News Release

Railway Technical Research Institute

October 28, 2020

Numerical Simulation of Train Cabin Ventilation by Open Windows

RTRI numerically simulated the ventilation of an urban commuter train with windows opened, using the airflow simulator which RTRI developed, and evaluated its effect. (Fig.1)

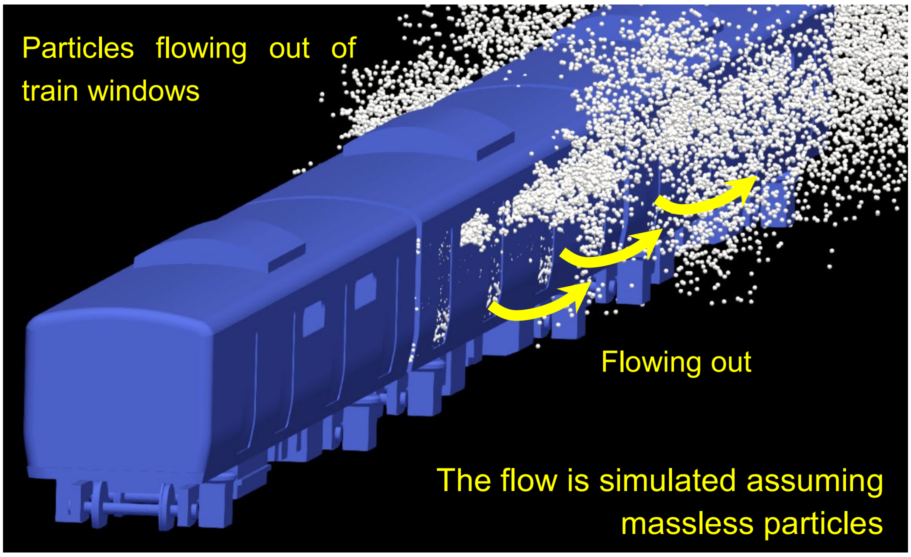


Fig. 1 Cabin air ventilated through open windows

[Outline of the result]

- The volume of the air ventilated from a train window is proportional to the opening areas and train running speeds.
- The volume of ventilated air is not substantially affected by passenger occupancy rates.
- When a train is running at 70 km/h with 6 windows opened by 10 cm, the ventilated volume through the windows is 0.36 ㎥/s, which means that the air inside a train cabin is completely replaced with the fresh air once every 5 to 6 minutes. The total ventilated volume combining air conditioners and open windows is 0.78 ㎥/s, meaning that the cabin air is replaced once every 2 to 3 minutes.

* Ventiration rate = Ventilated air volume per second

[Evaluation of ventilation rate]

* Posted on the website of the Ministry of Land, Infrastructure, Transport and Tourism on June 5, 2020

Fig.2 and 3 shows some of the simulation results. Fig. 2 shows ventilated volumes from 6 windows with different opening areas at train running speeds of 72 km/h and 45 km/h, with the passenger occupancy of 0% and Fig.3 shows the volumes at different speeds. As you can see from these graphs, ventilated volumes are proportional to opening areas and train speeds. For example, if a train is running at 70 km/h with windows pulled down 10 cm (opening area 0.72 ㎡), the ventilated volume of the car will be 0.36 ㎥/s. It means that the air inside the cabin is completely replaced with the fresh air once every 5 to 6 minutes.

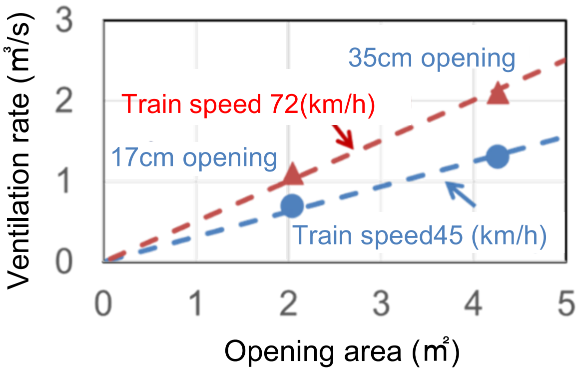


Fig. 2　Ventilation rate by opening area

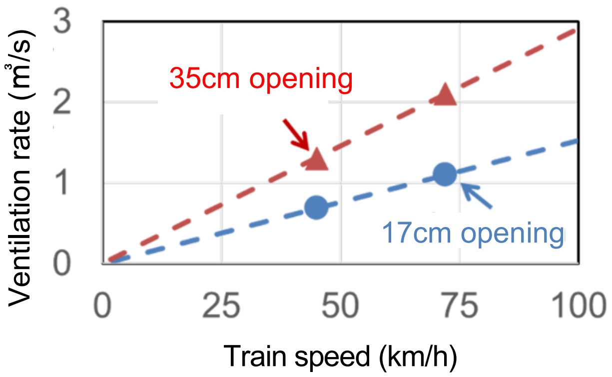
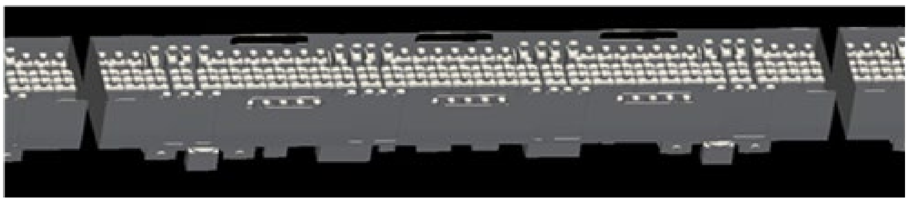


Fig. 3　Ventilation rate by train speed

[Evaluation of the impact by occupancy]

Using the models assuming 50% and 100% passenger occupancy shown in Fig.4, we analyzed the impact of the occupancy on ventilation rate. In the 50% model, all the seats are occupied and passengers are standing near the doors and around the center of the aisles. In the 100% model, passengers are standing with 10 to 20-centimeter distance from each other. The result of ventilation simulation under these conditions is shown in Fig.5, which indicates that the ventilated volumes decrease only a little, even if the occupancy rates go up.

(a) Occupancy（80 passengers）



(b) Occupancy（160 passengers）

Fig. 4　Passenger occupancy model

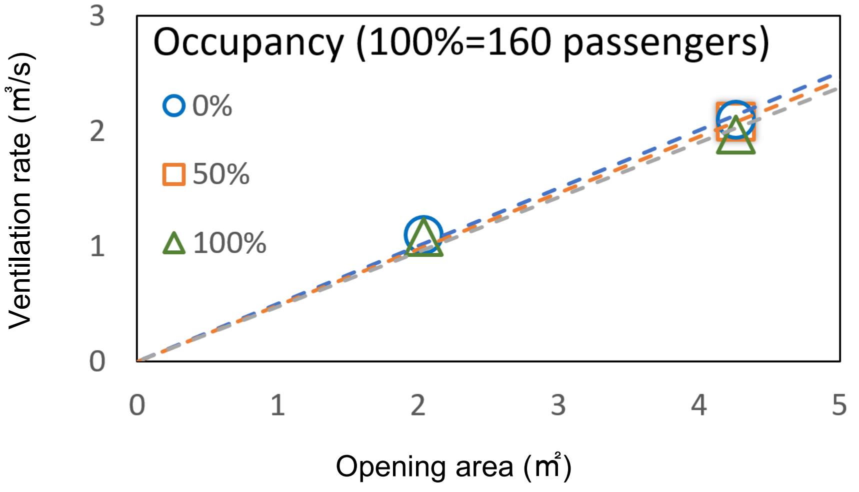


Fig. 5 Ventilation rate by occupancy

[Evaluation of the effects by air-conditioners and fans]

Using a model assuming that air-conditioners and fans are working (Fig.6), we have analyzed the relationship between air-conditioning effects and ventilated volumes. (Fig.7) The result is shown in Fig.8 and indicates that air-conditioning has little impact on the air volumes ventilated through open windows. Therefore, if a vehicle is equipped with air-conditioners taking in outer air, the ventilation rate will be the total of the intake by air-conditioners and the volume ventilated through windows. For example, as is shown in Table 1, if the intake of outer air by air-conditioners is 0.43 m^3/s, the air inside a cabin is completely replaced by fresh air every 2 to 3 minutes.

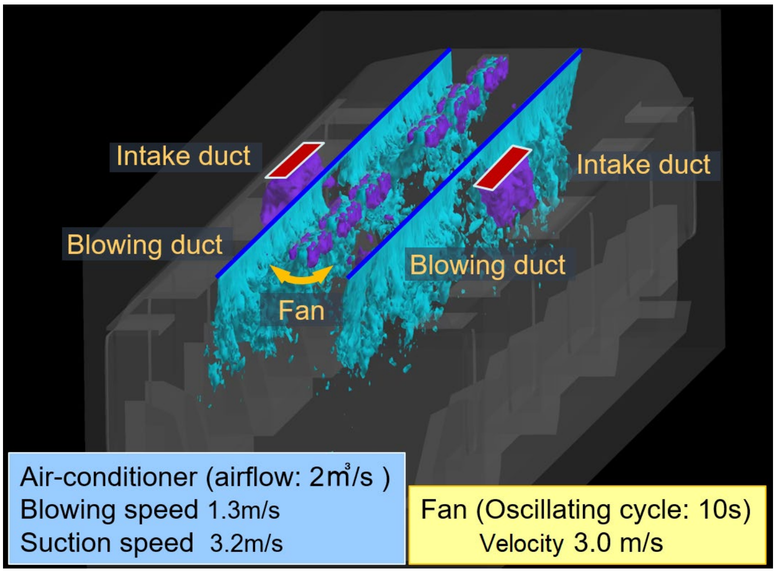


Fig. 6 Air-conditioned and fanned cabin model

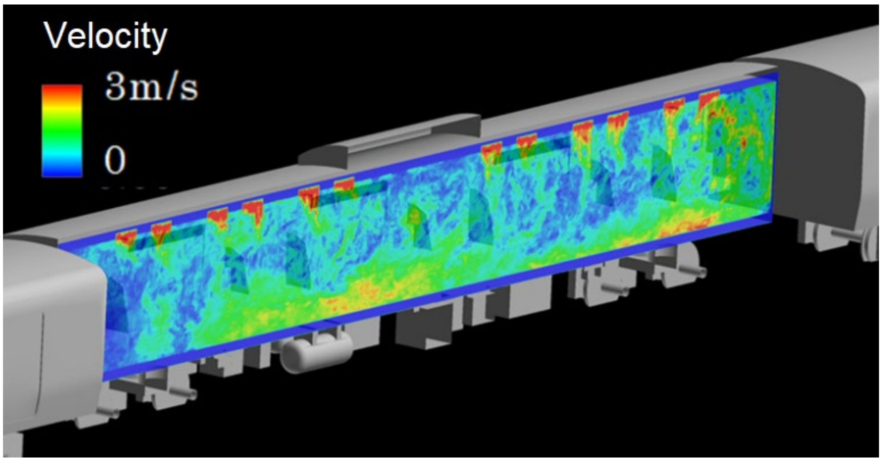


Fig. 7　Velocity distribution in a cabin

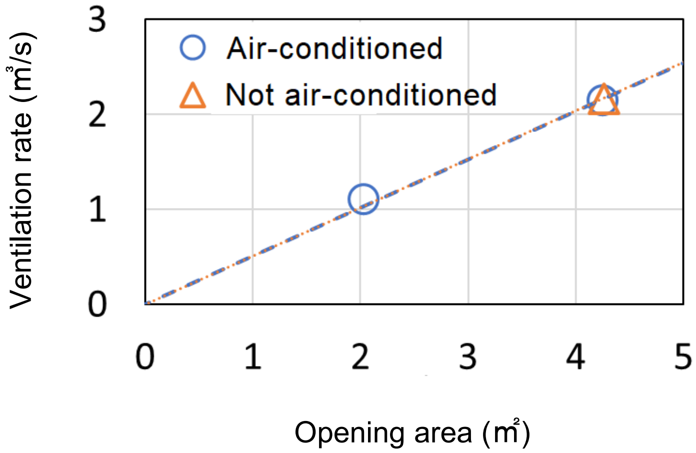


Fig. 8　Ventilation by windows and air-conditioning effects

Table 1　Ventilation effects by air conditioners taking in outer air

	With outer air intake	Without outer air intake
Ventilated volume by windows	0.35 m^3/s	0.35 m^3/s
Outer air intake by air conditioner	-	0.43 m^3/s
Time for complete replacement of air	5.3 minutes	2.4 minutes

[Further confirmation and evaluation]

We will confirm the accuracy of the numerical simulation through measurement on actual train vehicles and analyze the ventilation effects of the sideway seat arrangement and gangways. We will also evaluate in detail the airflow at different areas of such vehicles.