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MODERNIZATION OF THE MACHINE FOR HYDROTHERMAL TREATMENT OF GRAIN

Abstract

The purpose of hydrothermal processing of grain is to change its initial technological properties in the direction of stabilization and maintaining them at the optimal level for the further process of processing it into the final product - flour or cereals. The use of devices of continuous action allows the steaming process to become more efficient, while hydrothermal treatment occupies a special place in the technology of processing cereals, obtaining them high consumer properties. The analysis of designs of devices of continuous action, shows that the most widespread have devices of horizontal type where the main working body of the steamer has functions of transportation and hashing. This design allows to achieve uniformity of steaming during processing of the product. To achieve a flexible change in the exposure of steaming, it is proposed to introduce a two-stage variator in the drive of the working body, which will significantly change the steaming time and use the apparatus for steaming more different crops, and to ensure a constant set steam pressure the design of which allows to carry out these operations without pressure losses. In the two-stage version of the variator, the rotation from its drive shaft by means of a V-belt is transmitted to the intermediate shaft, and from it by means of an additional V-belt to the main working shaft. The gear ratio is adjusted by turning the glasses and their synchronous shift in the axial direction.At the same time there is a simultaneous movement of movable conical disks, transfer of a V-belt and an additional V-belt to other diameters. We use sluice gates with a flat sealing surface and a fluoroplastic gasket to supply grain to the working chamber under pressure and unload it. This design allows the most effective sealing of the working chamber under pressure and to maintain the working pressure within the specified limits, with continuous loading and unloading of the device. The calculations show the feasibility and efficiency of modernization of the steamer by ensuring the tightness of the unloader and the uniformity of the speed of the product processed in the working chamber by using a two-stage gearbox or drive motor with a frequency converter.

Key words: hydrothermal treatment, grain, groats, steaming, calculation, unloader, reducer.

Problem statement

Hydrothermal treatment occupies a special place in the technology of processing cereals and obtaining cereals and their derivatives (flakes, muesli, flour, dietary products, etc.) with high consumer properties.

The analysis of designs of devices of continuous action, shows that devices of horizontal type with the transporting - mixing body have the greatest distribution. This design allows to achieve uniformity of steaming by mixing the product.

The use of continuous devices allows the steaming process to become more efficient.

To achieve a flexible change in the exposure of steaming, it is proposed to introduce a variator in the drive of the transporting body, which will significantly change the steaming time and use the apparatus for steaming more different crops, and to ensure a constant set pressure which allows you to perform these operations without pressure loss.

In the two-stage version of the variator, the rotation from the drive shaft by means of a V-belt is transmitted to the intermediate shaft, and from it by means of an additional V-belt to the ice shaft. The gear ratio is adjusted by turning the glasses and their synchronous shift in the axial direction. At the same time there is a simultaneous movement of movable conical disks and transfer of a V-belt and an additional V-belt to other diameters.

We use sluice gates with a flat sealing surface and a fluoroplastic gasket to supply grain to the working chamber under pressure and unload it. This design allows the most effective sealing of the working chamber under pressure and to maintain the working pressure within the specified limits, with continuous loading and unloading of the device.

1. Description of the functional diagram of the machine.

Before the start of the steamer (Fig. 1) is the connection of the machine to the mains and steam line, then the drive is turned on and the manual valve 7 supplies steam to the vessel 1 to heat it for 5-10 minutes. After warming up the apparatus, the control valve 8 is adjusted depending on the required pressure in the apparatus by moving the loads 9 on the valve lever. The required pressure is monitored by a manometer 6 mounted on the housing 1 of the working chamber. A safety valve 5 is also installed on the housing. Next, steam enters the apparatus through the distribution steam collector 11 and through the nozzles 12. The required drive speed is set depending on the required exposure.

After the steam pressure in the vessel has been adjusted and the required steaming exposure has been established, the feeder 3 and the unloader 4 are switched on and the grain is loaded into the apparatus. The grain enters from the hopper into the loading pipe of the feeder 3, successively filling the cell of the rotating rotor. The cells transfer the grain from the loading pipe to the unloading pipe of the feeder and when the cell coincides with the unloading pipe, the grain is pushed out of the cell into the working chamber by a jet of steam supplied through the cell channel, coinciding with the supply channel on the feeder housing.

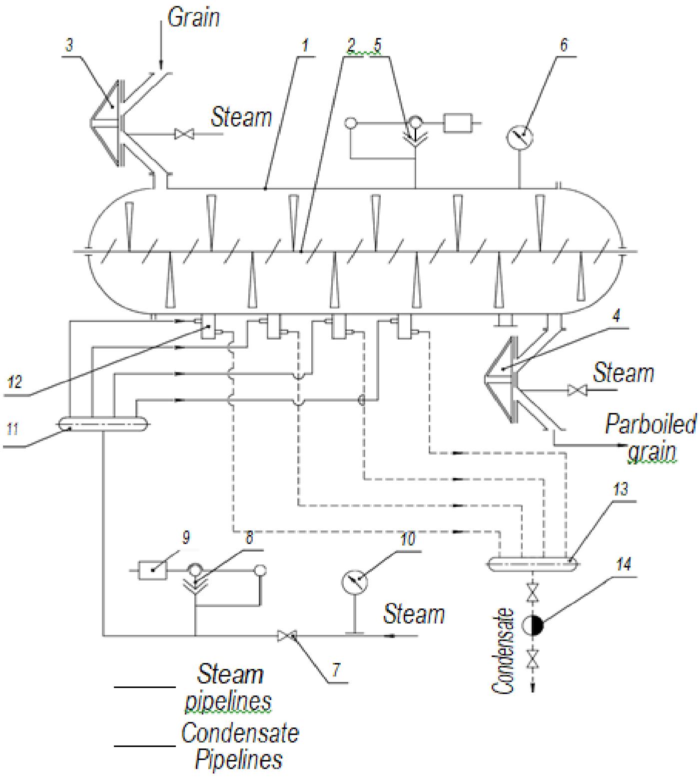

Fig. 1. Functional diagram of the steamer

After emptying the cell from the grain and disconnecting it from the working chamber, the cell through the hole in the sluice body connects to the atmosphere, as a result of which the pressure in it becomes equal to atmospheric and the cell is prepared for the next grain loading.

The grain entering the vessel moves from the loading hole in the vessel to the unloading blade auger 2, along the way subjected to heat treatment with steam, with vigorous stirring of the auger blades and a jet of steam that penetrate the product layer.

At the end of the vessel, the steamed product enters through the discharge pipe into the unloader 4. The operation of the unloader is similar to the operation of the feeder 3.

Condensate through the nozzles 12 and the collector 13 is removed from the apparatus by the condensate drain 14.

2. Technological calculation.

The task of calculation: to determine the geometric dimensions of the steamer housing (Fig. 2), sluice gates (Fig. 3) and the speed of rotation of the blade auger.

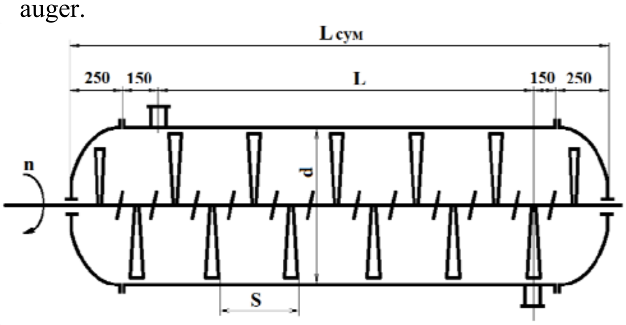

Fig. 2. Steamer's auger body and blade

Data for calculation:

productivity Q= 5 *t/h* =5000 *kg/h*;

body diameter d=*1000mm* ;

maximum and minimum steamer exposure:

t_{max}=*6 min*; t_{min}=*1 min*;

the unloading sluice gate should have productivity on 20% more than loading.

Calculation conditions: volumetric mass of oats γ=500 *kg / m3.*

It is necessary to calculate the geometric dimensions of the body of the steamer and the speed of the blade auger:

The calculation of the volume of the device is on the lightest grain (oats) with a bulk density:

γ = 500 *kg/m3* and by calculating the steaming exposure t = 5 min.

$$V = \frac{Q}{\gamma} \cdot t = \frac{5000}{500} \cdot \frac{5}{60} = 0{,}835 \ m^3, \quad (1)$$

Taking the filling factor of the vane auger ψ = 0.4 we find the total volume of the housing

$$V_1 = \frac{V}{\psi} = \frac{0{,}835}{0{,}4} = 2{,}1 \ m^3, \quad (2)$$

When the diameter of the body d = 1000mm determine the cross-sectional area of the body

$$F = 0{,}785 \cdot d^2 = 0{,}785 \cdot 1^2 = 0{,}785 \ m^2, \quad (3)$$

The length of the steamer housing from the loading to the unloading pipe

$$L = \frac{V_1}{F} = \frac{2{,}1}{0{,}785} = 2{,}680 \ m = 2680 \ mm, \quad (4)$$

The size of the case taking into account elliptical bottoms (250 mm) and distance from the center of branch pipes to edge of a shell (150 mm), will make:

$$L_{сум} = 2680 + 2 \cdot 250 + 2 \cdot 150 = 3480 \ mm. \quad (5)$$

Determining the parameters of the blade auger

The maximum allowable number of revolutions of the auger

$$n_{max} = \frac{A}{\sqrt{D}} = \frac{65}{\sqrt{1}} = 65 \ r/min \quad (6)$$

where *A=65* – coefficient for grain; *D=1m* – screw diameter.

The maximum number of revolutions should be at the minimum exposure.

Based on the minimum exposure t_{min}=1 min (60 s), with the length of the steaming section from the loading to the unloading pipe L = 2680 mm, the speed of movement of the material should be

$$v = \frac{L}{t_{min}} = \frac{2{,}68}{60} = 0{,}045 \ m/s. \quad (7)$$

The auger must have the maximum speed.

We accept n_{max}=*60 r/min* або *1 r/s.*

From here we determine the pitch of the auger. In one turn, the auger must move the material by 1 step, ie S'=*0,045 m*.

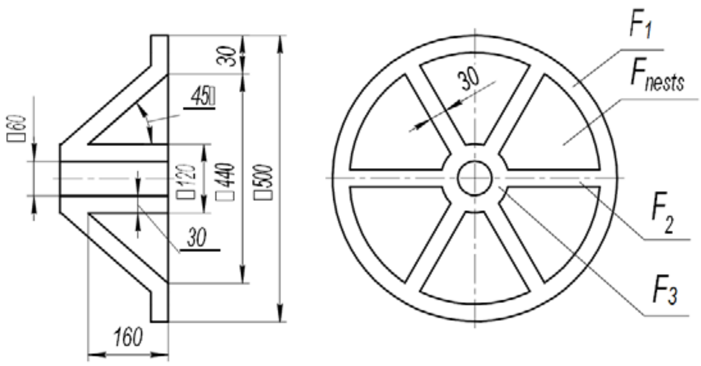

Fig. 3. Sluice gate

For advancement and hashing of the steaming product we accept the blade screw recommended for movement and hashing of sticky products.

Preliminarily, we take the ratio of the area of the vane auger and the area of the solid auger φ = 0.25. Then to maintain the productivity of the auger increase in accordance with the reduction of the area of his step

$$S = \frac{s'}{\varphi} = \frac{0,045}{0,25} = 180\ mm. \qquad (8)$$

Increase the step to *S = 280 mm* and get *φ=0,045/0,28=0,161.*

The minimum number of turns of the auger is determined from the ratio of exposures

$$n_{min} = \frac{n_{max}}{\tau_{max}/\tau_{min}} = \frac{60}{6/1} = 10\ {}^{r}/_{min} \qquad (9)$$

Calculation of the geometric dimensions of the rotors of the sluice gates and their speed:

To supply grain to the working chamber under pressure and unload it, we use sluice gates (Fig. 3) with a flat sealing surface and a fluoroplastic gasket. This design allows the most effective sealing of the working chamber under pressure and to maintain the working pressure within the specified limits, with continuous loading and unloading of the device.

Concerned in advance with the diameter of the rotor of the sluice gate 500 mm, the angle of the cone 450, the number of cells n = 6 and the minimum width of the sealing surfaces of 30 mm determine the capacity of the rotor.

The rotor capacity is calculated as the volume of the truncated cone minus the volume of the hub and partitions h

$$V_{tr.c.} = \frac{1}{12}\cdot\pi\cdot h\cdot(D^2 + D\cdot d + d^2), \qquad (10)$$

$$V_{tr.c.} = \frac{1}{12}\cdot 3,14\cdot 16\cdot(44^2 + 44\cdot 12 + 12^2) = 10900\ cm^3 = 10,9\ l.$$

$$V_{cyl.} = \frac{\pi\cdot d^2\cdot h}{4} = \frac{3,14\cdot 12^2\cdot 16}{4} = 1800\ cm^3 = 1,8\ l., \qquad (11)$$

$$V_{partitions} = \frac{1}{2}\cdot\left(\frac{D-d}{2}\right)\cdot h\cdot b\cdot n = \frac{1}{2}\cdot\left(\frac{44-12}{2}\right)\cdot 16\cdot 3\cdot 6 = 2,3\ l. \qquad (12)$$

Total cell capacity:

$$\sum V = V_{tr.c.} - (V_{cyl.} + V_{partitions}) = 10,9 - (1,8 + 2,3) = 6,8\ l. \qquad (13)$$

Based on the productivity of the gateway *Q = 5000 kg / h* for grain with a bulk density *γ = 500 kg / m3 = 0.5 kg / liter,* determine the speed of the loading sluice gate taking into account the cell fill factor *φ=0,8*

$$n_{load.} = \frac{Q}{\varphi\cdot\sum V\cdot\gamma\cdot 60} = \frac{5000}{0,8\cdot 6,8\cdot 0,5\cdot 60} = 30,7\ {}^{r}/_{min}. \qquad (14)$$

Since the unloading sluice gate must have a capacity of 20% more than the loading then its speed will be

$$n_{unl.} = 30,7 + \frac{30,7\cdot 20}{100} = 36,84\ {}^{r}/_{min}.$$

Conclusion from the calculation:

The length of the body of the steamer from the loading to the unloading pipe L = 2680 mm; the size of the case taking into account elliptical bottoms and distance from the center of branch pipes to edge of a shell Lsum. = 3480 mm; case diameter d = 1000 mm; screw pitch S = 280 mm; the maximum speed of rotation of the blade auger n_{max}*=60 r/min*; the minimum speed of rotation of the blade auger n_{min}*=10 r/min*;

the rotor speed of the loading sluice gate $n_{loa.}$*=30,7 r/min*;

rotor speed of the unloading sluice gate $n_{uol.}$*=36,84 r/min.*

3. Description of the kinematic scheme of the machine.

The task of calculation: to determine the kinematic parameters of the drive of the machine.

Data for calculation:

- the maximum speed of rotation of the blade auger n_{max}*=60 r/min*;
- the minimum speed of rotation of the blade auger n_{min}*=10 r/min*;
- the rotor speed of the loading sluice gate $n_{loa.}$*=30,7 r/min*;
- rotor speed of the unloading sluice gate $n_{uol.}$*=36,84 r/min.*

Terms of calculation:

the rotational speed of the rotor of the electric motor of the blade auger drive $n_{дв.ш}$=1460 *r/min*; the rotational speed of the rotor of the motor of the feeder drive $n_{дв.п}$=960 *r/min*; speed of rotor of the electric motor of the drive of the unloader $n_{дв.р}$=960 *r/min*;

In the drive of the vane screw we use a variator of the VC type with an initial speed $n_{в.\ min}$*= 300 r/min;* $n_{в.\ max}$ *=1800 r/min.*

4. Kinematic calculation.

To obtain the required speed on the auger shaft, we use a reducer of the RCD type with a gear ratio of ip = 31.5.

Determine the gear ratio of the chain drive

$$i_c = \frac{n_{в.min}}{n_{min}\cdot i_p} = \frac{300}{10\cdot 31,5} = 0,952, \qquad (15)$$

$$i_c = \frac{n_{в.max}}{n_{max}\cdot i_p} = \frac{1800}{60\cdot 31,5} = 0,952. \qquad (16)$$

We accept a chain with a step t = 38,1 mm and the number of teeth of the leading star Z1 = 25, then the number of teeth of the driven star will be

$$Z_2 = Z_1\cdot i_c = 25\cdot 0,952 = 23. \qquad (17)$$

Specify the speed of the auger shaft

$$n_{min} = \frac{n_{в.min}}{i_c\cdot i_p} = \frac{300}{0,952\cdot 31,5} = 10\ r/min, \qquad (18)$$

$$n_{max} = \frac{n_{в.max}}{i_c\cdot i_p} = \frac{1800}{0,952\cdot 31,5} = 60\ r/min. \qquad (19)$$

The feeder is driven by an electric motor with a rotational speed $n_{en.n}$=960 *r/min*. To obtain the required speed on the feeder shaft, we use a reducer of the RCD type with a gear ratio of ip = 31.5.

Specify the speed of the feeder

$$n_{loa.} = \frac{n_{en.n}}{i_p} = \frac{960}{31,5} = 30,4\ r/min.$$

The feeder is driven by an electric motor with a rotational speed

$n_{дв.р}$=960 *r/min*. Since the unloader must have a capacity of 20% more than the feeder, we use a reducer type RCD with a gear ratio of ip = 25.

Specify the speed of the unloader

$$n_{unl.} = \frac{n_{en.n.}}{i_p} = \frac{960}{25} = 38,4\ r/min.$$

Conclusion from the calculation:

The blade auger is driven by an electric motor with a rotational speed $n_{en.n}$ =1460 *r/min*, through a variator of the VC type with an initial speed $n_{v.\ min}$= *300 r/min;* $n_{v.\ max}$ =*1800 r/min* with the control range 6, through a reducer of the RCD type with a gear ratio ip = 31.5 and a chain drive with a gear ratio ic = 0.952 (the number of teeth of the chain drive Z1 = 25; Z2 = 23).

The feeder is driven by an electric motor with a rotational speed $n_{en\ n}$=960 *r/min*, through a reducer of the RCD type with a gear ratio i_p=*31,5*.

The unloader is driven by an electric motor with a rotational speed $n_{en\ n}$=960 *r/min*, through a reducer of RCD type with a gear ratio of ip = 25.

Maximum blade speed n_{max}=*60 r/min*;

Minimum blade speed n_{min}=*10 r/min*;

Frequency of rotation of a rotor of a loading sluice gate $n_{loa.}$=*30,4 r/min*;

Frequency of rotation of the rotor of the unloading sluice gate n_{unl} =*38,4 r/min.*

Thus, the calculations show the feasibility and efficiency of modernization of the steamer by ensuring the tightness of the unloader and the uniformity of the speed of the product processed in the working chamber by using a two-stage gearbox or drive motor with frequency converter.

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МОДЕРНІЗАЦІЯ МАШИНИ ДЛЯ ГІДРОТЕРМІЧНОЇ ОБРОБКИ ЗЕРНА

Анотація

Мета гідротермічної обробки зерна - зміна його вихідних технологічних властивостей у напрямку стабілізації та підтримці їх на оптимальному рівні для подальшого процесу переробки його в кінцеву продукцію - борошно чи крупу. Застосування апаратів безперервної дії дозволяє процес пропарювання стати більш ефективним, при цьому, гідротермічна обробка займає особливе місце в технології переробки круп'яних культур, отримання йми високих споживчих властивостей. Аналіз конструкцій апаратів безперервної дії, показує, що найбільшого поширення мають апарати горизонтального типу де основний робочий орган пропарювача має функції транспортування і перемішування. Така конструкція дозволяє досягти рівномірності пропарювання за час обробки продукту. Для досягнення гнучкої зміни експозиції пропарювання пропонується в складі приводу робочого органу ввести двоступінчастий варіатор, який дозволить суттєво змінювати час пропарювання і застосовувати апарат для пропарювання більш різних культур, а для забезпечення постійного заданого тиску пари в апараті пропонується для завантаження і вивантаження апарату застосовувати шлюзові затвори, конструкція яких дозволяє виробляти ці операції без втрат тиску. При двоступінчастому виконанні варіатора обертання від його ведучого валу за допомогою клинового ременя передається проміжному валу, а від нього за допомогою додаткового клинового ременя – основному робочому валу. Регулювання передавального відношення здійснюється при повороті склянок і їх синхронному зсуві в осьовому напрямку. При цьому відбувається одночасне переміщення рухомих конічних дисків, переклад клинового ременя і додаткового клинового ременя на інші діаметри.Для подачі зерна у робочу камеру під тиском і розвантаження його застосовуємо шлюзові затвори з плоскою ущільнюючою поверхнею і прокладкою із фторопласта. Така конструкція дозволяє найбільш ефективно герметизувати робочу камеру під тиском і забезпечити підтримку робочого тиску в заданих межах, при безперервному завантаженні та розвантаженні апарату. Проведені розрахунки показують доцільність і ефективність модернізації пропарювача за рахунок забезпечення герметичності роботи розвантажувача і рівномірності швидкості руху продукту, що обробляється в робочій камері, шляхом застосування двоступінчастого редуктора або приводного електродвигуна з частотним перетворювачем.

Ключови слова: гідротермічна обробка, зерно, крупа, пропарювання, розрахунок, розвантажувач

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