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INNOVATIVE SOLUTIONS FOR MODULAR DRYERS

Annotation

If a few years ago, with a twofold increase in yields and a severalfold increase in the export potential of the domestic grain industry, there was a 140% shortage of capacity and almost 150% of drying capacity [4], now the deficit of this capacity has not only not decreased, but also increased. And the reason for this is not the low pace of construction or renewal of the production potential of grain procurement enterprises, but rather the outpacing of the growth rate of gross grain production over the pace of construction of new elevators.

Given the deficit of the world balance in plant foods and the potential of domestic agricultural production, the disparity between the rate of growth of grain growing capacity and post-harvest processing technologies will require operational research and investment decisions for a long time. An important component of them is the improvement of existing and the introduction of innovative technologies to intensify the processes of post-harvest processing of grain.

In the period of the formed balance of domestic volumes of production of grain with capacities of grain-harvesting enterprises of the post-Soviet period the dominant share of grain drying units were dryers of mine type. Such well-studied dryers during the half-century period of their operation, domestic scientists have improved if not all parameters, then almost all. And producers have thoroughly studied their features and ways to adapt to the needs of drying different cereals, different purposes. However, the last few decades have been marked by the intensive introduction of modular grain dryers. It is the share of which already accounts for the dominant volumes of dehydration of grain harvested.

Of the great variety of manufacturers of modular grain dryers, the most innovative are the American ones. Given the great interest in dryers of American production, the peculiarities of their technology and methods of leveling layer-by-layer uneven heat and mass transfer, solutions to reduce energy losses of working gases and layer-by-layer grain differences in moisture content and temperature, methods of controlling the recovered heat -technological features and attention is paid in this work.

As part of the tasks, the authors tried to identify the most distinctive features of such modular dryers, to analyze the design, technological, aerodynamic and thermophysical features on the example of American grain dryers modular type new models 40FIDPX. The publication presents an analysis of innovative solutions to improve drying technology and features of production operation of such dryers. The causes of heat-aerodynamic imbalance of modular dryers are established and the decision on their elimination is given. The reasons for the reduction of the active surface of heat and mass transfer are revealed and the ways of reducing the energy losses of the working gases and unproductive losses of the heat and mass transfer surface are substantiated.

Key words: grain dryer, moisture exchange, working gases, heat, partial pressure, potential of drying gases.

Formulation of the problem

In this article, we have narrowed our tasks to the actual analysis of innovative solutions of modern American (US) grain dryers of modular type and the possibility of using them to improve similar grain dryers of European and domestic manufacturers.

The authors are aware of the importance of the opportunity and assistance in research work on the study of foreign grain dryers in production conditions and express their sincere gratitude to the administration of the agricultural holding and the elevator of this holding.

To save printing space and due to the high professional level of training of readers of this magazine, we will not overload the presented material with mathematical formulas, methods of proving the reliability of the results or arguing their legitimacy. Note only that the publication is based on studies of grain dryers in production conditions, for which the author's and generally accepted calculation methods were used, thermophysical and aerodynamic laws of state and

interphase interaction of environments of different states of mobility and enthalpy were used, [1, 2, 5].

Since the dominant majority of modular grain dryers is characterized by the lack of uneven heat and moisture exchange along the length of the chambers [5 - 9], so the main focus of research is on the uniformity of grain drying. The unevenness of the grain moisture content in the dryer chamber is directly related to the length of these chambers, the parameters of the heat-aerodynamic flow and the methods of intra-chamber equalization of the heat flow by the difference of gas pressures. The uneven moisture content of dehydrated grain in the horizontal plane of modular dryers of different designs and performance (chamber length) can range from three to 6 % or more. And this is not only an increase in the duration of redistribution of moisture and heat of different grains, as well as overuse of heat and injury of overdried grain. We all remember that as the moisture content of a grain decreases, the cost of dehydrating it increases, and the "last" percentage of



Fig. 1. Appearance of a metal-collecting elevator with a conical roof of cans.

dried moisture is several times harder to remove than the original. And for corn grain, at the speed of drying, the last percentage of dehydration to the critical moisture content is almost four times more energy-intensive than the initial one. Therefore, the thesis of possible equalization of moisture between overdried and underdried grain in containers is economically unjustified.

Research results

In the modular grain dryer of the 40FIDPX model range discussed below, these and other shortcomings have been eliminated. In Fig. 1 shows a general view of the elevator with metal-collecting tanks, Fig. 2 shows the view of the drying and cooling chambers of the dryer model series 40FIDPX. In Fig. 3 aerodynamic regulators of recovered gas flows and in Fig. 4 unloading device of this dryer.

This grain dryer unit consists of the actual heat

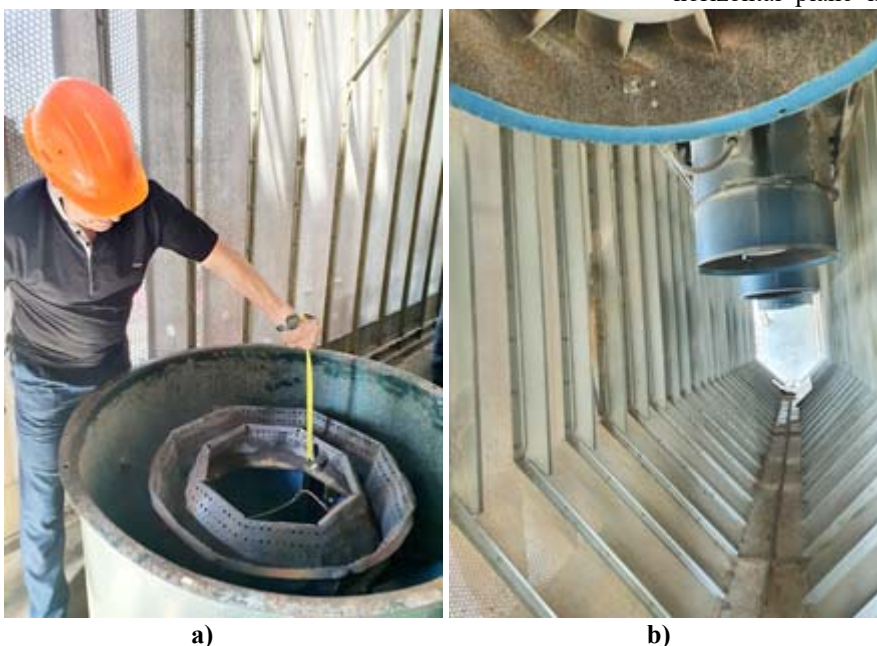


Fig. 2. Modular grain dryer: a) drying chamber with fan and burner and b) cooling chamber with aerodynamic air ducts

and moisture exchange chambers, super-drying screw and drying chain conveyors in accordance with the supply of wet grain to the dryer and unloading dry, mechanical device volume unloading dry grain, four axial fans equipped with dryers, four gaseous fuel burners located at the outlet of the air flow from each fan to the drying chamber, automatic maintenance of specified drying modes and prevention of unusual situations, sensors of grain above the drying chamber, temperature of drying gases and grain,

complete combustion of coolants, structural fasteners and fasteners its technological service, the reinforced concrete stationary base and communication binding.

From the description of the dryer readers have already noted that its main design features include the following:

a) air-blowing machines with burners equipped in them (Fig. 2) are moved to the heat exchange chamber;

b) to control the amount of recovered heat and aerodynamic pressure, the grain cooling chamber is equipped with devices for heat recovery (Fig. 3);

c) for the redistribution of heat and moisture in the layers of grain, in the upper part of the drying chamber are arranged flow channels;

d) to equalize the balance of aerodynamic drag of the dry and wet layer of grain - the thickness of the grain layer of the cooling chamber (set the distance between the sieve surfaces) is set to 0.31 m, and drying - 0.30 m.

e) prevention of uneven gas flow in the horizontal plane is provided by gas supply ducts and burner design.

g) productivity and uniformity along the length of the dry grain unloading chamber is provided by sectional bulk unloaders (Fig. 4);

h) reduction of intra-capillary resistance to moisture diffusion in the grain body is achieved by redistribution of moisture and temperature in its layers. To do this, the sieve surface of the drying chamber with a height of 0.8 m was replaced with a metal screen to prevent the supply of drying gases. Such a reduction in the active surface will not affect the productivity of the dryer, but the quality of drying (elimination of injury to thermolabile components of the periphery of the grain body) and the



Fig. 3. Aerodynamic devices for control of heat recovery processes: 1 – cooling chamber, 2 – aerodynamic devices, 3 – mechanisms of grain unloading

reduction of specific heat consumption is clearly the same. Similar solutions, including the authors, were successfully tested on a bench at different dehydration rates 15 years ago. And later their importance in production testing of modernization of the paired drying complex DSP-32 was proved by additional reduction of moisture to 3% for corn grain with simultaneous reduction of its fracturing from 17 to 5% [4]. That is why they deserve attention.

The surface area of heat and mass transfer chambers is important for controlling the amount of heat flux of heat-sensitive bodies to which the grain belongs. That is why the productivity of the dryer and the quality of drying depend on its area. The surface area of the drying chamber of the dryer is 231 m² and the cooling 72 m². This ratio of chamber sizes (3.2: 1) for drying speeds with drying gas temperatures up to +110 °C is critical, especially for late cereals. The dispersion of the drying and cooling zones further aggravates the grain cooling regime by the presence of inflow windows of the cooling chamber. Therefore, based on the heat balance of different chambers and aerodynamic features of the dryer, it would be advisable to increase the size of the grain cooling chamber by 35% relative to the total area.

Control of the share of recovered heat and aerodynamic resistance to the flow of working gases in the dryer for different environmental parameters and grain provide inflow windows (Fig. 3), evenly spaced on both sides of the cooling chamber. Flow windows are an important feature of the design of this model of dryer. They can significantly affect both the kinetics and heat energy of drying. By opening the windows we thereby, on the one hand, reduce the share of recovered heat (negative side effect) and moisture content of exhaust gases (positive effect), and on the other hand, reducing aerodynamic drag, increase the flow of working gases in the drying chamber, improve layer homogeneity grains of mass and heat exchange and we intensify interphase heat and moisture exchange in the drying chamber (positive effect). However, due to the insufficient size of the grain



Fig. 4. Mechanism of grain unloading: 1-volume grain unloader, 2-scraper conveyor

cooling chamber, the expediency of their use is contradictory.

An important parameter of the dryer to influence the efficiency of the potential of drying gases and, accordingly, the specific heat consumption is the thickness of the grain layer. The thickness of the grain layer in the inter-chamber space of the dryer varies from 0.310 m, cooling zone, to 0.300 m drying. The difference in the thickness of the grain layer of different chambers, in our opinion, is due to the different aerodynamic drag of wet (larger) and dry (smaller) grain. This is half the thickness of most domestic models of dryers [4, 5]. It should be noted that the greater the thickness of the layer provides, on the one hand, a longer trajectory and duration of the working gases in the grain environment, and hence their greater filling with moisture. That is, the potential of the working gases is better used and this is good. However, this reduces the uniformity of temperature and moisture content of grains in the grain layer, increases the aerodynamic drag of the grain layer and at the same time reduces the moisture absorption capacity of working gases (in the case of pressurized working gases, as in our version of the grain dryer). supersaturation with moisture [5]. And in the future, with the cooling of the gases on the periphery of the grain layer, vapor condensation may even occur, especially in the upper part of the drying chamber. This is actually the case for most grain dryers of various models, including mine [3, 5].

Design features of the dryer provide its technological and heat-aerodynamic differences. Of which it should be noted:

- combined method of supply of working gases: drying zone - under injection, cooling - under vacuum;
- minimized heat loss from heating the dryer structure;
- minimum aerodynamic losses on the movement of working gases;
- aligned field of layered heat and moisture exchange in the horizontal plane of the dryer chambers;
- eliminated the uneven heat and moisture along the length of the chambers;

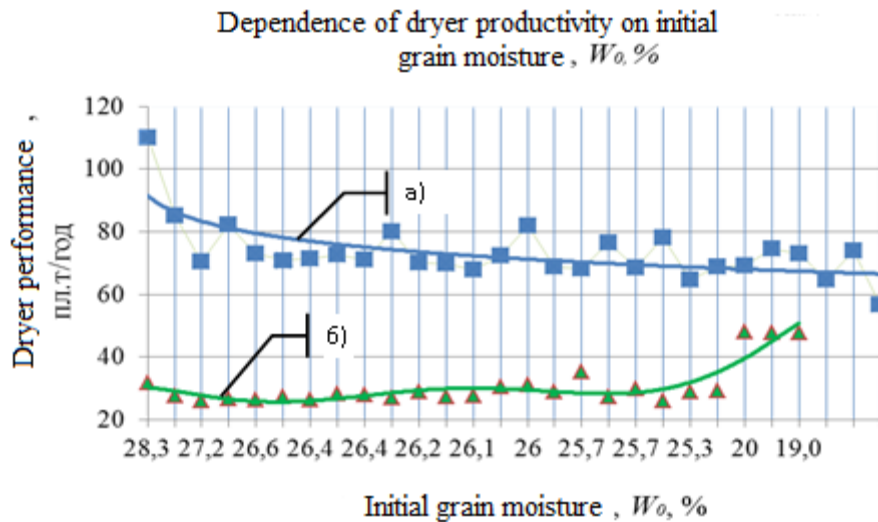


Fig. 5. Influence of energy of connection of moisture with grain on productivity: a) - in planned tones for an hour; b) - in physical tones per hour.

- increased the driving potential of the working gases with a variable pressure gradient of the working gas flow, which additionally provides moisture up to 2-3%;
- the number of blowers was reduced due to the combined use of fan energy to create the pressure difference between the chamber and the environment: injection - drying zone, vacuum - cooling.

The effect of the energy of moisture bonding with the body of the grain is directly related to the productivity of the dryer and the specific heat consumption. This connection can best be observed in the kinetics of grain drying. According to the indicators of energy consumption and dryer productivity for drying grain of different initial moisture, we can approximate the kinetic dependence of energy consumption and improve drying regimes to reduce heat loss by controlling the intracapillary resistance to moisture diffusion. However, different understandings of the planned tone by foreign manufacturers of dryers and domestic technologists complicate this task.

In Fig. 5 we can clearly see the discrepancy between the performance of different units of

measurement. Thus, the productivity of the dryer in the planned tones [1], with increasing energy of the connection of moisture with the body of the grain, decreases (dependence a) Fig. 5). However, in physical tones (dependence b) Fig. 5) it increases.

Simple arithmetic calculations allow us to establish that with a decrease in the initial moisture content of corn grain (W_0), the productivity of the dryer in the planned tones decreases by an average of 2.1 pl.t / h ($\Delta G = 2.5\% / 1\%$) for each percentage decrease in grain moisture.

The results of industrial research on the influence of environmental parameters, drying regimes and the range of dehydration of grain on the productivity of dryers (intensity of interphase heat and mass transfer) are presented in Fig.6. Shown in Fig. 6 dependence proves that with decreasing ambient temperature, the productivity of the dryer may not only not decrease, but also increase due to the reduction of moisture content of environmental gases and the corresponding increase in the potential of working gases. In our case, with a decrease in ambient temperature by $\Delta t = +11 \text{ }^\circ\text{C}$, the moisture content of environmental gases decreases by $\Delta d = 7 \text{ g / kgf.}$ and the potential of the working gases increases by so much.

Parameters of the sieve surface of the chambers. With the reduction of the size of the dehydrated body (rapeseed, sorghum, mustard, etc.), reduce the size of the holes in the sieve surface, and with increasing size of such bodies (soybeans, corn) - on the contrary, increase. For sieve surfaces with hole diameters of $\text{Ø}1.54 \text{ mm}$ and $\text{Ø} 2.1 \text{ mm}$, the living cross section is 26.6 and 23.5%, respectively. This is a lot or a little - can be estimated in comparison with a similar figure for the well-known domestic mine grain dryers such as particleboard, for which this figure is four times lower.

Sometimes, in the practice of drying grains of different sizes (rapeseed - corn), they try to use a "suitable for all crops" universal sieve ($\text{Ø}1.54 \text{ mm}$). That is, with the smallest size of holes. However, in these circumstances, the increase in aerodynamic drag of sieve surfaces, reduction of fictitious speed of working gases and slowing of layer-by-layer thermal conductivity in dehydrated grain and deterioration of interfacial heat and mass transfer are sometimes neglected. This disadvantage is

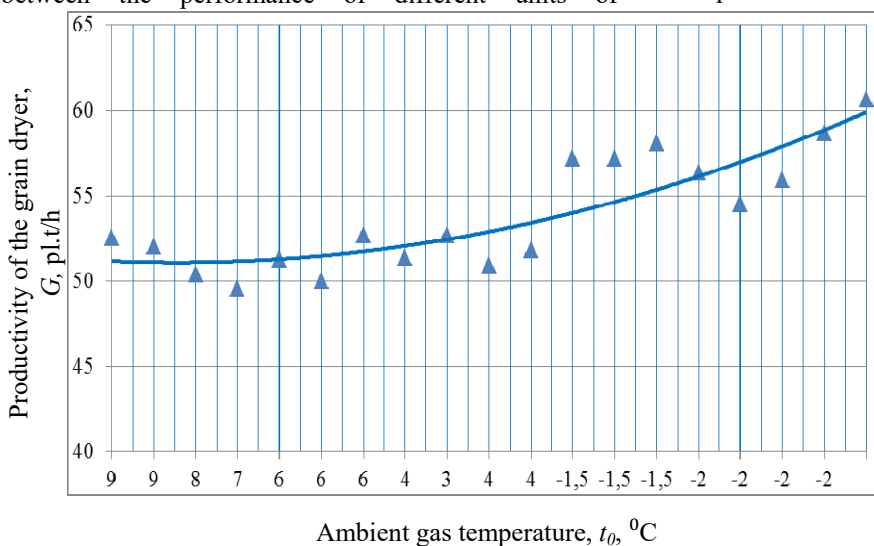


Fig. 6. Influence of parameters of environmental gases on productivity of the modular grain dryer on corn grain



somewhat offset by the reduction of heat flow and productivity of the dryer.

According to the analysis of thermo-aerodynamic calculations, we found that by reducing the diameter of the sieve surface from Ø2.54 mm to Ø2.1 mm, living cross section 27%, for grains of sphericity 0.7 - 0.9 and layer thickness 180 - 220 grains, reduction layer-by-layer interphase heat and mass transfer is 19 - 25%. This is quite significant given the corresponding decrease in the productivity of the grain dryer and the layer-by-layer uniformity of dehydration, and hence the increase in grain impurities.

According to the estimated data, it is established that the thermal capacity of the burners of these models significantly (up to 35%) exceeds their passport productivity (nominal and maximum). Most likely, the reserve of thermal power provides for the need to cover the features of the current operation of the dryer and its maintenance in a long grain harvesting period of operation.

Conclusions

1. American (US) chamber grain dryers of the

40FIDPX series have progressive design and technological differences. Among which the presence of:

a) flow channels in the upper part of the drying chamber for mixing grain of different temperature and humidity;

b) zones of redistribution of heat and moisture in the layers of the grain body in the drying chamber;

c) inflow windows in the grain cooling chamber;

d) use of energy of rarefaction of air-blowing machines of the cooling and pressure zone - grain drying;

d) aligned thermal field in the horizontal plane of the dryer chambers;

2. As the ambient temperature decreases, the productivity of the dryers may increase;

3. To build the kinetics of grain drying and improve the operation of foreign dryers, it is advisable to calculate their productivity in the planned tones;

4. It is possible to reduce aerodynamic losses by increase in diameter of apertures of a sieve surface;

6. The size of the "blind zone" of the dryer can be reduced by reducing the coefficient of aerodynamic losses and changing the flow vector of the working gases in the dryer chamber.

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ІННОВАЦІЙНІ РІШЕННЯ МОДУЛЬНИХ СУШАРОК

Анотація

Якщо ще кілька років тому, за двократного збільшення обсягів вирощеного урожаю та кількратного зростання експортного потенціалу вітчизняної зернової індустрії, було заявлено про 140 % дефіцит ємностей і майже 150 % сушильних потужностей [4], то наразі дефіцит цих потужностей не лише не змінився, а й зріс. І причиною цього власне не низькі темпи будівництва чи оновлення виробничого потенціалу зернозготівельних підприємств, а швидше за все випередження темпів зростання валового вирощування зерна над темпами будівництва нових елеваторів.

З огляду на дефіцит світового балансу в продуктах рослинного харчування та потенціал вітчизняного агропромисловства, – диспаритет між темпами нарощування потужностей вирощування зерна та технологій післязбиральної його обробки буде ще тривалий час вимагати оперативних науково-інвестиційних рішень.



Важливою складовою їх є удосконалення існуючих та впровадження інноваційних технологій інтенсифікації процесів післязбиральної обробки зерна.

У період сформованого балансу вітчизняних обсягів виробництва зернових з потужностями зернозаготівельних підприємств пострадянського періоду домінуючою часткою зерносушильних агрегатів були сушарки шахтного типу. Такі, добре вивчені сушарки впродовж півстолітнього періоду їх експлуатації, вітчизняні науковці удосконалили якщо не всі параметри, то майже всі. А виробничники досконало вивчили їх особливості та способи пристосування до потреб сушіння різних зернових культур, різного цільового призначення. Однак останні кілька десятиліть відзначилися інтенсивним впровадженням саме модульних зерносушарок. Саме на частку яких вже припадають домінуючі обсяги зневоднення зерна зібраного урожаю.

Із великої різноманітності виробників модульних зерносушарок, інноваційно вигідно вирізняються саме американські. З огляду на великий інтерес до сушарок власне американського виробництва, особливостей їх технології та способів нівелювання поширеної нерівномірності тепло-масообміну, рішень зі зменшення втрат енергії течії робочих газів й поширової в шарах тіла зернини відмінності вологовмісту та температури, способів управління часткою рекуперованої теплоти та інших конструктивно-технологічних особливостей і приділено увагу в даній роботі.

В рамках поставлених завдань, автори спробували виокремити найбільш відмінні особливості таких модульних сушарок, виконати аналіз конструктивних, технологічних, аеродинамічних та теплофізичних особливостей на прикладі американських сушарок зерна модульного типу нових моделей 40FIDPX. В публікації викладено аналіз інноваційних рішень з удосконалення технології сушіння та особливості виробничої експлуатації таких сушарок. Встановлено причини тепло-аеродинамічного дисбалансу модульних сушарок та наведено рішення з їх усунення. Виявлено причини зменшення активної поверхні тепло-масообміну й обґрунтовано способи зменшення втрат енергії течії робочих газів та непродуктивних втрат поверхні тепломасообміну.

Ключові слова: зерносушарка, вологообмін, робочі гази, теплота, парціальний тиск, потенціал сушильних газів.

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