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Test on cooling grains with intellectual ventilation system

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Abstract

The grain ventilation technique has been widely used in China. New grain depot with 55.5 billion kilograms capacity built from 1998 has all been outfitted with machine ventilation facilities. The automatic ventilation control system studied by Chengdu Grain Storage Research Institute of State Administration of Grain Reserves can execute many functions such as automatic control, automatic ventilation to lower temperature, drying etc. In 2005, Daminggong Grain depot in Xi'an of State Grain Reserves had adopted this automatic ventilation system to carry out the test on ventilating and cooling grains in winter. Four axis flow fan with 0.55 kw had been used to ventilate automatically for 484 hours in test depots, then the average temperature of grains decreased from 14.9 ºC to 7.5 ºC with 0.018 kW h/t unit energy consumption. While that, contrast depot had been managed by stakeholder with rich experience to ventilate by 6 centrifugal fans with 15 kw for 140 hours, then the average temperature of grains decreased from 15.8 ºC to 4.5 ºC with 0.097 kW h/t unit energy consumption. The energy consumption of test depot was just 18 % of that of contrast depot. The result showed that automatic ventilation control system was helpful to lighten labor consumption, to increase ventilation efficiency and also to reduce energy consumption of ventilation.

Key words: intellectual ventilation, ventilation and cooling grains.

Introduction

Machine ventilation technique is one of grain storage technology widely used in China. New grain depot with 55.5 billion kilograms capacity built from 1998 has all been outfitted with machine ventilation facilities. Worker with wide experience in grain ventilation often carry out aeration according to the weather of local areas. However, because the parameters of temperature and humidity of grain bulk and the environment condition change dynamically, confirming the aeration occasion by workers maybe lead to low efficient or inefficient aeration, even harmful aeration result.

Automated ventilation system can share grain condition datum by combination with present grain testing and controlling system, collect datum of temperature and humidity influencing ventilation in real time, catching optimum ventilation occasion automatically, and then solve the problem of judgment of ventilation time, increase ventilation efficiency with reduction of energy consumption at same time. In 2005, Daminggong grain depot in Xi'an of State Grain Reserve adopted the intellectual ventilation system to carry out ventilation and cooling test for grain, which was developed by Chengdu Grain Storage Research Institute, State Administration of Grain Reserve (CSR).

Materials and methods

Test depot

Test depot was No.5 depot of Daminggong

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grain depot, which was new big warehouse built in 1998. The depot face north with 60 m x 30 m size,6 m maximum height of grain bulk. The contrast depot is No.17 depot similar with test depot in configuration, 43 m x 30 m size, 6 m maximum height of grain bulk.

Grain samples

The grains stored in No.5 depot and No.17 depot are common new harvest wheat inputted in 2004 and 2005 respectively. The height of grain bulk is 6 m. Table1 showed some indexes about wheat quantity and quality.

Test facilities

In order to meet the intellectual ventilation, the ventilation windows and vent opening of No.5 test depot had been done automatization remodel for computer autocontrol. There were total 20 ventilation windows respectively in south and north main walls. Through selection and optimizing combination, 4 vent windows in every two main walls were confirmed to carry out intellectual ventilation demonstration, while other windows closed. So one electromotor was used to simultaneously control the opening and closing of 4 vent windows in south wall, the situation of north wall was same as south wall. 6 vent openings in two main walls were all reformed to automatic ventilation openings. There were total 4 axial fans with 0.55 kW in south and north walls, 6 centrifugal fans with 15 kW in bottom of two walls of depot. Circuitry of all fans were laid in indicated site.

There were 4 vent openings in No.17 contrast depot. These vent openings were all foursquare and 800 x 800mm size, locked with bolts around, outfitted 4 fans (type is 4-72 8 ºC) with 15 kW power.

The parameters about equipments outfitted are showed in Table2.

Method

Intellectual ventilation control system was adoptted to cooling grains in No.5 test depot in winter. Computer had collected real time datum of air weather, air humidity, depot temperature, depot humidity and grain depot, then judged weather the ventilation occasion is good according to conditions including average temperature of every layers of grain bulk, relative humidity of vent openings and the temperature and humidity of air. If the ventilation conditions were appropriate, the 6 vent openings would been opened automatically in turn, and No.8,11,14,17 axial fans turned on to ventilate (Figure 1). The temperature of grains then fallen because the flowing

Table 1. The quality of inputted wheat in test depot and contrast depot.

Depot No.	Intake time	Capacity (T)	Bulk Density (g/l)	Impurities (%)	Moisture content (%)	Unsound kernels (%)	Viscidity (mm^2/s)	Gluten water capacity (%)
5	2004	8002	760	0.5	10.8	5.2	4.4	195.5
17	2005	5598	774	0.4	11.8	5.8	4.9	200

Table 2. Parameters of Equipment.

Equipment	Type	Quantity	Power (kW)	Airflow rate (m^3/h)	Total pressure (Pa)	Rotate speed (r/min)
Centrifugal fan	4-72 8C	4	15	13643	1570	1250
Axial fan	T35-11-5.6	4	0.55	7800	145	1400

air from top to bottom took out heat of grain bulk. When air temperature raised or humidity was over high, that is to say, the ventilation conditions were inappropriate, axial fans stopped automatically, and then closed the 6 vent openings, suspended ventilation. When temperature of grain fallen down to proposed temperature, winter cooling ventilation was over, the system recorded ventilation time automatically.

Special warehouse houseman with rich experience was responsible for No.17 contrast depot, judged ventilation occasion by datum offered from temperature testing system and environment, went to bin to turn vent openings and centrifugal fans by hand in good occasion, recorded ventilation time by himself.

Arrangement of sampling point

Determine moisture content of grains in test depot and contrast depot before ventilation test. Furthermore, made sign in every sampling site for sampling to contrast after ventilation.

Quantity of sampling sites

Lay 6 sampling sites among 3 aeration flues of one vent opening, sample in 4 layers such as the upper, the middle, the middle below, the lower in every site, sum to 24 samplings. Sample 500 g in every layer, determinate moisture content of every layer and blended samples. Upper layer is 0.5 m from grain surface, middle layer is 2 m from surface, below middle layer is 4m from surface and lower layer is 5.5 m from surface.

Position of sampling sites

As show in Figure 2, No.1 and 4 sampling sites are in font of ventilation flue with 2m distance from wall, No.2 and 5 sites are in middle of two ventilation flues, No.3 site is in middle ventilation flues with 2m distance from wall, No.6 site is in middle of ventilation flues.

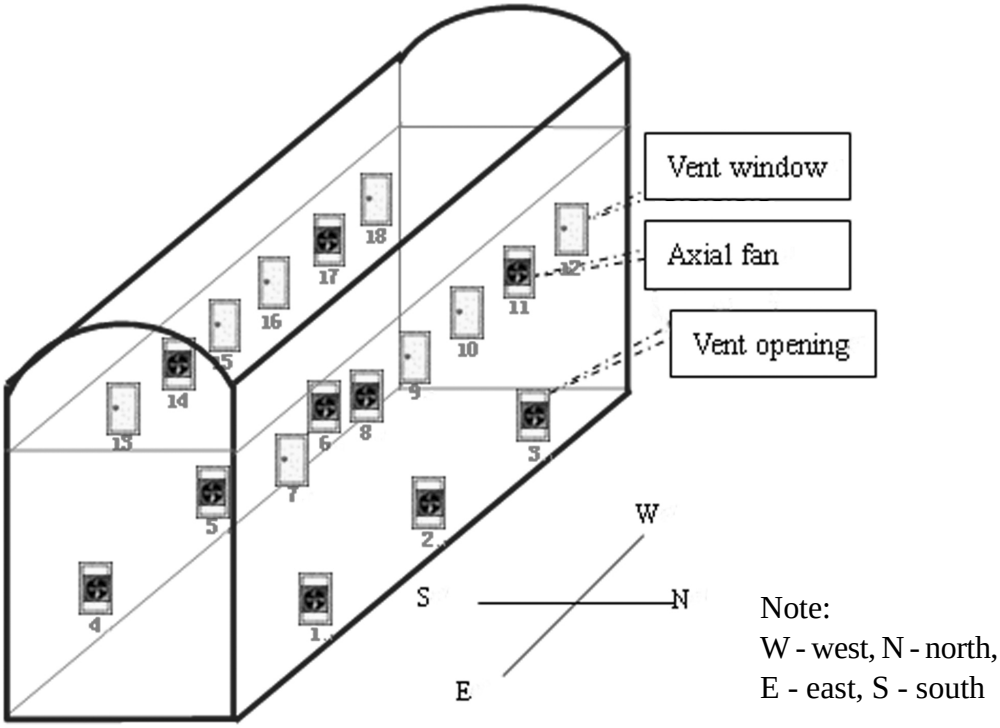

Figure1. Layout of ventilation system.

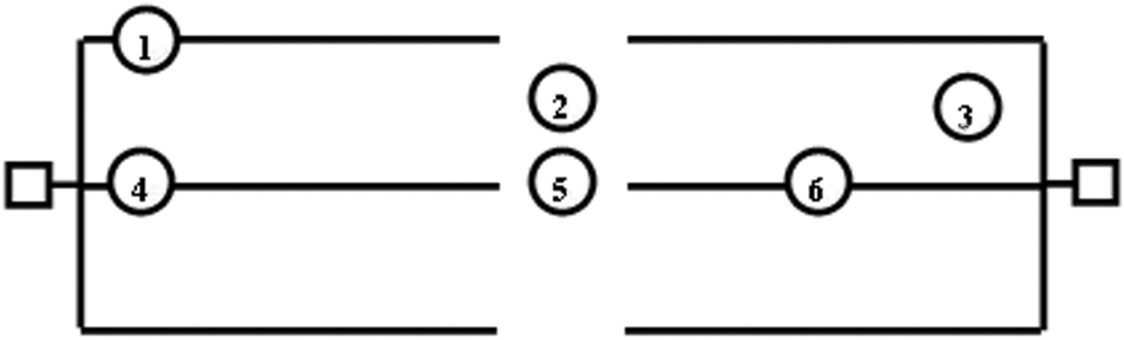

Figure 2. Distribution of sampling sites.

Results

Temperature variety of grains bulk by air temperature

From Figure 3, depot temperature was influenced by air temperature to great degree, but when grain temperature started to lower with ventilation and then depot temperature lowered slowly. When depot temperature was lower than that of upper layer, it would reverse to rise up because of influence of layer temperature. The decreasing range of temperature of upper grain was greatest with 16.8 ºC range, from 25.4 ºC to 8.6 ºC. Grain of middle and below middle was in cold core area with low temperature, so the decreasing range of temperature was small, only 5.3 ºC and 3.8 ºC.

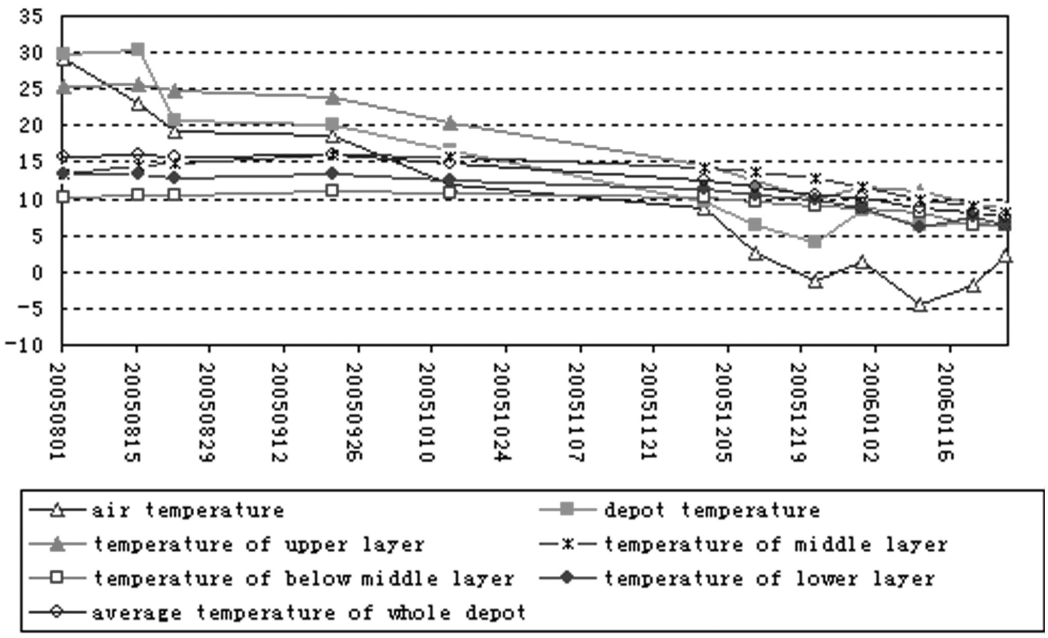

Figure 3. Temperature variety of grains by air temperature.

Air temperature started to be lower than average temperature of every layer from Nov., thus the ventilation occasion should be after Nov.. In order to realize tempered ventilation by fans with little airflow and low power to bring down grain temperature more (meet to 0 ºC ~ 5 ºC), cooling grain by ventilation in winter can been arranged in Nov. ahead. In addition, ahead ventilation time can avoid grain dew because of big temperature difference of grain temperature and air temperature.

Selection of ventilation occasion

The statistic analysis of datum about temperature and environment humidity collected by ventilation system from 1th Des. 2005 to 26th Jan. 2006 are showed in Table3.

From Table 3, there were more occasion when temperature difference was higher than 6 ºC, occasion of temperature difference was easier. In this temperature condition, the time when air relative humidity was less than 50 % took 28.8 %, while the time when air r.h ≥ 90 % took 29.4 %, the factor of air humidity was more difficult to catch. According to the analysis of Table3 combined with the lower moisture content of grain bulk in No.5, the ventilation condition was set as temperature difference ≥ 6 ºC, 60 % ≤ air humidity < 90 %. To catch ventilation occasion by workers was more difficult, while intellectual ventilation can realize automatic judgment of ventilation, selection of optimum occasion, meanwhile can avoid inefficient and bad ventilation.

Contrast of energy consumption of ventilation

Table 4 showed that the unit energy consumption for ventilation of No.5 depot was only 18 percent of No.17 depot. The cooling range of No.5 depot was 7.5 ºC because its average temperature was lower than No.17 after discharging heat in summer. Furthermore, the aeration ability of axial fans was less. While the low temperature season of Xi'an area is relatively long, so ventilation can been carried out ahead in low temperature condition in Nov., then grain temperature will lower more and meet ideal temperature 0 ºC ~ 5 ºC.

The moisture content of grains in No.5 depot were low, ventilation was carried out in humidity 60 %RH ~ 90 %RH. After ventilation, the moisture content of grain bulk kept stable without apparent increase. Thus, according to out design, account and the experience of other industries, for grains with very low moisture content, highest relative humidity can been increase to 90 % to keep stable and reasonable moisture content of grains.

Table 3. Statistic datum of temperature difference.

Difference between highest average temperature of grain and air temperature(ºC)	Time(h) Total time (h)	Range of relative humidity					
		< 50 %	50 ≤ ≤ RH < 60	60 ≤ < RH 70	70 ≤ < RH 80	80 ≤ < RH 90	90 ≤ < RH 100
< 6 ºC	164	62	14	48	34	6	0
≥ 6 ºC, and < 7 ºC	78	14	0	12	26	20	6
≥ 7 ºC, and < 8 ºC	104	18	4	8	34	22	18
≥ 8 ºC, and < 9 ºC	180	26	10	4	34	54	52
≥ 9 ºC, and < 10 ºC	154	18	12	4	14	32	74
≥ 10 ºC	728	140	88	70	78	88	264
Total(h)	1408	278	128	146	220	222	414

Table 4. Contrast of energy consumption of ventilation in two depot.

Depot No.	Grain weight (t)	Average temperature of depot (ºC)			Total ventilation time(h)	Energy consumption (kW.h)	Unit energy consumption (kW.h/t. ºc)
		Before ventilation	After ventilation	Cooling temperature			
No.5	8002	14.9	7.4	7.5	484	1065	0.018
No.17	5598	15.8	4.5	11.3	140	6160	0.097

Conclusions

a) For area where the temperature is low in winter and last for a long time, axial fans with small airflow and low power can been adopted to ventilate to cool grains in the aid of intellectual ventilation. This system will judge ventilation condition automatically without human's operation, can choose optimum ventilation occasion, avoid inefficient and bad ventilation. The unit energy consumption is just 18 percent of old ventilation method.

b) Intellectual ventilation can choose suitable relative humidity for keeping moisture content of grains efficiently, which is very important to decrease grain loss.

c) Adopting intellectual ventilation improved level of automatization management, which is significant to establish a energy saving and friendly environment society. Thus this technique is worth delivering widely.