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COMPARISON WITH PRESSURE SWING ADSORPTION AND MEMBRANE SEPARATION NITROGEN FOR REDUCE OXYGEN AT STORED GRAIN IN HORIZONTAL WAREHOUSE

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ABSTRACT

In the 180t capacity of test horizontal warehouse，the research was made for comparison with pressure swing adsorption(PSA) and membrane separation(MS) nitrogen for reduce oxygen. During the research we had detected gas tightness of warehouse, full nitrogen flux and time, energy consumption, and oxygen decrease. The research results indicated that using facilities PSA reduced oxygen in grain mass with flux 45 Nm3/h and 49 Nm3/h, from 20.7% in normal atmosphere fall 15%, 10%, 5%和 2%，the average energy consumption were 55and 37.6 kWh, 83 and 71 kWh，139 and 105kWh，189 and 160 kWh respectively. That were 61and 42 kWh,102 and 85 kWh，124 and 152kWh，193 and 195 kWh using facilities MS with flux 15.8 Nm3/h and 18.1 Nm3/h. And the average energy consumption of MS was higher than that of PSA. With higher flux it cost fewer energy but usage of nitrogen is lower. The paper had introduced the models and regulation for reducing oxygen in stored grain, also.

Key words: Stored Grain, Reduce oxygen, Pressure Swing Adsorption, Membrane Separation Nitrogen, Energy consumption.

INTRODUCTION

As the resistance of pests becomes stronger, reduced chemical application is the important task for grain storage (Benhalimaa et al. 2004, Bruce et ai. 1962). The research showed that under lower oxygen environment, the physiological activities of pests could be inhibited. Below 2% of oxygen (O_2) concentration for 20 days, the grain pests, such as *Sitophilus zeamais* Motschulsky and *Tribolium castaneum* Herbst, could be killed. Below 5%, the growth and development of pests could be inhibited. So low O_2 technology has been adapted to inhibit and kill grain pests without chemicals (Navarro 1978, Gilberg 1991).

For low O_2 process, high concentration carbon dioxide or nitrogen will be used to reduce the concentration of O_2 in barn (Valentin 1993). But comparing these two kinds of media, using nitrogen should be more cheap and handy. In principle of making nitrogen, there are two kinds of equipment: pressure swing adsorption (PSA) and membrane separation (MS).

In this paper, PSA and MS were used for low O_2 process. And O_2 reduction time and consumption was used to compare these two kinds of equipment. At the same time the low O_2 model was also discussed.

MATERIALS AND METHODS

Test Horizontal Warehouse

The test horizontal warehouse is 180t capacity pilot-scale horizontal warehouse located in pilot-scale test base of Academy of State Administration of Grain. And its length is 9 meters, width 4.5 meters and grain loaded height 6 meters.

Nitrogen produced equipment

PSA equipment: max flux 50.35Nm^3/h and max O_2 concentration 99%(v/v%).
MS equipment: max flux 35Nm^3/h and max O_2 concentration 99%(v/v%).

Method of detection O_2 concentration

O_2 sensors were used to detect O_2 concentration. The O_2 sensors were distributed in three layers and six sensors in each layer. The distance form the first layer (bottom layer) to the bottom is 3m, the second layer (middle layer) 5m and third layer (top layer) is on the surface of the grain.

Method of power measurement

A power meter was installed on the input circuit of the making nitrogen equipment. And the power was record during the experiments.

Experiment method

Before the experiment, the nitrogen produced equipment was connected with the ventilation pipe using flexible pipe. The input nitrogen concentration was kept at 99% level. When nitrogen was input the barn, the power and the O_2 concentration for different layer was record. The equipment will be stopped until the average O_2 concentration of top layer is under 2%.

RESULTS AND DISCUSSION

Low O_2 process using PSA

Two different flux have been made to test the performance of PSA. The results showed in Fig. 1 (with flux 45Nm^3/h) and Fig.2 (with flux 49Nm^3/h).

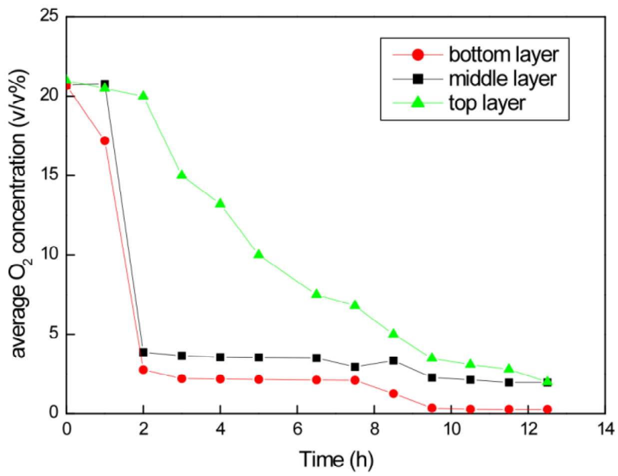

Fig. 1- The change curve of average O_2 concentration in different layer with time using PSA (flux $45Nm^3/h$).

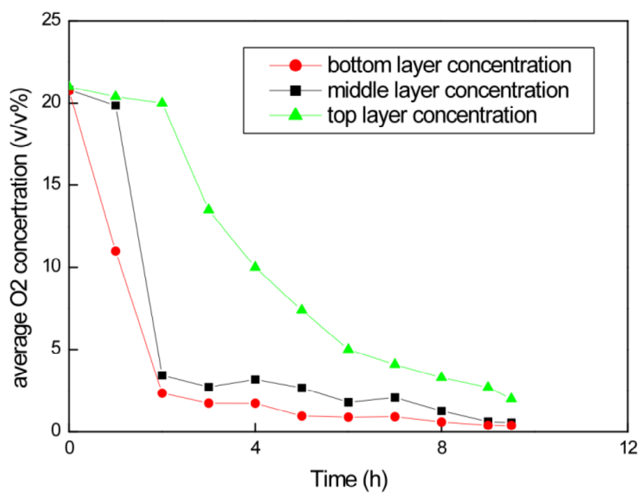

Fig. 2- The change curve of average O_2 concentration in different layer with time using PSA (flux $49Nm^3/h$).

As showed in Fig.1, Compared the different layers, the reduce rate of average O_2 concentration is depend on the distance of detection location. More close to the nitrogen inlet, it is faster for O_2 concentration to reach 2%. It spent 7.5 hours for O_2 to reduce to 2% for bottom layer and 13 hours for top layer. The same results are also showed in Fig.2 and the time is 3 hours and 9.5 hours. Compared Fig.1 with Fig. 2, the time to reach 2% is shorter with flux $49Nm^3/h$ than that with flux $45Nm^3/h$.

The power consumption with different flux is shown in Fig. 3 and Table 1. The total energy consumption is 189kWh for flux 45Nm^3/h and 160kWh for flux 49Nm^3/h. That means it consume less energy with higher flux. The energy consumption per hour and is higher with higher flux also, but energy consumption per concentration decreased is lower. The calculate data is shown in table1. As it discussed above, it is compatible to using PSA with higher flux.

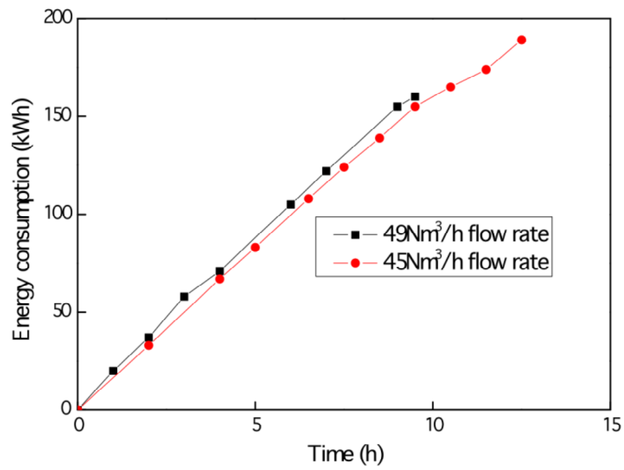

Fig. 3- The energy consumption curve using PSA with different flux.

Low O_2 process using MS

Two different flux have been made to test the performance of MS. The results showed in Fig. 4 (with flux 15.8Nm^3/h) and Fig. 5 (with flux 18.1Nm^3/h).

Table 1. The energy consumption using PSA with different flux

Flux (Nm^3/h)	O_2 average concentration of top layer (v/v%)	Time (h)	Energy consumption (kWh)	Energy consumption per hour(kWh/h)	Energy consumption per concentration decreased
45	15	3	55	18.3	9.5
	10	5	83	16.6	7.7
	5	8.5	139	16.3	8.8
	2	13	189	14.5	10.1
49	15	2.2	37.6	18.0	6.5
	10	4	71	17.8	6.6
	5	6	105	17.5	6.6
	2	9.5	160	16.8	8.5

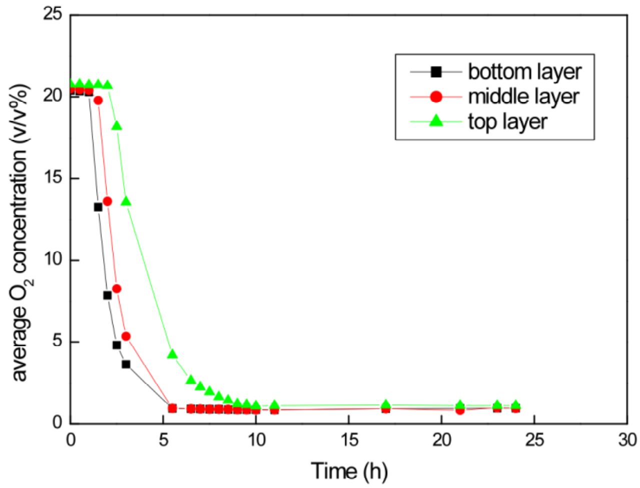

Fig. 4- The change curve of average O_2 concentration in different layer with time using MS (flux 15.8Nm^3/h).

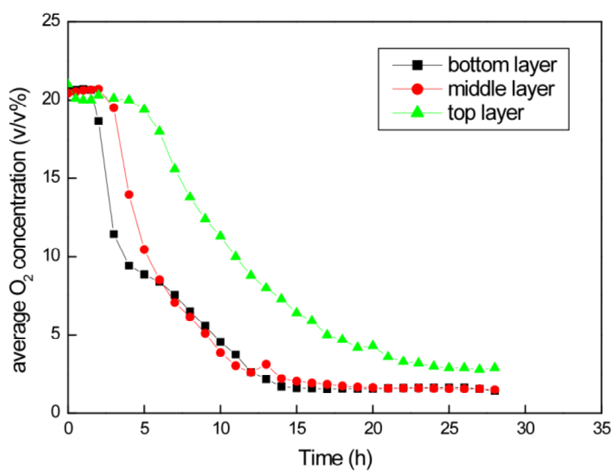

Fig. 5- The change curve of average O_2 concentration in different layer with time using MS (flux 18.1Nm^3/h).

As using PSA, the reduce rate of average O_2 concentration is depend on the distance of detection location when using MS. More close to the nitrogen inlet, it is faster for O2 concentration to reach 2%. It spent 5.5 hours for O_2 to reduce to 2% for bottom layer and 7.5 hours for top layer with flux 15.8Nm^3/h. The same results are also showed in fig.5 and the time is 4.2 hours and 14 hours. Different with using PSA, the time to reach 2% is shorter with lower flux when using MS. The reason for this difference may be due to the different flux. Using PSA, the flux is three times of using MS. When using PSA, the nitrogen flux cannot be used to replace O_2 component efficiently and more nitrogen has been vent to the air. The power consumption with different flux is also shown in Fig. 6 and Table 2.

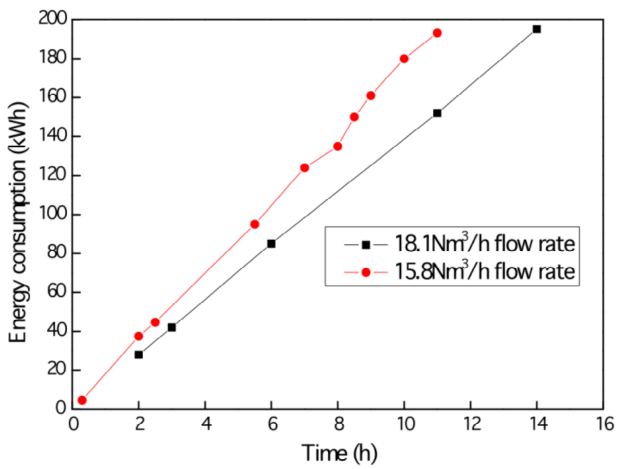

Fig. 6- The energy consumption curve using MS with different flux.

The total energy consumption is 193kW for flux 15.8Nm^3/h and 195kW for flux 18.1Nm^3/h. that means it consume almost the same energy with higher flux. The energy consumption per hour is lower with higher flux but energy consumption per concentration decreased is lower. The calculate data is shown in Table 2. As discussed above, it is compatible to using MS with higher flux also.

Table 2. The energy consumption using MS with different flux

Flux (Nm^3/h)	O_2 average concentration of top layer (v/v%)	Time (h)	energy consumption(kWh)	energy consumption per hour(kWh/h)	energy consumption per concentration decreased
15.8	15	3.2	61	19.1	10.5
	10	5.4	102	18. 9	9.4
	5	7	124	17.7	7.8
	2	7.5	193	25.7	10.2
18.1	15	3	42	14.0	7.2
	10	6	85	14.2	7.8
	5	11	152	13.8	9.6
	2	14	195	13.9	10.2

Compared with PSA, it cost more energy with MS. This is because the rate of work using MS is higher than using PSA.

According to the flux individually, the total nitrogen volume input into the bam is calculated in Table 3.

Table 3. Total nitrogen volume input into the bam with different flux

Flux(Nm^3/h)	Total nitrogen volume(m^3)
15.8	118.5
18.1	253.4
45	585.0
49	465.5

From Table 3, it is very clear that with high flux a large amount of nitrogen has been released to the air without used although it is quickly to reach the final. If considering the efficiency and usage of nitrogen, the low O_2 technology must be changed.

Low O_2 models

The low O_2 model is made to describe the average O_2 concentration changes with time. According to the three layers, total average O_2 concentration (C_w) has been made to be dependent variable as shown in expression 1.

$$C_w = \frac{\sum_1^n c_i}{n} \quad (1)$$

C_w: total average O_2 concentration (v/v%)
C_i: O_2 concentration of each detection sensor
i: the detection number
n:total detection number
The model function is adapted to simulated low O_2 process as shown in expression 2.

$$C_w = A_2 + (A_1 - A_2)/[1 + (t/t_0)^{A_3}] \quad (2)$$

C_w: total average O_2 concentration (v/v%)
t: time (h)
A_1,A_2,A_3,t_0: model coefficient
The model coefficients are shown in table 3.

From table 3, the correlation coefficient (R) and residual sum of squares (RSS) can be made to prove it is a suitable to describe the low oxygen process using the model as expression 2. And the comparison between calculated data and test data is shown in Fig. 7.

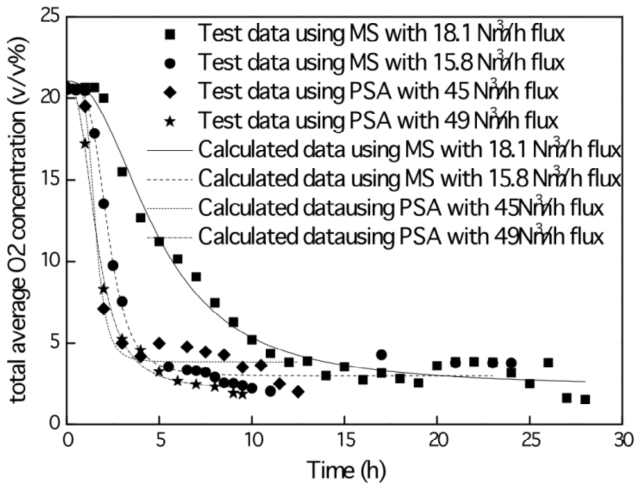

Fig.7- Comparison between calculated data and test data

CONCLUSION

- It is suitable using nitrogen produced equipment with high flux, it is cost fewer energy and energy consumption per concentration decreased.
- Using PSA has more advantage than using MS if the equipment running individually.
- Using single equipment, the usage of nitrogen is very lower. The low O_2 technology must be changed.
- The model can be used to describe the process of low O_2.

$$C_w = A_2 + (A_1 - A_2)/[1 + (t/t_0)^{A_3}]$$

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