The influence of design parameters of rotary dryer on sunflower seeds drying

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Abstract

Introduction. In order to improve the drying of sunflower seeds in the apparatus of the rotary type, it is appropriate to model processes in this devices using computer simulation software.

Materials and methods. Simulation of sunflower seeds drying was based on the finite element method using the software package Flow Vision (company "TUSYM") and mathematical and statistical methods.

Results. Mathematical models were obtained that show the dependence of pressure of coolant (air) in the drying chamber of rotary dryer on the rate of the coolant, the open cross-sectional area of the gas distributor plate and its resistance, the dependence of duration of sunflower seeds drying on fill factor of the drying chamber and its volume as well as the final material moisture content.

The equilibrium distribution of the coolant pressure in the drying chamber of rotary dryer was obtained. It provides a constant height of the fluidized bed of sunflower seeds and quality of its drying.

The design of rotary dryer was improved by providing the tangential supply of coolant and installing a spiral partition under gas distribution grid, which allows to uniformly distribute the coolant in the drying chamber.

Conclusion. The drying process of sunflower seeds in a rotating dryer was improved. It is advisable to use the experimental result when choosing the mode of drying at the design stage of drying equipment.

Introduction

The existing constructions of dryers consist of different elements designed to heat the air and to mix the cold air with coolant, heat chambers, drying chambers, chambers for mixing dried grains with wet, chambers for cooling grain and its maturing, and so on. There are a number of different methods and classifications of dryers depending on the combination of these elements. Designs of dryers influence such process parameters as temperature, duration of staying of the product in the dryer and temperature distribution in the fluidized bed height.

When choosing a dryer for sunflower seeds drying there are problems associated with changes of oil quality indicators, the destruction of bran covering through drying, fire hazard, the uneven heating and drying, increased coolant flow, low productivity and long duration of drying.

Therefore there is a question for choosing the rational design of dryers for drying of sunflower seeds or improving the existing ones.

After analyzing the existing designs of dryers for sunflower seeds drying, their advantages and disadvantages the rotary dryer with fluidized bed was selected for improvement, which will provide drying of sunflower seeds with minimal materials consumption, low energy intensity and reasonable performance. This is achieved by using a sectional dryer, which provides a tangential supply of heat to the mixed seed and by installing of partition under the grid, which provides the same height of the fluidized bed through cross section of the dryer and uniform drying of sunflower seeds.

Fluidized bed dryers are widely used in the food industry due to the simplicity of constructional design.

This paper presents the investigation of the infenence of constructional features of the improved design of rotary dryer on drying process of sunflower seeds.

The technological value of sunflower seeds is determined by its oil content that is important to maintain during drying. During the drying process synthesis or decay of fatty oil components can occur. The direction of these changes depends on the seed moisture, temperature and duration of the drying process. Under optimal mode of drying oil content in sunflower seeds increases. Accompanying substances contained in the seeds such as phosphates, carotenoids, sterols, waxy substance, passes to the oil.

The problem number one at present is the development of new methods for drying of grains and oilseeds, creating of small dryers, and in particular improving of dryers with fluid (boiling) layer known for its high efficiency and speed of drying, simplicity of construction and operation, performance quality and flexibility of drying process control.

Recently in addition to physical models mathematical models are often used when creating new types of equipment and improving of existing ones. These calculations allow to follow the technological processes in the equipment and optimize them with less time and material resources.

Materials and methods

At present the patterns of structural effects arising from the interaction of fluidized (boiling) layer and the degree of influence of these effects on the intensification of heat transfer process are not carefully studied. To determine the expediency of the use of rotary dryer during the drying of sunflower seeds, it is necessary to conduct further invessigation and mathematical modeling.

The software package Flow Vision was used to simulate the coolant motion, its velocity vector distribution and determine the pressure in the drying chamber, to build diagrame and visualization of the nature of air motion and to obtain the experimental data.

The geometric model of the drying chamber was developed to determine the main design parameters of the equipment and rational modes which are able to ensure the effective implementation of the drying sunflower seeds in graphics editors (Fig. 1). The model of air chamber was developed to study the air flow motion under the drying grid (Fig. 2).

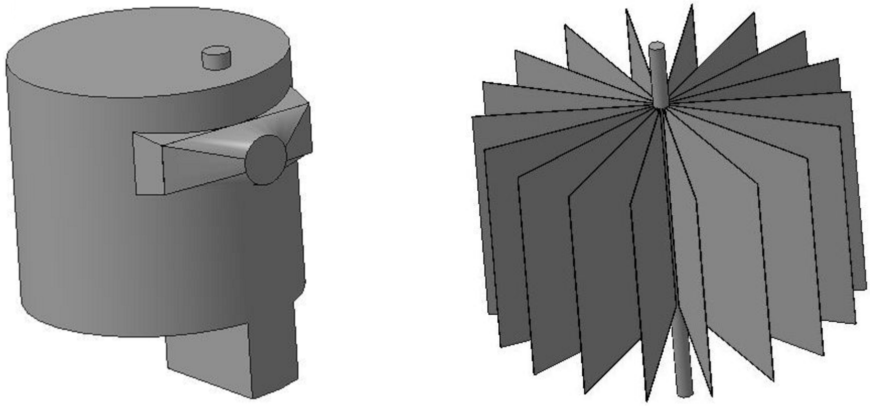


Fig. 1 The geometric model of the drying chamber and blades

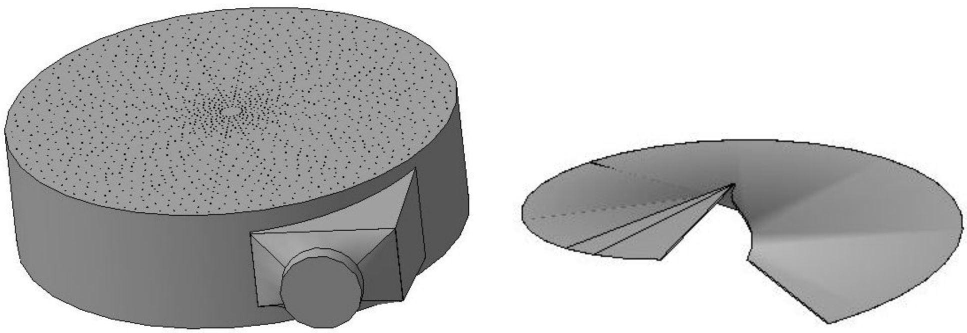


Fig. 2 The model of air chamber and partition

The procedure of the research in the software package Flow Vision consist of the next step:

1. Open the Flow Vision file with the studied model.
2. Choose the mathematical model for calculation using the available models in the program complex Flow Vision and the calculated parameter. In our case the calculated model is "Incompressible fluid" because the laws of this model fully meet the challenge.
3. Imput the boundary conditions for model. Boundary conditions should be three: the coolant outlet boundary conditions, boundary conditions of the chamber wall, partitions, blades, shaft, grid, and boundary condition of coolant input.
4. Input the physical properties of the model.
5. Specifiy the number of computational cells along the each axis of the coordinate system of the model.
6. Specifiy criteria for mesh adaptation for solution and boundary conditions.
7. Specifiy the parameter of calculation methods .
8. Start of calculation without user intervention.
9. Viewing the calculation results in graphical form (visualization of the results of the calculation).

10. Defining and saving of numerical calculations of the parameters in the form of files.

11. Evaluation of the accuracy of calculations.

After the simulation such images of the results are expected to get (Fig. 3...5):

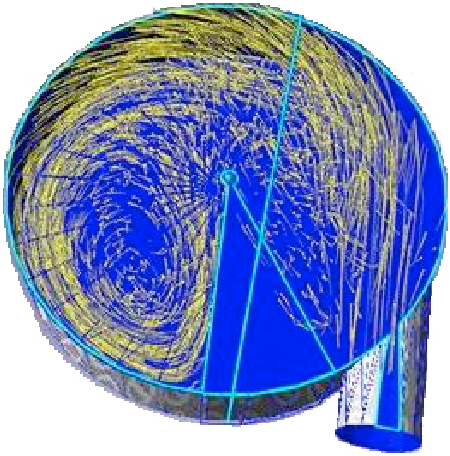


Fig. 3 Simulation of motion (velocity) of the coolant at the bottom of the chamber under the partition

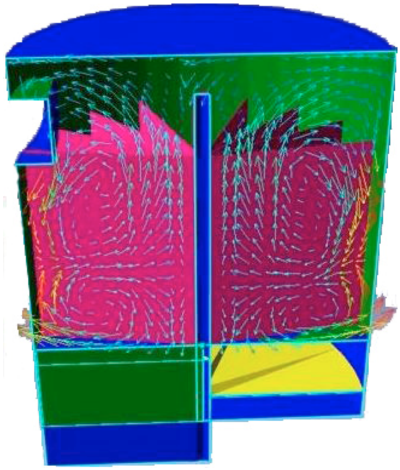


Fig. 4 Velocity distribution in the cross section of the drying chamber

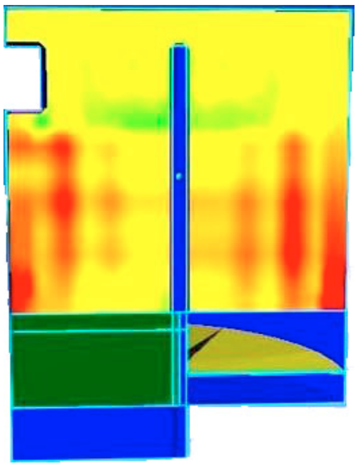


Fig. 5 Distribution of pressure in the cross section of the drying chamber as fill

Typically, the static model is supplied in the form of linear or non-linear, algebraic or transcendental equation or system of equations or inequalities. If information about the dependence of the characteristics is insufficient for their accurate identification or connections are random, the object of modeling will be considered as a "black box" for which only inputs and outputs are allocated, and internal communications are considered unknown.

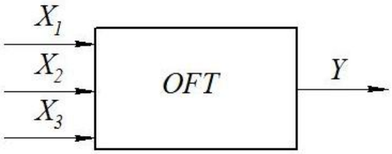


Fig. 6 General scheme of mathematical and statistical model

Consider the situation when the object hes one output variable and number of input variables. Such objects in the conceptual model are presented in the form shown in Fig. 6, where X_1, X_2, X_3 are input variables (factors. regressors), Y is output variable (review). To establish the optimal technological regime of drying of sunflower seeds it is necessary to develop a mathematical model of the process by full factorial experiment.

Results and discussions

The main objective of the study is to analyze the distribution of coolant and intensity of the drying agent under the drying chamber and the equal pressure above the grid, as this factor is one of the key figures in obtaining high-quality parameters of drying. When drying it is necessary to enable the optimal conditions for the process: the speed of the coolant should be 1...2 m/s, the open area of the grid through which the coolant passes should be 0,01...0,05%, the grid resistance during the passage of air through the openings should be 0,75...0,9. High speed contributes to a sharp increase in energy consumption.

It was found that the maximum rate of the air (coolant) occurs at the entrance to the chamber, then after hitting the walls its speed decreases and movement occurs in the radial direction.

Analyzing the distribution of vector velocity of the coolant in the drying chamber, it was found that the greatest air velocity is observed near the walls of the drying chamber, as the rotating blades of the dryer accelerate the movement of the air particles, which taking run bump on the walls of the shell. The layer of sunflower seeds begins to twist forming circulation areas. Closer to the center of these areas the speed reduces because of the reduced radius of the area where the coolant motion occur. The flow is aligned higher forming a fluidized bed and is drawn with drops of water through the pipe of coolant drainage.

According with outbreaks of vector velocity of the coolant it was found that the layer of the air captured by blades of rotary dryer form funnels moving along a spiral trajectory. Under the action of gravity component funnels evenly distribute throughout the volume between the blades forming circulation areas. This facilitates the process of fluidized bed. In this state, the layer resembles a boiling liquid acquiring some of its properties. Also the close contact is achieved between sunflower sund and drying agent that intensifies the drying process.

Analyzing the distribution of the coolant pressure in the drying chamber it can be seen that a significant impact on its distribution in the fluidized bed hes the pressure of the layer and the grid. That's why the biggest pressure will be above the grid surface of the drying chamber.

Also it was found that the pressure in the drying chamber is uniform through its height and provides the equal height of fluidized bed. This would allow to dry sunflower seeds evenly throughout its volume. The pressure is aligned over the blades since the fluidized bed height is only 1450 mm while the height of blades is 1500 mm.

The lowest value of coolant pressure is observed at the inlet to the chamber and the maximum on the wall. This is because the coolant enters the cell, and then moving over the grid pressure on the chamber walls and consequently increases.

Simulation of the coolant velocity showed the turbulence in the lower chamber, in a fluidized bed, between the blades and over them. It was found that the larger area of contact of the product with the coolant will be the more intensive will be the drying process.

Analyzing the results of the investigation it can be said that the pressure in the chamber is uniform over its height. It would allow high-quality to dry sunflower seeds in a fluidized bed forming the same height of fluidization.

The improved design of rotary dryer (patent 77691, UA) works as follows.

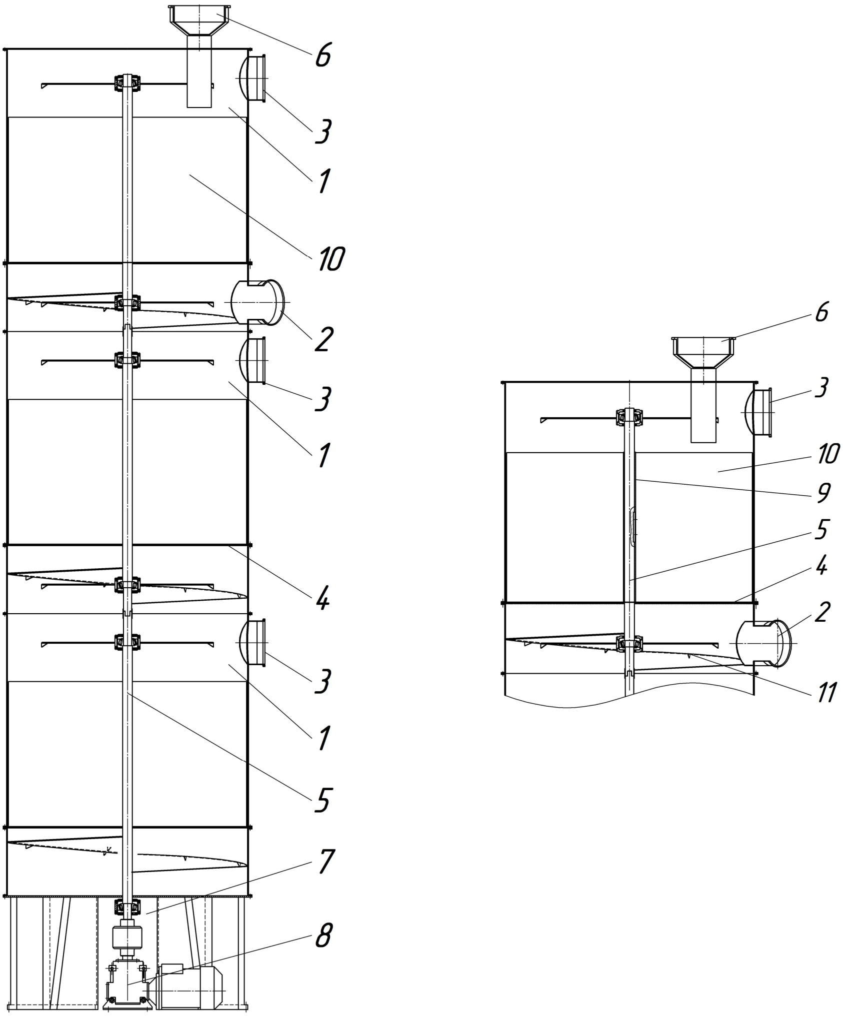
Rotary dryer (Fig. 7) consists of three chambers: the upper drying, the middle drying and the lower cooling. Wet granular material is introduced into the upper drying chamber 1 while the coolant is fed through tubes 2 above the partition 11 below the grid 4 into the drying chamber 1, creating a fluidized bed. The product is moved by means of the blades 10 driven by drive 8 through shaft 5. The spent coolant is removed through the nozzles 3 to the atmosphere from loading zone to unloading zone. The placement of partition 11 below the grid 4 and the tangential supply of the coolant allow evenly to distribute the coolant throughout the volume of the drying chamber and to provide the equal height of the fluidized bed product that will intensify the drying process. The drying of seeds in each sector is carried out periodically. The dryer runs continuously.

The seeds moisture decreased from 18…20 to 5...9 % per cycle duration approximatdy in 8 min. (drying 4-5 min., cooling 2-3 minutes.) without degradation of the quality of seeds during the drying of sunflower seeds in a rotating dryer at a temperature of coolant 160...170 °C and the height of layer 250 mm. In addition, this method of drying significantly reduces the seeds infestation.

Similarly, the drying process takes place in all chambers. The coolant is fed with a lower temperature in the cooling chamber. Fig.7b depicts the drying chamber, where the drying agent enters the air injection chamber and then passing through the holes in the grid enters the drying chamber. The material slowly moves to the unloading point into the chamber below. Before being discharged the next section is cut off from the air by the solid sector and is discharged through a special unit. The dried product is discharged from the cooling chamber through a device 7. Pouring of the product from chamber to chamber occurs through a hole in the grid.

An important factor to intensify the drying process in a rotating dryer is a uniform distribution of the drying agent under the grid and fluidized bed height above the grid. For this purpose the mathematical modeling was used for its investigation. Such calculations allow to optimize the process and to obtain the numerical values of parameters that can not be measured by existing instruments. To solve this problem the mathematical and statistical models were developed to determine the pressure in the drying chamber and optimal duration of drying.

The input parameters that influence the pressure in the drying chamber are: v_c – velocity of the coolant in the holes of gas distribution grid; φ – open cross-section area of the grid; C – resistance coefficient of the grid. The input parameters that influence the duration of the drying process are: β – fill factor of the chamber by material; $V_{d.c.}$ – the volume of the drying chamber; ω_2 = 5...10% – the final moisture content of the material.



a *b*

Fig. 7 The Rotary Dryer (a – sectional view of dryer, b – drying chamber):
1 - drying chamber; 2 - pipe of coolant supply; 3 - drainage pipe; 4 - perforated grid; 5 - drive shaft; 6 - boot device; 7 - unloading device; 8 - drive; 9 - tube; 10 - blade; 11 - partition

The mathematical models were defined using a full factorial experiment.

The mathematical model of the pressure in the drying chamber:

$$P = 12{,}97 - 2{,}75 \cdot \frac{v_c - 1{,}5}{0{,}5} - 5{,}09 \cdot \frac{\phi - 0{,}03}{0{,}2} - 2{,}69 \cdot \frac{v_c - 1{,}5}{0{,}5} \cdot \frac{\phi - 0{,}03}{0{,}02} - \\ - 1{,}49 \cdot \frac{v_c - 1{,}5}{0{,}5} \cdot \frac{C - 0{,}82}{0{,}08} - 0{,}07 \cdot \frac{\phi - 0{,}03}{0{,}2} \cdot \frac{C - 0{,}82}{0{,}08} + 5{,}127 \cdot \frac{v_c - 1{,}5}{0{,}5} \cdot \frac{\phi - 0{,}03}{0{,}2} \cdot \frac{C - 0{,}82}{0{,}08} \quad (1)$$

The mathematical model of the duration of the drying process:

$$\tau = 9,72 + 4,1575 \cdot \frac{\beta - 0,3}{0,2} + 5,5625 \cdot \frac{V_{\text{d.c.}} - 15}{5} + 2,16 \cdot \frac{\omega_2 - 7,5}{2,5} + \\ +0,5175 \cdot \frac{\beta - 0,3}{0,2} \cdot \frac{V_{\text{d.c.}} - 15}{5} - 1,2 \cdot \frac{\beta - 0,3}{0,2} \cdot \frac{\omega_2 - 7,5}{2,5} - 0,6 \cdot \frac{V_{\text{d.c.}} - 15}{5} \cdot \frac{\omega_2 - 7,5}{2,5} - \\ -2,7175 \cdot \frac{\beta - 0,3}{0,2} \cdot \frac{V_{\text{d.c.}} - 15}{5} \cdot \frac{\omega_2 - 7,5}{2,5} \quad (2)$$

The obtained mathematical models allow to calculate the required parameters of drying of sunflower seeds and ability to influence the quality of the final product.

Conclusion

1. The design of rotary dryer was improved. The installing of tangentially placed nozzles and spiral partition in the lower chamber were confirmed by the results of studies performed using the software package Flow Vision.
2. The proposed reconstruction makes it possible to evenly heat and dry the product in a fluidized state at any point of intersection of the drying chamber without disturbance of its properties.
3. Mathematical models for determining the pressure of the coolant in the drying chamber and duration of drying of sunflower seeds were obtained that allow determining the optimal working modes of dryer.

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