EXPEDIENCY OF USING THE WORKED OUT AGENT OF THE DRYING

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Аннотация: двухшахтные сушилки типа ДСП-32 есть наиболее распространенные в Украине. Фактическая энергоемкость сушки зерна в таких сушилках в два раза превышает расчетную потребность на фазовые превращения влаги в зерне. Наибольшие потери тепла происходят с отработанными рабочими газами. Целесообразность использования теплоты этих газов необходимо сопоставлять с затратами на техническое обеспечение предложений по рекуперации. Наименее затратные, но менее экологически- безопасные предложения могут окупаться в пределах 0,5 сезона работы сушилки. Экологически безопасные предложения с использованием тепловых труб могут окупиться в течении 5 лет.
Ключевые слова: сушка, зерно, энергоемкость, сушилка, рекуперация тепла.

The fundamental component of the losses of the convective method of the drying of grain and by the source of the decrease of the energy content of drying is repeated use of heat of the worked out agent of drying [1, 2, 4, 6]. Studies of the different authors established that for different cultures, technological regime and conditions of environment, loss with the exhaust gases they can put to 25% from total heat expenditures for desiccation, or to 47% of heat from the need for the evaporation of moisture from the grain [2, 4]. Therefore in the publications most frequently propose the solutions to use the heat-exhaust gases by a course of these gases into the furnace department or for the mixing with the newly prepared flue gas [1, 2, 4, 6]. In this case frequently ignore the correctings with respect to a change in the moisture content of these gases, their enthalpy and coefficients of the heat-moisture exchange, increase in the expenditure of the newly obtained mixtures of gases, which leads to the errors of mass-exchange processes.

We propose below based on the example to the most common construction of the grain dryer of type DSP-32ot to examine the economic expediency of the technological solutions of the repeated use of the exhaust gases taking into account the part of the corrections outlined above. After complexity and material consumption of introduction these solutions can be divided into two groups: relatively simple and complex.

The first group of the solutions does not require complex constructions and adaptations.

To it can be attributed such.

1.1. Recovery of the exhaust gases after the second of the Dryer grain zone into the furnace department.

Profitable constituting. For evaluating the economic expediency of the second use of the worked out agent of drying, let us determine the heat of the worked out agent for the drying apparatus to type of DSP according to the known formula [3, 4, 7]:

$$Q_{vt.a} = L_m \cdot [1{,}004 \cdot (t_2 - t_0) + 2{,}5 \cdot (d_1 - d_0) + (1{,}842/1000) \cdot (d_1 \cdot t_2 - d_0 \cdot t_0)], \quad (1)$$

where L_m - expenditures of the agent of drying, kg/h; t_0 and t_2 - temperature of air of environment and worked out agent of drying, wasps; d_0 i d_1 - moisture content of air of environment and worked out agent of drying, g/kg $_{d.a}$.

After substituting the appropriate values, we will obtain: $Q_{vt.a}$ = 4170 MJ/hour. With the condition of using the diesel fuel with specific heat of the combustion of q= 42,6 MJ/kg and cost of 13 grn/kg (course 1 dol/USA = 7,99 grn.), the cost of the heat of the recovered in the furnace worked out agent of drying will compose:

$$E_h = (Q_{vt.a} / q_p) \odot t_{sdp} = (4170/42{,}6) \odot 13 = 1273 \text{ grn/hour, or } 159 \text{ \$/ hour} \quad (2)$$

In the recomputation to the season of the work of drying apparatus the cost of the losses of heat with the exhaust gases will comprise: $E_s = E_h \cdot \tau_s / 1000$ = 103 thous $/sezon, where τ_s=650 hour. Expensive component includes single expenditures for the re-equipment of drying apparatus and expenditures for an increase in the expenditure of the agent of drying with the increased moisture content.

The first part of the expenditures for the recovery of the worked out agent in the furnace together with the cost of metal structures, construction-assembly and setting up and initial operation works, transport services and other expenditures vary in limits of 13... 17 thousand $.

The second part of the expenditures is connected with the need for compensating the increased moisture content of the newly formed mixture.

The precise expenditures of the agent of drying, with the correction for moisture content, can be designed from the formula:

$$L_m = W\, 1000/(d_2 - d_3), \text{ kg}_{d.a.}/\text{ hour} \quad (3)$$

where W - quantity of evaporated moisture from the grain in the zone of drying, kgf; $W = (\omega_f - \omega_s)/(100 - \omega_f)$. For the drying of grain from 20 to 14% of humidity W = 2230 kg; d_3 and d_2 - moisture content of the agent of the drying before and after of drying, g/ kg$_{d.a}$. The moisture content of the agent of the drying of d_{3i} before the process of drying can be calculated from the moisture balance:

$$d_{3i} = (L_1 \cdot d_1 + L_2 \cdot d_0)/(L_1 + L_2), \text{ g/ kg}_{d.a} \quad (4)$$

where L_1 and L_2 - expenditure of the agent of drying in the first and second drying zones, m^3/hour.

For the summer conditions for the work of drying apparatus, the precise expenditure of the agent of drying, with the constant thermal conditions, will be about 124 thous. m^3/hour.

It is here necessary to note that for the work of drying apparatus in autumn additional expenditure of the agent of drying will be high. Additional expenditures of energy consist of expenditures for transportation and heating of the additional volumes of gases of the quantity: ΔV = (124 - 120) = 4 thous m^3/ hour. Expenditures for heating can be designed from the known formula:

$$Q_{BT.} = G_2 \cdot c_2 \cdot (\theta_2 - \theta_0), \quad (5)$$

They will be 394 MJ/hour. In the cost expression, in the transfer into the diesel fuel, the expenditures will be near 15 $ / hour or in the conversion to the season of the work of drying apparatus of approximately 10 thous. \$. Additional expenditures for the transportation of the increased gas flow for the season will comprise:

$$Z_d = 1000 \cdot N_f \cdot ц_e \cdot \tau_c = 0{,}9 \text{ thous. \$ /season,} \tag{6}$$

where N_f - power of the electric motor of fan, kW; C - cost of 1 kW of electric power, grn.

They will comprise entire of expenditure: $\Sigma Z = Z_{p.з}/\tau_p + Z_c + Z_{доп} = 15$ thous.\$, (7)

where $Z_{p.з}$ - of the expenditure of the reconstruction (re-equipment) of drying apparatus, thous.grn; τ_p - period of the amortization of expenditures on the reconstruction, season.

Thus, expenditures for the second use of the worked out agent of drying can be justified in the limits of one drying season (15 /159 = 0,1 season). For the later (cold) operating cycle of drying apparatus the precise expenditure of the agent of drying can comprise to 150… 160 thous.m^3/hour. The appropriate values of the temperature of heating the agent of drying are set to J- d of diagram.

Let us lead below the calculations of the return on expenditures from the repeated use of the worked out agent of drying by using its heat for the partial heating of grain by mixing to the agent of the drying of the first and second drying zones with the use of heat exchangers.

1.2. The worked out agent after the second of the Dryer grain zone they direct into the bunker of the preheating of grain or furnace.

The effectiveness of this version also is sufficiently high. For preheating of grain of the cereal crops of food designation the necessary heat expenditures are designed from the formula:

$$Q_{h.g} = G_2 \cdot c_2 \cdot (\theta_2 - \theta_0) = 2016 \text{ MJ/hour,} \tag{8}$$

where $Q_{h.g}$ - of heat for the heating grain, MJ/hour; G_2 - productivity of drying apparatus, pl.t/hour; c_2 - heat capacity of grain, kJ/(kg of °C); θ_2 and θ_0 - respectively initial and final temperature of heating grain. For the summer operating cycle of drying apparatus. With the exhaust gases after the second of the Dryer grain zone we will be able to use $Q_{h.g}$ *= 4170 MJ/hour (see calculation in previous paragraph 1.1).*

This heat it is sufficient for heating of grain to $\delta\theta = Q_{h.g} /(G_2 \cdot c_2)$. I.e. to the temperature, that it does not exceed the temperature of the exhaust gases (we have accepted 40 °C) and the boundary temperature of heating the grain.

Theoretically, by the heat of the exhaust gases of the second drying zone of drying apparatus it would be possible to heat grain to $\delta\theta = 62$ °C. However, because of the existing limitations (actual temperature of the exhaust gases and the existing limitations of the tempera of heating grain) the temperature of grain can be increased to 40 wasps.

The remained part of the heat of the exhaust gases can be used for the mixing with the agent of drying by the first either second of drying zones or directed into the furnace department.

The part of the flow of the worked out agent of drying after the second drying zone can be calculated on the basis of a quantity of heat of the necessary for the heating grain to the temperature of these gases: $Q_{h.g} = G_2 \cdot c_2 \cdot (\theta_2 - \theta_0) = 1344$ MJ.

Thus, by the part of the heat of the worked out agent of drying it will be possible to heat grain to 40 °C, and the remained part of the heat (4170-1344=2826 MJ) - for the mixing with the agent of drying.

After producing calculations after formula 5 let us determine, that this part of the heat is equivalent to the heat of 28,7 thous.m^3/h of the agent of the drying of the first of the Dryer grain zone.

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After producing calculations after formula 5 let us determine, that this part of the heat is equivalent to the heat of 28,7 thous.m^3/h of the agent of the drying of the first of the Dryer grain zone. Thus, the supplemental heat of grain in the drying apparatus will compose 55 - 40 = 15 °C.

Direct expenditures for the realization of this recommendation will compose the robots of grain dryer of the production of the installation of new equipment and these expenditures vary in limits of 28… 32 thous. $.

Profitable part consists of the straight savings of the second use of heat of the exhaust gases, decrease of specific expenditures for the evaporation of moisture due to an increase in the coefficient of diffusion of moisture and decrease of the latent heat of vaporization (*r*), and also increase in the productivity of drying apparatus.

From the heat balance of grain dryer, on the evaporation of moisture total heat expenditures consist of expenditures for heating of grain $Q_{h.g}$ and evaporating the moisture $Q_{h.p}$.

Earlier we established that for heating of grain in the drying apparatus of type DSP from 22 to 55 °C it is necessary to 2218 MJ/hour. Heat expenditures for the evaporation of moisture are designed from the formula:

$$Q_{h.p} = W \cdot (r + \Delta r), \qquad (9)$$

where W - quantity of evaporated moisture, kg/h; r - hidden heat of vaporization of water at a temperature of grain of θ_2, kJ/kg_{lq}; is calculated by the formula $r = 2500 - (2{,}3 + 0{,}0014 \cdot \theta_2)$ given above θ_2 = 2362 kJ/kg_{lq}. Δr - specific heat for overcoming of internal resistance to the moisture transfer, of G.S. Zelinskiy they put for corn $\Delta r = 0{,}11r$. After substituting the appropriate values, we will obtain:

$$Q_{h.p} = 2230 \cdot (2362 + 260) = 5847 \text{ MJ/hour}.$$

Thus for heating of grain and evaporating the moisture the necessary heat expenditures will compose: $Q_{n.b} = Q_{h.g} + Q_{h.p} = 2218 + 5847 = 8065$ MJ/hour.

In our case, with the use of heat of the exhaust gases for heating of grain, total heat expenditures for evaporation will be less and they will compose $Q_{n\,k} = Q_{n.b} - Q_{n.p} = 5129$ MJ/hour. Where $Q_{n.p}$ - utilized the heat- exhaust gases, $Q_{n.p}$ = 2936 MJ/hour.

With the constant parameters of the thermal conditions of the functioning of drying apparatus, its productivity will grow on $(8065/5129)\cdot 100 - 100 = 57\%$.

The Economy of Heat in terms of money in the conversion to the diesel fuel will be about 71 thous.$/sezon, and the period of the return on expenditures (30/71=0,42) - in the limits of one season of the work of drying apparatus.

Version 1.3. it is realized during mixing of the exhaust gases of the zone of cooling to the agent of the drying of drying zones.

The procedure of calculations of heat economy and the determination of economic expediency are analogous to the previous calculations. Expenditures for realization will be about 12… 13 thous.$ and the operations of grain dryer can be justified also in the limits of one season.

The second group of measures is based on the use ecological- clean technologies.

In particular on the use of heats-utilizer of the heat of the exhaust gases.

For calculating the heat-utilizer should be taken into consideration such initial data. The expenditure of the drying agent for an example of the drying apparatus of DSP-32otwill compose in the first drying zone $V_1 = 80$ thous m^3/hour, the second drying $V_2 = 42$ thous. m^3/hour and zones of cooling V_{cools}=48 thous. m^3/hour.

But the height of drying chambers composes 4686, 2886 and 3678 mm respectively with the cross section is 3250*1000 mm. The temperature of the drying agent at the output from the drying zones, as a rule, they are not normalized, but it is placed as initial condition with the determination of drying regimes and is within the limits of 40… of 65 °C. The temperature of the drying agent at the output sometimes calculate from the formula

$$t_2 = 0{,}125\cdot(2t_1+\theta_1+\theta_2) = 45\ °C, \quad (10)$$

after these data it is possible to approximately determine the losses of heat (energy) with the drying agent at the output from the drying apparatus according to the formula:

$$Q = V\cdot\rho\cdot c\cdot t_2, \quad (11)$$

after substituting the appropriate values, energy losses will be 1100, 641 and 497 kJ/sec respectively in the first and second drying and cooling zones of drying apparatus. For heating of atmospheric air are used, as a rule, the heat exchangers "gaz-gaz". For determining the area of heat exchange it is possible to use the known equation of heat transfer from the gas to the wall and from the wall to the gas when the heat-transfer coefficients of $\alpha 1$ and α_2 are known. The value of δ/λ can be ignored with [isplzovanii] of heat exchangers with the steel or brass tubes, since. thermal resistance in them is insignificant:

$$K = \frac{1}{\dfrac{1}{\alpha_1} + \dfrac{1}{\alpha_2} + \Sigma\dfrac{\delta}{\lambda}} \quad (12)$$

after literature data the coefficient of the heat exchange of $\alpha 1$ with the heating or cooling metal tubes by gases is within the limits of $\alpha_1 = 10…50$ W/(m^2·°K), and in the grain dryers of $\alpha_{max} = 29$ W/(m^2·°K) [2].

Thus. the coefficient of heat transfer it is possible to accept K = 25… 30 W/(m^2·°K).

Then the surface area of heat exchanger- the utilization on the zones will compose 1465 m^2, 610 m^2 and 830 m^2 with respect to the first and second drying and third cooling of the zones of drying apparatus. With the cost of 1 m^2 of the surface area of heat exchanger of approximately 125 $, the cost of entire heat exchanger will compose about 260 thousand $. Profitable part, in the recomputation to the natural gas will compose 35 thousand m^3, or 15,5 thousand $ for the season. On the basis of that presented above, the payback period single initial costs of heat exchanger will exceed 16 years, and with the use of diesel fuel - 5 years. It is necessary to note that the relatively low economic effectiveness of heats-utilizer under the prevailing until today conditions, does not diminish their scientific significance and the possible prospect for practical application.

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