Analysis of Uniformity and Energy Consumption in Supermarket installed DurkeeSox Air Dispersion System with PE Air Dispersion Model

Summary: Taking partial area of a large supermarket for example, to simulate the airflow distribution of DurkeeSox Air Dispersion System with PE (Permeation and Orifices Ejection) air dispersion Model, to verify the simulation reliability by experiment. DurkeeSox air dispersion system effectively prevents airflow blocking by store shelves in contrast to air supply through diffuser outlets, enables the <u>airflow quickly reach the working area, forms a tridimensional air dispersion effect with great comfort, overall even airflow, greatly improve air distribution efficiency and reduce the energy consumption</u>.

0 Introductions

DurkeeSox[®] Air Dispersion System (also known as fabric air duct) is an innovative air supply mode, it disperses airflow through both fabric permeation and high velocity multi-row orifices designed and no insulation is required. <u>Air volume dispersing through fabric permeation is controlled less than 5% to prevent condensation, meanwhile more than 80% permeation air volume will be affected by inducing cold air flow going down to the floor and ensure no waste of energy.</u> Compared to traditional air supply, DurkeeSox makes airflow quickly reaching the working area, reduces heat exchange in the high space, and forms more uniform air velocity & temperature distribution. For supermarket, dispersing airflow through traditional lower velocity diffuser outlets, the airflow will be blocked by shelves and difficult to reach required working area. Moreover, low air velocity diffuser outlet results in greater loss of energy due to longer time and more heat exchange in higher space.

1 Physical Modeling

1.1 Building facts

The supermarket is located in Wuhan city, China. the selected area for simulation is a part of the supermarket, size 10m × 9m × 5m (L × W × H) & 90 square meters. Shelf size inside 3.3m × 0.83m × 3m (L × W × H), details refer to Figure 1:
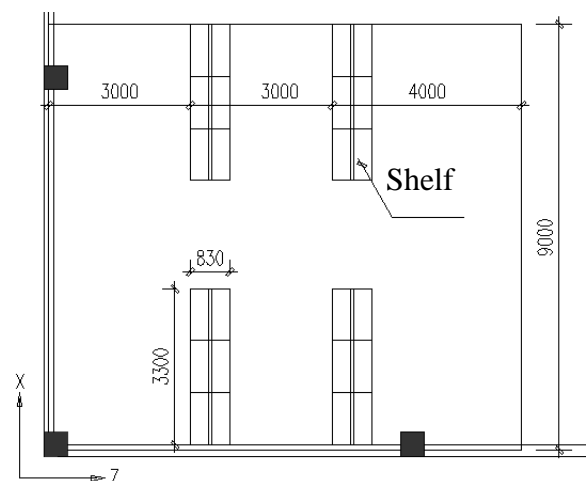

Figure 1 Supermarket Partial

1.2 Air supply system profiles

DurkeeSox® air dispersion system as shown in the figure consists two fabric air ducts with double row orifices for air supply, and single-layer grille for return air, the main transportation duct connected with DurkeeSox and AHU is metal duct. DurkeeSox fabric air duct diameter is 305mm, the BOD of the duct to the floor is 4m. Two pcs of return air grille is arranged on the side wall X = 0, size 1000mm x 250mm (width × height), the distance from the lower edge of the return air grille to the floor is 0.15m, distance between two grilles is 3m, distance from outlet edge to Y-axis is 2.5m. The orifice direction of fabric air duct is at an angle of 30 °pointing to the earth vertical direction, orifice size is 0.5 inches (12.7 mm) , orifice spacing 80mm, total 216 pcs orifices. Air volume per duct is 1800 m ³/ h (138 m ³/ h going through fabric permeation) , pressure 150Pa, supply air temperature 18 °C. Outdoor temperature is 35.2 °C DB in summer; indoor design temperature is 25 ± 2 ° C, taking the actual high density of people into account, designed end air velocity in working area is 0.3 to 0.5m/s.
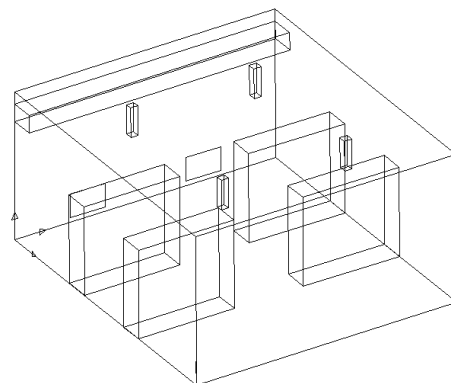
Air supply system of grille diffuser outlet is as shown below, diffuser outlet size is 250mm x 250mm, total four pcs, the outlet spacing at X direction is 4m, spacing at Z direction is 5m, the distance from lower end of the outlet to the floor is 4 m.

Air volume for four diffuser outlet and DurkeeSox air dispersion system is equal, air velocity is 4m / s, the supply air temperature is 18 °C; Other boundary conditions are same as the fabric air duct.

Location and size of the return air grille are also same as fabric air duct.
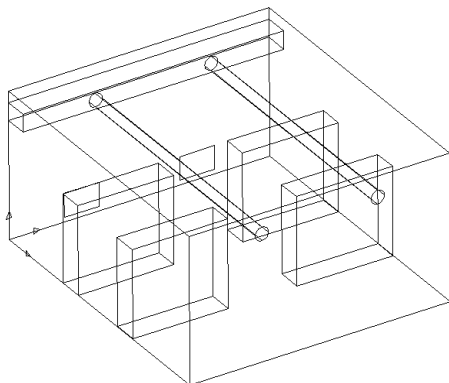
DurkeeSox® Air Dispersion System Layout   Traditional Diffuser Outlet Layout

2. Numerical simulation of Mathematical model

Turbulence model adopted K-ε double equation model

Boundary conditions - Main parameters settings:

a. Permeation air velocity of fabric air duct 0.005m / s, airflow going out vertically to the wall.

b. Orifice is simplified to be mesh slot based on design air volume, inlet air velocity is 12.3m / s (converted from unchanged air quantity).

c. Calculates regional the solid wall boundary, for the external walls of Z = 0 and x = 0, using the constant heat flux boundary conditions, heat flux density is 20W / m ², and the remaining wall is set to the interior wall of the adiabatic boundary conditions.

d. Using a standard wall function to eliminate the limitations of the standard turbulence model at near wall area.

e. The supply air temperature is 18 ℃.

3 Actual Experiments

This test is conducted in summer. Since the working area is a rectangle, namely as symmetrical area, also the fabric air ducts are arranged symmetrically. Therefore, we only need to measure the following areas (0 ≤ X ≤ 4.5,0 ≤ Z ≤ 10), so as to reflect the flow field of the entire work area . Arrange measuring points in the simulation area uniformly, measuring points distribution at activity area are shown in Figure 3:
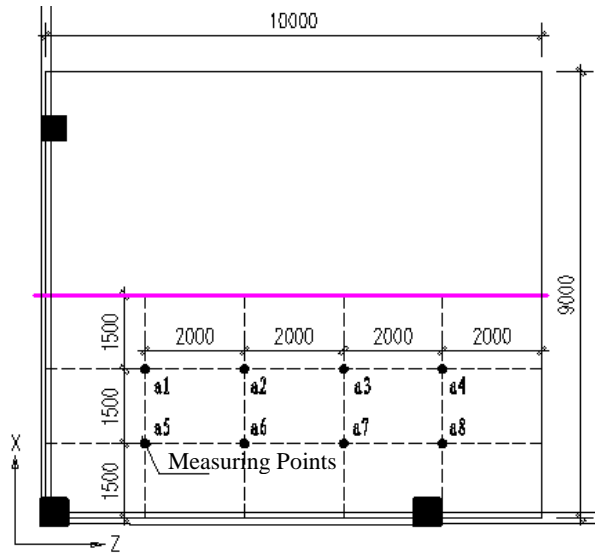

Figure 3 Measure Points Layout

Choosing y = 1.5m cross-section, comparison of flat temperature and air velocity. The measured values and results of numerical simulation as well as fitting curve are shown in Figure 4, Figure 5.
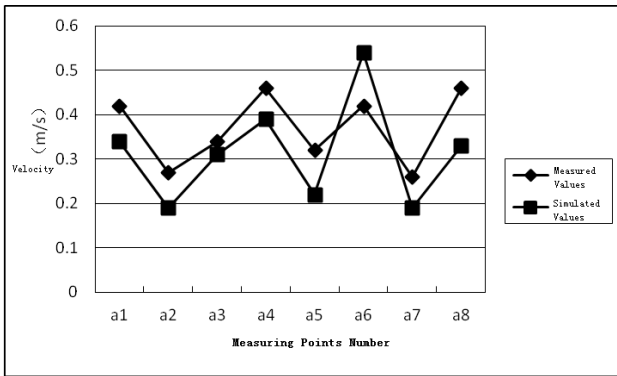

Figure 4 Y = 1.5m Height Measured Air Velocity and Simulated Velocity Comparison Diagram
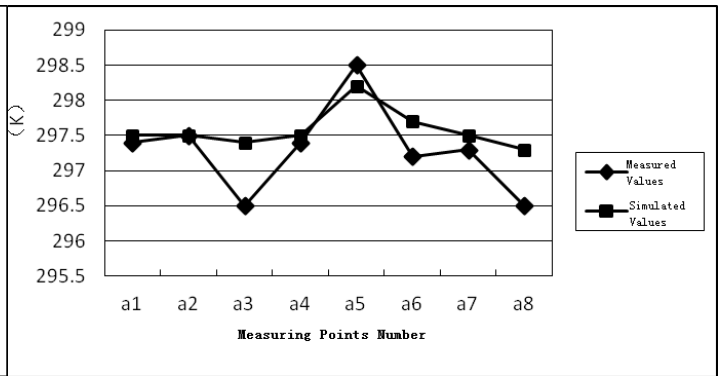
Figure 5 Y = 1.5m Height Measured Air Temperature and Simulated Temperature Comparison Diagram

As can be seen from Figure 4 and 5, measured air velocity is slightly greater than the simulated values generally, less than simulated values only in few measuring points. Measured temperature values are 0.2 to 0.5 °C higher generally. Since the simulation assumes that the area is closed area, but actually there are small amount of air leakage due to the doors and windows, causing outdoor air into the room, and the room temperature rises. We can find that the variation trend of both measured values and simulated values of air velocity and temperature at measuring points are same, the numerical simulation results match the actual circumstances described herein, thus the selected calculation model, the boundary condition are feasible.

## 4 Contrasts of DurkeeSox® system and Traditional grille diffuser Air Supply

The figure below shows Y = 1.5m cross-section fabric air duct and grille diffuser air velocity distribution in summer condition. As we can be seen, the airflow distribution of fabric air duct is more uniformed due to perpendicular to shelves, the air velocity is also more uniformed; meanwhile, we can also find out that air velocity of DurkeeSox air dispersion system is higher at the same height comparing to grille diffuser air outlet (air velocity is 0.45m / s), fabric air duct is more conducive for the airflow to quickly reach the ground and reduce high-altitude heat exchange, we can see from the distribution of temperature field that the average temperature of fabric air duct solution is 1-2 degrees Celsius lower than the grille diffuser solution at the same height.
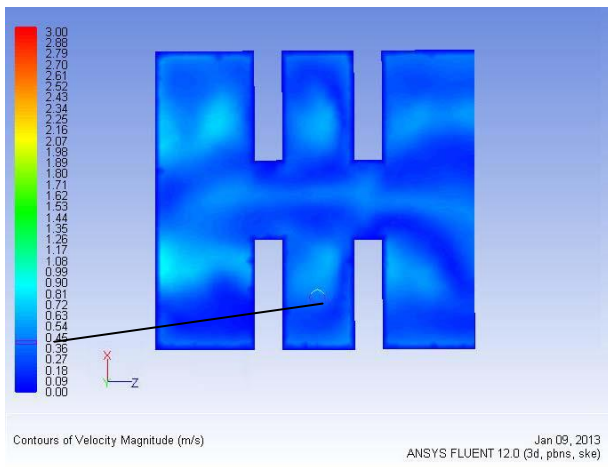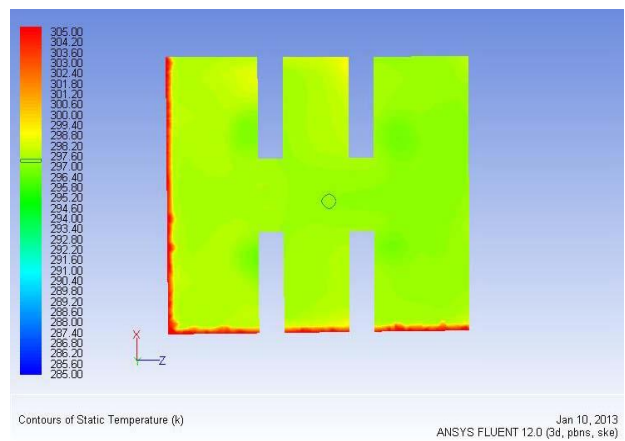

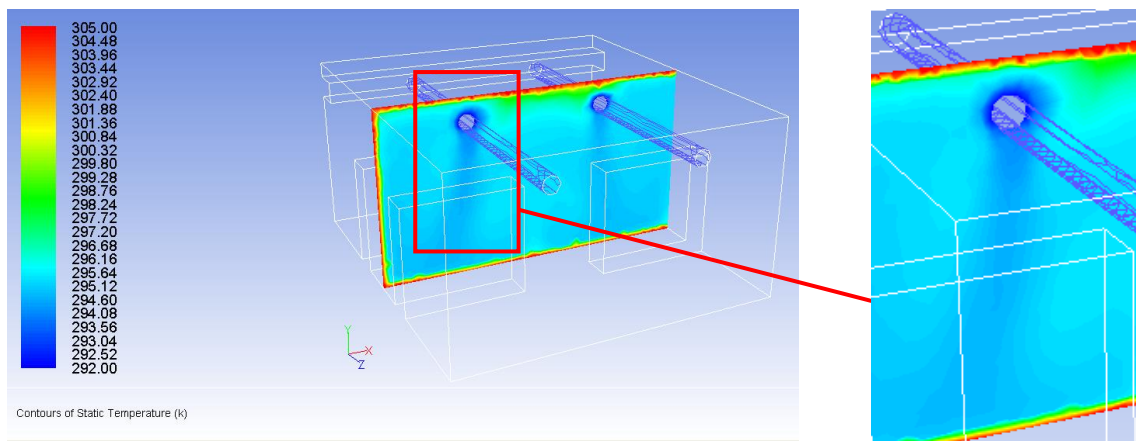Fabric air duct air velocity distribution
(Y = 1.5m)
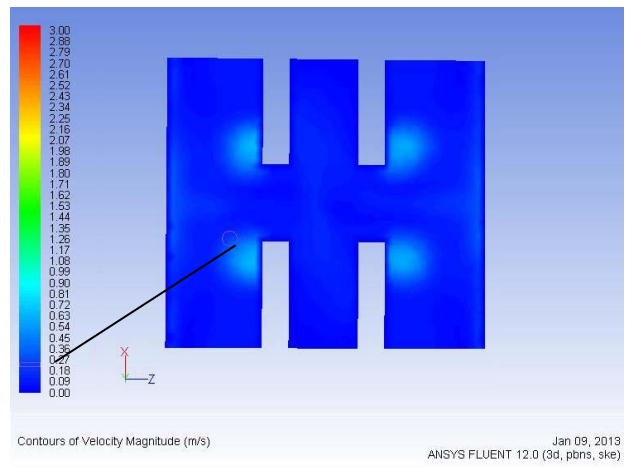
Louver speed distribution
(Y = 1.5m)
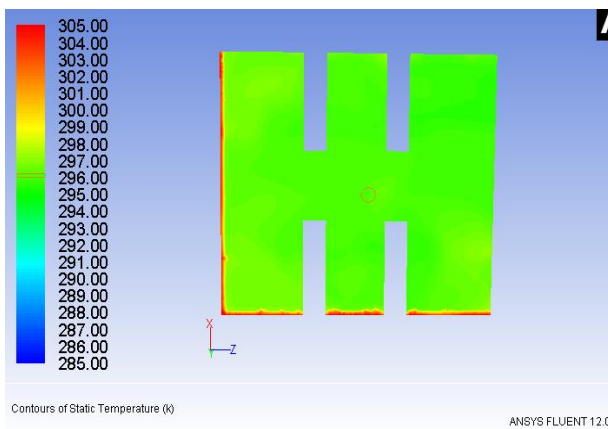
Fabric air Duct Air Temperature Fields
(Y = 1.5m)

Traditional diffuser Outlet Air Temperature Fields
(Y = 1.5m)

4.1 Studying on Fabric air Duct Energy Loss through fabric permeation

Contours of Static Temperature (k)

About 5% permeation air quantity on fabric air duct surface is used to prevent condensation, it forms a clear cold layer (blue ring) on the duct surface, but it does not spread to the surrounding, and it is induced fast to the ground (light blue airflow) by the inducing flow model as above, thus greatly reducing the energy consumption of fabric air duct due to material permeation and it is negligible.

4.2 Brief Analysis of the Causes

Firstly, according to the design parameters, orifice air velocity of fabric air duct is 12.3m / s, diffuser outlet air velocity is only around 5 m / s. Due to large area of diffuser outlets and slow air dispersion flow, so the velocity is low at the end of the jet flow, and the temperature is low, the sense of the airflow is obvious. Fabric air duct has smaller orifice diameter, bigger spacing, more numbers of holes, more rapid decay of supply air jet flow, and the formation of induced air supply induces fast indoor air mixing, thus the flow rate in the staff activity area will remain within comfort range.

Secondly, fabric air duct is vertically arranged to the shelves, and orifices are placed with a right angle which can reduce the airflow blocking by the shelves, enabling the jet flow reach the working area. By using rational designed orifice size, spacing and direction, the end air velocity is to be controlled to meet various air distribution requirements for different places.

Thirdly, by using fabric air duct, the above effect can be realized within 45 minutes after turning on the machine, but for louver the required time is 1.5 hours. The reasons are: fabric air duct does have permeation airflow which prevents the condensation, but due to high orifice air velocity, most of the actual permeation airflow will be induced to working area, the actual cooling capacity (air volume) loss is only 3%, besides, high velocity jet flow will result in no dispersion of AC air above working area, it is only to be dispersed as soon as reach the working area, so the heat exchange time is short, the energy loss is small; But for louver outlet air distribution, due to lower air velocity, there will be much more heat exchange, the actual cooling capacity at working area will be much less than fabric air duct solution, also due to the uniformity of air supply, the air mixing time will be longer too.

![DurkeeSox logo]

The following airflow distribution models also prove the above analysis.

Airflow Distribution of DurkeeSox Air Dispersion System
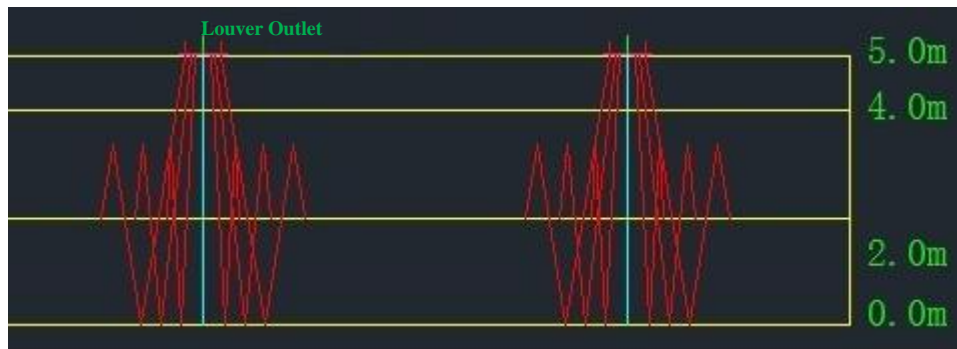
Airflow Distribution of Louver Outlet

5. Conclusion

The numerical calculation results of the partial area of supermarket are consistent with onsite measuring results, small biases can be explained, thus, using CFD to simulate the air flow distribution in some of the area of the supermarket is feasible, the results are reliable.

For supermarket scenarios, using conventional louver outlet air supply, the air flow are easily affected by shelves, resulting ununiform of regional velocity it will greatly affect the comfort level; low velocity air supply can cause upper air energy loss, also the effect in working area will take a lot more time.

By adopting fabric air duct air supply will avoid the airflow blocking by the shelves, making airflow quickly reached the working area, reduce air supply dead ends, reduce heat exchange time, enhance comfort level; in the meanwhile, the small amount permeation airflow by fabric air material will be induced to working area, the energy loss happens here can be ignored. So, fabric air duct air supply mode is more energy saving about 15% compare to traditional diffuser model. In addition, by adopting fabric air duct, it can effectively improve the uneven temperature distribution at staff activity area, reducing the difference between the maximum and minimum temperatures at the same height horizontally. Fabric air duct has the better cooling effect under the premise of the same air volume. **– END -**