Testing of cross ventilation system in granary

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Abstract

A series of cross ventilation equipment was designed and installed in a 180 ton capacity testing granary, and a mass of pitot tubes were placed in a cross ventilation system and the grain. The variation of cross ventilation system resistance under the condition of different airflow rate was obtained for the first time by measuring air velocity, volume, pressure distribution and air resistance of the ventilation system. The resistance characteristics of the system and uniformity of aeration were analyzed. The results showed that the resistance of the ventilation system is under 2000Pa when the airflow rate was less than 25m^3/h·t. The airflow distribution in the grain bulk is very uniform according to the static pressure data.

Keywords: cross ventilation, aeration duct, air resistance

1. Introduction

Grain mechanical aeration can be used for temperature and moisture control of the grain bulk, nd can also be used for phosphine re-circulation fumigation. Therefore, the structure and properties of the grain storage mechanical aeration system are very important. In China, the grain storage aeration system commonly used is a vertical aeration system, with the ventilation ducts installed on the floor of the warehouse. The airflow vertically passes through the grain bulk from bottom to surface or from surface to bottom by fans, and the heat and moisture can be exchange during the vertical aeration. Often the airflow cannot be well distributed in the grain bulk, labor costs may be high, and aeration will sometimes cause a loss in grain moisture content (Gu et al., 2006).

The Academy of State Administration of Grain developed a new aeration system - transverse aeration technology for grain storage. In the new system, the aeration ducts are directly fixed on the two opposite interior walls of the granary. The grain surface is sealed by plastic film during storage. During aeration, the airflow is sucked from one side of aeration ducts and exhausted out from the other side of aeration ducts after horizontally passing through the grain bulk. It can also circulate the airflow through the circulation pipeline with the recirculation blower. Since the system makes the airflow horizontally pass through the grain bulk during aeration, the airflow is distributed equally and there is no aeration blindness space under the negative pressure aeration condition. It is not necessary to repeatedly disassemble the aeration duct when the granary is loaded and unloaded. The storage technologies, such as aeration, grain cooling, fumigation and atmosphere control can be done without removing the film during the storage period. Therefore, the application of granary transverse aeration system will obtain better economic and social benefits.

In order to have an in-depth understanding of the resistance characteristics and aeration uniformity of the transverse aeration system, so as to accurately assess the aeration features and technical feasibility of the transverse aeration system, the tests on the simulation granary transverse aeration device were done on the pilot platform of Beijing Grain Storage and Transportation National Engineering Laboratory. The aeration resistance of the transverse

aeration system with different aeration volume, the static pressure of the grain bulk, and the airflow distribution in the grain bulk were studied and discussed.

2. Materials and Methods

2.1. The testing grain

170 tons of corn is used for the test. The qualitative data is shown in Table 1.

Table 1 Basic information of testing grain

Variety	Quantity (t)	Warehousing Time (yy/mm/dd)	Volume Weight (kg/m^3)	Moisture (%)	Average Grain Temperature (°C)	Impurities (%)	Fatty Acid Value mg KOH/100g
Corn	170	2011.4.30	723	13.3	11.4	0.9	36.8

2.2. The testing granary

A large double-layer steel structure simulation granary with 180t capacity was used, which was fixed in the pilot platform of the Grain Storage and Transportation National Engineering Laboratory of the Academy of State Administration of Grain. The internal net size of the testing granary is 9 meters long, 4.2 meters wide and 7.7 meters high. The grain bulk was 6 meters high. The grain bulk surface is one-sided sealed with five layers of PA/PE co-extrusion nylon film.

2.3. Aeration duct

2.3.1. Aeration duct design

A group of aeration ducts are provided respectively on both the west and east interior walls of the testing granary. The aeration duct size, structure and form are shown in Figure 1. A group of three branch ducts vertically arranged, which are connected to a main duct arranged horizontally on the east wall. The air inlet of the main duct is at the bottom of the testing granary. A group of four branch ducts horizontally arranged, which are connected to a main duct arranged vertically on the west wall. The air inlet of the main duct is at the top of the testing granary. The sealing of the main duct with plug is equivalent to form a static pressure distribution box. The airflow passes through the main duct and distributes to each branch uniformly.

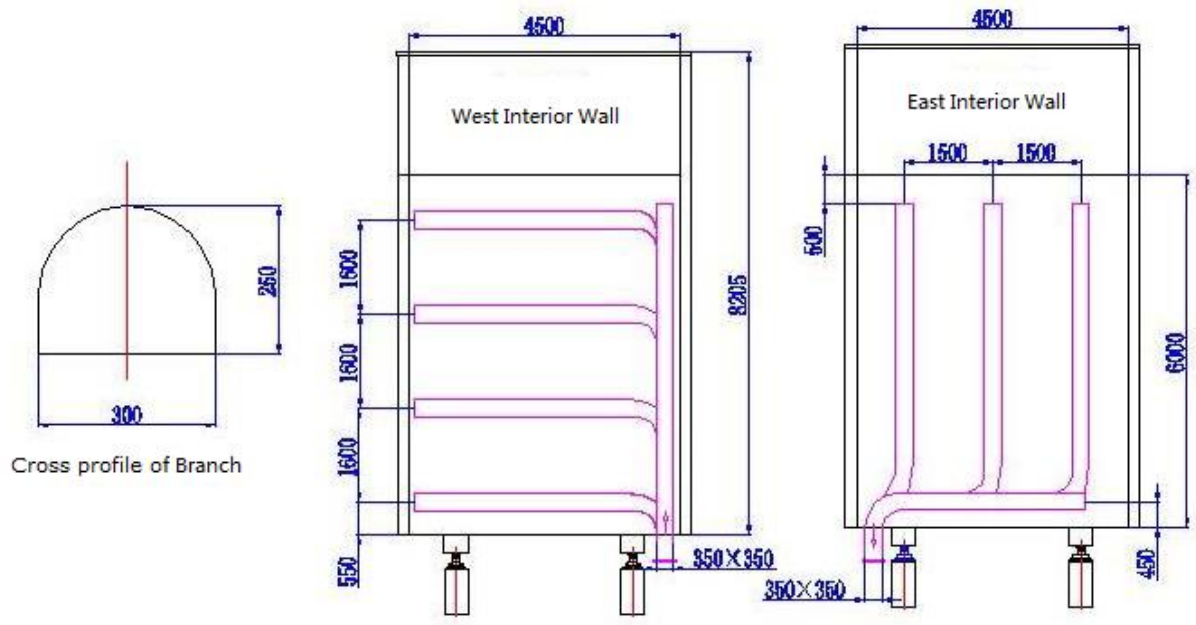

Figure 1 Structure of the aeration ducts.

2.3.2. Aeration equipment

A frequency regulation fan is used for the aeration air, $Y160M_2$-2 of model, 16000 m^3/h of rated air volume, 2940Pa of rated air pressure and 15kw of rated power. The air inlet at the bottom of the testing granary is connected with a PVC testing duct. The inner diameter of the testing duct is 480mm.

2.4. Testing instrument

In order to obtain accurate parameters of the aeration system, the testing instrument listed in Table 2 is used. Wherein, the pitot tubes are embedded in the grain bulk and various testing points of the aeration duct in advance.

Table 2 Aeration testing instrument.

S/N	Instrument	Specification and Model	Manufacturer	Testing Contents
1	Embedded pitot tubes	6-800PT800	Shanghai Huaxiao Instrument Co., Ltd.	Pressure
2	Handheld pitot tube	6-1000PT1000	Shanghai Huaxiao Instrument Co., Ltd.	
3	U-type pressure gauge	UFT-10kPa	Shanghai Zhicheng Electronics Co., Ltd.	
4	Handheld pressure gauge	BOKM-01	Beijing Baiao Chemetall Science and Technology Co., Ltd.	
5	Hot-wire anemometers	TES-1340A	TES Electrical Electronic Corporation	Air speed, air volume
6	Clip-on ammeter	DT-3352	Shenzhen Everbest Machinery Industry Co., Ltd.	Current, voltage
7	Frequency converter display	$Y160M_2$-2	Oriental Fude Technology Co., Ltd.	Fan frequency

2.5. Testing methods

The dynamic pressure, static pressure, total pressure and air speed of the testing ventilation duct were detected by the Pressure gauge and Hot-wire anemometer, with the equal-area airflow detection method (Anonymous, 2008). Four different working frequency of the fan were detected, which are 50, 40, 30, 20 Hz. The static pressure of the gain bulk was detected by the pressure gauge under different ventilation volume, which can be adjusted by the fan with a frequency converter.

2.6. Measuring points of transverse aeration device

2.6.1. Total air volume and resistance test points

The anemograph and pitot tubes are used to measure the air speed, dynamic pressure, total pressure and static pressure of each point at the A and B cross profile of the testing duct(As Fig.2 shown) ,with the equal-area airflow detection method, so as to understand the total air volume and resistance under different working conditions.

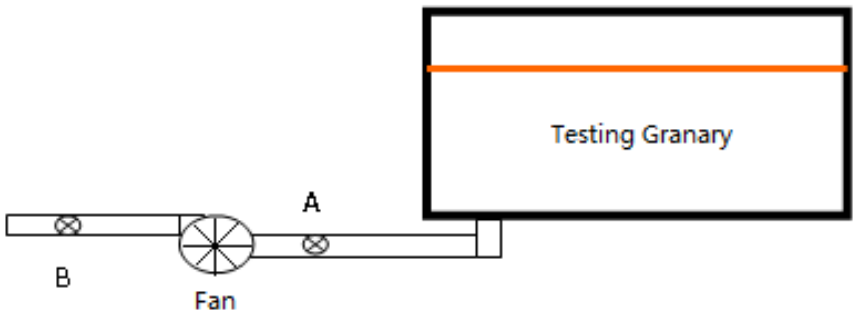

Figure 2 Measuring profile of total air volume and resistance of aeration system.

2.6.2. Measuring points in main aeration duct

The main aeration duct on the East and West sides are arranged four measuring points respectively, including E1-E4 and W1-W4 (Fig.3 and Fig.4). The embedded pitot tube is used to measure the static pressure of the cross profile, the air speed, air volume and pressure distribution uniformity of the main aeration duct and the total resistance of the aeration duct can be studied.

2.6.3. Measuring points in branch duct

There are two measuring points on each branch duct of both sides, as Fig.3 and Fig.4 show.

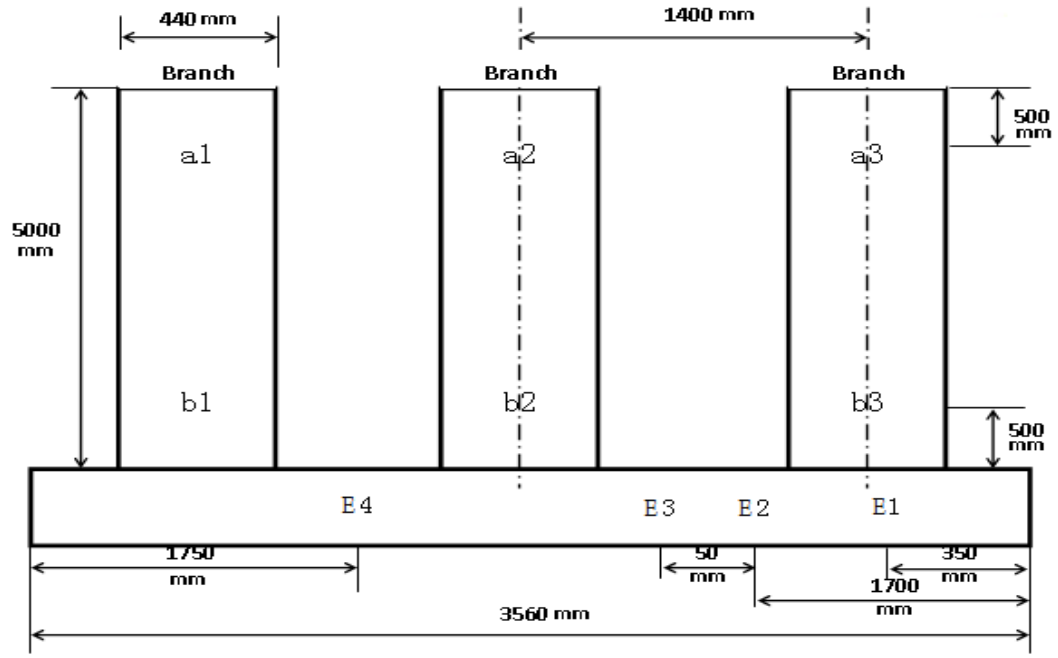

Figure 3 Measuring points of East side aeration ducts.

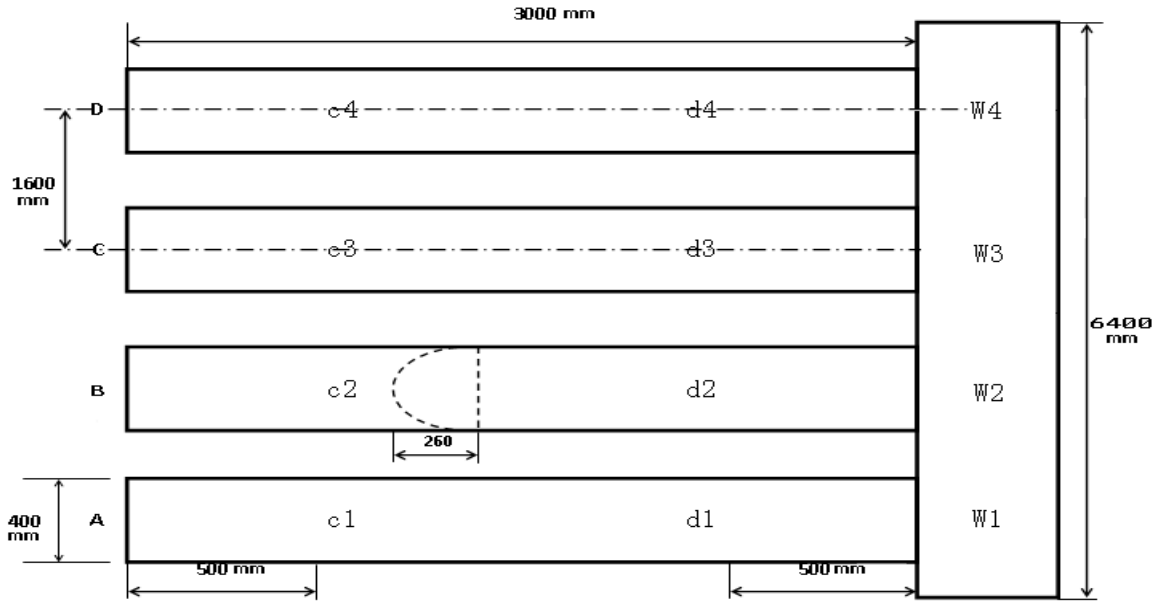

Figure 4 Measuring points of West side aeration ducts**.**

2.6.4. Grain bulk measuring points

There are 5 static pressure testing layers in the grain bulk, the layer height are 0.4, 1.6, 2.8, 4.0, 5.2 meters. There are ten testing points in each layer as Fig.5 shows.

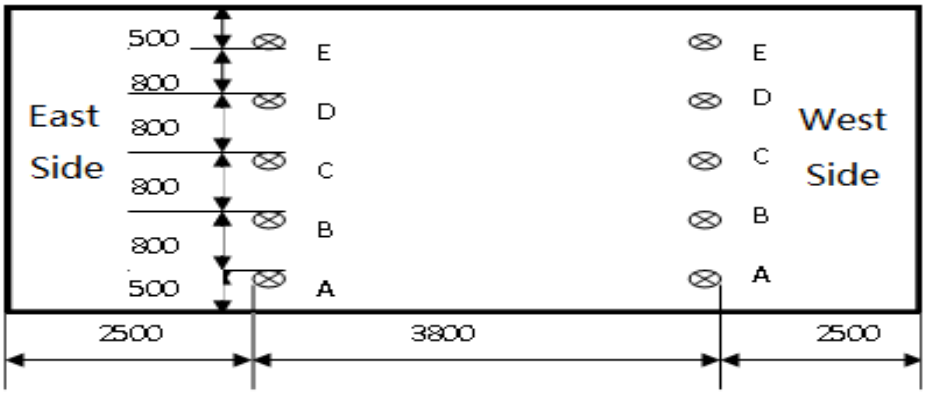

Figure 5 Plane layout of the grain bulk pressure measuring points.

3. Test results and analysis

3.1. Total air volume and resistance of the transverse aeration system

The duct resistance, the total resistance of the transverse aeration system and the unit aeration volume at different working frequency are shown in Table 3.

Table 3 The total resistance of the transverse aeration system at different working frequency.

Fan Frequency (Hz)	Total Air Volume of System (m^3/h)	Unit Aeration Volume (m^3/ht)	Total Resistance of System (Pa)	Duct Resistance (Pa)	Fan Output Power (kw)
50	5482	32.2	3348	219	6.99
40	4572	26.9	2169	117.6	3.64
30	3178	18.7	1216	83	1.87
20	1921	11.3	539	38.2	0.8

The duct resistance and the total system resistance both increase with the rise of the unit aeration volume. And the duct resistance occupy only 6.5-7% of the total resistance. The relationship of the total aeration volume and system resistance of the transverse aeration system is described as Fig.6. shows.

The functional relation is $H = 0.0013 \cdot Q^{1.7035}$ (1)

Wherein, H refers to the total resistance of the transverse aeration system (Pa)

Q refers to the total air volume of the transverse aeration system (m/s)

Therefore, the formula can be used for calculating the system resistance of the corn transverse aeration system.

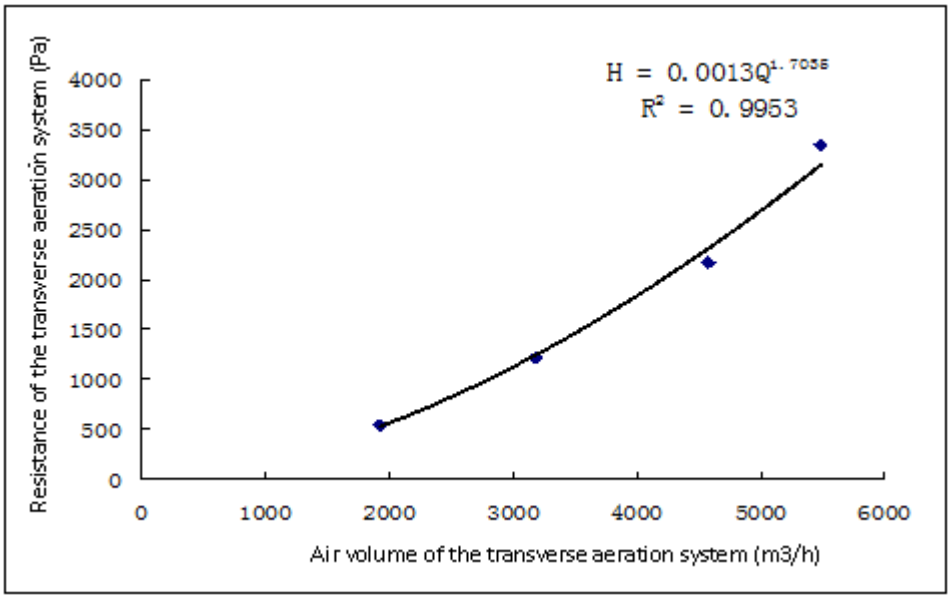

Figure 6 The relation curve of the air volume and resistance of the transverse aeration system.

From Fig.6, we can determine the total aeration volume and the system shows a smooth power function curve of 1.7th power.

3.2. Layer Resistance of Corn in Transverse Aeration System

The values of grain layer resistance of the transverse aeration at different grain bulk air speed and air volume are shown in Table 4.

Table 4 Data of layer resistance of corn in transverse aeration.

Frequency (Hz)	Air volume per unit area and per unit time ($m^3/m^2 \cdot s$)	Unit Aeration Volume (m^3/ht)	Average Static Pressure of Grain bulk (Pa)		8.5m Grain Layer Resistance (Pa)	Resistance of per Meter Grain Layer (Pa/m)
			West Side	East Side		
50	0.060	32.2	-751	-861	187	22
40	0.050	26.9	-493	-584	154.7	18.2
30	0.035	18.7	-274	-339	110.5	13
20	0.021	11.3	-118	-155	62.9	7.4

The relation curve of the unit grain layer resistance and the air speed of grain bulk profile can be expressed in the following formula:

$$H_{\text{Layer resistance}} = 401.28 \cdot u^{1.0322} (Pa) \qquad (2)$$

Wherein, $H_{\text{Layer resistance}}$ refers to the unit grain layer resistance during transverse aeration (Pa)

u refers to the air volume per unit area and per unit time of the grain bulk ($m^3/m^2 \cdot s$), which is same as the air speed of grain bulk profile (m/s).

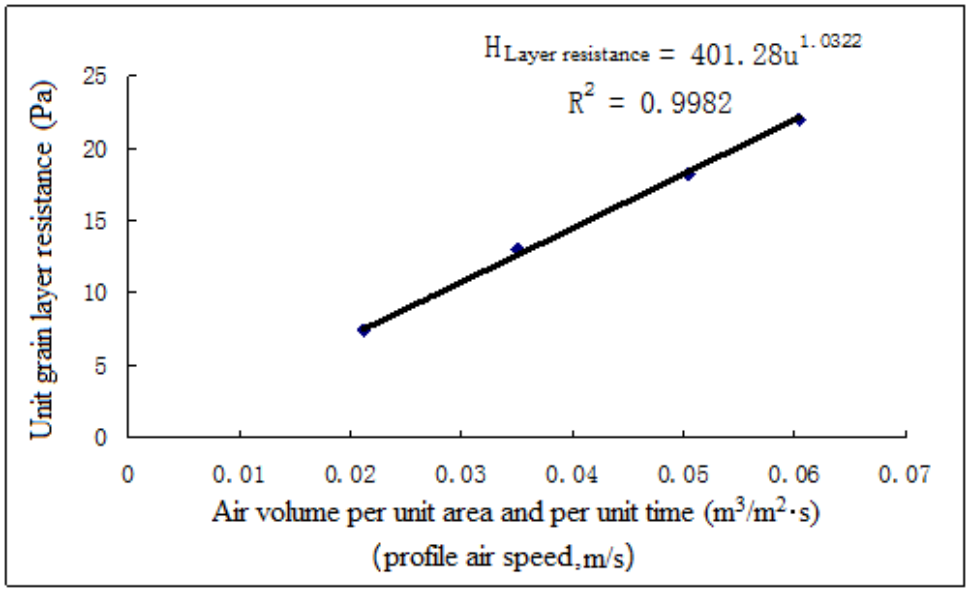

Figure 7 The relationship between the air speed of bulk profile and the unit grain layer resistance.

We can determine grain layer resistance increases with the rise of the air speed of the bulk profile, which almost a linear relationship.

3.3. Static pressure distribution laws of aeration duct of transverse aeration system

The average static pressures of the transverse main aeration duct are detected, and the results are shown in Fig.8. The test results show that the static pressure distribution in the main aeration ducts on both east and west sides is very uniform. It almost displays a horizontal linear distribution along the air flow direction, indicating that the airflow distributed to each branch duct is uniform. It also proves that the aeration duct of the transverse aeration system is design reasonably.

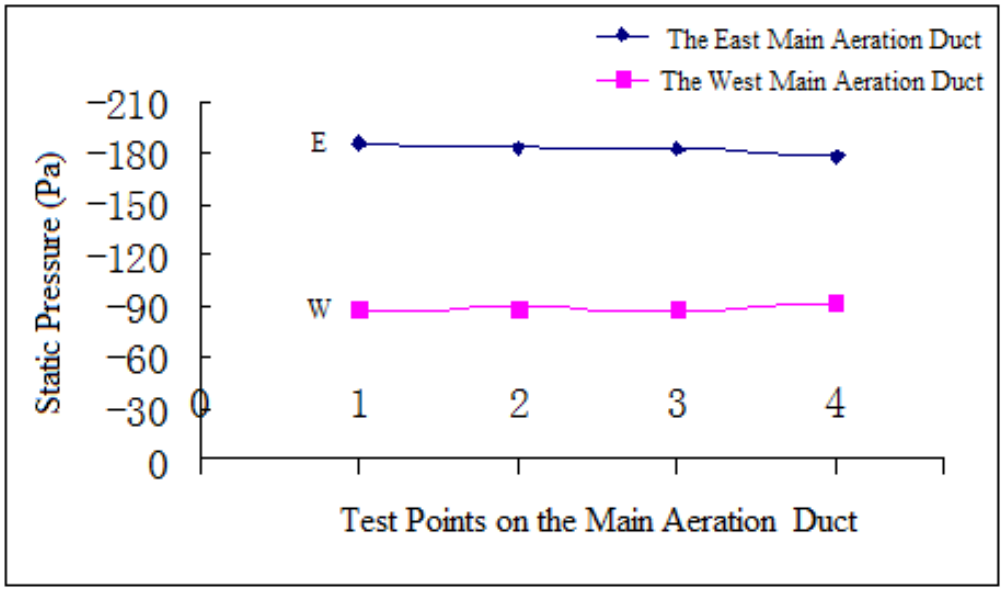

Figure 8 Static pressure of the testing points on the main aeration ducts.

3.4. Static pressure distribution laws of grain bulk with transverse aeration system

The average static pressures of each layer in the grain bulk are detected, and the results are shown in Fig.9. The test result shows that the static pressure distribution in different height on both east and west bulk side is very uniform. It also indicates that the static pressure of the vertical profile in the bulk is very uniform.

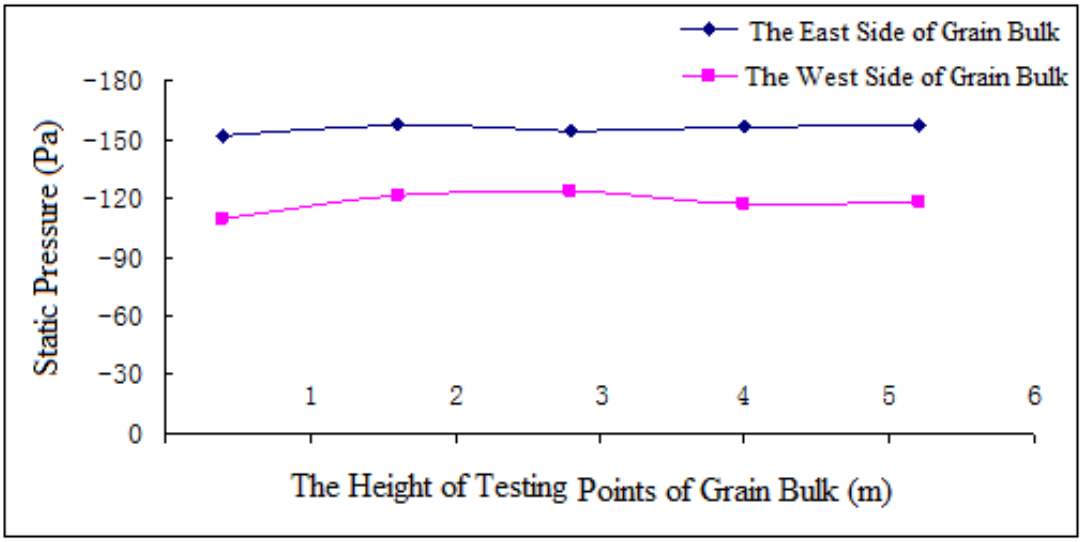

Figure 9 The average static pressure of the east and west side in the testing grain bulk.

4. Conclusions

4.1. The duct resistance and the total system resistance both increase with the rise of the unit aeration volume.

4.2. The system resistance should be controlled below 2000Pa and the unit aeration volume should not be higher than 25 $m^3/h{\cdot}t$.

4.3. The static pressure distribution in the main aeration ducts on both east and west sides is very uniform, which indicates the airflow distribution in each branch duct is equal.

4.4. The static pressure distribution in different height on both east and west bulk side is very uniform, the static pressure of the vertical profile in the bulk is very equal. It indicates the airflow distribution in the grain bulk is very equally.

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