Anti-snow optimization in equipment cabin of high-speed trains based on wind-snow wind tunnel tests

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SUMMARY:
To investigate the influence of the filter density at the fairing grille of the equipment cabin on the snow particle accumulation distribution and snow quality inside the cabin, this paper conducted a single-phase flow wind tunnel test and a wind-snow two-phase flow wind tunnel test on a typical anti-cold high-speed train full-scale equipment cabin model based on the icing snow wind tunnel test bench of Central South University. The test results show that the increase in filter density has little effect on the airflow in the equipment cabin and little effect on the equipment work in the cabin without snow. In the wind-snow environment, the increase of filter density has a better blocking effect on the snow particles entering, and the average snow thickness on the windward side of the cabin is reduced by 55.1% when the high-density filter is replaced, and the total snow volume in the cabin is reduced by 66.3%.

Keywords: High-speed train equipment cabin; Full-scale model; Icing-snowing wind tunnel

1. INTRODUCTION

The high-speed railway (HSR) network of China is gradually expanding to the middle to high latitudes of freezing and snow-rich areas. The low temperature in winter in freezing snow-rich areas lasts for a long time, and the amount of snowfall during the low temperature is large, so there is often severe snow accumulation on the track of HSR (Yan et al.,2015). When trains run on snowy lines, the snow particles on the track are disturbed by the train indued wind to follow the train movement and attach to the surface of the car body, which seriously interferes with the regular operation of the train (Feng et al.,2017; Wang et al., 2018a).

For the optimization of anti-snow in the lower region of the car body of the high-speed train (HST), scholars' research has focused chiefly on the bogie region (Han et al., 2020; Wang et al., 2018b; Gao et al., 2020; Miao and He, 2018; Wang et al., 2018c). In the operation of HSTs, the phenomenon of snow particles entering the equipment cabin of the lower part of the car body through the fairing grille is also more severe and will lead to the train stopping when serious. At present, there still needs to be more research on anti-snow in the equipment cabin area of trains. Therefore, this paper is based on the wind tunnel test bench of Central South University to investigate the influence of the filter density on the amount of snow accumulation in the equipment cabin of the HST.

2. ENVIRONMENT SETTINGS

2.1. Test environment

The test was carried out in the icing snow wind tunnel test bench of the High Speed Train Research Center of Central South University. The wind tunnel is a reflow type low-speed and low- temperature wind tunnel. The airspeed environment range is 0~30m/s, and the temperature range is -15~50℃. The wind tunnel test section is 6.3m long, 1m high, and 4m wide, with a 5m diameter turntable and track at the bottom, which can realize 0-90° rotation of 10t test object. The snow-making system is a subcooled water spraying system, where the subcooled water is sprayed out by the nozzle to form a mist and condenses and crystallizes naturally in the wind tunnel. The wind tunnel contraction section has a liquid nitrogen release system, which can realize snow particles' secondary cooling and drying.

2.2 Test model

The test model is a full-scale train equipment cabin with a bogie motor ventilator suspended inside the cabin and a fan outlet at one side of the end plate. The equipment cabin fairing is equipped with a grille and filter, the cabin is perpendicular to the test section entrance, and the gap of the cabin is sealed by filling. The grille of the leeward side fairing is enclosed.

This paper uses two different densities of filters: the low-density original filter (LDOF) and the high-density optimized filter (HDOF). The external dimensions and structure of the two filters are identical, and only the number of filter filler layers within the structure differs, and a comparison of their structure and porosity rate can be seen in Fig. 1.

LDOF HDOF

Figure 1. Comparison of porosity rate.

3. COMPARISON AND ANALYSIS OF TEST RESULTS

3.1. Airflow velocity

Fig. 2 compares the airflow velocity at the measurement point near the grille. Compared with the LDOF, the airflow velocity at the measurement point of the HDOF did not change significantly. Fig. 3 show the airflow velocity monitoring values at the inlet and outlet of the motor ventilator, respectively. Compared with the LDOF, the HDOF also has less effect on the airflow velocity at the inlet and outlet. In summary, increasing the filter density has no significant effect on the airflow at the grille of the equipment cabin fairing and the air supply performance of the motor inside the cabin.

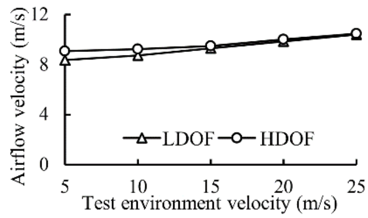

Figure 2. Comparison of the air flow velocity at the grille.

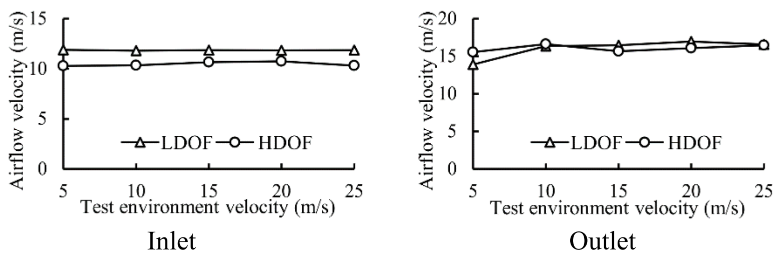

Figure 3. Comparison of the air flow velocity at the ventilator.

3.2. Snow particles accumulation

Tab. 1 shows the snow thickness in the equipment cabin. It can be found that the average snow thickness at the measurement points after adopting the HDOF is reduced by about 55.1%, and it is mainly concentrated on the bottom plate surface. The snow thickness at the base of the fairing was reduced less and increased at some sampling points.

Table 1. Snow thickness in the equipment cabin.

Measurement point	LDOF/cm	HDOF/cm
Bottom plate 1	4.5	0.2
Bottom plate 2	4	0.7
Bottom plate 3	3.4	0.8
Bottom plate 4	4.4	0.9
Bottom plate 5	3.3	1.2
Base 1	3.6	2.4
Base 2	2.1	1.8
Base 3	1.9	4.2

Fig. 4 shows the snow mass inside the equipment cabin with different density filters. The total snow mass in the equipment cabin is reduced by 66.3% after adopting HDOF, among which the snow mass in the bottom plate is reduced significantly, and the snow mass in the windward side fairing is increased, which highly corresponds to the change of snow thickness in the previous section, indicating that the HDOF can weaken the kinetic energy of snow particles when entering the equipment cabin through the fairing grille and significantly reduce the snow mass inside the cabin.

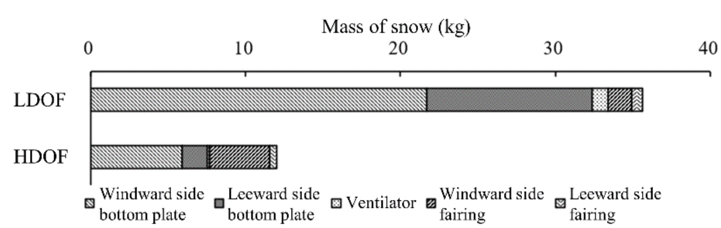

Figure 4. Snow mass inside the equipment cabin.

4. CONCLUSION

In this paper, the wind tunnel tests of single-phase flow and wind-snow two-phase flow of the full-scale equipment cabin model of the HST were carried out by relying on the icing snow wind tunnel test bench of Central South University. The influence of airflow velocity, the filter density on the snow particle accumulation distribution, and snow quality inside the cabin was investigated, and conclusions were obtained.

(1) The airflow velocity at the fairing grille of the equipment cabin, the inlet and outlet of the motor ventilator in the cabin with the LDOF and the HDOF are not found to be significantly different, indicating that the airflow of the equipment cabin and the ventilator has been stable. The airflow at the fairing grille and the air supply performance of the motor ventilator inside the equipment cabin are not significantly affected by increasing the filter density.

(2) Compared with LDOF, the average thickness of snow particles on the windward side of the equipment cabin after changing HDOF is reduced by 55.1%, the total mass of snow is reduced by 66.3%, and the distribution of the severe area of snow accumulation is significantly shifted outward to the windward side, which shows that increasing the density of the filter can effectively weaken the kinetic energy of snow particles entering the equipment cabin and reduce the mass of snow inside.

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