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Design of wind barrier on the transition section for the railway bridge

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Abstract: The wind barrier is often used on the railway bridge for the running safety of the train in the wind field. But the wind forces on the train will suddenly change when a train moves into or out of the wind barrier called the transition section because of the change of aerodynamic coefficient of the vehicle induced by the wind barrier. So it is very important to propose the counter measures for the wind barrier in the transition section. The interaction analysis model of vehicle-bridge system with wind barrier under wind load is built, and the effect of wind barrier on the running safety of the train is analyzed, then the counter measure is discussed deeply. For a 12-span simply-supported bridge with single-side 3.5 m wind barrier, and considering the different design parameters of the wind barrier in the transition section, the running safety indices of the vehicle are calculated by the self-written program on basis of the analysis model. The results are compared with those of the case without special measure in the transition section. It can be seen that the sudden change of wind forces caused by wind barrier has great influence on the lateral acceleration of the car-body and ride comfort. The running safety of the train considering the wind barriers with gradual height is better than those without special design in the transition section.

Key words: Wind-train-bridge system; Wind barrier; Special design in the transition section; Running safety; Car swaying.

1 Introduction

The strong wind makes the aerodynamic performance of vehicles deteriorated, affecting their lateral stability and ride comfort, and even causing the train to overturn in severe cases. The wind-induced accidents of train have been reported on a number of occasions in the early 20th century (Qian 2009, Liu *et al*. 2008). These accidents occurred in China, Japan, and Switzerland etc., on bridges, on high embankments or in mountain regions on narrow gauge track (Andersson, 2004). Particularly in recent years, railway vehicles has a clear trend towards lighter mass to conserve energy, reduce the track damage and wheel/rail wear, and increase the speed. But it is very unfavorable to overturning under

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strong crosswinds. So the safety of the train under cross wind becomes a hotspot study (Baker 2013, Xiao *et al*. 2014, Kikuchi *et al*. 2015, Giappino *et al*. 2016, Yan *et al*. 2018). In order to increase safety, vehicles are sheltered by wind barriers that are installed on bridges or embankments to reduce the loads acting on the train. And experience of Japan's Shinkansen has shown that setting wind barrier is an effective measure to reduce the impact of wind on the train and stopping operation times, as the running safety of the train is greatly improved (Noguchi *et al*. 2000, Fujii *et al*. 1999). However, the sudden change of the wind load on the train after installing the wind barrier when the train driving into and out of the wind barrier will affect the running safety and ride comfort of the train, such as violent car swaying (Pan 2016).

There have been a lot of studies on the aerodynamic properties of vehicle-bridge system in wind field for different vehicle types and bridge structures (Suzuki *et al*. 2003, Cheli *et al*. 2010, Schober *et al*. 2010, Li *et al*. 2013, Guo *et al*. 2015), and the vibration response of the vehicle-bridge coupling system under wind load (Cai *et al*. 2004, Li *et al*. 2005, Guo *et al*. 2007, Xia *et al*. 2011). For the wind barrier design on the bridge, some results are obtained by wind tunnel tests or numerical simulation method regarding the possibilities of protecting the vehicles on the railway bridge and the influence of wind barrier on the aerodynamic performance of vehicle-bridge combination system (He *et al*. 2015, Zhang *et al*. 2013). In addition, Kwon *et al*. (2011) and Kim *et al*. (2011) presented the design criteria required for wind barriers to protect vehicles running on an expressway under a high side wind and a decision-making process for installation of wind barriers. Li *et al*. (2014) and Guo *et al*. (2015) present the design reference parameters for wind barriers to protect vehicles running on a railway bridge under a high side wind and the optimization design of wind barrier on basis of wind-vehicle-bridge coupling dynamic theory. And Zhang *et al*. (2013) and Guo *et al*. (2015) also has progressed some research work for the running safety of the train considering the wind barrier on the high-speed railway bridge in strong wind field and gives the wind velocity threshold curve of the train running on the bridge safely. But the research on the running safety and ride comfort of the train into and out of the wind barriers, which will lead to the sudden change of the wind force on the train, is given little attention. Zhang *et al*. (2015) has carried out the analysis for the impact of the wind barrier on the train, and the dynamic response of the train considering the sudden change of wind forces, the results show that the overturning risk of the train will increase and the ride comfort of the train will decrease when the train driving into and out of the wind barrier that is called the transition section.

As above mentioned, wind load on the train will be greatly reduced with wind barriers to improve operating safety, but when the train runs into or out of the wind barrier on the bridge, the wind load will suddenly change due to different aerodynamic properties of the front or rear vehicle. This change will induce additional vibration of the vehicle, which may lead to safety problems of the train. Therefore, the wind barrier design in the transition section is very important to ensure the running safety and ride comfort of the train.

In this paper, the running safety and ride comfort of the train considering the sudden change of the wind load acting on the train is analyzed when the train passes into or out of the wind barrier, and the design parameter of the wind barrier in the transition section is discussed. The calculation formulas of the wind load on the vehicle are derived in the whole process that the train runs into the wind barrier until