Effect of Air Mixing on Subway Cabin Temperature during Heating in Winter Season

Youngmin Cho, Woo-Sung Jung, Soon-Bark Kwon, Duck-Shin Park
Korea Railroad Research Institute Uiwang, 437-757, Republic of Korea

***Abstract*—Public interest on the thermal comfort of subway cabin is increasing, since more than 90% of the complaints from passengers are about the thermal discomfort. Some passengers may feel hot, while the others may feel cold even in the same cabin due to the uneven temperature distribution in the cabin. For this reason, the temperature difference in the cabin should be as small as possible. In our present study, the effect of air mixing on the temperature inside the subway cabin during heating was studied by using a climatic chamber. Ambient temperature was set at around –20°C, and the heaters of cabin were operated. Thermocouples were installed inside the cabin, and the temperature of each point was monitored. Various numbers of small house-hold fans were installed inside the cabin to induce the air mixing. It was found that the maximum vertical temperature difference could be reduced by increasing the number of fans.**

Keywords-: climatic test; heating; air mixing; wind; thermal comfort

I INTRODUCTION

The importance of thermal comfort in railroad passenger cabin is increasing due to the higher expectation of passengers on the thermal comfort in the cabin. The number of reported complaints is increasing. Some passengers may feel hot, while the others may feel cold even in the same cabin due to the uneven temperature distribution in the cabin. For this reason, the temperature difference in the cabin should be as small as possible. There can be several methods to reduce the temperature difference in the cabin.

In our present study, the effect of air mixing on the temperature inside the subway cabin during heating was studied by using a climatic chamber. The air mixing was prepared by using several fans inside the cabin. Ambient temperature was set at around –20°C, and the heaters of cabin were operated. Thermocouples were installed inside the cabin, and the temperature of each point was monitored. Various numbers of small house-hold fans were installed inside the cabin to induce the air mixing. It was found that the maximum vertical temperature difference could be reduced by increasing the number of fans.

II EXPERIMENTAL

A subway cabin was placed in a climatic chamber as presented in Fig. 1. 100 VDC and 3 phases 200 VAC were supplied to the car. 10 kW of heaters installed under the passengers' seats were turned on during the test. T type thermocouples were installed inside and outside of the tested train car to monitor the temperature change during the experiment. The location of the installation was basically carried according to the test method described in EN14750-2. However, the location was modified to investigate the vertical temperature distribution in the cabin. 15 thermocouple sets were installed inside of the train car as presented in Fig.2. At each measuring point, 5 sets of thermocouples were installed at various heights from floor of 0.1 m, 0.6 m, 1.1 m, 1.7 m, and 2.0 m. Obtained temperature values were saved to a data logger.

Fig.1: A subway cabin in a climatic chamber for the experiment

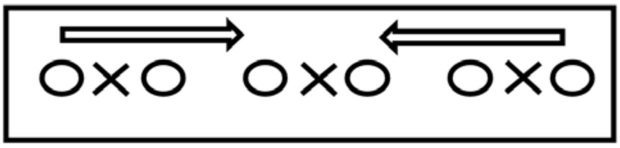

Fig.2: Location of thermocouple sensors (X) and fans (O) inside the cabin

Fig.3 shows the layout of climatic chamber used in this study. Temperature of this chamber can be controlled from -40 °C to +60 °C. In this study, temperature of the climatic chamber was set at -20 °C, and the heaters of the cabin were operated with 10 kW of output. The thermal equilibrium inside and outside of the cabin was reached after more than 12 h of equilibrium time. The effect of air mixing on the temperature distribution in the cabin was extensively studied by operating conventional fans inside the cabin. The location of fans installed was also presented in Fig. 2.The fans were facing the centre from each end.

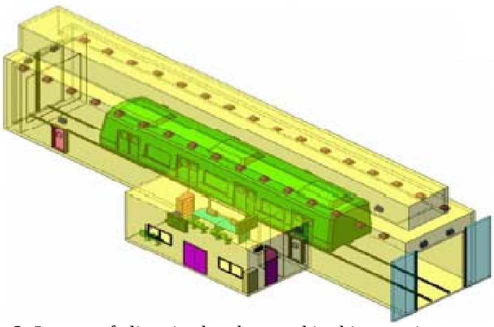

Fig.3: Layout of climatic chamber used in this experiment

III RESULTS AND DISCUSSION

Temperature changes before and after the operation of the additional fans on the cabin temperature was presented in Table 1. When no additional fan was operated, temperature at 0.1 m was around -0.4 °C, while that at 2.0 m was around 9.7 °C. This shows the significant temperature difference in the cabin around 10.1 °C. However, as soon as the fans were operated as light wind, the temperature at 0.1 m increased upto 1.9 °C, and the temperature at 2.0 m decreased to 8.6 °C.

TABLE 1:MEASURED TEMPERATURE FOR STRONG WIND EXPERIMENTAL CONDITION

Height	No wind	2 Fans	4 Fans	6 Fans
0.1 m	-0.4	4.7	4.6	4.9
0.6 m	8.9	7.3	7.0	7.4
1.1 m	9.4	7.6	7.1	7.5
1.7 m	9.6	7.8	7.1	7.5
2.0 m	9.7	7.8	7.1	7.5
Avg	7.4	7.0	6.6	6.9

However, there was no significant change in the average temperature due to the operation of fans. The maximum temperature difference in the cabin also drastically decreased as presented in Fig. 4.

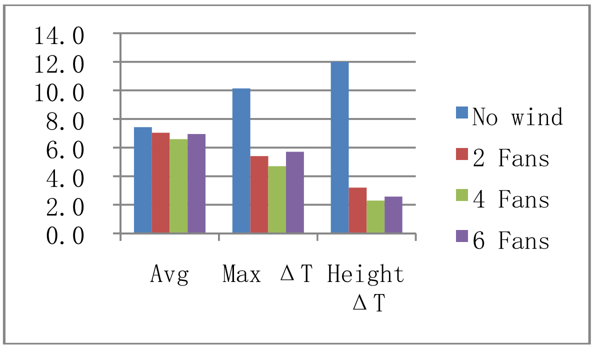

Fig.4: Average temperature, maximum temperature difference, maximum temperature difference between average temperatures at each height with strong wind experimental condition.

When more fans were operated, the temperature at 0.1 m increased, and temperature at 2.0 m decreased though the average temperature was not significantly changed. This shows that the operation of fans in the cabin can make more thermally comfortable space. When the wind was changed strong, as presented in Table 2, the temperature at 0.1 m increased more, while the temperature at 2.0 m decreased more

TABLE 2:MEASURED TEMPERATURE FOR LIGHT WIND EXPERIMENTAL CONDITION

Height	No wind	2 Fans	4 Fans	6 Fans
0.1 m	-0.4	1.9	4.0	3.8
0.6 m	8.9	8.4	7.9	7.3
1.1 m	9.4	8.4	7.8	7.8
1.7 m	9.6	8.6	7.8	7.8
2.0 m	9.7	8.6	7.7	7.7
Avg	7.4	7.2	7.0	6.9

As shown in Fig. 5, the average temperature was a little bit lower than with the light wind condition. Though the maximum temperature could be drastically lowered with this strong condition, this strong wind can cause the thermal discomfort for the passengers. However, there was no change in the average temperature due to the operation of fans. The maximum temperature difference in the cabin also drastically decreased as presented in Fig. 5.

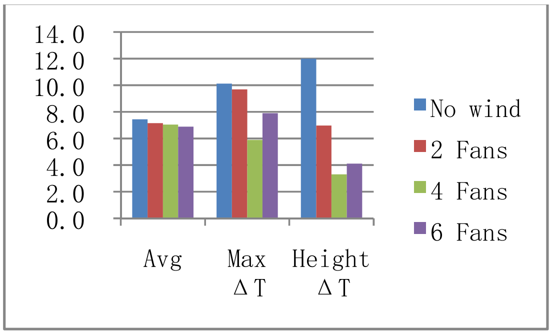

Fig.5: Average temperature, maximum temperature difference, maximum temperature difference between average temperature at each height with light wind experimental condition

IV CONCLUSIONS

The effects of air mixing on the temperature distribution inside the subway cabin during heating were studied by using a climatic chamber. When the fans were operated the temperature difference in the cabin could be drastically decreased, while the average temperature was kept constant. It means thermally more comfortable environment can be prepared by simple air-mixing. When more fans were operated, and stronger wind was prepared, the temperature difference in the cabin could be lowered. However, since the strong wind may cause the discomfort of the passengers, optimal wind condition for the thermally comfortable environment is needed to be studied.

ACKNOWLEDGEMENTS

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