Intensification of secondary dampening of grain before milling

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Abstract. This article describes the problems encountered by grain processing industries. In this regard, we are looking for methods of intensive grain dampening, allowing to reduce the technological cycle of flour production by reducing the time of softening. The article also considers the process of secondary dampening of grain before milling by using pulsating vacuuming and subsequent pulsing pressure. An experimental unit for grain dampening before milling is presented and the basics of its operation are described. In addition, the paper provides the results of the experimental study of wheat grain dampening using pulsating vacuum and subsequent pulsing pressure, and provides control results of the experimental study of wheat grain dampening without vacuum and pressure. The results of the experimental study were analysed; according to said analysis it is evident the increase in moisture content of wheat grain in case of dampening with the use of pulsating vacuum and subsequent pulsing pressure is more intense than in case of dampening without the use of vacuum and pressure, which leads to a two-fold reduction of the softening time. The dependence between the dampening increment ΔW and the grain processing time t in the experimental dampening unit was determined. Having analysed this work, were made our conclusions that are presented in the article as well.

1. Introduction
The humidity of grain coming for processing is usually low, while the structural and mechanical properties of the endosperm and shells differ slightly. Therefore, it is difficult to separate them, and the grain gets poorly processed, i.e., the output and quality of the finished product do not meet the requirements of the “Rules for Organizing and Conducting the Technological Process at Mills” [1].

To change the technological properties of the grain, various methods of hydrothermal treatment (HTT) may be used. The first priority of the mills using HTT is to enhance the difference between the properties of the shells and the endosperm [2].

Intensity of grain dampening significantly affects the the effectiveness of HTT process. In this regard, we are looking for ways of intensive grain dampening that would allow us to reduce the technological cycle of flour production by reducing the time of softening, while maintaining the product yield and the quality of the produced flour at the same level [3].

2. Research material and methods
Based on the above, the aim of our work is “to increase the effectiveness of grain dampening before milling using variable pressure in the dampening chamber”.

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The device proposed by us (utility model patent No. 171424) improves the quality of dampening, while being small in size and requiring not much supply power [4]. This problem can be solved by using pulsating vacuuming of the grain before dampening, after which the actual dampening takes place and subsequent pulsating pressure in the dampening chamber occurs [5].

For the purpose of the experiments, the following experimental setup was developed and constructed; this setup is intended primarily for the study of the effect of variable vacuum before dampening and variable pressure after dampening on the intensity of moisture content increase in wheat (figure 1).

In order to reduce the loss of pressure and vacuum, in this experiment, we used an installation, in which grain was loaded and unloaded in portions; the loading and unloading device securely sealed the working area of the auger conveyor from the environment. In terms of process conditions, the dampening chamber can be divided into three parts. The first part generates pulsating vacuum, in which the grain is treated by pulsating vacuum; the second part dampens the grain at a constant vacuum, which prevents moisture entrainment by the vacuum pump; the third part of the chamber generates pulsating pressure and intensifies grain dampening. In this case, the grain is dampened constantly and not in portions.

In addition, we chose a dampening chamber of a small size in order to avoid the "receiver effect" that smoothens the pulsations of vacuum and pressure, which reduces the intensity of grain dampening and can make the proposed measures useless.

**Figure 1.** Experimental installation for grain dampening.

1 – frame, 2 – electric motor, 3 – vacuum pump, 4 – electric motor, 5 – reducer, 6 – flange, 7 – loading hole, 8 – air venting cock in the auger conveyor, 9 – nozzle, 10 – cock, 11 – vacuum meter, 12 – vacuum pulsator, 13 – vacuum pipeline, 14 – pressure pipeline, 15 – pressure pulsator, 16 – pressure gauge, 17 – water pipeline, 18 – dosing pump, 19 – housing, 20 – spiral auger conveyor, 21 – discharge hole, 22 – compressor.

The experimental installation works as follows. At the start of the experiment, we need to determine the moisture content of the grain that we need to moisten to 16.4% in order to understand, what amount of water is required for dampening. Based on the amount of water identified, we shall set the time for water injection into the dampening chamber. After that, we pour the grain into the dampening chamber and level it with the auger, then turn on the vacuum pump and treat the grain with pulsating vacuum using the vacuum pulsator. During the experiment, the auger constantly stir the grain in the chamber for better effect of vacuum, pressure and water mist during dampening of each grain. In order to avoid entrainment of a part of moisture through the vacuum pump, we need to set a permanent vacuum and dampen the grain by injecting water in the form of mist into the chamber through nozzles for a specified
time. Next, we set the pulsating pressure in the chamber using the compressor and pressure pulsator; the set time must be observed as well. At the end of the experiment, we pour the grain with the auger conveyor into the dampening chamber and determine its moisture content [6].

3. Research results
The figure 2 shows the results of the experimental study of wheat grain dampening using pulsating vacuum and subsequent pulsating pressure, and provides control results of the experimental study of wheat grain dampening without vacuum and pressure. The numerical value of the grain moisture content obtained through wheat dampening without the use of pulsating vacuum and subsequent pulsating pressure is given in table 1.

Table 1. Grain dampening without the use of pulsating vacuum and subsequent pulsating pressure

| Experiment number | Before dampening | After dampening | Note |
|------------------|------------------|-----------------|------|
| 1                | 12.44 ; 12.34    | 15.90 ; 15.90   | Dampening time: 30 sec. |
| 2                | 12.70 ; 12.98    | 15.99 ; 16.36   | Dampening time: 1 min. |
| 3                | 12.54 ; 12.48    | 16.03 ; 16.06   | Dampening time: 2 min. |
| 4                | 13.16 ; 13.25    | 16.04 ; 16.17   | Dampening time: 3 min. |
| 5                | 13.11 ; 13.27    | 16.25 ; 16.29   | Dampening time: 4 min. |
| 6                | 13.16 ; 13.38    | 16.19 ; 16.40   | Dampening time: 5 min. |
| 7                | 13.07 ; 13.19    | 16.21 ; 16.35   | Dampening time: 6 min. |
| 8                | 12.84 ; 13.05    | 16.31 ; 16.38   | Dampening time: 7 min. |

The numerical value of the grain moisture content obtained through wheat dampening with the use of pulsating vacuum and subsequent pulsating pressure is given in table 2.

Table 2. Effect of pulsating vacuum (kPa) up to -60kPa and subsequent pulsating pressure (kg/cm²) up to 7kg/cm² on wheat grain moisture content

| Experiment number | Before dampening | After dampening | Note |
|------------------|------------------|-----------------|------|
| 1                | 13.15 ; 13.29    | 16.92 ; 17.01   | – 30 sec. ; – 30 sec. |
| 2                | 13.51 ; 13.45    | 17.01 ; 16.64   | – 1 min. ; – 1 min. |
| 3                | 13.33 ; 12.91    | 17.16 ; 16.90   | – 2 min. ; – 2 min. |
| 4                | 13.27 ; 13.24    | 17.90 ; 17.71   | – 3 min. ; – 3 min. |
| 5                | 13.19 ; 12.94    | 17.72 ; 17.39   | – 4 min. ; – 4 min. |
| 6                | 13.42 ; 13.29    | 17.62 ; 17.52   | – 5 min. ; – 5 min. |
| 7                | 13.16 ; 13.31    | 17.80 ; 18.00   | – 6 min. ; – 6 min. |
| 8                | 12.52 ; 12.97    | 18.37 ; 18.18   | – 7 min. ; – 7 min. |

According to the analysis of the experimental study, generation of pulsating vacuum and subsequent pulsating pressure in the dampening auger conveyor significantly speeds up the process of wheat dampening, and, according to the graph, the grain reaches the optimum moisture content of 16.4% within the first 15-30 seconds, whereas when grain is dampened in the same auger conveyor without pulsating vacuum and pulsating pressure, wheat grains reach said parameters only by the eighth minute.
According to the analysis of the experiment results, it is evident that the increase in moisture content of wheat grain in case of dampening with the use of pulsating vacuum and subsequent pulsing pressure is more intense than in case of dampening without the use of vacuum and pressure.

Let us determine the dependence between the dampening increment $\Delta W$ and the grain processing time $t$ in the experimental dampening unit. The correlation and regression analysis shows that the following dependencies approximate the observation data quite well:

- Linear dependence $y = 3.012x - 9.3984$ ($R^2 = 0.747$)
- Exponential dependence $y = 0.024e^{1.094x}$ ($R^2 = 0.635$)
- Second degree polynomial $y = 0.3516x^2 + 6.1407x - 16.211$ ($R^2 = 0.7552$)

Any of them can be used for forecasting, but the linear one is preferable (figure 3).

So, if the grain received for processing has the moisture content of 13.2%, and it needs to be moistened to 16.6%, then it will take $y = 3.012 \times (16.6 - 13.2) - 9.398 = 0.84$ minutes to treat the grain.

The correlation coefficient is 0.865, which indicates a close dependence of the grain moisture change on the time of its processing in vacuum.

The dispersive analysis suggests that by using a linear dependence, the risk of getting an incorrect forecast is 0.002.
4. Conclusion
1. The experimental study has shown that the proposed dampening system reduces the time of grain dampening by 2 times.
2. The correlation and regression analysis shows that the following dependencies approximate the observation data quite well: linear dependence $y = 0.024e^{1.094x} (R^2 = 0.6353)$; exponential dependence $y = 3.012x - 9.3984 (R^2 = 0.7475)$; second-degree polynomial $y = 0.3516x^2 + 6.1407x - 16.211 (R^2 = 0.7552)$.

References
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