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Crosswind action on rail vehicles: Wind tunnel experimental analyses

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Abstract

Extensive wind tunnel tests have been carried out on train scale models. The experimental tests have been performed on three types of rail vehicles, in different configurations. The wind tunnel tests allowed to point out the most critical wind conditions with respect to running safety and to perform a sensitivity analysis on the principal parameters that can influence the aerodynamic behaviour of rail vehicles. In particular, the effects of the turbulence intensity and of the train motion on the aerodynamic coefficients have been studied.

Keywords: Rail vehicles; Crosswind; Aerodynamic coefficients; Wind tunnel tests

1. Introduction

One of the most critical problems connected with the running safety of trains consists in the aerodynamic loads due to crosswind action.

Many researchers, in various European countries, have analysed the problem that involves both standard rolling stock and high speed vehicles (Baker, 2002; Baker et al. 2004; Robinson, 1987; Suzuki et al., 2003). Moreover, the problem of wind effects on rail vehicles is today of topical interest, since new technical standards on this specific theme are under definition, within the interoperability project of the European railway network.

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The main risk associated with crosswind is vehicle overturning, which is particularly critical when the train exits a tunnel (as a consequence of the sudden variation in the aerodynamic forces) or when the train runs in curve (in combination with high values of lateral acceleration). Another possible risk is related to track stability under the lateral forces exerted by the train; as a result of the wind action on the vehicle, the overall lateral force on a bogie can increase, leading to track settlement and possible train derailment.

The first step, in order to establish safety criteria, is the aerodynamic characterization of rail vehicles. For this reason, within a research project on the crosswind effects on rail vehicles, extensive experimental tests have been carried out on scale models in the new Politecnico di Milano wind tunnel. The experimental tests have been performed on different types of still/moving trains, in low and high turbulence flow. Moreover, the experimental set-up was designed for reproducing different operating conditions.

The wind tunnel tests have two different objectives. The first one is to perform a sensitivity analysis on the principal parameters that can influence the aerodynamic loads on a rail vehicle (wind direction, turbulence intensity, viaduct or embankment scenario, effect of different kind of wind fences, etc.). The second objective is to collect all the experimental data necessary to set-up a numerical model of the aerodynamic forces acting on trains, to be implemented in the computer programs for rail-vehicle dynamics simulation. The methodology to define the aerodynamic loads acting on a rail carbody, based on the wind tunnel experimental campaign described in this paper, has been reported in Cheli et al. (2004) and Cheli et al. (2003).

2. Wind tunnel tests

An extensive experimental campaign has been carried out over the last years in the Politecnico di Milano wind tunnel, in order to measure the aerodynamic forces acting on rail vehicles subjected to crosswind.

Tests have been performed on three different train 1:20 scale models:

- ETR480, 1st–2nd vehicles (power cars) and 3rd vehicle (trailer coach, Fig. 1);
- ETR500, locomotive and two trailer coaches (Fig. 2(a));
- IC train, UIC-Z1 control trailer coach and two coaches (Fig. 2(b)).

In the first phase, the sensitivity of the aerodynamic coefficients to the test conditions has been investigated: tests have been carried out in low and high turbulence conditions, and, in order to highlight the Reynolds number independency, with different mean wind speeds.

In the second phase, different configurations have been considered in order to characterize the aerodynamic behaviour of a rail vehicle in the following operating conditions:

- train on viaduct or on embankment (Figs. 1 and 2);
- train leeward (Fig. 3(a)) or windward (Fig. 3(b));
- with or without solid/porous fences.

The viaduct scale model has been designed according to the geometry of standard high-speed European viaducts: the height of both viaduct and embankment is equal to 6 m at