Aspects of comparison and selection of grain dryers

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Abstract

A preliminary comparison on the different type of grain dryers currently being used in Heilongjiang Province of China is made in this paper, on the bases of knowledge of their development. Suggestions on the selection of grain dryers and fundamental technical specifications on grain dryers are proposed.

Introduction

In 1997, the total grain output of China were nearly 0.5 billion tons, among which total amount of moist grain (moisture content was about 30% w. b.) procured by the grain depots in the North-eastern four provinces and regions were 32.2 million tons. Grain drying in China is the world most difficult one due to large amount of moist grain to be dried, poor quality of grain and great moisture removal.

As a developing country and a great agricultural country, China has paid much attention on the research and design, importation and manufacture of grain dryers. Currently, there are 527 sets grain dryers installed in over 800 grain depots in Heilongjiang Province, total drying capacity of which are 6 million tons per year. Difference in drying cost, dried grain quality, specific initial capital cost and pollution produced in drying operation, resulted difference in economic and social benefits to the users and the surrounding regions. In this paper, some basic criteria for selection of grain dryers and the recommended dryers are given, based on a comparison study on several dryers which are popular in Heilongjiang Province.

A Review of Grain Dryers in North Eastern China

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Brick structure mixed flow dryer

One type was the brick structure mixed flow dryer used in series combination of several dryers (2, 3 or 4 drying towers in combination, 1 or 2 cooling towers in combination), either directly heated or indirectly heated.

Steam dryer

Another type was steam dryer. Like brick structure dryers, steam dryers were also used in serial combination. Grain was heated by steam flowing inside pipes through conduction. The cooling structure of steam dryer is the same as brick structure dryer.

Other types of grain dryers, such as hot water dryer, cross flow dryer, concurrent flow dryer, chain conveyer dryer, fluidized bed dryer, rotary dryer and fixed bed dryer etc. were also available in that period, but the dominate dryers were the above mentioned two dryers.

After 1992, with the reform of grain industry, investing in grain dryers became a hot point. Nearly 100 manufacturers began to produce grain dryers although many of which were poorly equipped. Thus resulting many problems in using grain dryers, such as unreasonable design of process, or unable to reach designed drying capacity and moisture removal, or worn out in less than 2 years, caused great losses to the users.

Focusing on grain dryer model selection, in 1994, we began to enhance the management of the procurement of grain dryers. Five aspects of innovation on grain dryers were pointed out based on experts' evaluations, which were as follows:

1. Full steel structures should be used in dryers manufacturing in stead of brick structures.
2. Several dryers in serial combinacion and multi-pass elevation of grain should be replaced with single dryer incorporating preheating, drying and cooling sections.
3. Direct heating should be replaced with indirect heating, manual operated furnace should be replaced with mechanical transmitted grate furnace.
4. Dryers should come from specialised factories in stead of being built by the depots themselves.
5. The drying installation should be equipped with upper and down flow buffer bins, on-line moisture meters and central monitoring systems.
6. Through several years' hard work and taking advantages of the central government's great attention on the
construction of grain distribution facilities in 1996 and 1997, we enhanced the general management of the procurement of grain dryers. New model dryers began to be introduced into grain depots. Three dryers were imported from France and the U.S.A. Since then, 285 sets of new dryers have been built, increasing the yearly drying capacity by 3 million tons. The major newly built dryers are:

**Fig. 1. Brick structure mixed flow dryer.**

**Mixed flow dryer**

The former mixed flow dryers were of bricks structures, now they are fully made of steels. With the application of new technology, drying capacity and drying uniformity have been improved. The daily through-put and moisture removal of the newly built dryers are 200 – 500 tons and 10 – 15% respectively.

**Concurrent flow dryer**

Concurrent flow dryers normally have 3 concurrent drying sections and 1 counter flow cooling sections. The daily through-put and moisture removal is 100 – 500 tons and 10 – 15% respectively.

**Cylindrical cross flow dryer**

The main working parts of the dryer are two concentric cylindrical column screens. Grain flow downwards between the two screens, whereas drying air crosses the grain layer to remove the moisture from grain.

The dryer’s structure is very simple, drying and cooling are accomplished in one single dryer. The daily through-put and moisture removal are 100 – 500 tons and 10 – 15% respectively. Seasonal wind affects the drying uniformity of this dryer, frequent cleaning of the screens is needed. It is difficult to adjust the drying uniformity of this dryer.

**Fig. 2. Steel structure mixed flow dryer.**
Rectangular cross dryer

This cross flow dryer features a simple structure and low initial cost. Like cylindrical cross dryer, the rectangular cross flow dryer is not suitable for removing moisture content of more than 15%, due to its poor drying uniformity.

Selection of Dryers

Currently, mixed flow dryer, concurrent flow dryer and cross flow dryer are the most popular dryers in China. Comparisons on the three types of dryers are shown in the attached table.

Such comparisons are based on the basic principles and the actual operating efficiencies of the dryers. In practice, fire danger is also a criterion for evaluating dryers' performance. As far as fire danger is concerned, from the most dangerous to the least dangerous are mixed flow dryer, concurrent flow dryer and cross flow dryer.

Hot Air Furnace for Grain Dryer

On the basis of over 20 years' research and practice experience, co-operated with Zhengzhou Institute of Grain Science, we successfully developed a coal-fired chain transmitted grate tubular lined exchanger furnace, which has proved to be quite reliable.

The followings are the main points to be considered in the design and manufacturing of furnaces.

1. The burning chamber and the heat exchanger shall not be connected to each other directly, to avoid heat exchanger from damaging caused by irradiation shock.
2. The length of fume ducting connecting the burner and heat exchanger shall be as short as possible in order to reduce the heat loss and pressure drop.
3. The heat exchanger shall be made from vertically placed steel tubes, fume shall flow inside the tubes, whereas air shall flow outside the tubes, for the convenience of cleaning the filth accumulated in the interior surface of the tubes.
4. The former steel-brick structure of heat exchanger shall be replaced by steel-steel structure to get a better sealing effects.
5. Properly select and control four important operating parameters of the heat exchanger. Those are:
   - Temperature of fume at the entrance of heat exchanger. Too low fume temperature will result in low heat exchanging efficiency; too high fume temperature will cause damage to the tubes.
   - Temperature of fume leaving the heat exchanger. The greater this temperature is, the lower the heat exchanging efficiency will be, and if this temperature is decreased down to the dew temperature of the fume, ash and sulphur it contained will cause blockage to the tubes.
   - Velocity of fume. Velocity of fume shall be properly designed, for it is related to the heat exchanging coefficient, the cleanliness and corrosion of tubes and the power installation of fans.
   - Velocity of air. It is also related to the power installation of fans and whether the required air temperature and flow rate will be achieved.

Aspects of Requirements on the Selection and Manufacturing of Grain Dryers

The existing national standards 'Test methods of grain dryers' (code of standard: GB 8876-88) and 'Technical specifications for grain dryers' (code of standard: GB 6970-86) provide bases for the procurement and manufacturing. But these two standards are fairly rough, can not meet the
requirements of the development of drying technology. Concluded from many years’ experience and technical specifications for the procurement of grain dryers in China, Grain Distribution and Marketing Project funded by a loan provided by the World Bank, the following technical criteria shall be carefully considered:

1. Species of grain to which the dryer is applicable;
2. Maximum allowable moisture removal while quality of grain is maintained;
3. Drying quality, breakage ratio, discoloration, pollution to grain, burnt kernels;
4. Specific heat consumption;
5. Adaptability to fuels;
6. Level of automatic control (control of grain level and temperature, measurement of moisture content and through-put, computerised control and process monitor);
7. Reliability (break down probability, safety);
8. Adjustment of temperature and humidity, waste heat recycling system;
9. Reasonable ground area it covered general arrangement of equipment and appearance;
10. Air pollution (altitude and intensity of smoke (fume) emission), dust and noise emission;
11. Unit initial cost;
12. Operating cost, fuel and electricity consumption;
13. Ambient temperature suitable for operation;

Fig. 5. Cylindrical cross flow dryer.

Fig. 6. Schematic structure of a chain transmitted grate coal-fired furnace.

Heilongjiang Province is in the furthest north of China, ambient temperature is low and the frost free period is short. Grain drying in Heilongjiang Province features low ambient temperature, high initial moisture content and short available drying time. The general requirements on grain dryers are: advanced process design, good dried grain quality, reasonable equipment price, long service life, high drying capacity and heat efficiency, large moisture removal, low operating cost, high level of automatisation and reliable operation. The followings are our major criteria for selecting grain dryers in recent years:

1. Moisture removal ability shall be good, the dryer shall be able to dry grain from an initial moisture content of 33% down to a safe storage moisture content in one pass.

2. Specific heat consumption shall be less than or equal to 1600 - 1900 kcal/kg, water, which is 20 - 30% less than the existing dryers’.

3. The dryer shall consists of drying sections and cooling section in one structure and be able to work in outdoor conditions (ambient temperature: - 30°C). Its expected service life shall be more than 15 years.

4. The expected service life of the burner and the heat exchanger constituting the major parts of the furnace shall be more than 5 and 15 years respectively.

5. The furnace shall be able to use bituminous coal as fuel. It shall be mechanically fed, shall be equipped with mechanical chain transmitted grate, mechanical cinder remover and tubular heat exchanger.

6. Items and ways of automatic control shall be:
   - air temperature, the variance of air temperature shall be within ±10°C;
   - automatic interlock control and alarm of grain levels in the buffer section of grain dryer;
   - automatic indication and alarm of air temperature and temperature of fume entering the heat exchanger;
   - automatic indication of grain temperature;
   - grain discharging speed could be easily adjusted manually.

7. the dryer shall be equipped with upper flow and down flow buffer bins, shall be loaded and unloaded mechanically.

8. the non-uniformity of moisture content of dried grain shall be within 2%, and the temperature of dried grain shall not be greater than the ambient temperature +8°C.

The above 8 criteria have been announced to the manufacturers and end users of grain dryers by the provincial grain bureau. The manufacturing and procurement of grain dryers shall be in accordance with these criteria.

**Fig. 7.** A fairly perfected grain drying system flowchart

**Other Major Problems**

Above are some basic consideration on the technology, grain drying is also in close relation to aspects of policy, planning and allocation etc. There are still some problems in practice.

1. The allocation of grain dryers shall be in accordance with the pattern of grain distribution. There used to be an argument on either 'carrying water' or 'carrying coal' in our province. Whether grain shall be dried in primary depots or intermediate grain depots have been considered in the scheme design of China Grain Distribution and Marketing Project. Based on many years' experience, we decide to build a grain dryer in a grain depot only if the quantity of moist grain is 3 - 5 times greater than its sun drying capacity.

2. Factors such as quantity of moist grain, initial cost of dryer, yearly operating cost and operating times shall be considered in determination of the designed drying capacity of a grain dryer, among which operating factor is the key factor. The most appropriate operating times are 75 days. The formula to determine the design capacity is: designed capacity = (quantity of moist grain-
(quantity of grain dried by sun light + quantity of grain transferred to intermediate depot)/75

3. The relationship between existing drying capacity and restricting moisture content policy on grain procurement.

<table>
<thead>
<tr>
<th>Type</th>
<th>Maximum moisture removal</th>
<th>Energy consumption</th>
<th>Adaptability to different type of grain</th>
<th>Break down probability</th>
<th>Pollution to the environment</th>
<th>Initial cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed flow</td>
<td>16%</td>
<td>small, with waste heat recycle</td>
<td>most of the grain species, for its air temperature could be adjusted</td>
<td>small, for simplicity of the whole installation</td>
<td>small, meet the requirement of the related National Standards</td>
<td>high</td>
</tr>
<tr>
<td>Concurrent flow</td>
<td>16%</td>
<td>fairly small, air temp. of each section is different</td>
<td>many grain species for air temp of each section is different</td>
<td>fairly high, for it has quite a few fans</td>
<td>greater than mixed flow, waste air exhausting from different sections causing pollution to the dryer and environment</td>
<td>less than mixed flow dryer</td>
</tr>
<tr>
<td>Cross flow</td>
<td>12%</td>
<td>fairly small, waste heat could also be recycled</td>
<td>limited grain species, for its uneven drying</td>
<td>fairly high, for frequent blockage to the screens</td>
<td>small, but cylindrical cross dryer is worse</td>
<td>low</td>
</tr>
</tbody>
</table>

Usually, moisture content of maize grown in our provinces when it is matured is fairly high, because of the geological and climatic conditions of the province, the maximum can be as high as 40%. This year a policy on procurement of maize with restriction on moisture content will be implemented. 25% is the standard moisture content for procurement of maize. A discount in weight and price will be given for the seller whose maize moisture content exceeds 25%. Such policy will encourage the farmers to grow early maturing varieties, therefore, the normal harvested moisture content of maize will be less than 30% and the existing drying capacity of the grain industry will be more efficiently used. We disagree to develop new dryers for the farmers, it is better to decrease the moisture content of farmer’s maize through improvements on variety and field drying instead of building farmer’ dryers. But the existing dryers of the state farm system shall still be fully used.

**Suggestions on the Further Development of Grain Dryers**

A newly stable research team engaged in grain drying research, development and manufacturing of drying equipment shall be built, in order to enhance the macro-control, speed up the development of drying industry and conduct the training on operation and maintenance of grain dryers.

Speed up the work on model selection and evaluation of grain dryers, realise the finalization, standardization and serialization of grain dryers. More detailed national standards shall be worked out to unify the dryer evaluating works, in order to eliminate the grain dryers of poor quality from entering the market.

Set up regularized grain dryer manufacturing base. Grain drying is a kind of very professional, technical and systematic work, experience in research, manufacturing and operating is very essential.

**References**