EurAsian Journal of BioSciences
Eurasia J Biosci 13, 1057-1065 (2019)

Container-modular equipment for the storage of soybeans with active ventilation for farms of Kazakhstan

Aibek Atykhanov [1], Sholpan Duisenova [1], Dimitar Karaivanov [2*]

[1] Department of Agricultural Machinery and Technology, Faculty of Engineering, Kazakh National Agrarian University, 8 Abay Ave., 050010 Almaty, KAZKHSTAN
[2] Department of Applied Mechanics, Faculty of Metallurgy and Material Sciences, University of Chemical Technology and Metallurgy,8 Kliment Ohridski Blvd., 1756 Sofia, BULGARIA
*Corresponding author: Dimitar Karaivanov

Abstract

Due to the increased world demand for soybean products, Kazakhstan farms sharply increased soybean production. At the same time, there were problems with the safety of products, the lack of special equipment for its storage due to the rather difficult weather conditions. When collected in such weather, it is impossible to wear even during the night, as this can lead to self-heating and, as a result, to a decrease in quality and losses. In addition, the newly harvested grain must ripen for 3-4 weeks. This process is characterized by the release of water and the absorption of heat. At this time, the grain must be well ventilated, otherwise it spoils from the accumulation of moisture. Finally, at high humidity and temperature, the grain may begin to germinate, which is associated with the consumption of carbohydrates, proteins, fats. Along with this, rodents and birds cause great damage. The object of the study is the process of storing soybeans in containers with active ventilation. It is proposed to use widely used containers of various capacities.
The aim of the study is to provide scientific substantiation of main parameters of the container-modular equipment for the storage of soybeans with active ventilation in conditions of farms.
To substantiate the 20, 30, 40 ton container-modular equipment for the storage of soybeans with active ventilation in farm conditions, the method of calculating the intake units is adopted. This is a classic method of selecting a pneumatic transporter with nominal parameters, as well as the least squares method using the MATLAB program, which is necessary for obtaining optimal equipment parameters.
As a result of the research, proposed container-modular soybean storage technology with active ventilation in farm conditions in counting per standard 40, 20, 10 t containers.

Keywords: pneumatic transporter, soybean storage, soybean ventilation

Atykhanov A, Duisenova S, Karaivanov D (2019) Container-modular equipment for the storage of soybeans with active ventilation for farms of Kazakhstan. Eurasia J Biosci 13: 1057-1065.

© 2019 Atykhanov et al.
This is an open-access article distributed under the terms of the Creative Commons Attribution License.

INTRODUCTION

Soybean is a unique plant, a miracle of wildlife. Soybean is now the leading culture of world agriculture, the pinnacle of perfection and universality in the whole plant world. Due to the rich and varied chemical composition, soybean does not know its peers in terms of production growth, it has long been widely used as a universal food, feed and oilseeds (Singh 2014). According to the Ministry of Agriculture of the Republic of Kazakhstan in 2016, about 220 thousand tons of soybeans were produced. Of which about 20 thousand tons amounted to exports. The main region of soybean production in Kazakhstan is the Almaty region, where the cultivation area is 150000 ha. In the future, the country plans to implement the investment cluster program “MoZhoCo-2020”, which envisages an increase in crops to 400,000 ha and produce up to 1 million tons of soybean per year. In 2016, Kazakhstan sold 10.8 thousand tons to Sweden, 1.4 thousand tons to Kyrgyzstan, 1.6 thousand tons to Tajikistan, and 6.1 thousand tons to Uzbekistan. A total of about 19.9 thousand tons out of 220 thousand produced. Because of this, soybean producers are forced to sell to Chinese buyers for a price two times lower than the world price. In addition, in Kazakhstan there is an opportunity to supply not only raw materials (soybeans), but processed soy products (meal, oil and other related products), so there are already three soybean processing plants: JSC Vita-Soya productivity - 150 thousand tons per year, LLP Soybean processing plant Extra - 24 thousand tons per year, LLP Company Sary Bulak - 24 thousand tons per year (Economy newspaper 2018). Unfortunately, they cannot reach the planned capacity due to the lack of a stable source of raw materials throughout the year,

Received: March 2019
Accepted: July 2019
Printed: August 2019

OPEN ACCESS

which implies its storage and preparation in appropriate conditions, as soybeans with a high content of protein and fat, as well as increased seed hygroscopic moisture, with unfavorable conditions (the presence of organic impurities, high humidity) deteriorates rapidly.

Rather difficult conditions for post-harvest processing of soybean seeds are created in adverse cold and rainy weather. It is impossible to leave soybeans harvested in such weather even during the night, as this can lead to self-heating and, as a result, to lower quality and losses. Therefore, the main task of his post-harvest handling is to clean and dry as quickly as possible. Freshly harvested grain ripens within 3-4 weeks. This process is characterized by the release of water and the absorption of heat. At this time, the grain must be well ventilated, otherwise it spoils from the accumulation of moisture. Finally, at high humidity and temperature, the grain may begin to germinate, which is associated with the consumption of carbohydrates, proteins, fats.

Humidity and temperature - these two factors are very interconnected. Thus, with an increase in humidity, respiration increases, and this, in turn, causes an increase in the temperature of the grain. Sometimes in spring, the upper layer of grain begins to warm up, and in the place of contact of the warmer layer with the cold, moisture is released on the grain, it “sweats up”. If such a layer of moistened, “sweat” grain is not dried, then it can cause damage to the entire embankment. With an increase in the humidity and temperature of the grain, the activity of microorganisms — bacteria and mold fungi — increases. Feeding on ready-made organic substances of grain, they also increase its temperature with their vital activity. Post-harvest processing of soybean crops takes place on typical grain-cleaning units and complexes, on production lines, equipped with a series of machines for cleaning and transportation, and on individual mobile seed-cleaning machines. According to the agro-technical requirements for post-harvest processing, the whole soybean crop is divided according to seed regime into the following fractions: unsuitable for use and fodder waste, food grains, seed material (Minister of Agriculture of the Republic of Kazakhstan 2015).

The grain dryer is a device for stable industrial blowing of grain. The main function of drying cereals and oilseeds, that is, reducing the humidity of the dried product to values at which the product (grain) can be safely stored for a long time, without fear of the occurrence of self-heating. With a properly selected drying mode, physiological ripening of the grain occurs and its quality improves (Yukish and Ilyina 2009).

In this regard, the foregoing suggests that active ventilation of the material is most suitable for the storage of soybeans. In this case, the material itself moves in the air flow. As a result, cooling or drying of the material is achieved without mixing it in order to prevent or eliminate self-heating during mass harvesting, leveling the temperature and humidity of the material during storage, eliminating clumping and the formation of local areas of rotting, etc.

To solve this problem, a technology is proposed that provides for the storage of grain (soybean) in modernized cargo containers of 20, 30, 40 tons, installed vertically. As well as the main device of the equipment is a pneumatic transporter with which the grain (soybean) is ventilated.

The aim of the study is to provide scientific substantiation of container-modular equipment for the storage of soybeans with active ventilation in conditions of farms.

RESEARCH METHODS

To substantiate the 20, 30, 40 ton container-modular equipment for the storage of soybeans with active ventilation in farm conditions, the method of calculating the intake units is adopted. This is a classic method of selecting a pneumatic transporter with nominal parameters, as well as the least squares method using the MATLAB program, which is necessary for obtaining optimal equipment parameters.

Step 1: Calculation of the Intake Unit

Baseline data for the calculation. Pneumatic transport unit for ventilation of soybean for three container equipment with average daily capacity for the first container equipment Q_{c1} = 40 t/day, for the second Q_c = 20 t/day, for the third Q_c = 10 t/day. Soybean density ρ_s = 3160 kg/m^3. The equivalent diameter of soybean d_{eq} = 6400 μm. Unloading is carried out from the vehicle. The transport tube has two rotations of 90°C each. Material loading height for equipment with container 40 t, H_1 = 18m, for 20t H_2 = 10m, for 10t H_3 = 10m. Horizontal pipeline length for 40t L_1 = 18 m, for 20t L_2 = 10 m, and for 10t L_3 = 10 m.

The technical performance of the unit is determined by formula

$$Q_T = \frac{Q_a \cdot k \cdot k_1}{3600 \cdot t}, \text{kg/s} \quad (1)$$

where

Q_a- average daily productivity (Vdovenko 1966);

k- coefficient of uneven material supply to the pneumatic line during the day, 1.5;

k_1- coefficient taking into account the prospects of performance, 1.25;

t- time of the unit work per day.

Reliably transporting air velocity calculated by the following method. First, determine the velocity of the soybean flurries for the vertical section.

$$\vartheta_w = R_e \frac{v}{d}; \text{ m2/s} \quad (2)$$

$$R_e = \frac{A_r \cdot (1-\beta)^{4.75}{}_1}{18+0.61\sqrt{A_r \cdot (1-\beta)^{4.75}}}; \quad (3)$$

$$\beta = \frac{1}{1+\frac{\rho_T}{\mu \cdot \rho_G}}; \quad (4)$$

$$A_r = \frac{d^2 \cdot g(\rho_T - \rho)}{\rho \cdot \upsilon^2}; \quad (5)$$

$$\upsilon = \frac{\mu^*}{\rho}; \mathrm{m/s} \quad (6)$$

Conventions and dimensions of the quantities included in the equations (Maron and Kuzmin 1977)

ϑ_w- velocity of gas flurries in the vertical section of the pipeline, m/s;

υ - kinematic viscosity of the gas at the temperature of transportation, m^2/s;

μ * - dynamic viscosity of the gas at the temperature of transportation, kg/m·s;

(μ * = 2·10-5 kg/m·s);

d - equivalent diameter of soybean, m; (d = 6400 μm = 64·10-4 m);

μ - concentration of the mixture for grain from 1-5, (let's assume for soybeans μ = 3.6 kg/kg);

Ar, Re - Archimedes and Reynolds criteria;

β - volume fraction of the solid phase;

ρ, ρ_G - gas density at the temperature of transportation, kg/m^3; (for air ρ = 1.2 kg/m^3);

g = 9.81 m/s^2, the acceleration due to gravity m/s^2;

ρ_T = 3160, kg/m^3 - density of the transported material;

Reliably transporting air velocity for pneumatic transport is:

$$\vartheta = 2\vartheta_w; \ \mathrm{m/s} \quad (7)$$

Determine the second air flowrate:

$$Q_{\text{В}} = \frac{Q_T}{3600 \cdot \rho \cdot \mu}; \mathrm{m^3/s} \quad (8)$$

Determine the diameter of pipeline:

$$d_{\text{T}} = \sqrt{\frac{4 \cdot Q_{\text{В}}}{3600\pi \cdot \vartheta}}; \mathrm{mm} \quad (9)$$

and round up to the nearest larger or smaller, according to the current GOST for pipes,

diameter 140mm for 40t, 110mm for 20t, 75mm for 10t.

By the formula, we calculate the final value of $Q_В$

$$Q_{\text{В}} = F\vartheta = \frac{\pi \cdot d_{\text{T}}^2}{4} \cdot \vartheta; \ \mathrm{m^3/s} \quad (10)$$

(F - cross-sectional area of the pipeline) according to the rounded diameter, and according to the formula, specify the mass concentration of the transported material;

$$\mu = \frac{Q_T}{\rho \cdot Q_{\text{В}} \cdot 3600}; \mathrm{kg/kg} \quad (11)$$

According to the final value of $Q_В$, we choose a cyclone unloader for equipment 40t, CR №25 (capacity 25 m^3/min. m_{40} = 0.086;

for equipment 20t, CR №15 (capacity 15 m_3/min. m20 = 0.240;

for equipment 10t, CR №7 (capacity 7 m_3/min. m10 = 0.945;

The resistance of the unloader is determined by the formula

$$P_{unl} = \overline{m} \cdot Q_{\text{В}}^2; \mathrm{kg/m^2} \quad (12)$$

Determine the resistance of dust collectors. For self-extinguishing fabric intake filters R_{wat}, take 60 mm of water column = 60 kg/m^2 (Mills 2004).

Find the value of the total pressure loss in the network:

$$\sum P_c = \left(\lambda \frac{\sum l_{driv}}{d_t} + \sum \xi_i\right) \frac{\rho \cdot \vartheta^2}{2g}(1 + k\mu) + \rho\mu \sum H + \Delta P_a + \sum \Delta P_{wat}; \mathrm{Pa} \quad (13)$$

where:

λ= 0.02 coefficient of friction of clean air against the wall;

$\sum ldriv$ - the sum for all sections of horizontal, vertical and equivalent outlets;

$\sum \zeta_i$ - the sum of local resistance coefficients;

k - taken according to the directory, 0.4;

$\sum H$ - the sum of the lengths of vertical sections-18, 10, 10 m;

ΔP_a - pressure loss at acceleration, calculated by the formula:

$$\Delta P_a = K_a \cdot \mu \frac{\rho\vartheta}{2g}; \mathrm{Pa} \quad (14)$$

$$\sum \Delta P_{wat} = P_{unl} + P_{wat}; \mathrm{Pa} \quad (15)$$

K_a = 2,0 - resistance coefficient of the accelerating part. Since the pipe has two rotations of 90° each with radii *R = 10*□*dT* = 3m, each rotation is equivalent to the resistance of 10m of the pipe horizontal section. Thus, we get the value

$$\sum l_{driv} = L + 2 \cdot 10m; \quad (16)$$

$$\sum \xi_i = \xi_1 + \xi_2, \quad (17)$$

where $\xi_1 = 1, \xi_2 = 2$;

ξ_1- coefficient of local resistance at the entrance to the pipeline;

ξ_2- coefficient of local resistance at the entrance to the separator;

From the reference book, taking into account the total pressure loss in the network and air flowrate, the fan is selected and its drive power is calculated using the formula:

$$N = \frac{k_1 \cdot Q_{\text{В}} \cdot k_2 \cdot \sum P_C}{102\eta}; \text{кВт} \quad (18)$$

where:

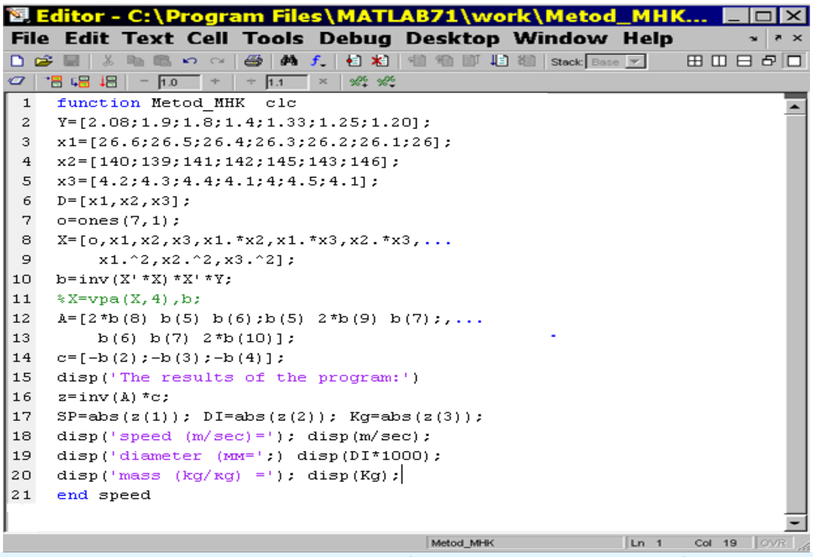
k_1 = 1.15 - coefficient taking into account the flow in the network;

k_2=1.1 - coefficient of unaccounted losses in the transport pipeline;

η– efficiency, accepted - 0.6 on the aerodynamic characteristics of the machine;

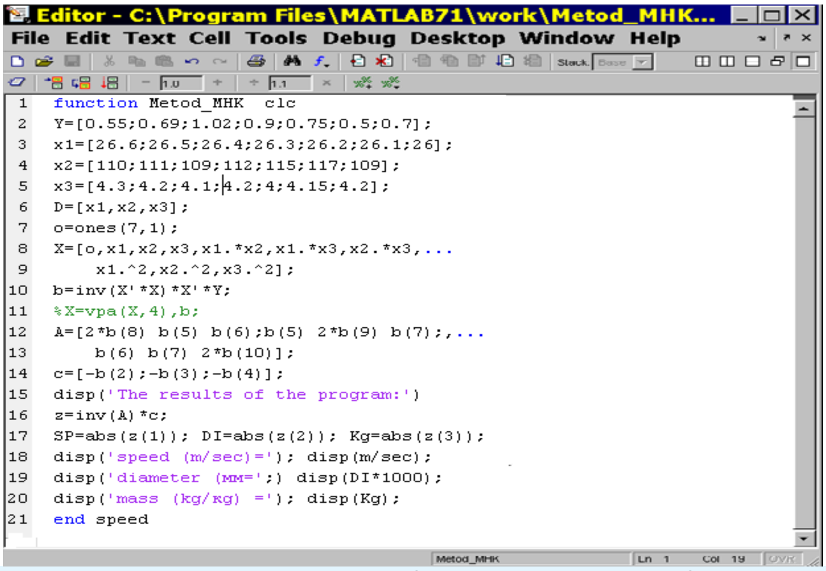
Step 2

To obtain the optimal equipment parameters for a given pneumatic transporter capacity, the calculated concentration of the air mixture, which conveys the air velocity in the pipeline and the diameter of pipeline using the formulas (7,9,11). The formulation of the problem will be considered as an application statistics problem using the least square method (LSM) for multidimensional systems. The program for solving the problem can be implemented on the basis of Bednárová (2009) using the mathematical system MATLAB. The program is shown in **Figs. 1-3**.



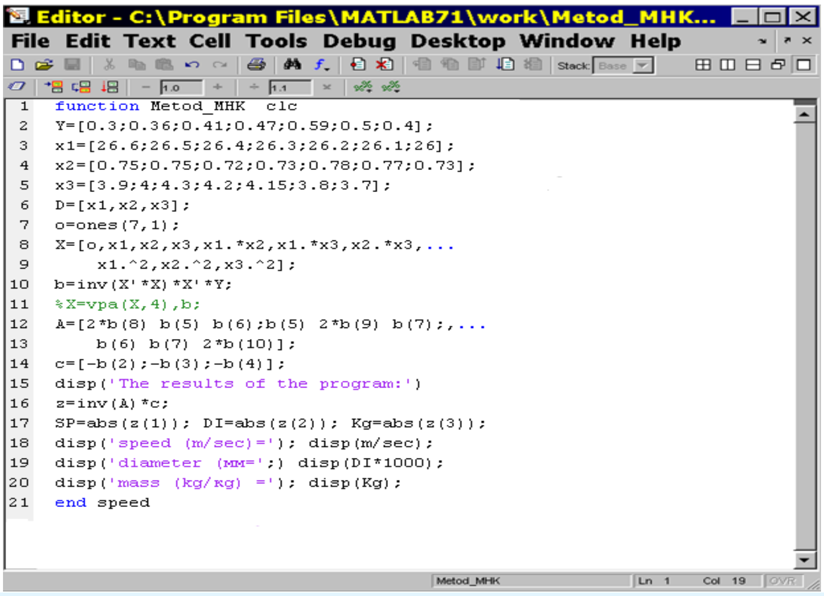

```
function Metod_MHK  clc
Y=[2.08;1.9;1.8;1.4;1.33;1.25;1.20];
x1=[26.6;26.5;26.4;26.3;26.2;26.1;26];
x2=[140;139;141;142;145;143;146];
x3=[4.2;4.3;4.4;4.1;4;4.5;4.1];
D=[x1,x2,x3];
o=ones(7,1);
X=[o,x1,x2,x3,x1.*x2,x1.*x3,x2.*x3,...
    x1.^2,x2.^2,x3.^2];
b=inv(X'*X)*X'*Y;
%X=vpa(X,4),b;
A=[2*b(8) b(5) b(6);b(5) 2*b(9) b(7);,...
    b(6) b(7) 2*b(10)];
c=[-b(2);-b(3);-b(4)];
disp('The results of the program:')
z=inv(A)*c;
SP=abs(z(1)); DI=abs(z(2)); Kg=abs(z(3));
disp('speed (m/sec)='); disp(m/sec);
disp('diameter (мм=';) disp(DI*1000);
disp('mass (kg/кg) ='); disp(Kg);
end speed
```

Fig. 1. The program for calculating the optimal parameters of a pneumatic transporter for 40 t equipment




```
function Metod_MHK  clc
Y=[0.55;0.69;1.02;0.9;0.75;0.5;0.7];
x1=[26.6;26.5;26.4;26.3;26.2;26.1;26];
x2=[110;111;109;112;115;117;109];
x3=[4.3;4.2;4.1;4.2;4;4.15;4.2];
D=[x1,x2,x3];
o=ones(7,1);
X=[o,x1,x2,x3,x1.*x2,x1.*x3,x2.*x3,...
    x1.^2,x2.^2,x3.^2];
b=inv(X'*X)*X'*Y;
%X=vpa(X,4),b;
A=[2*b(8) b(5) b(6);b(5) 2*b(9) b(7);,...
    b(6) b(7) 2*b(10)];
c=[-b(2);-b(3);-b(4)];
disp('The results of the program:')
z=inv(A)*c;
SP=abs(z(1)); DI=abs(z(2)); Kg=abs(z(3));
disp('speed (m/sec)='); disp(m/sec);
disp('diameter (мм=';) disp(DI*1000);
disp('mass (kg/кg) ='); disp(Kg);
end speed
```

Fig. 2. The program for calculating the optimal parameters of a pneumatic transporter for 20 t equipment




```
function Metod_MHK  clc
Y=[0.3;0.36;0.41;0.47;0.59;0.5;0.4];
x1=[26.6;26.5;26.4;26.3;26.2;26.1;26];
x2=[0.75;0.75;0.72;0.73;0.78;0.77;0.73];
x3=[3.9;4;4.3;4.2;4.15;3.8;3.7];
D=[x1,x2,x3];
o=ones(7,1);
X=[o,x1,x2,x3,x1.*x2,x1.*x3,x2.*x3,...
    x1.^2,x2.^2,x3.^2];
b=inv(X'*X)*X'*Y;
%X=vpa(X,4),b;
A=[2*b(8) b(5) b(6);b(5) 2*b(9) b(7);,...
    b(6) b(7) 2*b(10)];
c=[-b(2);-b(3);-b(4)];
disp('The results of the program:')
z=inv(A)*c;
SP=abs(z(1)); DI=abs(z(2)); Kg=abs(z(3));
disp('speed (m/sec)='); disp(m/sec);
disp('diameter (мм=';) disp(DI*1000);
disp('mass (kg/кg) ='); disp(Kg);
end speed
```

Fig. 3. The program for calculating the optimal parameters of a pneumatic transporter for 10 t equipment

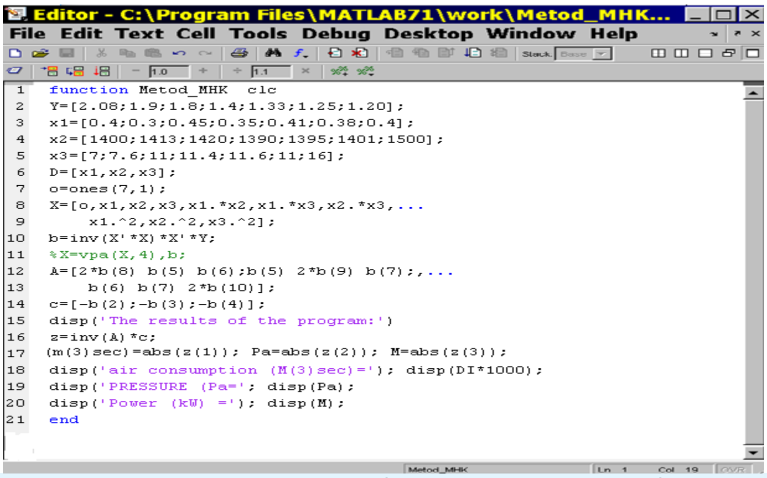


Fig. 4. The program for calculating the optimal parameters of a pneumatic transporter for 40 t equipment

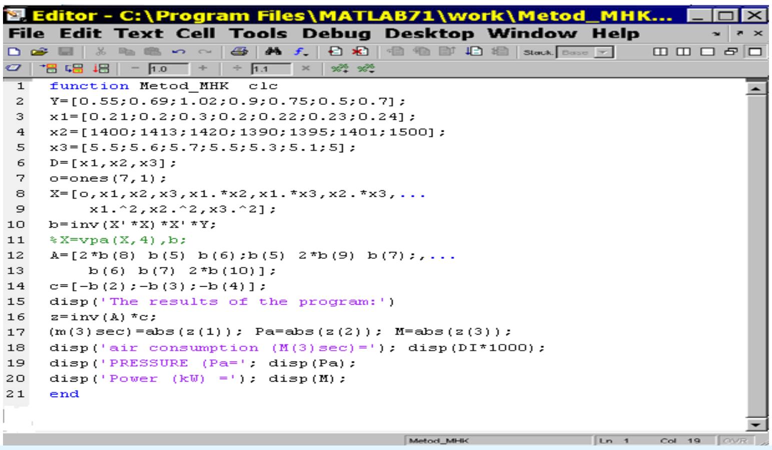


Fig. 5. The program for calculating the optimal parameters of a pneumatic transporter for 20t equipment

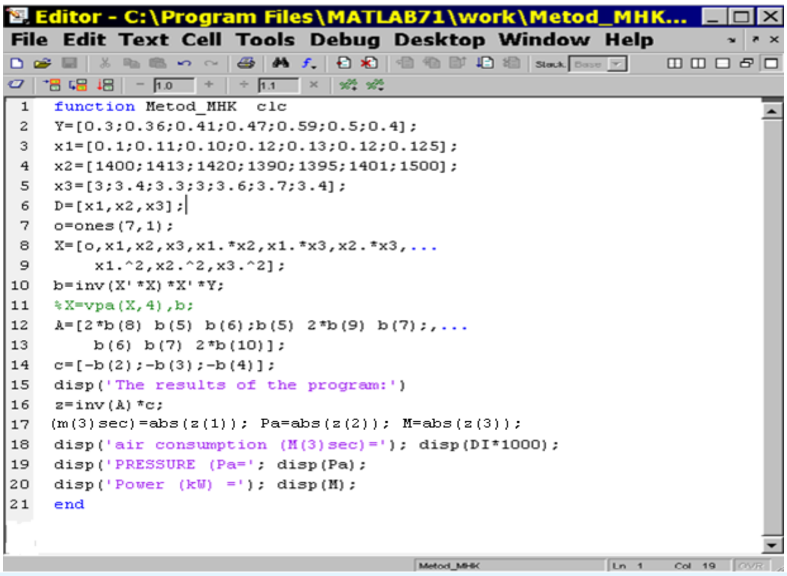


Fig. 6. The program for calculating the optimal parameters of a pneumatic transporter for 10t equipment

Step 3

To obtain the optimal equipment parameters for a given pneumatic transporter performance, the calculated second air flowrate, the total pressure loss in the network and the power of the electric motor according to the formulas (10,13,18). The formulation of the problem will be considered as an application statistics problem using the least square method (LSM) for multidimensional systems. The program for solving the problem can be implemented on the basis of Bednárová (2009) using the mathematical system MATLAB. The program is shown in **Figs. 4-6**.

Table 1. Data for standard containers

Average daily productivity	**40 t/day**	**20 t/day**	**10 t/day**
Work time, h/day	10	10	10
Horizontal pipeline length, m	18	10	10
The number of turns, C	2 to 90°	2 to 90°	2 to 90°
P Turning radius of the pipeline, m	3	3	3
Lifting height, m	18	10	10

Table 2. Main technological and operational parameters

With an average daily productivity	**40 t/day**	**20 t/day**	**10 t/day**
Technical productivity, kg/s	2.08	1.02	0.51
The concentration of air mixture, kg/kg	4.2	4.34	3.94
Soybean flurries rate, m/s	13,3	13,3	13,3
Conveying air velocity in the pipeline, m/s	26,6	26,6	26,6
Diameter of the internal pipeline, mm	140	110	75
Second air flowrate, m^3/s	0.4	0.2	0.1
Total pressure loss in the network, Pa	13622	13720	15248
Required lifting power of grain mass, kW	11,7	5,7	3,5

In **Figs. 1-3**, the numerical values of the input data are given in the lines of the programs 2, 3, 4, and 5, which are calculated by the formulas (7, 9, 11) and in **Figs. 4-6**, the numerical values of the input data are given in the lines of the programs 2,3,4, and 5, which are calculated by the formulas (9,13,19). The output data (numerical values) in the program are given in line 2. In line 10 of the program, the coefficients, the so-called regression coefficients, of the approximate polynomial type are calculated:

$$F = b_1 + b_2x_1 + b_3x_2 + b_4x_3 + b_5x_1x_2 + b_6x_1x_3 + b_7x_2x_3 + b_8x_1^2 + b_9x_2^2 + b_{10}x_3^2. \quad (19)$$

Further, as can be seen from the program, the definition of the optimal parameters of the input data is calculated in the program in lines: 12, 13, 14. Here it should be noted that the coefficient matrix (line 12 and 13) is the coefficient matrix obtained from the partial differential equations for each variable ($\partial F / \partial x_i = 0$), approximation polynomial (19), analytically. Line 14 contains the free terms of linear equations. The solution of linear equations, in order to determine the optimal parameters of the input data values, is carried out by the expression in line 16.

Step 4

Next, we determine the loss of humidity during the ventilation of soybean - **Fig. 14**.

Capacity on wet material - G_1 = 40 t/h = 7500 kg/h = 2.08 kg/s

Absolute humidity of soybean: initial ω_{a1} = 15%; final storage required ω_{a1} = 12%

Parameters of ventilated equipment:

The ventilating material is air.

The outlet of material from the container through the lower pipe for ventilation:

Temperature of environment - t_0 = 25C

Calculation of the relative humidity of soybean (GOST 13586.5-2015 Grain)

At the outlet for venting from the bottom of the pipe of the container **Fig. 14**.

$\omega_{o1} = 100\ \omega_{a1} / (100 + \omega_{a1})$ (20)

```
The results of the program:
speed (m/sec)=
 26.5
diameter (мм=
 140.0124
mass (kg/кg) =
 4.2001
end speed
```

Fig. 7. The results of optimal parameters

After circulation 10 hours a day from the bottom of the container pipe:

$\omega_{o2} = 100\ \omega_{02} / (100 + \omega_{02})$ (21)

Average absolute humidity of the material:

$\omega_{a\ av} = 0,5\ (\omega_{o1} + \omega_{o2})$ (22)

THE MAIN RESULTS OF THE RESEARCH

On the basis of the classically made calculation of the investigated structure (**Fig. 14**) with the following input data for standard containers with a capacity of 40, 20, 10 tons in **Table 1**.

As a result, calculated in the process applies of the classical calculation for the proposed equipment (**Fig. 14**), the main technological and operational parameters are set in **Table 2**.

The optimal parameters are the concentration of air mixture, which conveys the air velocity in the pipeline and the diameter of the pipeline using the MATLAB program, which were determined using the commands in the program lines: 12, 13, 14 and 16 from **Figs. 1-3**. The counting results are shown in **Figs. 7-9**.

From the results of the calculation, **Fig. 7** shows what the optimal parameters of the pneumatic transporter should be, ensuring a capacity of 40 tons/day.

From the results of the calculation, **Fig. 8** shows what the optimal parameters of the pneumatic transporter should be, ensuring a capacity of 20 tons/day.

```
The results of the program:
speed (m/sec)=
 26.402
diameter (мм=
 107.0302
mass (kg/кg) =
 4.04
end speed
```

Fig. 8. The results of optimal parameters

```
The results of the program:
speed (m/sec)=
 25.0202
diameter (мм=
 074.0421
mass (kg/кg) =
 3.49
end speed
```

Fig. 9. The results of optimal parameters

```
The results of the program:
  air consumption (M(3)sec)=
     0.39
  disp('PRESSURE (Pa=
     13700
  disp('Power (kW) =
     10.5
```

Fig. 10. The results of optimal parameters

```
The results of the program:
  air consumption (M(3)sec)=
     0.25
  disp('PRESSURE (Pa=
     14200
  disp('Power (kW) =
     5.1
```

Fig. 11. The results of optimal parameters

From the results of the calculation, **Fig. 9** shows what the optimal parameters of the pneumatic transporter should be, ensuring a capacity of 10 tons/day.

The optimal parameters of the second air consumption, the total pressure losses in the network and the power of the electric motor using the MATLAB program were determined using the commands in the program lines: 12, 13, 14 and 16 from **Figs. 4-6**. The counting results are shown in **Figs. 10-12**.

From the results of the calculation, **Fig. 10** shows what the optimal parameters of the pneumatic

```
The results of the program:
  air consumption (M(3)sec)=
     0.1
  disp('PRESSURE (Pa=
     15000
  disp('Power (kW) =
     3.4
```

Fig. 12. The results of optimal parameters

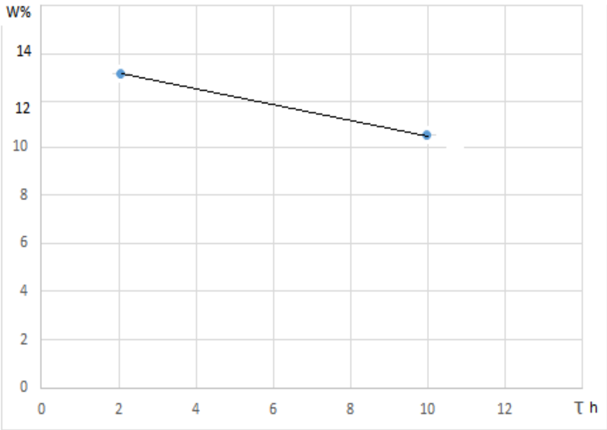


Fig. 13. Lost humidity during ventilation of soybean

transporter should be, ensuring a capacity of 40 tons/day.

From the results of the calculation, **Fig. 11** shows what the optimal parameters of the pneumatic transporter should be, ensuring a capacity of 20 tons/day.

From the results of the calculation, **Fig. 12** shows what the optimal parameters of the pneumatic transporter should be, ensuring a capacity of 10 tons/day.

According to the research, a graph was built (**Fig. 13**), from which it follows that after 10 hours of soybean ventilation using equipment, humidity W decreases from 13% by 10.71%, that is, by 2.29%, with an average absolute humidity of 11, 85%.

DISCUSSION OF THE DATA AND CONCLUSION

The data obtained as a result of the study made it possible to select the optimal parameters of the proposed container-modular technology for storing soybeans with active ventilation in farm conditions per standard containers of 40, 20, 10 tons.

In **Fig. 14** is a flowchart of the equipment.

Active ventilation is carried out by a signal from humidity sensors 10 placed at three equidistant levels

Table 3. The results of the technological calculation

Relative humidity of soybeans at the outlet for ventilation from the bottom of the container pipe ω_{o1}, %	13
Relative humidity of soybeans after circulation for 10 hours ω_{o2}, %	10.71
The average absolute humidity of soybean $\omega_{a\ av}$, %	11.85

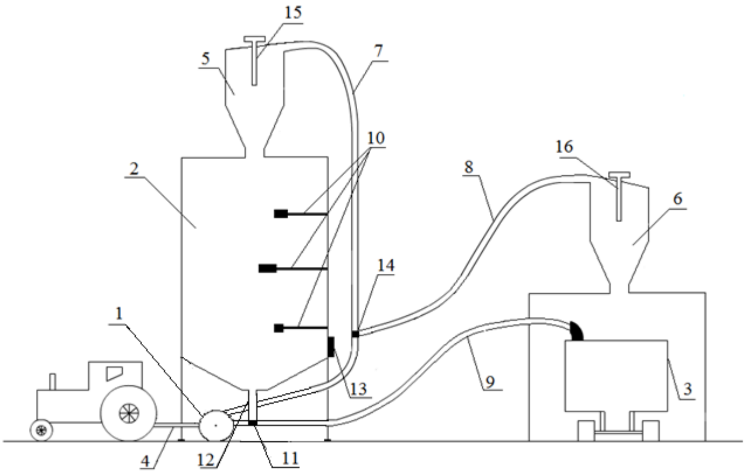


Fig. 14. Scheme of equipment for the storage of soybeans with active ventilation
1 - pneumatic transporter, 2 - equipped container; 3 - vehicle loading and loading grain from where; 4- mechanical pneumatic transporter drive; 5,6 - cyclones; 7 - pipeline for active ventilation of the grain mass; 8 - pipeline for unloading the grain mass; 9 - pipeline for loading the grain mass; 10 - humidity sensors of the grain mass; 11 - two-way valve; 12- lower pipe; 13 - control panel and control sensors; 14 - two-way valve; 15,16- pipe to divert the air flow from the cyclone (Atykhanov et al. 2018)

along the height of the container on its side by fastening through metal pipes. The signals from the humidity sensor then go through the adapter to the control block on the control and monitoring panel 13. When the specified upper limit of humidity is reached, for example 14%, the pneumatic transporter electric drive 1 is activated. The ventilation process continues until the humidity decreases to 12%, after which the electric drive of the pneumatic transporter 1 is turned off. Accordingly, with active ventilation, no additional expensive heat sources such as gas, fuel oil, or coal are used as a drying agent, which leads to a decrease in energy and material costs for storage.

For controling and monitoring the grain moisture, a control and monitoring panel is provided by sensors 13 installed on the side outside of the equipped container 2 with free access to the staff at the level of an average person's height (150 cm).

The pneumatic transporter 1 has an electric drive from the mains at 380 V. In the absence of electric current in the farms, a mechanical drive of the pneumatic transporter 1 from the tractor's power take-off shaft (PTO) 4 **Fig. 14** is provided.

Pneumatic ventilation is a vertical pipe (**Fig. 14**) with a constant cross-section of 10–18 m length. Wet material is fed from the bottom of pipe 12 from a container. It is picked up by air and ventilated on the passage through the equipment. From pipe 7, air with particles suspended in it enters the cyclone to trap the dried product. In the cyclone apparatus, ventilation continues efficiently. This reduces the length of the vent. So much humidity should be removed from the pipe to prevent material from sticking to the walls of the cyclone.

The air velocity in the pipe must be greater than the velocity of the flurry (particle deposition rate). It is selected depending on the size and density of particles from 10 to 35 m/s. Therefore, the stay of the material in the ventilation in the pneumatic tube, the air and the material move in the same direction (co-current), this ventilation is effective for removing the surface humidity of the material. Due to active ventilation, elevated coolant temperatures are permissible even for heat-sensitive products. The simplicity of active ventilation makes the drying of many materials cost-effective.

REFERENCES

Atykhanov AK, Karaivanov DP, Duisenova ShT (September 24, 2018) Patent for utility model №3135 of the Republic of Kazakhstan, Equipment for storage of grain masses with active ventilation KZ (13) U (11) 3135.

Bednárová D (2009) Metóda ortogonálnej regresie a jej aplikácia v modelovaní a riadení, PhD Thesis, Faculty of BERG, TUKE (in Slovak).

Economy newspaper (July 20, 2018) Kazakhstan annually increases the area of soybean crops.

GOST 13586.5-2015 Grain. Method for determination of humidity (with correction) MKS 67.060. Introduction date 2016-07-01.

Malis AYa (1969) Pneumatic transport of bulk materials.

Maron FP, Kuzmin AV (1977) Handbook of calculations of the mechanisms of hoisting-and-transport machines. Minsk.

Mills D (2004) Pneumatic conveying design guide, Second edition. Oxford: Elsevier Butterworth-Heinemann.

Minister of Agriculture of the Republic of Kazakhstan (June 26, 2015) On approval of the Rules for the storage of grain. Order of the Minister of Agriculture of the Republic of Kazakhstan № 4-1/573. Registered in the Ministry of Justice of the Republic of Kazakhstan on August 4, 2015 № 11839.

Singh, G (2014) Soybean-biology, production, use. Kiev: "Zerno" Publishing House.

Spivakovsky AO, Dyachkov VK (1983) Transporting machines.

Vdovenko OP (1966) Pneumatic transport in the chemical industry.

Yukish AE, Ilyina OA (2009) Technique and technology of grain storage. DeLi, 2009.