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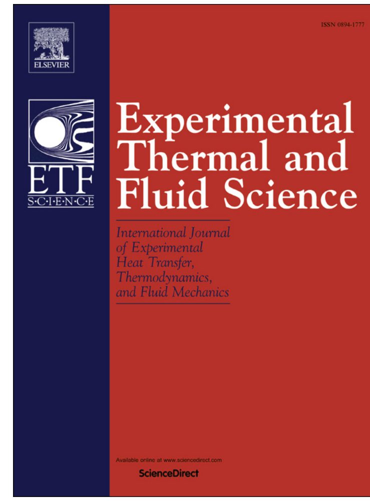

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Experimental research on the aerodynamic characteristics of a high-speed train under different turbulence conditions

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Abstract: The aerodynamic characteristics of a high-speed train in an atmospheric boundary layer are investigated in a wind tunnel. In addition, different atmospheric boundary layer simulations are performed by changing the turbulence intensity generated by a collection of spires in a wind tunnel. Turbulent flow information, measured with the Cobra probe, is used to describe the atmospheric boundary layer. Furthermore, the effect of velocity on the atmospheric boundary layer is also studied. Both the train's unsteady aerodynamic force and surface pressure are measured at a Reynolds number of 7.5×10^5, and their mean and standard deviation are used to describe and explain the effect of turbulence and observed trends with varying turbulence intensity.

Keywords: High-speed train; wind tunnel; atmospheric boundary layer; turbulence; aerodynamic characteristic

1 Introduction

The atmospheric boundary layer occurring during train operation is in a turbulent state. Furthermore, complex road conditions along the railway exacerbate the transition of flow fields around the train. As is well known, turbulence is a very common phenomenon in nature and engineering, and it is also one of the most complex flow phenomena, having the characteristics of strong randomness, a chaotic state of fluid flow presenting a wide range of three-dimensional vortices of different temporal and spatial scales. Turbulence often worsens other phenomena. For example, turbulence worsens the aerodynamic performance of the train, causes the frequency of vortex shedding from the train to be closer to the resonant frequency of the train, and further aggravates the train vibration. Especially for objects with high speed, it may even induce serious accidents, resulting in a serious threat to life and property. So far, serious accidents have mainly occurred with aircraft. With improvement of train speeds and high-speed railway construction in complex terrain, the detriment of turbulence for trains will be increasingly serious.

With the development of high-speed railways and increases in train speed, more and more attention has been paid to the effects of unsteady aerodynamic load on high-speed trains on the atmospheric boundary layer. Considerable research has been performed on train unsteady aerodynamic characteristics through numerical simulation and real vehicle testing [1–5]. Ren et al. [6] studied the dynamics frequency transference from the wheel/rail interface to the car body of a high-speed EMU by analyzing the train vibration characteristics. Baker et al. [7] studied the influence of the ground and the Reynolds number in a test of train drag and found that there was a significant difference in drag amplitude between the model test and the full-size test, and the influence of the train's surface boundary layer on the train's aerodynamic performance was greater than the ground effect. According to the studies of Kim and Geropp (1998), Kwon et al. (2001) and Zhang et al. (2016) [8, 9, 10], the ground effect does not change the flow structure around the train significantly, and the affected area is mainly concentrated at the bottom of the train. Cheli et al. [11] simulated a train's aerodynamic performance in the atmospheric boundary layer with different turbulence intensities and researched the effect of the turbulence intensity on the train's aerodynamic performance with a sideslip angle of 30~90°. Bocciolone et al. [12] reported that the train's aerodynamic force coefficients are significantly affected by the turbulence intensity, especially at a large sideslip angle. Cheli et al. [13] also researched the change of heavy-duty drag coefficient with the sideslip