IMPROVEMENT METHOD OF THERMAL ENVIRONMENTAL NEAR WINDOWS DURING HEATING PERIOD - OUTLET CHARACTERISTICS AND CFD MODELLING METHOD OF THE SLOT LINE DIFFUSER

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Abstract

To improve the environment of the perimeter space, the slot line diffusers are widely used in Japan as the terminal equipment of air conditioning and ventilation system. In this research, two deflection panels are installed inside of the slot line diffuser to decrease the outlet area and increase the outlet airflow wind speed for improving the heating effect. However, the impact of the deflection panels and the slight outlet size make the diffuser's outflow characteristic complicated. So a full-scale experiment is carried out, the slot line diffuser set up in a free field, the temperature and velocity at diffuser's outlet space were measured, both the case of the air supply temperature and the outlet area are adjusted as parameters. Also, a detailed CFD model of the diffuser's outlet airflow is tried to build. A hotwire anemometer measured the velocity distribution at the diffuser's outlet surface in high frequency, and the turbulence statistics calculated to use as the boundary condition of a detailed CFD model of the slot line diffuser. Compare to the experiment data, the arrival range of outlet airflow in CFD simulation is probably predicted, as well as the discrepancy in the distribution of airflow in high speed was founded. Grid dependence and anisotropy of the CFD model will be examined in future studies.

Keywords: Slot line diffuser, Full-scale experiment, CFD

1 Introduction

The outlet airflow of slot line diffuser has limited reaching range in heating usage compared to cooling usage due to the impact of buoyancy. Without changing the outlet air volume (easy to balance the heating load), two deflection panels are installed inside the diffuser (*Fig.1*, *Fig.2*). Outlet air can jet out from only in the central part of the diffuser or all of the diffuser by adjusting the panels angle, so the outlet velocity is variable in the same air volume condition.

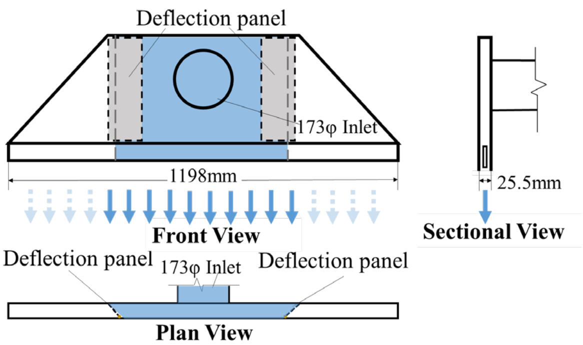

Figure 1. *Detail view of the slot line diffuser*

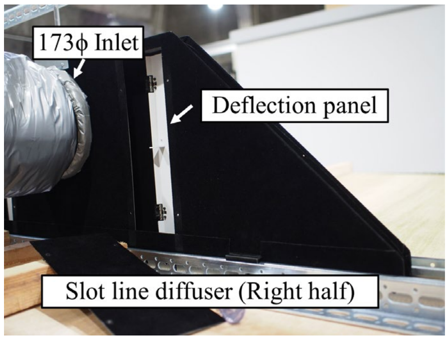

Figure 2. *Photograph of the slot line diffuser*

A full-scale experiment carried on in a free field. Velocity and temperature distribution of the diffuser's outlet airflow is measured by ultrasonic anemometer and thermocouple. Also, the velocity distribution in the diffuser's outlet surface is measured by a hot-wires anemometer with an X-type probe. A detailed CFD model of the diffuser's outlet airflow is built based on the outlet velocity data, and the accuracy is compared with the result of ultrasonic anemometer measurement.

2 Full scale experiment of slot line diffuser

2.1 Experiment facilities

The experiment was conducted at the building environment laboratory at Osaka University. A 3m(L) x 3m(W) x 3m(H), with ceiling but no envelope walls experiment space was built, regarded as a free field with ample space. The slot line diffuser is installed in the century of 3m height ceiling, connecting to a duct fan and electronic heater by a spiral duct to jet out heating or isothermal air. Also, the volume damper setting in the inlet area and the ultrasonic flowmeter setting between fan and diffuser can be used to control the outflow volume. (*Fig.3, Fig.4*)

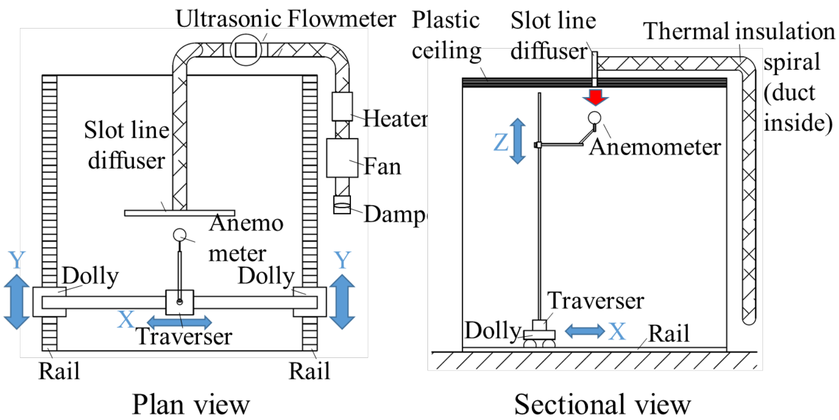

Figure 2. Detail view of the experiment facilities

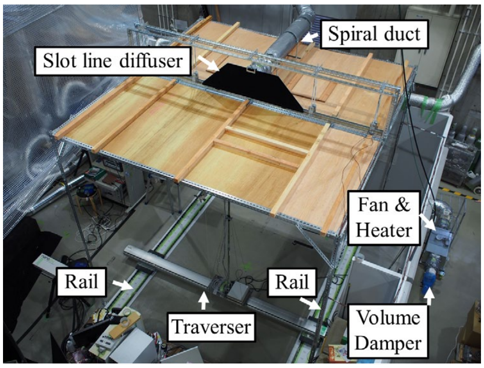

Figure 3. Photograph of experiment facilities

2.2 Measurement method & Essential conditions

Ultrasonic anemometer (10 Hz) and thermocouples (1Hz) were used to movement measured the vector velocity and temperature description in outlet space, at 7×11×4=308 points. Locations of the measurement points in outlet space are shown in Fig.4. At the Fl+2997mm height surface (3mm from diffuser's outlet), X-type probe hot-wires anemometer (1000 Hz) was used to movement measured the vector velocity in uvw components, at 7×11=77 points. Locations of the measurement sections and points at the outlet surface are shown in Fig.5. The measurement at the outlet surface only accrued in the right half of the diffuser.

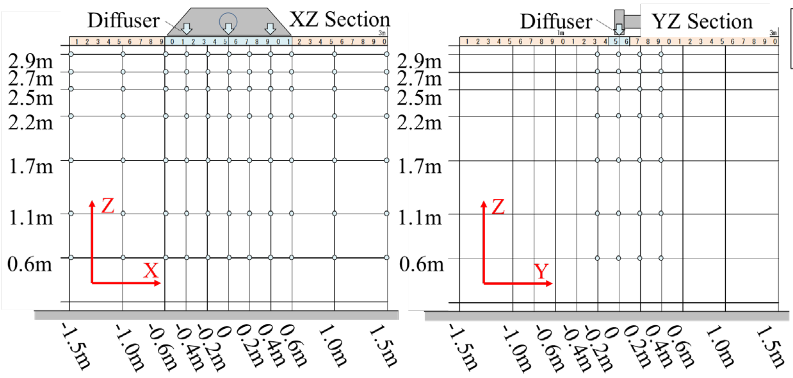

Figure 4. Measurement points in outlet space

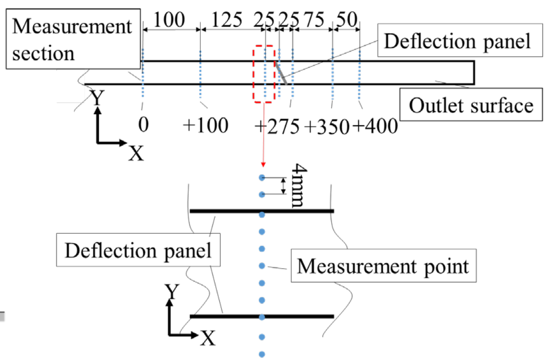

Figure 5. Measurement point at the outlet surface

The temperature of the duct's inlet, diffuser's outlet, and the laboratory's vertical distribution were also measured to ensure the experiment's essential temperature condition. In this study, all the cases have the same outlet volume as 200Nm^3/h, and the outlet temperature in the heating supply case is 8°C higher than the laboratory's indoor temperature.

3 CFD modelling of the slot line diffuser

3.1 Simulation model and boundary conditions

Only the central isothermal outlet case is being examined by CFD. The model of outlet space is shown in *Fig.6*, diffuser's outlet surface is divided into 7×22=154 boundary conditions as *Fig.7*. Calculation conditions used in CFD are shown in *Table.1*. Every outlet boundary condition has a unique velocity characteristic based on the modified experiment data. Modified data (experiment data after the averaging approximation and the interpolation correspond to the locations of boundary conditions) which used as the boundary conditions, are shown in *Fig.8* and *Fig.9*.

***Table 1**: CFD Calculation conditions*

Analysis Method	CFD code	STREAM V14.1
	Turbulence Model	Standard k-ε model
	Algorithm	SIMPLER
	Discretization Scheme	QUICK
	Number of Mesh	742560
Boundary Condition	Ceiling	No-slip
	Wall	Free-slip
	Floor	No-slip
	Inlet	Velocity regulation
	Outlet	Flow rate regulation
Turbulence statistics	Kinetic energy k	0.738[m^2/s^2]
	Dissipation rate ε	34.38[m^2/s^3]

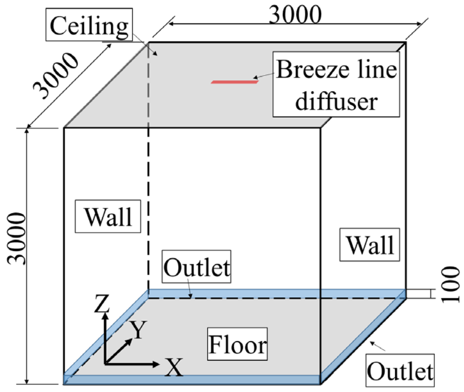

***Figure 6**. Image of outlet space in CFD model*

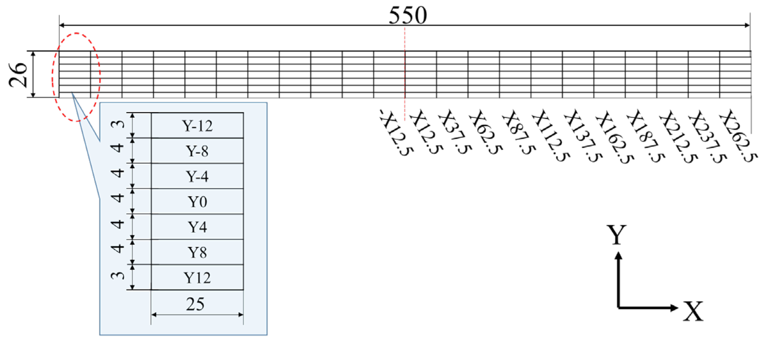

***Figure 7**. Distribution of outlet boundary condition*

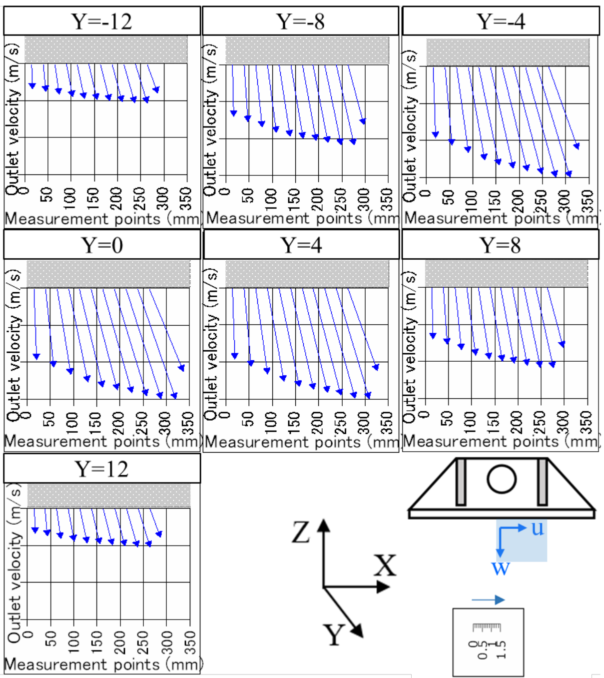

***Figure 8**. Boundary velocity(uw) after modified*

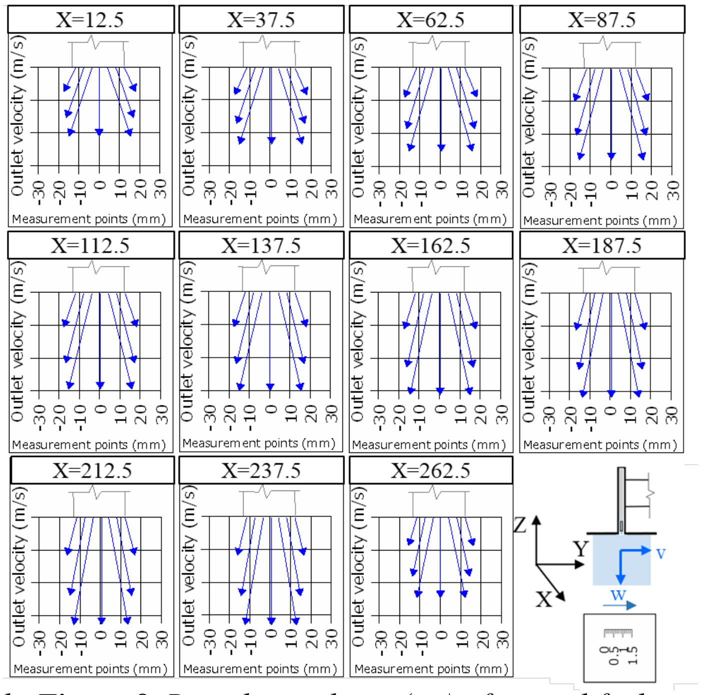

***Figure 9**. Boundary velocity(vw) after modified*

3.2 Turbulence statistics

The turbulence statistics of outlet airflow are calculated based on the wind speed data measured by hotwire anemometer at the frequency of 1000*Hz* in 60 seconds. All the outlet boundary conditions use the same kinetic energy (k=0.738[m^2/s^2]) and turbulence length scales (l=0.00224[m]), which is the average value calculated from all the measurement points in the range of diffuser's outlet area.

4 Results

Fig.10~Fig.15 shows the scalar wind speed and temperature description in outlet space based on measurement data. *Fig.16* shows the scalar wind speed description by CFD simulation (Only isothermal central outlet case).

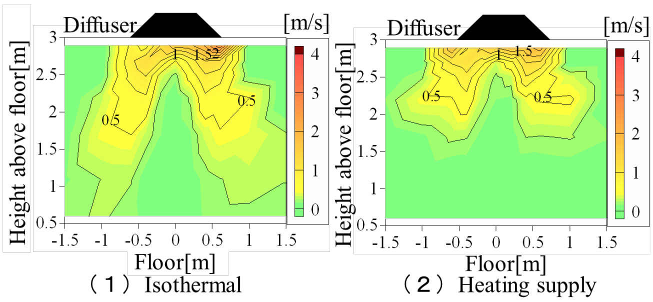

***Figure 11**. Wind speed of Y section(1/1outlet)*

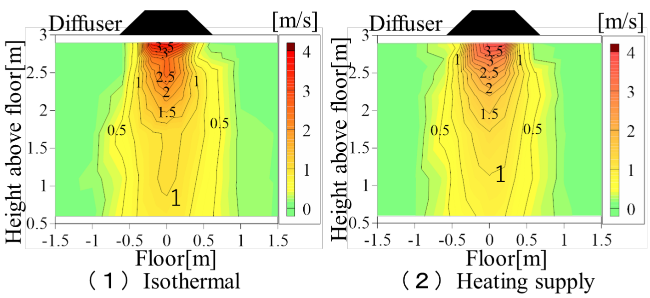

***Figure 12**. Wind speed of Y section(1/2outlet)*

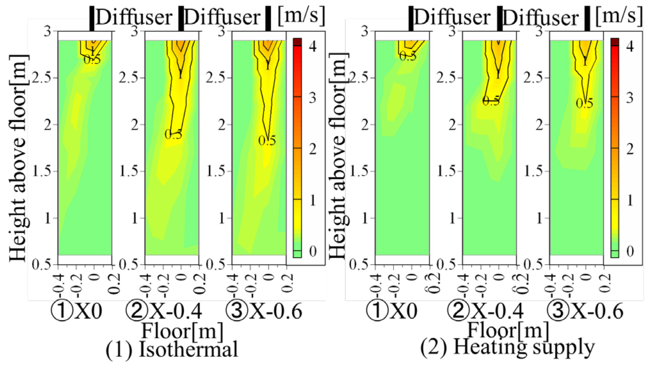

***Figure 13**. Wind speed of X section(1/1outlet)*

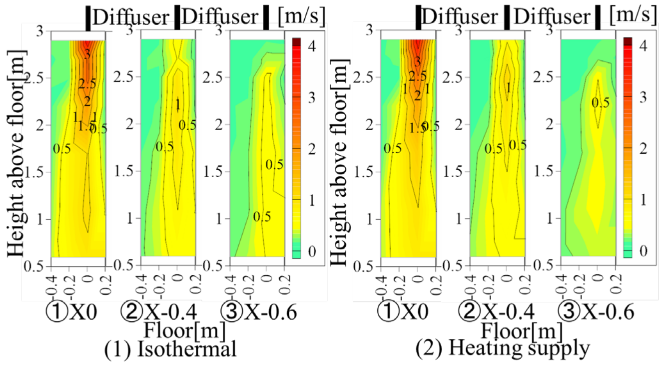

***Figure 14**. Wind speed of X section(1/2outlet)*

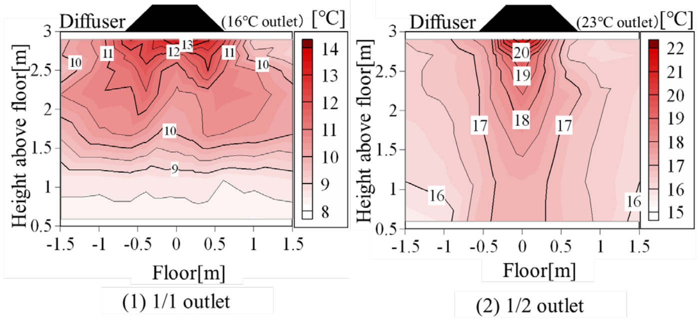

***Figure 15**. Temperature of Y section*

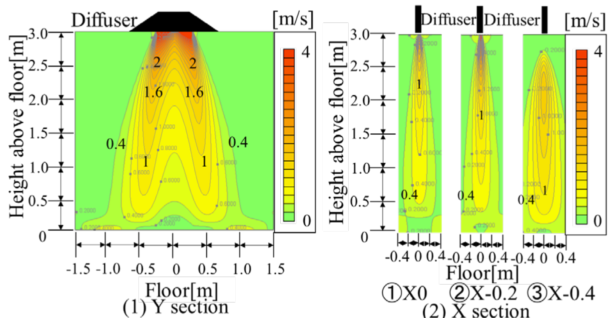

***Figure 16**. Wind speed of Y section(1/2outlet) by CFD*

5 Conclusions

At the same outlet air volume, slot line diffuser's heating efficacy is limited due to the heating airflow cannot reach the living area. However, setting the deflection panels can make the velocity of heating airflow fast enough to go through into the living zone even closed to the floor, which is proved to enhance the diffuser's heating efficacy. A detailed CFD model of slot line diffuser with deflection panel closed was built based on the outlet velocity data measured by the hot-wire anemometer. The spread range of outlet airflow was probably predicted, but the description of airflow at high speed near the diffuser is d from the experiment data. Grid dependence and anisotropy of the CFD model will be examined in future studies.

6 References

Shaoyu Sheng, Toshio Yamanaka, Tomohiro Kobayashi, Jihui Yuan, Masahiro Katoh, Saori Yumino, 2019, *Study on Thermal Environmental Control Using the Breeze Line Diffuser Near the Window During the Heating Period,* Proceedings of Annual Meeting of SHASEJ (In Japanese), pp345-348.