

Analysis of Hot Air Invasion Characteristics of Cold Storage Smart Door During Opening and Closing Process

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Abstract: Cold storage belongs to a low-temperature process, which is a form of warehouse, but the biggest difference with the warehouse is "cold", that is, internal cold and external heat. Due to the different nature of use and inventory goods, the warehouse is always at low temperature and high humidity and environments with frequent changes in temperature and humidity. In the process of opening and closing the cold storage door, there will be a large amount of energy consumption, so how to improve energy utilization and reduce costs has become an important issue.

Keywords: Cold Storage; Numerical Simulation; Air Infiltration.

1. Introduction

With the continuous expansion of China's economic scale and the continuous improvement of people's living standards, people's demand for fresh food is also becoming increasingly strong, resulting in the continuous expansion of the scale of the cold storage market. Encourage primary processing cold chain facilities such as pre-cooling, storage and preservation of agricultural products, and accelerate the elimination of non-standard and high-energy-consuming cold storage buildings. With the development of the cold chain logistics system and the expansion of cold storage capacity, a series of energy consumption problems have also followed. The energy saving and emission reduction of cold storage has received more and more attention. This makes it particularly important to explore the energy-saving ways of cold storage, reduce the power consumption per unit cooling capacity of refrigerated products, improve system utilization, strengthen warehouse management, etc., and how to reduce costs and achieve system energy saving has become an urgent problem to be solved.

The flow field near the cold storage door is affected by many factors, including the structure of the cold storage, the temperature difference between the inside and outside of the warehouse, whether there are protective measures, the form and orientation of the storage door, etc., resulting in a very complex flow field. Although some scholars have simplified theoretical calculations based on the principle of hot pressure ventilation, the theoretical calculation results cannot accurately predict the actual situation of the flow field. At this time, the superiority of computational fluid dynamics is reflected, this method does not need to consume a lot of resources, only through computer numerical simulation calculation and image display methods, it can quantitatively calculate the numerical solution of the flow field in time and space, so as to solve the physical problems that need to be studied.

2. Reptile Design Process

2.1. The Harm Caused by Hot Air Intrusion into Cold Storage

After the row pipe of the cold storage is formed into an ice coat, because the thermal conductivity of ice is much greater than the thermal conductivity of frost, the thermal resistance will increase, the heat exchange of the pipe will change, the storage temperature is difficult to reduce heat ammonia frosting time is extended, to reach the storage temperature before opening the door, it is necessary to extend the boot time. The heat released by the 1m³ of hot air entering the warehouse is shown in Table-1.[1]

Table 1. The heat released by 1m³ of hot air entering the cold storage

T1/°C \ T2/°C	0	-2	-10	-18	-20
20	62.3	67.5	85.6	102.3	106.5
25	85.6	90.9	109.7	127.3	131.6
30	116.4	122	141.8	161	165
35	154	160	181.1	200.9	205.8
38	180.7	186.6	208.6	229.2	234.4

indicates the temperature of different conditions, # Temperature in the cold storage, ## Temperature out of the cold storage.

Once the temperature of the freezing room of meat processing enterprises cannot be reduced, it will increase dry consumption, reduce physical indicators such as color and appearance, and seriously make frozen products deteriorate and taste. For cold drink production enterprises, the storage temperature fluctuation of the refrigerator is too large, which will deform the product and affect sales, and the fruit and vegetable varieties with strict requirements for the temperature of the warehouse will become black and soft.

Due to the aging and deformation of the sealing strip on the cold storage door or the net of the cold storage door, damage, when the cold storage door is closed, there will be a gap

between the door and the clean tree, cold and hot air will collide at the place, light will produce dripping phenomenon, heavy will freeze the door and the clean bar together, making the door difficult to open, only with a pry bar, aggravate the damage of the cold storage door and hardware. When the cold storage door is opened, the hot air forms new water droplets on the inside of the storage door, and when the cold storage door is closed, these water droplets freeze again, increasing the gap between the cold storage door and the clean hall.

2.2. The Influence of Cold Storage Door Form on Hot Air Intrusion

Fritzsche and Lilienblum [2] measured the Kumen seepage wind velocity using an anemometer in 1968 and corrected it based on the Tamm [3] empirical formula. The model assumes that the volume flow of air entering the cold storage is equal to the volume flow of air leaving the cold storage, and this assumption holds when the temperature difference between the inside and outside the storage is not too large. The empirical formula is as follows:

$$K_{f,L} = 0.48 + 0.004(T_w - T_n) \quad (1)$$

$$I = 0.333 K_{f,L} A (gh)^{0.5} \left[\frac{\rho_n - \rho_w}{\rho_n} \right]^{0.5} \left[\frac{2}{1 + (\rho_w / \rho_n)} \right]^{0.5} \quad (2)$$

In the formula:

T_w : The temperature of the air outside the cold storage, °C;

T_n : The temperature of the air in the cold store, °C;

g : Acceleration due to gravity, m/s²;

h : The height of the cold storage door, m;

A : The area of the cold storage door, m²;

It can be seen from the empirical formula (2) that the height of the cold storage door has a power of 1.5 relationship with the air seepage rate, while the width of the library door has a power of 0.5 relationship with the air seepage rate, that is, the influence of the height of the warehouse door is greater than the influence of the width of the library door, so the air seepage of the library door with different opening and closing methods has become a factor affecting the air seepage rate of the library door. Based on this theory, the roller shutter door changes the height of the library door during opening and closing, and theoretically has a lower air seepage rate than the sliding door. The following compares and analyzes the two types of warehouse doors of sliding doors and roller shutters to study the opening and closing methods of warehouse doors with better performance.

For the sliding door form cold storage, when the warehouse door is opened, under the action of gravity, the hot air in the hall enters the cold storage from the upper part of the warehouse door, and the temperature drops rapidly after heat exchange with the air in the warehouse. The cold air in the cold storage flows out of the cold storage from the lower part of the warehouse door, resulting in the loss of cold storage cold capacity. For the cold storage in the form of roller shutter door, when the warehouse door is just opened, the air flow movement into the cold storage is not strong, and with the movement of the warehouse door, the position of the neutralization surface gradually moves up.

The hot air entering the cold storage will have a great impact on the temperature field in the upper part of the cold storage and near the cold storage door, and the temperature rise in some areas reaches more than 2 °C. Therefore, when stacking goods, try to avoid placing the goods in the area where the warehouse door is 2~3m away from the warehouse door.[4]

By setting up temperature monitoring points in the cold

storage during the simulation calculation process, the temperature data in the cold storage can be read in real time, and the data shows that in the process of opening and closing the cold storage door in 20s, the average temperature in the sliding door cold storage increases by 0.38 °C, and in this process, the average temperature in the roller shutter door cold storage increases by 0.32 °C. This result shows that the roller shutter warehouse door can reduce the air seepage effect in the opening and closing process of the warehouse door, and the use of the library door in the form of roller shutter door should be considered in the design of the cold storage to reduce the impact of the air seepage of the warehouse door on the environment in the cold storage.

2.3. The Influence of the Opening Time of the Cold Storage Door on the Environment in the Cold Storage

In the actual operation of the cold storage, the opening time of 20s can only be for the pickup time of the rapid automated cold storage, for ordinary cold storage, it is necessary for people to drive a forklift into the cold storage to pick up goods, so the opening time of the warehouse door will be longer. In order to study the changes in the internal environment of the cold storage with the opening time of the warehouse door, modify the Profile file, extend the opening and closing cycle of the push-pull library door from 20s to 60s, that is, the opening process of the 0~5s library door, keep the library door open for 5~55s, and the closing process of the 55-60s library door. In this way, the situation of the cold storage environment at different times is studied.

From the experiment, the hot air area entering the cold storage expands rapidly, the first affected is the air above the cold storage door, the temperature rises rapidly, the hot air entering the cold storage spreads around the cold storage when it touches the top of the cold storage, and when it reaches the wall of the cold storage, due to inertia, it begins to move downward, and finally mixes with the cold air in the cold storage and disappears. But directly on the wall facing the cold storage door, because the hot air acts for a longer time, the inertia is greater, and the downward movement speed is greater when the hot air of this part reaches the wall, so it will affect a larger area of the cold storage.

The gas concentration in the cold storage will also change with the opening time of the cold storage door, because the oxygen concentration inside and outside the cold storage is quite different, so the oxygen concentration increases rapidly; Since the difference between the carbon dioxide concentration inside and outside the cold storage is small, the increase rate of carbon dioxide concentration is slower. In the time of 5s~55s, the gas concentration is a function of time, and at 60 seconds, the concentration of oxygen and carbon dioxide in the cold storage is no longer suitable for storing refrigerated food.

3. Recommendations for Hot Air Intrusion into Cold Storage

3.1. Temperature and Humidity

Temperature and humidity control strategies also have an important impact on the sealing performance of cold storage doors. The degree of hot air intrusion can be reduced through the following improvements:

Temperature difference control inside and outside the cold storage reducing the temperature difference inside and

outside the cold storage can be achieved by reasonable refrigeration system operation and strengthening of the insulated wall. A reduction in temperature difference reduces the likelihood of hot air intrusion.

Humidity control the humidity change in the cold storage to avoid wet air entering the cold storage. This can be achieved by humidity sensors and humidity control systems to ensure that the relative humidity inside the cold room is stable within the appropriate range.

3.2. The Structural Parameters

The structural parameters of the cold storage door will also have an important impact on the sealing performance. When optimizing your design, consider the following aspects:

3.2.1. Door Frame Sealing Performance

strengthen the sealing performance of the door frame to ensure that the sealing between the door frame and the wall is tight, which can be improved by selecting the sealing material, widening the door frame or increasing the sealing layer of the door frame.

3.2.2. Opening and Closing of the Door Leaf

The use of automatic door leaf opening and closing can reduce the chance of hot air intrusion and avoid the failure of the door leaf to close due to human causes.

Selection of door leaf material: choose materials with low thermal conductivity, such as high-efficiency thermal insulation materials, to reduce the conduction of hot air.

Optimization of door leaf structural parameters: optimize the structural parameters of the door leaf, such as the thickness of the door leaf, internal strengthening skeleton, etc. These improvements can improve the thermal insulation performance and strength of the door leaf and reduce the amount of hot air intrusion.

3.3. The Temperature Difference between the Inside and Outside

The temperature difference between the inside and outside of the cold storage and the opening time of the cold storage door will affect the hot air intrusion of the warehouse door. Under the condition that the temperature difference between the inside and outside the cold storage was 10°C, 15°C and 20°C, the air seepage rate reached 1.03 m³/s, 1.4 m³/s and 1.68 m³/s when it was stable. When the temperature difference between the inside and outside of the cold storage increases by 1 times, the additional load introduced by the air seepage of the cold storage door will increase by 2.44 times. After the hot air enters the cold storage, it mainly affects the upper part of the cold storage 1/3, and the air cooler of the monitoring equipment should be set up in the upper part of the cold storage to start and stop to avoid excessive temperature fluctuations affecting the storage environment of the goods; For the cold storage in this paper, the average temperature in the cold storage, the concentration of gas components in the cold storage and the opening time of the warehouse door are a function relationship, according to which the fluctuation of the environment in the warehouse

can be predicted, such as the carbon dioxide concentration in the cold storage in the cold storage room during the opening and closing of the cold storage door in 60s still meets the modified atmosphere storage parameters, and the oxygen concentration has deviated from the appropriate gas concentration range, then the modified atmosphere equipment should be turned on to adjust the gas concentration in the cold storage.

In the process of opening the cold storage door, the cold air in the cold storage flows to the outside of the cold storage under the action of gravity, and the hot air outside the cold storage enters the cold storage and quickly moves to the top of the cold storage, and moves along the top of the cold storage to the inside of the warehouse, in this process is cooled by the cold air in the cold storage, and then gradually affects some areas along the inner wall, and the hot air diffusion area in the cold storage using vertical lifting door is smaller than the side sliding door during the door opening process. The use of vertical lifting doors is beneficial to reduce the amount of air penetration and the average temperature rise in the warehouse during the process of opening and closing the door.

4. Conclusion

In this paper, we introduce the characteristics of hot air intrusion in cold storage doors from several aspects, first of all, the role and application of cold storage are generally introduced, and then the adverse effects of hot air intrusion into cold storage, the environmental impact brought by the form of cold storage doors, the impact of cold storage door opening time on cold storage, and suggestions for hot air intrusion into cold storage.

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