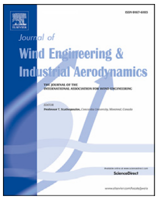
Journal of Wind Engineering & Industrial Aerodynamics 177 (2018) 186–196

Contents lists available at ScienceDirect

Journal of Wind Engineering & Industrial Aerodynamics

journal homepage: www.elsevier.com/locate/jweia



Representativeness of geometrical details during wind tunnel tests. Application to train aerodynamics in crosswind conditions

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ARTICLE INFO

Keywords:
Wind tunnel tests
Train aerodynamics
Geometrical details
Similitude

ABSTRACT

This work aims to highlight the influence of the scale of reproduction of geometric details on models during wind tunnel tests. An application is presented concerning the reproduction of high voltage lines present on the roof of trains. It is shown that the presence of these geometric artefacts deeply modifies the forces and moments measured under cross-wind. It is also shown that the reproduction of geometric details with the scale of the model is not a sufficient condition to ensure a good representativeness of the tests. It is necessary to ensure that the changes in the flow dynamics caused by the presence of the details are correctly reproduced (separation-reattachment process on the roof of the train in this study). The influence of the scale of reproduction of the geometrical details is also studied and a method is proposed to extrapolate the results obtained without roof-lines in order to predict the rolling moment in the presence of roof-lines.

1. Introduction

Similarity problems for small scale wind tunnel tests have been widely studied in the literature. However, few studies have examined the representativeness of the tests when geometric details are present on the model (mirrors on cars, high-lift devices for aircraft, holding cables for bridges, for example). The question of the relevant scale of reproduction of these geometric artifacts is always questionable when it is not possible to carry out the tests at full scale. Is the reproduction of these details at the same scale of the model sufficient to ensure good reproduction of the flow dynamics near these artefacts and thus their impact on the overall aerodynamics of the studied body? These issues arise often in the aerodynamics of trains which present numerous geometric details (intercar gaps, high voltage cables, pantographs, etc.). The first necessary condition of similarity is the respect of the Reynolds number. However, the Reynolds number, Re, of a train at full scale based on the height of the train (classically 3m) and on the flow velocity (around 80 $m.s^{-1}$) is close to 10^7. It is therefore very difficult to satisfy it in wind tunnel experiments. One can nevertheless try to work in a velocity range for which the results are independant of the Reynolds number (Mair and Stewart, 1985, Niu et al., 2016). This independance from the Reynolds number is much more difficult to obtain when studying the influence of geometric details. Indeed, even if independence to the Reynolds number is reached for the train aerodynamics, nothing ensures that the flow around these obstacles is also independent of the local Reynolds number based on the obstacle height, which is much lower. Even if *EN 14067-6* (En 14067-6:2010, 2009) regulation recommends to adopt a level of detail leading to a realistic representation of aerodynamic forces and moments, it does not specify any precise criterion on the appropriate level of detail. As these details can be of various kinds on a train, the present study focuses only on the reproduction of high voltage cables present on the roof which have generally a diameter of around 2% of the train height. More precisely, the aim of this work is to study the influence of the scale of reproduction of roof-lines on the prediction of the overturning moment on trains in cross-wind situations.

There are numerous studies detailing the aerodynamics of high-speed trains and the evolution of their forces and moments coefficients in crosswind conditions (Mair and Stewart, 1985; Copley, 1987; Chiu and Squire, 1992; Baker, 2010). From theses studies, the flow around trains may be classified into four regimes depending on the yaw angle, β, and on the non-dimensional longitudinal position along the train, X/D (D being the height of the train) (Fig. 1).

(i) Regime I or ’fully attached flow regime’ ($\beta < 10^\circ$): the boundary layer is attached over the whole body, (ii) Regime II or ’Steady slender body flow regime’: the boundary layer separates in the leeward corner forming a conical vortex, steady in space and time, in the leeward side,

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https://doi.org/10.1016/j.jweia.2018.01.040
Received 28 November 2017; Received in revised form 26 January 2018; Accepted 27 January 2018

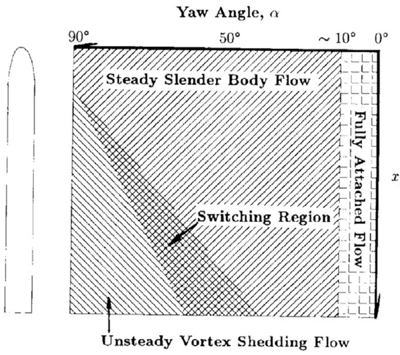


Fig. 1. Variation of flow regimes with respect of the yaw angle (extract from Chiu and Squire, 1992).

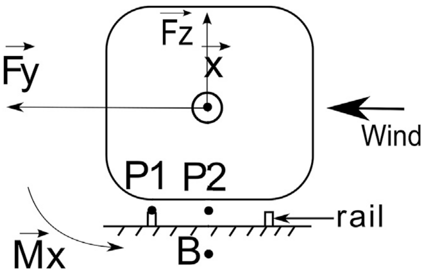
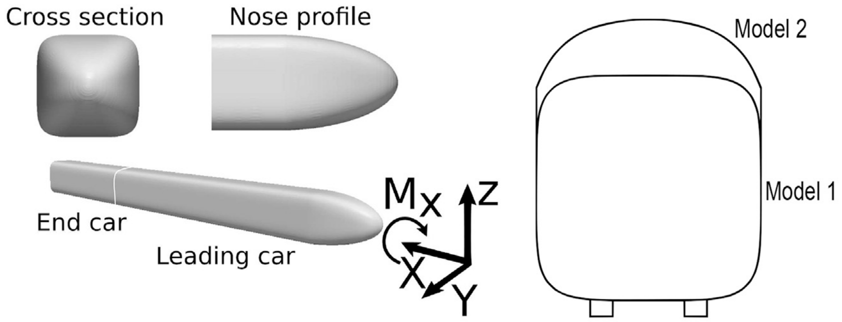


Fig. 4. Sign convention for the efforts and moment.

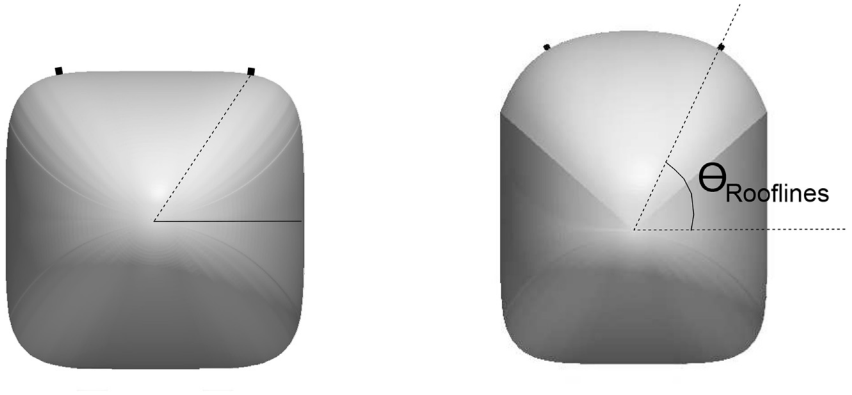
(iii) Regime III or 'Switching regime': An intermittent switching between the steady and unsteady regimes takes place at an intermediate distance from the nose which separates the steady flow closer to the nose and the 'Unsteady vortex shedding flow' farther from the nose, (iv) Regime IV or 'Unsteady vortex shedding flow': The flow is unsteady and massively separated. For yaw angles close 90°, the flow is similar to the flow observed around the 2D cylinders placed near a wall. The great majority of these studies were carried out on a train without any geometric details. We will therefore try to understand how the roof-lines affect the different flow regimes in wind tunnel experiments. The roof-lines are modelled by parallelepipeds located on the roof of the train. The resulting flow is locally similar to the one around a wall mounted 2D ribs at a yaw angle with the upstream flow. The effect of a wall-mounted obstacle on wake dynamics has been widely studied in the case of a perturbation placed on a 2D or 3D cylinder (see Ekmekci and Rockwell, 2010) and (Araújo et al., 2012) for example). The difference in the train configuration is that, unlike what happens with the cylinder, the flow which separates on the obstacle reattaches to the body. The configuration studied is closer to the work carried out on the flows around an upward facing step. However, the configuration is more complex for the train situation because it is necessary to take into account the pressure gradient generated by the curvature of the wall. Another important parameter of our study is the size of the wall-mounted obstacle which allows to vary the local Reynolds number and the ratio between the size of the obstacle and the thickness of the boundary layer. In this context, we may cite the works of Arie et al. (1975) on rectangular cylinders and Good and Joubert (1968) on fences.



(a) Geometry of model 1

(b) Comparison between the two models geometry

Fig. 2. Shape of the two models of train.



(a) Model 1

(b) Model 2

Fig. 3. Roof-lines position on the two models.