) rig facility. Firstly, a new crosswind generator has been designed, and will be accommodated within such existing facility, in order to deliver a transversal wind simulation adequate to undertake a series of significant tests. Meanwhile, an on-board measuring system which will be integrated into the moving model is under development. Such system will provide the aerodynamic loads acting on the vehicle, detecting the surface pressure distribution, or possibly directly the forces and moments. Afterwards, two series of experiments will be done, investigating a Class 390 Pendolino scale model in correspondence of a 30° yaw angle, in static and moving conditions respectively, and testing two different ground simulations: a flat ground and an escarpment. Finally, the impact of the vehicle movement simulation will be assessed, comparing the results from static and moving tests in terms of steady and also unsteady aerodynamic load coefficients.
**TRAIN rig**

The TRAIN rig is a test facility specifically dedicated to perform moving model experiments on rail vehicles at high Reynolds number (reaching values of about $6 \times 10^5$). Built at the end of 1980’s, and constantly developed during the 1990’s by the AEA Technology Rail, it has been largely employed in the last twenty years investigating different phenomena related to open air and tunnel train aerodynamics, and has been recently acquired by the University of Birmingham Railway Research Centre.

The rig consists of a series of three straight parallel tracks, each 150 m long, equipped with a mechanical propulsion system capable of catapulting a 1/25 scale model at speeds of approximately 75 m/s. The tracks are supported about 1.2 meters over the ground by a concrete structure, which presents a series of piers and a deck covered by a wooden board, and are located in central part of the building running along its entire length. The firing mechanism, accommodated in the area under the deck, is based on the use of tensioned elastic ropes driven by pulleys, in combination with a piston deformable tube employed in the braking phase, and has been specifically designed to enable a good simulation of the underbody flow.

**New crosswind generator design**

A bank of four low speed fans located at the trackside currently equips the TRAIN rig facility. However, due to the limitations of such existing system, mainly in terms of restricted dimensions of the crosswind section, low value of the mean wind speed, and inhomogeneity of the flowfield, no significant experiments on train models in crosswinds can currently be undertaken. The design of a new crosswind generator, therefore, is required, and a final solution has been worked out finding a compromise between the design requirements and the constraints related to the need of accommodating the new apparatus inside the existing building.

A series of 16 axial ventilation fans will be arranged at the trackside in two rows of eights. The delivered airflow will be accelerated through a convergent and blown perpendicularly over the tracks at about 12 m/s, in correspondence of a crosswind section about 6 m long and 1 m high. An improved and dedicated scheme of grids and a honeycomb screen, furthermore, to be developed during a dedicated experimental session, will be accommodated between the fans and the tracks to smooth the flow irregularities and reduce the turbulence level.

**REFERENCES.**