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# Exergy analysis of the production line preparing triticale grain for grinding

*Alexey* Drannikov[1], *Aleksander* Shevtcov[2], *Iana* Dombrovskaia[1], *Appa* Derkanosova[1,*], *Larisa* Frolova[1] and *Galina* Egorova[1]

[1] Voronezh State University of Engineering Technologies, 19, Revoljucii Avenue, Voronezh, 394036, Russian Federation
[2] Military Training and Scientific Centre of the Air Force Air Force Academy named after Professor N.E. Zhukovsky and Yu. Zhukovsky and Yu.A. Gagarin, Starykh Bolshevikov Street, 54a, Voronezh, 394064, Russian Federation

**Abstract.** In order to determine possible directions for improving the energy efficiency of technological schemes, it is necessary to assess the level of energy resources utilisation. For this purpose, the exergetic method of thermodynamic analysis is applied to assess the thermodynamic perfection of thermotechnological systems. The paper considers the influence of internal and external exergetic losses on the technological system of grain preparation for milling.

## 1 Introduction

During preparation of triticale grain for milling, the fundamental moments are improvement of basic qualitative indicators of grain during removal of moisture and its safety during storage in silos due to application of active ventilation. This involves increasing the efficiency of utilisation of exhaust heat-carriers in recirculation circuits, reduction of quantity of used external air and specific energy costs, using secondary material resources, achievement of high ecological efficiency of production.

The purpose of our work was to study the influence of internal and external exergy losses on the technological system of triticale grain preparation for milling. The aim was to perform the necessary calculations that allow us to carry out a comparative analysis of the obtained exergy efficiency of the proposed, the most promising to date, technology with the traditional one.

The task of exergetic analysis of thermodynamic perfection of the system of grain preparation for milling, as a whole, was to determine the stages of realised processes in technology, where the most significant exergetic losses take place. They allow improving the efficiency of the system functioning.

To increase the energy efficiency of the technology of grain preparation for milling, a heat pump technology has been developed, which allows significantly reducing specific energy consumption for the production of bakery products with a given productivity of flour-milling production (Figure 1).

The technological scheme of the heat-bearing technology of grain preparation for milling contains a grain dryer 1, a heating chamber 2, a cooler 3, a silo 4, a cyclone 5, elevators 6, 9, a complex of equipment for primary separation of impurities 7, rinsing machines 8, 23. It also includes a wet peeling machine 10, a screw press 11, a shell shredder 12, a shell dryer 13, a water collector 14, filters 15, intensive humidification machines 16, 19, 24, screw conveyors 17, 20, 25, first dehulling hoppers 18, second dehulling hoppers 21, final dehulling hoppers 26, a final impurity separation equipment set 22. There is a compressor 27, a condenser 28, evaporator with sections 29 and 30, thermostatic control valve 31; lines: wet grain 0.2, dried grain 0.2.1, dried grain 0.2.2, cleaned grain 0.2.3, hulls 0.7. The scheme involves wet hulls 0.7.1, crushed hulls 0.7.2, a grain after wet peeling machine 0.2.4, particles 0.2.5, technical water 1.2, sludge 9.4, circulating air 3.3, hot air 3.4, a refrigerant 6.0.

The wet grain is successively fed firstly into the heating chamber 2, where it is heated by the heat of the exhaust drying agent, then into the dryer 1, into which hot air is blown by the fan 33. Then dried grain is fed to the cooler 3, where it is blown with air by the fan 32. After that, with the help of the elevator 6, grain is fed for storage in silos 4.

The spent drying agent after the grain dryer 1 is directed to the cyclone 5 for cleaning suspended solids contained therein.

The cleaned drying agent is directed for drying and cooling in the evaporator sections 29 and 30 of the heat pump unit operating in the condensing mode. The dried and cooled drying agent in four streams is supplied respectively for active ventilation of grain in silos 4, in the cooler 3, in the shell dryer 13 with preheating in the condenser 28 of the heat pump unit and for drying grain

* Corresponding author: aa-derk@yandex.ru

in the grain dryer 1. The formed condensate from the collector 14 is pumped to the condenser 28 and further for defrosting the reserve section 30 of the evaporator of the heat pump unit operating in the regeneration mode. After defrosting, the condensate from the reserve evaporator section 30 is sent to the collection tank 14.

Grain after silos 4 is fed to the complex of equipment for primary separation of impurities 7 and further to the skinning machine 8 for cleaning the grain surface by means of husking. The husked grain is sent by the elevator 9 to the wet husking machine 10. Wet hulls are fed by the line 0.7.1 to the screw press 11, where they are mechanically squeezed. After the wet peeling machine, grain is fed to the intensive moistening machine 16 and further by the screw conveyor 17 to bunkers for the first dehulling 18. Grain is directed to the intensive moistening machine 19 and then by the screw conveyor 20 to the hoppers for the second dehulling 21.

The final separation of impurities is carried out in the complex of final separation of impurities 22, and cleaning the grain surface in the cleaning machine 23. After that, grain is sent to the intensive moistening machine 24 and further by the screw conveyor 25 to the bunkers for final dehulling 26.

After separation of impurities, grain is sent to the milling department, where grain is treated in the wet peeling machine 10 with water, which is supplied by the pump 38. And for moistening the grain in the intensive moistening machines 16, 19 and 24, the water is supplied from the collector 14 by the pump 39. Separated shells after peeling machines 8, 23 and the screw press 11 are fed to the chopper 12 and further to the shell dryer 13.

The generated contaminated water after the screw press 11 under pressure is alternately fed for filtration into two filters 15 installed in parallel, each of which periodically operates in the mode of separation with sludge removal and in the mode of countercurrent water regeneration of the filter element. The filtered water is discharged into the collection tank 14 and is partially used for regeneration of the filter element to form a recirculation circuit.

Therefore, the steam-compression heat pump provided preparation of heat carriers of different temperature potentials for continuous organisation of a technological cycle at all stages of grain preparation for milling.

## 2 Methods

Calculation of exergy losses of the proposed scheme was performed according to the method [1], according to which the technological line operating in accordance with the classical variant of the construction of technological stages of production and technological equipment (vapour-compression heat pump, equipment for hydrothermal treatment), which is auxiliary, were considered as a thermal technological system (Fig. 1). As a result, this system and the surrounding space were conditionally separated by a closed surface, in which control surfaces were defined due to the existing heat exchange processes:

I – heat treatment of grain;
II – grain pre-treatment;
III – hydrothermal treatment of grain;
IV – vapour compression refrigeration machine;
V – water regeneration.

In view of that, all performed calculations were based on the well-known Shargut model [2].

In each control surface of the studied technological system, consisting of classical irreversible processes, due to dissipation of energy, exergy decreases with time:

$$\sum E_з = \sum E_э + \sum D, \quad (1)$$

where $\sum E_З$ – total exergy of material and energy flows entering the control surface, kJ; $\sum E_Э$ – total exergy of useful material and energy flows leaving the control surface, kJ; $\sum D = T_0 \cdot \Delta S$ – total exergy losses (Huy-Stodola equation), kJ.

The equation (1) for the analysed technology [9] was considered in the form of:

$$E_П^I + \sum E_Э = E_{П1}^{II} + E_{П2}^{II} + E_П^{III} + E_П^{IV} + \sum D_i + \sum D_e, \quad (2)$$

where $E_П^I$ – exergy of initial grain, kJ; $\sum E_Э$ – exergy of the total amount of electric power for drives of technological equipment, kJ; $E_П^{III}$ – exergy of finished grain, kJ; $E_{П1}^{II}, E_{П2}^{II}\ E_П^{IV}$ – exergy of by-products formed in control surfaces II and V, kJ; $\sum D_i$ – total exergy losses due to irreversibility of processes inside the control surface, kJ; $\sum D_e$ – total exergy losses into the external environment, kJ.

Since the exergy of the initial wet grain, which is in thermodynamic equilibrium with the environment, is zero, it is excluded from the calculated balance.

Since the incoming wet grain is in thermodynamic equilibrium with the medium, its exergy is equal to zero and is not taken into account in the calculations. The chemical exergy of the grain also remains unchanged during processing. The temperature of the main and auxiliary streams undergoes significant changes.

Mechanical interactions are also taken into account due to the presence of a significant number of processes occurring with large pressure transformations of non-mainstream flows.

Therefore, both the thermal and mechanical components of the calculated exergy are taken into account.

The expansion from the current pressure to ambient pressure [11] is the mechanical exergy (exergetic power) of gaseous flows:

$$e_p = \frac{R}{M} T_0 \cdot \ln\left(\frac{P}{P_o}\right), \quad (3)$$

where $R$ – universal gas constant, kJ/(mol·K); $M$ – molar mass of gas, kg/mol; T – ambient temperature, K; $P$, $P_0$ – gas pressure in the considered flow and in the state of equilibrium with the environment, kPa.

The equation (1) can be written in the form (2) in the presence of flows in the system, which are also in a vacuum state, and not only under overpressure:

$$e_p = \frac{R}{M} T_0 \cdot \ln\left(\frac{P_1}{P_2}\right), \qquad (3)$$

where $P_1$ and $P_2$ are the gas flow pressure, kPa, with index 1 referring to the higher absolute pressure value and index 2 related to the lower one.

Hence, we can calculate a generalised measure of the mechanical superiority, both positive and negative, of a flow over its surroundings by applying the equation (3).

The mechanical component of pressurised water in the pipelines was calculated by considering its flow rate and recalculating the overpressure created by the pump.

The ambient temperature was 293.13 K. The fluxes having the temperature that is higher than that of the ambient are referred to the thermal component of exergy. Using the Huy-Stodoll equation, we can calculate the specific thermal exergy:

$$e_t = e - e_0 = h - h_0 - T_0(S - S_0), \qquad (4)$$

where $e$, $e_0$, $h$, $h_0$, $S$, $S_0$ – specific thermal exergy, kJ/kg, specific enthalpy, kJ/kg and entropy, kJ/(kg·K) of the product with the current process parameters and in the state of equilibrium with the environment, respectively.

The different flows, which are components of exergy, were not identical. Air flows in the process of drying and cooling the initial triticale grain were characterised by mechanical exergy, while thermal exergy during preparation of grain for milling is available for almost all flows of the thermodynamic system under consideration.

Both reference data of thermophysical properties of air, water and triticale grain and those obtained in experimental studies [18, 30, 125, 145] were used in the calculations.

In the work, the influence of internal $D^i$ and external $D^e$ exergetic losses on the technological system of preparation of triticale grain for milling and evaluation of thermodynamic perfection of the heat technological system of preparation of wheat grain for milling by exergetic efficiency is studied.

Internal exergy losses in total include losses from temperature differences resulting from convective heat exchange between air, dried and cooled triticale grain, as well as from recuperative heat exchange in the evaporator and condenser of a vapour-compression refrigeration machine, occurring between air and refrigerant. In addition, internal losses include electromechanical and hydraulic losses.

Internal losses occur due to temperature differences between streams:

$$D^{mo} = Q^{mo} \cdot \overline{\tau}e \qquad (5)$$

where $Q^{mo}$ is the mass fraction of heat transfer from a flow to a flow, kJ; $\overline{\tau}_e$ is the average value of the Carnot factor (or exergetic temperature function) for two interacting flows.

The Carnot factor is equal to the thermal efficiency of the Carnot cycle between the temperatures of the reference surface and the conventionally assumed ambient:

$$\tau_e = \left(T_{кп} - T_0\right) / T_{кп}, \qquad (6)$$

where $T_{кп}$ is the temperature of the coolant inside the control surface, K.

Due to a pressure drop of the superheated steam during its supply to the control surface, exergetic losses were determined by the equation:

$$D^e = g \cdot \Delta H_г \cdot \frac{T_{кп}}{T_{вх}}. \qquad (7)$$

where $T_{вх}$ – air temperature at the inlet to the control surface, K; $\Delta H_г$ – hydraulic losses, m.

## 3 Results

According to the Darcy-Weisbach formula [120], the hydraulic losses at the coolant inlet to the control surface are found as follows:

$$\Delta H_г = \xi \cdot \frac{v_{вх}^2}{2g}, \qquad (8)$$

where $v_{вх}$ is the average velocity of air passing through the cross-section of the supply pipeline, m/s; $\xi$ is the resistance coefficient determined by the ratio of the internal volume of the equipment, considered as a control surface, to the cross-section of the inlet opening.

Electromechanical exergy losses [11] occur in each equipment for the mechanical processing of triticale grain and by-products of the technology (shells, feed waste) and correspond to the power of the corresponding drives.

External losses $D^e$ are related to the conditions of the interface between the system and the environment. They are caused by temperature differences between the heat carriers and the environment, imperfections in the thermal insulation of the equipment.

The exergy losses into the environment due to imperfect thermal insulation were found according to the formula:

$$D^e = Q_{из} \cdot \tau_e, \qquad (9)$$

where $Q_{из}$ – total heat losses to the environment through the control surface, kJ; $\tau_e$ – Carnot factor.

Exergetic losses of the finished grain at the outlet of the mill preparatory compartment, when it reaches thermodynamic equilibrium with the environment, were calculated according to the formula:

$$D_{np} = h_{np} - h_{np}^0 - T_0 \cdot \overline{c} \cdot \ln\frac{T_{np}}{T_{np}^0} \qquad (10)$$

where $h_{np}$, $T_{np}$ – enthalpy (kJ/kg) and temperature (K) of the finished product, $\overline{c}$ – average specific heat capacity of grain between its current state at the moment of unloading and in the state of thermodynamic equilibrium with the environment, kJ/(kg·K).

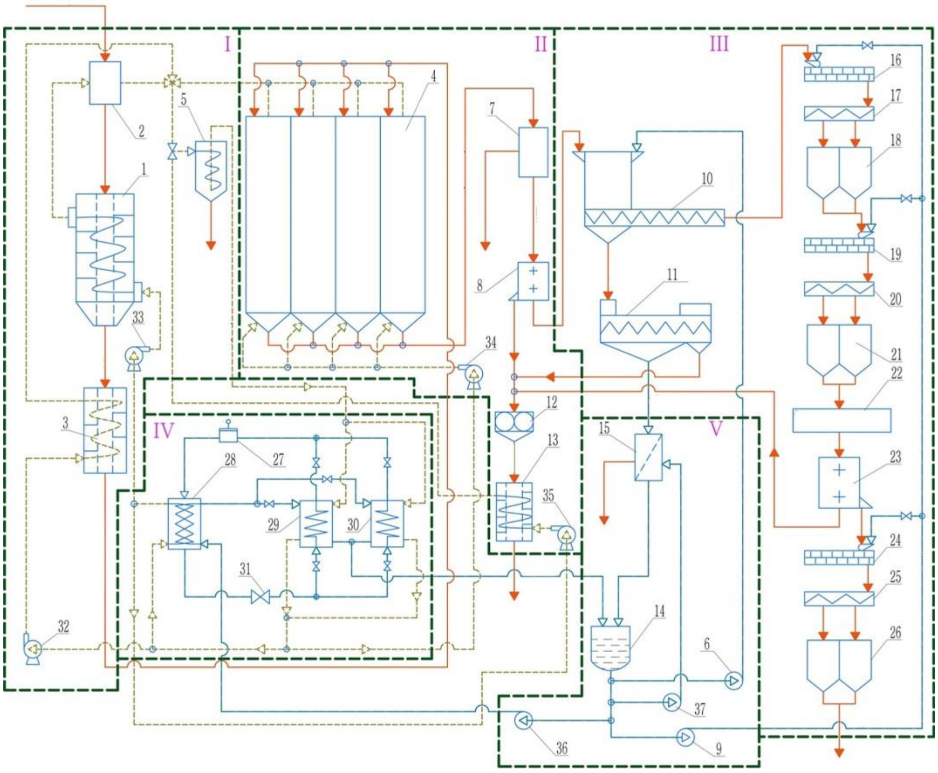

**Fig. 1.** Schematic diagram of the technological line of preparation of triticale grain for milling: 1 – grain dryer; 2 – heating chamber; 3 – cooler; 4 – silos; 5 – cyclone; 6, 9, 36, 37 – pumps; 7 – set of equipment for primary separation of impurities; 8, 23 – shelling machines; 10 – wet peeling machine; 11 – screw press; 12 – shell shredder; 13 – shell dryer; 14 – water collector; 15 – filters; 16, 19, 24 – intensive humidification machine; 17, 20, 25 – screw conveyors; 18, 21 – dehulling hoppers; 22 – set of equipment for final separation of impurities; 27 – compressor; 28 – condenser; 29, 30 – evaporator sections; 31 – TRV; 32-35 – fans; I – thermal treatment of grain; II – preliminary preparation of grain; III – hydrothermal treatment of grain; IV – vapour compression refrigeration machine; V – water recovery

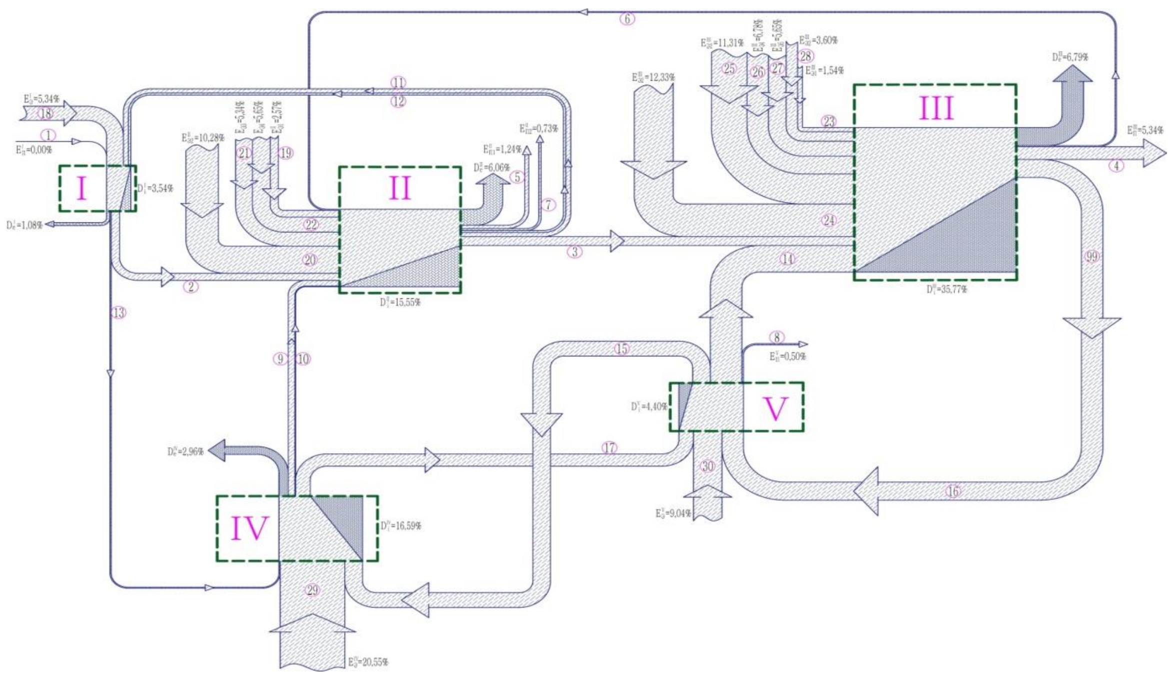

**Fig. 2.** Grassmann-Shargut diagram for the investigated technology. I–V – numbers of control surfaces

**Table 1.** Exergy balance of the technological line of wheat grain preparation for milling

| No. | Name of control surface | Absolute exergy capacity E, mJ/h | Relative exergy capacity, % |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| **I** | **Heat treatment of grain** | | |
| | Arrival | | |
| 1 | Wet grain | 0.00 | 0.00 |
| 2 | Electricity for fan drives (I) | 18.72 | 5.34 |
| | **Total exergy supplied to the control surface** | 18.72 | 5.34 |
| | Consumption | | |
| 2 | Internal exergy losses | 12.39 | 3.54 |
| 3 | External exergy losses | 3.77 | 1.08 |
| | **Total exergy dissipated from the reference surface** | 16.16 | 4.61 |
| **II** | **Preliminary grain preparation** | | |
| | Arrival | | |
| 1 | Electricity to drive the scalperator, separator, stone collector | 9.00 | 2.57 |
| 2 | Electricity for the drive of the shell shredder | 36.00 | 10.28 |
| 3 | Electricity for fan drives (II) | 18.72 | 5.34 |
| 4 | Electricity to drive the dehydrator (II) | 19.80 | 5.65 |
| | **Total exergy supplied to the control surface** | 83.52 | 23.84 |
| | Consumption | | |
| 1 | Feed waste | 4.33 | 1.24 |
| 2 | Ready-made shells | 2.55 | 0.73 |
| 3 | Internal exergy losses | 54.46 | 15.55 |
| 4 | External exergy losses | 21.24 | 6.06 |
| | **Total exergy dissipated from the reference surface** | 82.58 | 23.57 |
| **III** | **Hydrothermal treatment of grain** | | |
| | Arrival | | |
| 1 | Electricity for screw press drive | 5.40 | 1.54 |
| 2 | Electricity for humidifier drives | 43.20 | 12.33 |
| 3 | Electricity to drive the wet peeling machine | 39.60 | 11.31 |
| 4 | Electricity for auger drives | 23.76 | 6.78 |
| 5 | Electricity to drive the dehydrator (III) | 19.80 | 5.65 |
| 6 | Electricity for separator and triers drives | 12.60 | 3.60 |
| | **Total exergy supplied to the control surface** | 144.36 | 41.21 |
| | Consumption | | |
| 1 | Finished grain | 18.70 | 5.34 |
| 2 | Internal exergy losses | 125.30 | 35.77 |
| 3 | External exergy losses | 23.79 | 6.79 |
| | **Total exergy dissipated from the reference surface** | 167.79 | 47.89 |
| **IV** | **Vapor compression refrigeration machine** | | |
| | Arrival | | |
| 1 | Electricity for compressor drive | 72.00 | 20.55 |
| | **Total exergy supplied to the control surface** | 72.00 | 20.55 |
| | Consumption | | |
| 3 | Internal exergy losses | 58.11 | 16.59 |
| 4 | External exergy losses | 10.36 | 2.96 |
| | **Total exergy dissipated from the reference surface** | 68.47 | 19.54 |
| **V** | **Water regeneration** | | |
| | Arrival | | |
| 1 | Electricity for pump drives | 31.68 | 9.04 |
| | **Total exergy supplied to the control surface** | 31.68 | 9.04 |
| | Consumption | | |
| 1 | Precipitate | 1.7 | 0.5 |
| 2 | Internal exergy losses | 15.3 | 4.4 |
| | **Total exergy dissipated from the reference surface** | 15,3 | 4.4 |
| | **Common Arrival** | **350.3** | 100.0 |
| | **Common Consumption** | **350.3** | 100.0 |

**Table 2.** Flow designations on the Grassmann-Shargut diagram of the investigated scheme

| Position on the diagram | Name of flow | Reference surface | |
|---|---|---|---|
| | | giving | receiving |
| 1 | Initial product | – | I |
| 2 | Dry product | I | II |
| 3 | Purified product | II | III |
| 4 | Finished product | III | – |
| 5 | Feed waste | II | – |
| 6 | Primary shells | III | II |
| 7 | Ready-made shells | II | – |
| 8 | Precipitate | V | – |
| 9 | Hot drying agent | IV | II |
| 10 | Drying agent dried and cooled | IV | II |
| 11 | Circulating drying agent | II | I |
| 12 | Drying agent spent (II) | II | I |
| 13 | Drying agent spent (I) | I | IV |
| 14 | Process water (III) | V | III |
| 15 | Process water (IV) | V | IV |
| 16 | Waste water | III | V |
| 17 | Condensate | IV | V |
| 18 | Electricity for fan drives (I) | – | I |
| 19 | Electricity to drive the scalperator, separator, stone collector | – | II |
| 20 | Electricity to drive the shell shredder | – | II |
| 21 | Electricity for fan drives (II) | – | II |
| 22 | Electricity to drive the dehydrator (II) | – | II |
| 23 | Electricity for screw press drive | – | III |
| 24 | Electricity for humidifier drives | – | III |
| 25 | Electricity to drive the wet peeling machine | – | III |
| 26 | Electricity for auger drives | – | III |
| 27 | Electricity to drive the dehydrator (III) | – | III |
| 28 | Electricity for separator and triers drives | – | III |
| 29 | Electricity for compressor drive | – | IV |
| 30 | Electricity for pump drives | – | V |

Evaluation of thermodynamic perfection of the thermotechnological system of triticale grain preparation for milling was carried out by exergy efficiency, based on the value of exergy of the finished product:

$$\eta_{экс} = \frac{\sum_{k=1}^{l} e_i^{э}}{\sum_{i=1}^{n} e_i^{з}} = \frac{\sum_{i=1}^{n} e_i^{з} - \sum_{j=1}^{m} D_j}{\sum_{i=1}^{n} e_i^{з}}, \quad (11)$$

where $\sum_{k=1}^{l} e_i^{э}$ – total specific exergy of finished grain and by-products, kJ/kg; $\sum_{i=1}^{n} e_i^{з}$ – total expended specific exergy (brought into the system from outside), kJ/kg; $\sum_{j=1}^{m} D_j$ – total exergy losses, kJ/kg.

The exergy of the considered flows and exergetic losses allowed us to obtain the calculated balance of the proposed system of the studied processes (Table 1). To obtain the necessary diagrams, the exergetic power *E*, kJ/h, which is an absolute parameter of exergy, was selected according to the Grassmann-Shargut method (Fig. 2). This value is quite easy to apply when considering thermodynamic systems, whose explicit priority is the production of the required quantity of high-quality finished products, rather than energy production. The parameter *E* takes into account not only the mass flow rate of the product, but also how different the values of the flow and environmental parameters are. Table 2 shows the correspondence of flows onto control surfaces.

An exergetic method of thermodynamic analysis proposed by V.M. Brodiansky is based on the application of the concept of exergy to the study of technical processes. The study also used the methods for drawing up exergy balances and methods for calculating the efficiency of processes.

## 4 Conclusions

The calculated exergetic efficiency was 7.79 %, exceeding the efficiency of the heat engineering system of the known method by 2.32 % [10]. All this allows us to recommend the use of coolants in a closed mode, excluding pollution of the surrounding space due to the use of a refrigerating machine operating in the heat pump mode.

A sufficiently significant increase in the thermodynamic efficiency of the developed technological line in comparison with that of the prototype, as well as considering the production of the finished product of the required quality, indicates a high degree of its energy saving.

## References

1. V.M. Brodyansky, V. Fratscher, K. Michalek, *Exergetic analysis and its applications* (Energoatomizdat, Moscow, 1988), 288 p.
2. B.S. Sazhin, A.P. Bulekov, *Exergetic method in chemical technology* (Chemistry, Moscow, 1992), 208 p.
3. V.N. Gulyaev, N.V. Dremina, Z.A. Katz et al., *Reference book of the technologist of food-concentrate and vegetable-saucing production* (Light and food industry, Moscow, 1984), 488 p.
4. S.V. Bogoslovsky, *Physical properties of gases and liquids* (SPbSUAP, St. Petersburg, 2001), 73 p.
5. I.A. Chubik, A.M. Maslov, *Reference book on thermophysical properties of food products and*

*semi-finished products* (Food Industry, Moscow, 1970), 184 p.

6. T.N. Tertychnaya, I.V. Kuznetsova, A.A. Shevtsov, S.S. Kulikov, Investigation of moisture bonding forms in the grain of triticale variety Gorka by thermal analysis, Khleboprodukty **4**, 44–47 (2021)
7. T.N. Tertychnaya, I.V. Kuznetsova, A.V. Drannikov, A.A. Shevtsov, N.V. Zasypkin, Increase of morphogenetic activity of wheat callus using lipopolysaccharides of rhizobacteria, Actual Biotechnol. **1**, 124 (2021)
8. A.V. Drannikov, T.N. Tertychnaya, A.A. Shevtsov, N.V. Zasypkin, A.A. Ryndin, Study of thermophysical characteristics of a triticale grain variety "Gorka" by the method of non-stationary thermal regime, Bull. of Voronezh State Univ. of Eng. Technol. **2**, 17–22 (2021)
9. E.I. Yantovsky, *Flows of energy and exergy* (Science, Moscow, 1988), 144 p.
10. A.A. Shevtsov, A.N. Ostrikov, D.A. Britikov, E.V. Fursova, *Method of stabilisation of thermal-moisture characteristics of grain at its drying and storage*, RF patent no. 2303213, F26B 3/14, F26B 21/08, F26B 21/10, no. 2005133720/06; Applic. 02.11.2005; Publ. 20.07.2007, Bull. no. 20
11. Y.Z. Mateyev, D.B. Shalginbayev, S.Z. Mateyeva, M.V. Kopylov, A.N. Ostrikov, V.N. Vasilenko, Mathematical modelling of the extracting process of vegetable oil on auger equipment, EurAs. J. of BioSci. **13(2)**, 1875–1880 (2019)
12. A.A. Shevtsov, V.N. Vasilenko, A.V. Evdokimov, Control algorithm of the thermal applying drying plant for thermolabile materials, Autom. and Advan. Technol. **7**, 26–28 (2004)
13. A.N. Ostrikov, A.S. Rudometkin, V.N. Vasilenko, Automatic control and pressure adjustment in prematrix zone of extruders, Autom. and Advan. Technol. **8**, 14–18 (2002)
14. A.V. Drannikov, Ya.P. Dombrovskaya, E.V. Belokurova, D.S. Kitaev, A.A. Shevtsov, Application of water-honey extract of st. john's wort herb to improve biotechnological and rheological properties of wheat dough, IOP Conf. Ser.: Earth and Environ. Sci. International Conference on Production and Processing of Agricultural Raw Materials (P2ARM 2021) 012030 (2022)