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Crosswind assessment of conventional trains

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SUMMARY:
Crosswind can affect the stability of trains. Historically the attention has been devoted to high-speed trains. The aim of this study is to show that also the stability of conventional trains can be susceptible to the effects of crosswinds. Four trains representative of the Italian railway fleet have been analysed by means of wind tunnel tests on scaled models and by using multibody simulations for computing the Characteristic Wind Curves (CWC). From the experimental campaign in the Politecnico di Milano Wind Tunnel, it can be observed that first car of the train composition presents the highest aerodynamic coefficients and that double-deck trains have worse aerodynamic performance due to the larger area exposed to winds. By comparing the CWCs of the conventional and high-speed trains, it is possible to note that the lowest limit wind speed is similar for both train topologies but is reached at a much lower train speed for conventional trains.

Keywords: Crosswind, Wind Tunnel Test, Conventional Train.

1. INTRODUCTION

The exposure of trains to crosswind can lead to stability problems. As efficiency takes every day more interest, in the last years the design of railway vehicles is focused on incrementing the passenger capacity as well as reducing the weight of the vehicle resulting in bigger and lighter trains that may decrease the stability of the vehicle when subjected to crosswind.

For high-speed trains, the phenomenon has been widely studied (Baker 1991, Baker 2010, Cheli et al. 2012) and in the standards, requirements have been defined to ensure the stability of high-speed trains (TSI 2014, EN14067-6 2018). On the other hand, the stability to crosswind of conventional trains has acquired interest only in the last years (Giappino et al. 2016).

In this work the evaluation of the stability under crosswind of four different conventional trains, that are representative of the rolling stock fleet operating on the Italian railway system is presented.

The study is divided into two parts. The first one is about the wind tunnel tests carried out on four scaled models of conventional trains to determine the aerodynamic coefficients as function of the wind yaw angle. While the second part corresponds to the evaluation of the Characteristic Wind Curve (CWC) following the procedure presented in the European standard for high-speed trains, by means of multibody simulations and with an equivalent wind profile (‘Chinese Hat’).

2. WIND TUNNEL TEST

The first part of the study refers to the determination of the aerodynamic coefficients of the four railway vehicles under study. The experimental campaign was made in the Wind Tunnel of Politecnico di Milano. The tests were performed in the high speed/low turbulence test section of the wind tunnel (maximum speed of 55 m/s, turbulence intensity < 0.15%). The test section has a cross section of 4×3.84 m and is 6 m long. For this campaign, tests were performed at 50 m/s with 1:20 scaled models. The obtained Re number equal to 5×10^5 is compliant with the European Standard requirement.

The analysed trains were a commuter (MDVC), a double-deck commuter (CDPTR), an Intercity (IC) and a modern double-deck EMU commuter train. The 1:20 scaled convoys (see Fig. 1) were built following the directives of EN14067-6 standard and composed by three bodies: head car (instrumented), second car (instrumented), third car (half vehicle with rounded end, not instrumented). Trains were tested using the Single-Track Ballast and Rails (STBR) scenario according to the European standard.

Figure 1. Train models tested in wind tunnel.

The results of the tests are presented in Fig. 2, where aerodynamic coefficients for lateral force (CFy), vertical force (CFz), roll moment around the centre of the track (CMx) and roll moment around lee rail (CMxlee) are plotted. It can be noted that for all trains, the head car is the most critical from the aerodynamic point of view. Bigger coefficients are obtained for double-deck trains (CDPTR and EMU) in comparison with single-deck trains (MDVC and IC) due to the larger area exposed to wind. Single-deck trains present lower lift coefficient values: this behaviour is probably due to the fact that the higher gap under the car-body leads to an accelerated flow which reduces the lift force.

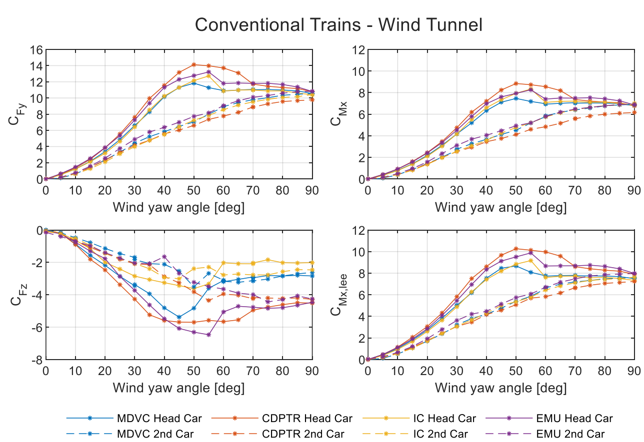

Figure 2. Aerodynamic coefficients for the four analysed conventional trains. Wind tunnel test: V=50 m/s.

3. CHARACTERISTIC WIND CURVES (CWC)

The CWC represents the limit wind speed for what the vehicle reaches the overturning condition, defined as an average wheel unloading for the most critical running gear over 90%.

For every train, the CWCs were computed for the first vehicle, being it the most critical one, as observed from the aerodynamic coefficients presented in the previous section. The wheel unloading condition was obtained from multibody simulations computed with the in-house multibody code ADTreS using the ‘Chinese hat’ wind profile for wind loads calculations.

In Fig. 3 the CWCs computed for the four trains are presented. For comparison the computed CWC of the ICE3 high-speed train is also plotted.

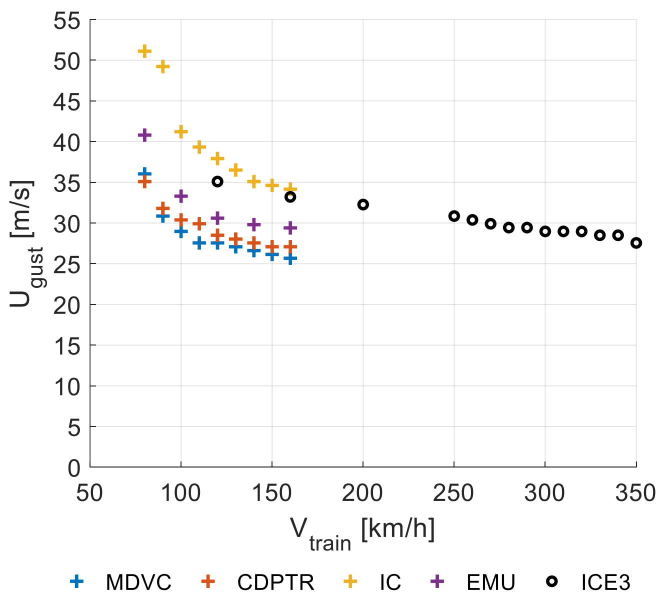

Figure 3. CWC comparison for the four analysed conventional trains and the ICE3 high-speed train.

From Fig. 3 it is possible to observe that the vehicle with the worst behaviour is the MDVC train. The big difference observed between the CWC of the IC and MDVC can be related to the mass of the MDVC being 30% lower. From the comparison between CDPTR and MVDC, it can be noted that even if the aerodynamic coefficients are 20% higher for CDPTR, its bigger mass and suspension characteristics balance the larger aerodynamic loads obtaining a better CWC. Finally, as expected from wind tunnel results, the new EMU double-deck train has a better performance when compared to the CDPTR train.

An important aspect that must be reported, is the fact that the CWCs obtained for conventional trains present critical wind speeds similar to the ones that lead high-speed trains to rollover conditions. This may be explained considering that, even if the wind-train relative speeds are lower for conventional trains with respect to high-speed trains, the corresponding relative yaw angles are higher: at 50deg-60deg, the aerodynamic coefficients are 2-3 times greater than those found at 20deg-30deg (typical yaw angles of the relative wind-train velocity for high-speed trains), leading to similar aerodynamic loads.

4. CONCLUSIONS

In this work an analysis of the stability of conventional trains under crosswind was performed. The study was based on the methodology proposed in the European standard for analysing high-speed trains.

By comparing the aerodynamic coefficients measured for the four trains analysed, it is possible to conclude that the CDPTR is the one with higher aerodynamic coefficients. For each convoy, the head car is the most critical coach. Double-deck trains have a lower performance due to bigger exposed area to wind. The bigger space between track and car body on single-deck trains seems to help to reduce the lift force due to an increased air flow underneath the car.

The Characteristic Wind Curves computed for the first vehicle according to the European Standards show that three of the studied conventional trains present critical wind speeds under 30 m/s at 160 km/h. Those values are similar to the ones obtained for high-speed trains over 300 km/h. Those results show that the overturning risk of conventional trains is therefore similar to that of high-speed trains at their maximum velocities.

Results show that the weight of the train plays a crucial role in train stability. With sustainability pushing weight reduction to improve efficiency, the study of the stability under crosswind of conventional trains becomes relevant in order to ensure the safe operation of this kind of vehicles.

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