Abstract. The fluid oscillator is a device that produces periodic alternating jets by supplying a certain pressure of the fluid. In this paper, the fluid oscillator is applied to the field of building ventilation. The supply air direction will change periodically and create a vortex shedding effect in the ventilated environment. By establishing a three-dimensional model of the double feedback fluid oscillator, CFD numerical simulation technology was used to study the indoor flow field characteristics when the fluid oscillator was used for ventilation and the slit air supply. The results show that the influence area of slotted air is small, and the energy is concentrated and distributed. Only a few eddies are generated on both sides of the main jet, and many stagnation zones are generated indoors. Fluid oscillator ventilation into the indoor airflow has a broader range of influence. The flow field distribution is uniform, and the jet energy dissipates quickly. The fluid oscillator will generate many eddy currents inside the room, effectively reducing the airflow stagnation zone in the room. Because the fluid oscillator can accelerate the disturbance of the flow field inside the room, it has a particular reference value to optimize the indoor air distribution.

1 Introduction

Building ventilation is a necessary technical means of artificial environment construction, effectively eliminating indoor heat generation and pollution. In order to improve ventilation efficiency and reduce energy consumption, it is necessary to adopt reasonable air distribution and supply air state parameters. Constant wind speed air supply is a standard air supply method in the current ventilation system. However, this air supply method can cause poor indoor air mixing and vortex stagnation zone [1], resulting in heat generation or accumulation of pollutants in this area, resulting in the decline of indoor air quality [2], affecting the comfort and health of personnel. For places with flammable and explosive gas leakage and even explosion due to the accumulation of local pollutants, it is necessary to use technical means to eliminate the airflow stagnation zone.

In order to effectively improve indoor flow mixing, Sandberg et al. [3] used a sinusoidal air supply to ventilate rooms. The results showed that the sinusoidal air supply creates secondary eddies that break off from the central flow zone and enter the stagnant zone in the room, causing airflow in the stagnant zone and disintegration of the stagnant zone. Compared with the constant supply airspeed, this air supply method benefits the uniform mixing of indoor air and improves ventilation efficiency. Jo-Hendrik Thysen et al. [4] analyzed the influence of period and amplitude of sinusoidal air supply on the indoor velocity field, turbulent kinetic energy, vorticity field, and pollutant distribution by using two-dimensional CFD simulation. The results show that the turbulent kinetic energy increases when the air velocity is smaller and the amplitude is more extensive. Therefore, the attenuation of pollutant concentration will increase. Alan Kabanshi et al. [5-6] studied the intermittent air injection system in classrooms, and the results showed that periodic intermittent supply created unstable airflow characteristics and minimized the risk of ventilation. The results show that regular air supply has a good effect. The regular air supply can effectively reduce the gas stagnation zone, make indoor air evenly mixed, and accelerate the elimination of indoor pollutants. The regular air supply is mainly by actively changing the air supply direction or using passive ventilation devices. Passive ventilation has many advantages over active air supply, such as saving energy and reducing equipment loss. The fluid oscillator is a better passive ventilation device.

The fluid oscillator is a fluid device that produces alternating jets by inputting a certain working fluid pressure. When a fluid passes through, periodic fluid oscillations will occur. Due to the advantages of simple structure, no moving parts, small size, convenient operation, reliable operation, and maintenance-free, fluid oscillators are widely used in the fields of expansion refrigeration [7], aerospace [8], and environmental treatment [9] and petrochemical [10]. The fluid velocity required by the above application fields is usually large, and some fields even involve supersonic fluid, so the Reynolds number of the fluid is also relatively large. However, studies have found that the fluid oscillator at a low Reynolds number still has...
the phenomenon of jet entrainment and fluid wall attachment [11] and thus generates periodic oscillation of jet under the action of control flow. The Reynolds number of the ventilation fluid used in our daily life is generally large, and the flow state of the fluid is in a turbulent state. However, compared with the supersonic fluid, the velocity of the ventilation fluid is relatively small. Therefore, fluid oscillation can be realized in the field of building ventilation. In this paper, the effect of regular air supply on the flow field of a room is preliminarily studied by using a fluid oscillator to ventilate the room, focusing mainly on the periodic characteristics of different locations of the ventilated space.

2 Methodology

A double feedback fluid oscillator has two feedback channels. The device does not need extra power. It only uses the Coanda Effect of airflow and backflow feedback, which will produce periodic oscillation airflow at the air outlet.

2.1 Fluidic oscillator designs

The fluid oscillator model studied in this paper is large, and the oscillator air supply port is similar to the slit air supply port. The fluid oscillator comprises an airflow inlet, mixing chamber, feedback channel, and airflow outlet. The model is 430mm long, 120mm wide, and 280mm high. The internal feedback channel is 40mm wide, and the mixing chamber is 100mm vast. It is composed of two wedge-shaped structures at the inlet and outlet of the mixing chamber, and the vertical direction is 60°.

![Fluid oscillator model](image)

**Fig. 1.** Fluid oscillator model.

After the ventilation airflow is introduced from the oscillator inlet, it is thoroughly mixed with the airflow from the feedback channel and enters the mixing chamber together. The ventilation flow will produce eddy currents at the corner of the mixing chamber. As the airflow continues to flow forward, the eddy current will also increase. At this time, the ventilation airflow will push the eddy current forward, constantly producing the wall effect. After the up-and-down airflow is generated in the mixing chamber, part of the gas will flow directly into the oscillator outlet from the mixing chamber and into the room. Another aspect of the gas will act on the inlet of the mixing chamber again through two feedback channels to continue the vortex.

All the time, the resulting vortex is moving inside the oscillator. Then the airflow with an inevitable periodicity swing up and down is formed at the air inlet. The connection of the components in the fluid oscillator has a certain Angle instead of a smooth circular arc connection, which is conducive to the vortex generation in the oscillator. The specific model structure of the oscillator is shown in Fig. 1.

2.2 CFD methods

The flow field in the computational domain follows the three-dimensional Navier-Stokes equations, as shown in Eq.(1) and Eq.(2).

\[ \rho \frac{dv}{dt} = pF + \nabla \cdot p \]  

\[ \rho = -pl + 2\mu (s + \frac{1}{3} \nabla \cdot u) + \mu' \nabla \cdot u \]  

Where \( p \) is the fluid stress tensor; \( l \) is the unit tensor; \( s \) is the deformation rate tensor, and its components in cartesian coordinates are Eq.(3).

\[ s_{ij} = \frac{1}{2} \left( \frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) \]  

In the flow and heat transfer problems, the governing equations of the variables can be expressed as Eq.(4).

\[ \frac{\partial (\rho \varphi)}{\partial t} + \text{div}(\rho u \varphi) = \text{div}(\Gamma \cdot \text{grad} \varphi) + S \]  

\( \varphi \) is a universal variable, which can represent \( u, v, w, T, c \) and other solving variables. The generalized diffusion coefficient is the \( \Gamma \); \( S \) is the generalized source term. Where \( \frac{\partial (\rho \varphi)}{\partial t} \) is the transient term, \( \text{div}(\rho u \varphi) \) is the convective term, \( \text{div}(\Gamma \cdot \text{grad} \varphi) \) is the diffusion term.

The flow in the fluid oscillator will be significantly affected by the wall surface, so the SST \( k-\omega \) model is selected as the turbulence model[12]. Compared with other \( k-\omega \) models, the SST \( k-\omega \) model adds the transverse dissipation derivative term. The turbulent shear stress transport process is considered in the definition of turbulent viscosity, and its transport equation is Eq.(5).

\[ \mu_t = \frac{n_k}{\omega} \frac{1}{\omega ma_1 \frac{1}{15 a_4 a_6}} \]  

Where \( S \) is the strain rate, \( a^* \) is for inhibiting turbulent viscosity, \( F_2 \) is Eq.(6) and Eq.(7).

\[ F_2 = \tan \lambda (\varphi_2^2) \]  

\[ \varphi_2 = \max \left[ 2 - \frac{\sqrt{K}}{0.096 y e}, \frac{500\mu}{\rho y^2 a_1} \right] \]  

\( y \) is the distance to the next surface. The model constant is \( \sigma_{k,1} = 1.176, \sigma_{\omega,1} = 2.0, \sigma_{k,2} = 1.0, \sigma_{\omega,2} = 1.168, \alpha_1 = 0.31, \beta_{1,1} = 0.075, \beta_{1,2} = 0.0828. \)

3 Results
3.1 Model information

This paper used three fluid oscillators to ventilate the room by supplying air from the sidewall. The ventilation model of fluid oscillators is shown in Fig. 2. The size of the room is length × width × height = 4.9 m × 3.5 m × 2.2 m. The return air outlet is located under the same side of the air outlet. In addition, three slit tuyere models of the same size as the air supply port of the fluid oscillator were established, and the Settings of other conditions were kept consistent. The tuyere is positioned in the middle of the room to maximize the oscillation amplitude of the oscillator airflow. Commercial CFD software FLUENT 2021 R2 simulated and calculated the indoor airflow field under two conditions.

Fig. 2. Fluid oscillator ventilation model.

3.2 Model parameter setting

After grid sensitivity testing, the total number of grids for fluid oscillator ventilation was 2 million, and the total number for slot ventilation was 1.8 million. SIMPLE-consistent (SIMPLE C) is adopted to solve the coupling problem of the pressure field and velocity field. The spatial discretization of all parameters selects the second-order upwind scheme. The speed of the supply air outlet is 4 m/s, and the return air outlet is the pressure outlet. The residual of computational convergence is set as 10^-6, indicating that the simulation result of each scalar no longer changes with the number of time steps. The speed of the slot air outlet is 4 m/s, the fluid oscillator inlet speed is 2 m/s, 3 m/s, 4 m/s, and the return air outlet is the pressure outlet.

3.3 Velocity field

After a while, the indoor flow field will reach a stable state. Fig. 3-Fig. 4 shows the X-Z plane velocity cloud with an air supply velocity of 4 m/s under two conditions.

Fig. 3. X-Z plane velocity cloud of 4 m/s fluid oscillator.

Fig. 4. X-Z plane velocity cloud of Slit ventilation.

When the fluctuating airflow enters the room, many vortexes will be generated on both sides of the main jet due to the constant deflection of the velocity direction. The energy emission of the vortex is faster so that the airflow can affect a more extensive range. The rear vortex constantly pushes the front vortex forward, and finally, the airflow will reach every region in the room, effectively reducing the airflow stagnation zone. Fig. 5-Fig. 6 shows the X-Z plane velocity cloud ventilated by the fluid oscillator with a wind speed of 3 m/s and 2 m/s.

Fig. 5. X-Z plane velocity cloud of 3 m/s fluid oscillator.

Fig. 6. X-Z plane velocity cloud of 2 m/s fluid oscillator.

When the slot air supply device with a constant airflow rate is used for ventilation, the air supply speed is 4 m/s, and the size and direction of the air supply speed remain unchanged, which is in a stable state. When the stable airflow enters the room, there is no primary eddy current on both sides of the main jet. At this time, the energy is concentrated inside the main jet and cannot be
dissipated. Finally, the airflow will only reach part of the region. The velocity is small on both sides of the jet flow, and there will be an apparent stagnation zone. Fig. 7 shows the period at 1m, 2m, and 3m away from the tuyere at the supply airspeed of 3m/s. The period of the periodic flow gradually decreases with the depth of the position.

Fig. 7. Period of oscillator at different positions.

The period and frequency of the oscillating airflow of the fluid oscillator at 2m/s, 3m/s, and 4m/s supply airspeed are shown in Fig. 8.

Fig. 8. Fluid oscillator period.

When the air supply speed is 2m/s, 3m/s, 4m/s, the oscillation period is 2.233s, 1.795s, 0.8439s respectively. The smaller the supply air velocity is, the wider the influence range in the Z direction is. However, due to its small velocity, the space that the air supply can reach is limited. The lower the oscillator speed, the longer the oscillation period, and the slower the frequency. Therefore, appropriate air supply speed should be selected according to the needs of different rooms.

4 Conclusions

This paper uses the CFD simulation method to compare oscillator and strip ventilation. The results show that at the same air supply speed, the eddy current generated by the oscillator ventilation can send the air to more places in the room, which dramatically improves the indoor ventilation degree and is conducive to improving the comfort of the human body. When slit tuyere is used for air supply, there will be many airflow stagnation areas in the room, which may cause temperature aggregation and pollutant aggregation and have adverse effects. The adjustment of the inlet velocity of the fluid oscillator will affect the amplitude of the fluctuation of the airflow, and the smaller the velocity is, the more comprehensive the range of vertical influence will be. Compared with a stable air supply, vibrator ventilation can thoroughly mix indoor air in some cases, which is of great significance for optimizing air distribution.

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