The Impact of Speed and Blockage Ratio on the Aerodynamics of the Evacuated Tube Transportation System

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The aerodynamic characteristics of the evacuated tube transportation system were investigated based on the Reynolds-averaged Navier-Stokes κ-ω shear-stress transport simulation model in this study. a full-scale tube train model placed at the axis of a vacuum tube is chosen, which consists of a cone head (train head), a cylinder pod body (train carriage), and a cone tail (train tail). A series of cases at various inlet speeds were conducted in this study, including U_∞ = 100, 200, 300, 400, 500, 600, and 700 m/s (corresponding to Ma_∞ = 0.288, 0.576, 0.864, 1.152, 1.440, 1.728, and 2.016, respectively). The static pressure (P_∞) was set to 1,013.25 Pa, equal to 0.01 atm. The static temperature (T_∞) was set to 300 K. The sensitivity study is performed on three different grids with different numbers of cells: coarse, medium, and fine grids consisting of 8.2 million, 19.4 million, and 34.5 million cells, respectively. In consideration of costs and accuracy of simulation, the medium mesh setting is applied in the following study.

The ETT systems with 10 m and 6 m diameter tube at the blockage ratio（β）of 0.09 and 0.25, respectively, are learned in this study. Fig. 1 elucidates drag of both system cases increases as the speed increases from 100 m/s to 500 m/s. Meanwhile, the drag of 0.25 blockage outclasses that in cases of 0.09 blockage at all speeds. The drag increases with the increasing traveling speed of the train at the blockage ratio of 0.25. However, it is fancy that there is a drag-drop at the speed of 600m/s at the blockage ratio of 0.09.

The Mach number contours in the (x, z) plane at y = 0 covering the partial area in front of the train and its wake region are shown in Fig. 2a to g, which correspond to cases of 100 m/s to 700 m/s of 0.09 blockage ratio, respectively. Fig. 2h to n correspond to cases of the 0.25 blockage ratio. The velocity in front of the train is lower than their corresponding traveling speed from 200 m/s to 700 m/s at the blockage ratio of 0.25. No doubt that choking has occurred in these cases. Due to the decrease of blockage ratio, choking is found only at speeds of 300 m/s, 400 m/s, and 500 m/s at the blockage ratio of 0.09. This means that the system has jumped over the Kantrowitz limit at the speed of 600 m/s.

In all, drag increases with the increasing traveling speed from 100 to 500 m/s for both systems. However, drag has a drop as the traveling speed jumped over the Kantrowitz limit at 600 m/s at the blockage ratio of 0.09. It is obvious that the flow structures are significantly different from each other whether the choking has happened. Reducing the blockage ratio is good to reduce the drag of the tube train. Meanwhile, higher drag reduction is found when the speed is out of the range of the isentropic and Kantrowitz limits.

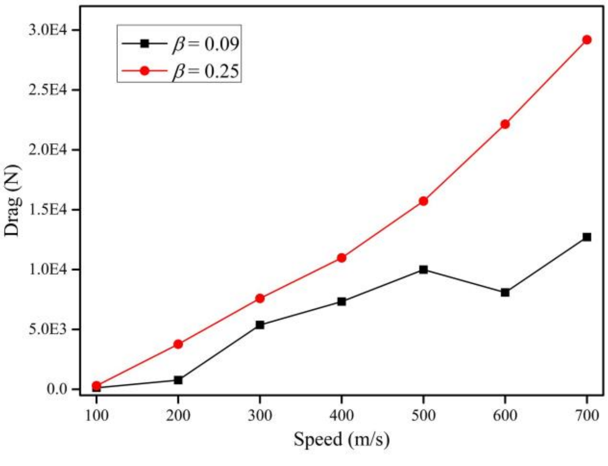

Fig. 1 Relationship between drag and traveling speed at the blockage ratio of 0.09 and 0.25

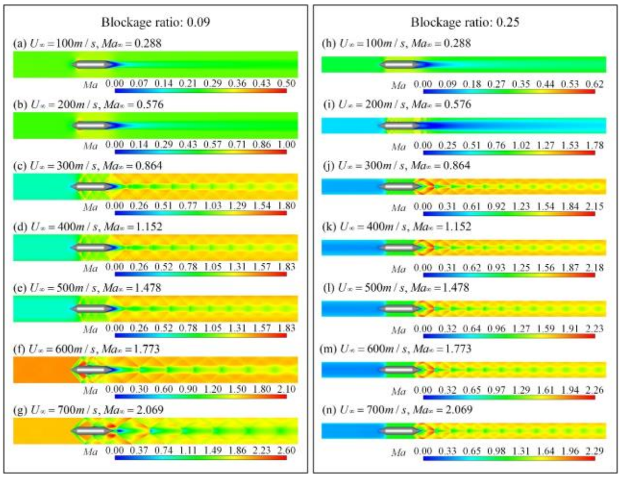

Fig. 2 Mach number contours in the (x, z) plane at y = 0