

Analysis of Aerodynamic Forces Acting on a Train Passing Through a Tornado

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Abstract : The crosswind effect on ground transportations has been extensively investigated for decades. The effect of tornado, however, has been hardly studied in spite of the fact that even heavy ground vehicles, namely, trains were overturned by tornadoes with casualties in the past. Therefore, aerodynamic effects of the tornado on the train were studied by several approaches in this study. First, an experimental facility was developed to clarify aerodynamic forces acting on a vehicle running through a tornado. Our experimental set-up consists of two apparatus. One is a tornado simulator, and the other is a moving model rig. PIV measurements showed that the tornado simulator can generate a swirling-flow field similar to those of the natural tornadoes. The flow field has the maximum tangential velocity of 7.4 m/s and the vortex core radius of 96 mm. The moving model rig makes a 1/40 scale model train of single-car/three-car unit run through the swirling flow with the maximum speed of 4.3 m/s. The model car has 72 pressure ports on its surface to estimate the aerodynamic forces. The experimental results show that the aerodynamic forces vary its magnitude and direction depends on the location of the vehicle in the flow field. Second, the aerodynamic forces on the train were estimated by using Rankin vortex model. The Rankin vortex model is a simple tornado model which widely used in the field of civil engineering. The estimated aerodynamic forces on the middle car were fairly good agreement with the experimental results. Effects of the vortex core radius and the path of the train on the aerodynamic forces were investigated using the Rankin vortex model. The results shows that the side and lift forces increases as the vortex core radius increases, while the yawing moment is maximum when the core radius is 0.3875 times of the car length. Third, a computational simulation was conducted to clarify the flow field around the train. The simulated results qualitatively agreed with the experimental ones.

Keywords : aerodynamic force, experimental method, tornado, train

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