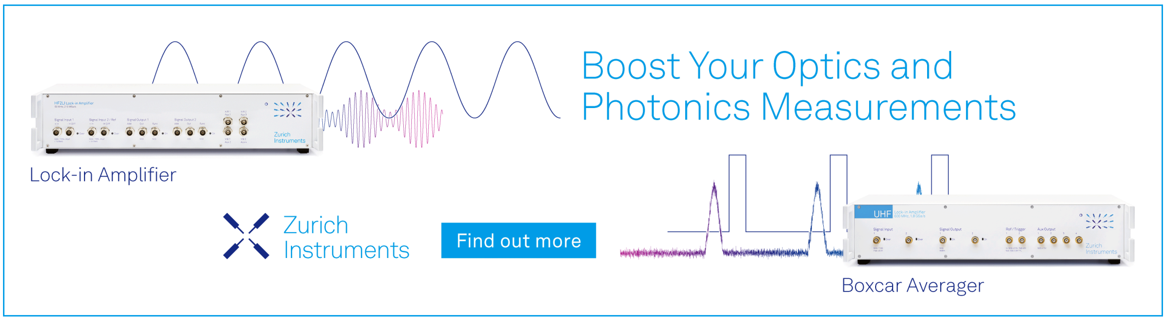
RESEARCH ARTICLE | OCTOBER 13 2022

Justification of the parameters and operating modes of the fan of the device for collecting grain, which is part of the reaper designed for two-phase harvesting in a batch way

Mikhail Konstantinov; Ivan Gluchkov; Igor Gerasimenko; Igor Ognev; Alexey Gretsov

AIP Conf. Proc. 2503, 030019 (2022)
https://doi.org/10.1063/5.0105427



Justification of the Parameters and Operating Modes of the Fan of the Device for Collecting Grain, which is Part of the Reaper Designed for Two-Phase Harvesting in a Batch Way

Mikhail Konstantinov[1, a)], Ivan Gluchkov[1, b)], Igor Gerasimenko[1], Igor Ognev[2, c)], and Alexey Gretsov[3]

[1]*Orenburg state agrarian University, Orenburg, Russia*
[2]*Ural Federal University named after the first President of Russia B.N. Yeltsin, Ekaterinburg, Russia*
[3]*Samara State Agrarian University, Samara, Russia*

a) Corresponding author: miconsta@yandex.ru
b) i-n-g2012@yandex.ru
c) ognev.i.i@yandex.ru

Abstract. Studies of the reaper designed for two-phase harvesting by batch method, conducted earlier showed the prospects for the development and research of technical means to preserve grain that can already be considered lost. As a solution to the problem, a modernized reaper designed for two-phase harvesting by batch method was developed, in the design of which a device was introduced for collecting grain that came out of the ear in contact with the main nodes of the header, which was called a device for collecting free grain. The fan is an important element of the device for collecting grain, so the justification of its parameters and operating modes described in this article is relevant. In the course of solving this problem, mathematical expressions were obtained that allow us to justify the choice of a fan for the particular case under consideration – for a device for collecting free grain that complements the design of a batch header. The article explains the choice of a specific type of fan. As conclusions on the article under consideration, the results of the conducted research are shown. In particular, the ranges of optimal values of a number of parameters of the considered fan, such as, for example, the power consumption of the fan and its performance, are presented. All the research results shown in the article relate directly to a particular case of a fan – a fan that is part of a device for collecting free grain.

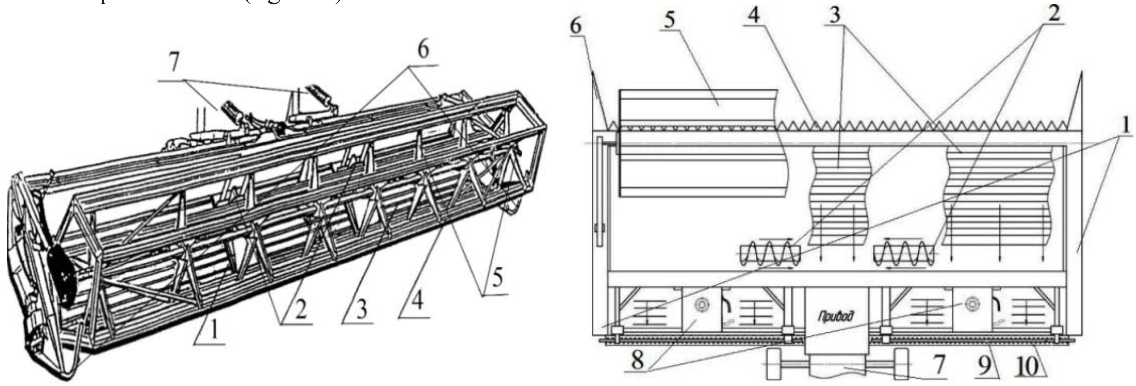
INTRODUCTION

The conducted studies of the reaper designed for two-phase harvesting by batch method, its design and technological features, allowed us to identify the optimal operating parameters of its operation and justify its design features in such a way as to minimize the loss of grain of all types [1, 2]. However, it should be understood that it is impossible to reduce grain losses to zero due to many factors – the inability to constantly maintain an optimal combination of natural and climatic and time intervals of harvesting, the heterogeneity of agrobiological properties and qualities of the harvested crop even on the scale of a single field, a significant gradation of weather conditions, the presence of vibrations and inertial processes inevitable for any mechanism, etc. [3-5]. This conclusion showed the prospects of research on reducing grain losses in another direction – the development of technical means to save grain, which in the context of standard technology can already be considered lost [6]. In addition to directly developing such a device, the justification of its technical and technological parameters is of indisputable importance.

International Conference on Modern Trends in Manufacturing Technologies and Equipment 2021
AIP Conf. Proc. 2503, 030019-1–030019-5; https://doi.org/10.1063/5.0105427
Published by AIP Publishing. 978-0-7354-4221-4/$30.00

METHODOLOGY

As a solution to the above problem, a modernized reaper designed for two-phase harvesting by batch method was developed, the design of which was introduced with a device for collecting free grain (RF patent No. 2523847), i.e. grain material that came out of the ear in contact with the main nodes of the reaper or due to over-ripening of the harvested crop in the field (figure 1).



a b

FIGURE 1. Design scheme of a reaper designed for two-phase harvesting by batch method with a device for collecting free grain: a – general view, b – top view: 1 – reaper frame; 2 – devices to prevent cut stems from getting under the wheels; 3 – conveyor belt; 4 – the cutting apparatus; 5 – the device for bringing the stalks to the cutting apparatus; 6 – dividers; 7 – reaper hitch; 8 – hopper of the device for free grain; 9 – sieve with funnels of the device for free grain; 10 – discharge gate

In the design and technological scheme of the device for collecting free grain, the fan is one of the main components. In this regard, both from a scientific and practical point of view, it is important to identify and justify the patterns that determine its operating modes and parameters, as well as the factors that influence them. Justification of these indicators and identification of their optimal values will optimize the process of preventing grain losses during the operation of the conveyor.

A radial fan is selected as the fan of the device for collecting free grain. The choice in favor of this type of fan is explained by the fact that it is not characterized by the well-known disadvantage of axial-type fans, which consists in the fact that the impact of the fan blades on the air particles is not the same along their length, that is, the closer the air particles are located to the center, the worse they are captured by the blades. In addition, axial fans create a relatively small air vacuum [7, 8].

The choice of the fan and its operating modes was justified taking into account its main parameters, such as drive power, fan speed, as well as the required air consumption [7, 9].

The optimal power for the fan drive can be set as follows [7]:

$$N_в \geq \frac{K_{зу} \cdot V \cdot P_в}{\eta_{пр} \cdot \eta_в}, \text{ W} \quad (1)$$

where $K_{зу}$ - stock ratio, equal to 1.5; V - required air flow, m^3/s; $P_в$ - pressure in the device for collecting free grain, Pa; $\eta_{пр}$ - efficiency factor of the drive; $\eta_в$ - efficiency factor of the fan.

$$P_в = 10^5 - \Delta P_\Sigma, \text{ Pa} \quad (2)$$

where ΔP_Σ - total pressure loss:

$$\Delta P_\Sigma = \Delta P_B + \Delta P_M + \Delta P_П + \Delta P_P, \text{ Pa} \quad (3)$$

where ΔP_B - pressure loss in the pipeline during the movement of clean air, Pa; ΔP_M - pressure loss during material movement, Pa; $\Delta P_П$ - pressure loss when lifting the material, Pa; ΔP_P - acceleration pressure loss, Pa [10].

$$\Delta P_B = \lambda_в \frac{L_{пр.в}}{d_T} \cdot \upsilon_в^2 \cdot \gamma_в, \text{ Pa} \quad (4)$$

where $\lambda_в$ - coefficient of resistance when moving clean air; $L_{пр.в}$ - the reduced length of the transport pipeline when moving clean air, m; d_T - pipeline diameter, m; $\upsilon_в$ - speed of the conveying flow, m/s; $\gamma_в$ - air density, kg/m^3.

When clean air is moving, the reduced length of the transport pipeline is equal to [7]:

$$L_{пр.в} = L_г + L_в \text{ , m} \tag{5}$$

where $L_в$ - length of the vertical part of the pipeline, m; $L_г$ - length of the horizontal part of the pipeline, m;

The value of the diameter of the device pipeline is defined as:

$$d_T = \sqrt{\frac{Q}{\pi \cdot \upsilon_в \cdot \mu}}\text{, m} \tag{6}$$

where Q - productivity, kg/s; μ - weight concentration of the mixture, kg/m^3.

In the case of working with a complex mixture – in our case, it is a mixture that includes grain, air and possible impurities – the value of the weight concentration will be 25 kg/m^3 [11].

The required productivity of the device for collecting free grain is defined as:

$$Q = \frac{B \cdot \Delta \cdot \Psi \cdot b_{м.в.} \cdot b_{ж}}{t_{раз}}\text{, kg/s} \tag{7}$$

where B - crop yield on the field in terms of per square meter, kg/m^2; Δ - coefficient of grain loss before contact with the device; Ψ - coefficient that takes into account the compensation of losses while maintaining free grain, 0.65…0.90; $b_{м.в.}$ - roll spacing (correction for areas of the header that are not occupied by the width of the conveyor), m; $b_ж$ - conveyor width, 8m; $t_{раз}$ - time of unloading a portion of bread mass, c.

The unloading time is calculated as follows:

$$t_{раз} = \frac{b_в}{\vartheta_{агр}}\text{, c} \tag{8}$$

where $b_в$ - roll width, m; $v_{агр}$ - reaper speed, m/s.

Substituting the expressions (7) and (8) into the dependence (6), and also taking into account that the values of some components in these expressions are known and constant, we obtain the following regularity for determining the diameter of the pipeline, which is characteristic of our particular case:

$$d_T = \sqrt{\frac{0{,}32 \cdot B \cdot \Delta \cdot \Psi \cdot b_{м.в.} \cdot v_{агр}}{\pi \cdot v_в \cdot b_в}}\text{, м,} \tag{9}$$

where 0,32 – a constant obtained as the ratio of the known values of the header width to the weight concentration of the mixture.

According to the results of the performed studies, the optimal values of the pipeline diameter of the free grain collection device were identified, which are in the range of 0.16-0.22 m.

During the movement of the material, the pressure loss will be determined as follows:

$$\Delta P_м = \lambda_м \cdot \mu \frac{L_{пр.м}}{d_T} \cdot \upsilon_в{}^2 \cdot \gamma_в\text{, Pa} \tag{10}$$

where $\lambda_м$ - the drag force during the movement of the mixture and air, which is selected according to the schedule; $L_{пр.м}$ - the reduced length of the pipeline for the case of movement of clean air with the material, which is set by the formula:

$$L_{пр.м} = L_г + L_в + L_{эсм}\text{, m} \tag{11}$$

where $L_{эсм}$ - pipeline length for local equivalent resistance, m.

To determine the pressure loss on the lifting of the material, you can do the following:

$$\Delta P_п = \mu \cdot \gamma_в \cdot H \cdot g \cdot \frac{\upsilon_в}{\upsilon_м}\text{, Pa} \tag{12}$$

where H - the height of the vertical section of the pipeline, m; $\upsilon_м$ - material movement speed.

Next, we determine the value of the pressure loss on the acceleration of the material:

$$\Delta P_p = \Omega \cdot \varepsilon \cdot \mu \cdot \upsilon_в^{\,2} \cdot \gamma_в\text{, Pa} \tag{13}$$

where Ω - number of inputs; ε - bending coefficient, (determined from the catalog, depends on the radius and angle of bending and the Reynolds number).

Can be can set the required air flow *V* for the current performance by using the following expression:

$$V = \frac{\pi \cdot d_T^{\,2}}{4} \upsilon_в\text{, m}^3\text{/s} \tag{14}$$

Substituting the expressions (2) and (14) in the formula (1), we get:

$$N_в \geq \frac{K_{зу}}{\eta_{пр} \cdot \eta_в} \cdot \frac{\pi \cdot d_T^{\,2}}{4} \upsilon_в \cdot \left(10^5 - \left[\frac{\lambda_в \cdot L_{пр.в} + \lambda_м \cdot \mu \cdot L_{пр.м}}{d_T} + \frac{\mu \cdot H \cdot g}{\upsilon_в \cdot \upsilon_м} \cdot + \Omega \cdot \varepsilon \cdot \mu\right] \cdot \upsilon^2{}_в \cdot \gamma_в\right) \tag{15}$$

RESULTS AND DISCUSSION

Performing some transformations of the resulting expression, taking into account the features characteristic of our particular case, took into account, among other things, that for grain, the speed of the transporting flow is 22 m/s [11], and the air density is selected depending on the design of the device according to the catalog – based on the operating conditions and features of the device known to us, we choose the air density value equal to 12 kg/m^3 [7]. Accordingly, the components $v_в^2$ and $\gamma_в$ for our case have constant and known values, and their product is 5808. You should also pay attention to the fact that the stock ratio of $K_{зу}$ is 1.5:

$$N_в \geq \frac{0{,}12 \cdot B \cdot \Delta \cdot \psi \cdot в_{м.в.} \cdot \upsilon_{агр}}{\eta_{пр} \cdot \eta_в} \cdot \left(10^5 - 5808 \cdot \left[\frac{\lambda_в \cdot L_{пр.в} + \lambda_м \cdot \mu \cdot L_{пр.м}}{d_T} + \frac{\mu \cdot H \cdot g}{\upsilon_в \cdot \upsilon_м} \cdot + \Omega \cdot \varepsilon \cdot \mu\right]\right) \tag{16}$$

In order to bring the above regularity to a more compact and convenient expression, we will replace some of the components that are inherently close to constant values with symbols:

$$K_1 = \lambda_в \cdot L_{пр.в} + \lambda_м \cdot \mu \cdot L_{пр.м}\text{, м;}\quad K_2 = \frac{\mu \cdot H \cdot g}{\upsilon_в \cdot \upsilon_м}\text{, м/с;}\quad K_3 = \Omega \cdot \varepsilon \cdot \mu$$

Taking into account the above, we will write down the final form of the resulting formula:

$$N_в \geq \frac{0{,}12 \cdot B \cdot \Delta \cdot \psi \cdot в_{м.в.} \cdot \upsilon_{агр}}{\eta_{пр} \cdot \eta_в} \cdot \left(10^5 - 5808 \cdot \left[\frac{K_1}{d_T} + K_2 + K_3\right]\right)\text{, W} \tag{17}$$

CONCLUSIONS

The conducted studies allowed us to justify the ranges of optimal values of a number of parameters of the fan of the device for collecting free grain. In particular, the fan power consumption of the device is in the range of 1.03-1.15 kW, the performance when operating without grain (determined for correlation with the factory data of serial fans when evaluating their suitability for use in the device in question) – 0.412-0.476 m^3/s, the rotation speed-up to $43c^{-1}$, and the created pressure (discharge) in the system-from 2.8 to 3.2 kPa.

REFERENCES

1. Konstantinov M., Glushkov I., Nesvat A., Gerasimenko I. and Ognev I. *Features of snow retention and counteraction to wind erosion of soils due to high stubble residues formed by a reaper designed for two-phase harversting by batch method*. Proceedings of International conference «International conference on modern trends in manufacturing technologies and equipment, ICMTMTE 2020», September 07-11, Sevastopol, Source: E3S WEB OF CONFERENCES, Publisher: EDP Sciences, P. 01016, (2020).
2. Konstantinov M., Glushkov I., Ognev I. *Justification optimal operating parameters of the conveyor, which is the mechanism of the header for two-phase harvesting by batch method, taking into account the minimization of losses of grain.* Proceedings of International conference «International conference on modern trends in manufacturing technologies and equipment, ICMTMTE 2019», September 09-13, Sevastopol, Source: E3S WEB OF CONFERENCES, Publisher: EDP Sciences, P. 00046, (2019)
3. I. V. Bumbar, V. V. Epifantsev, O. V. Shchegorets, V. T. Sinegovskaya, E. E. Kuznetsov, A. A. Kuvshinov, I. A. Lontseva, N. A. Kapustina, *Optimization of agrotechnical terms of harvesting of crops, design and operating parameters of crop-harvesting machines under conditions of the Amur region,* Russian Federation. Plant Archives, **18** (2), pp. 2567-2572, (2018).
4. S. R. Mkrtchyan, V. D. Ignatov, E. V. Zhalnin, N. I. Struzhkin, *Reapers separating the ear part from the stem: state and prospects of development*. Agricultural machines and technologies, **4**, pp. 18-21, (2013).
5. O. A. Fedorova*, Factors affecting the use of combine harvesters*, Proceedings of the lower Volga agrodiversity complex: science and higher professional education, **4** (48), pp.239-245, (2017).
6. M. M. Konstantinov, I. N. Glushkov, etc. *Justification of the parameters of the sieve holes of the device for collecting free grain, which is part of the reaper designed for two-phase harvesting in batches* // In the collection: Improving the engineering and technical support of technological processes in the agro-industrial complex: materials of the international scientific and practical conference. 2017. pp. 89-94.
7. M. M. Konstantinov, I. N. Glushkov, etc. *Justification of the operating and design parameters of the fan of the device for collecting free grain which is part of the reaper designed for two-phase harvesting in batches*. Collection of proceedings of the conference «Actual problems of scientific and technical support of processes and productions in the agro-industrial complex» // Novosibirsk State Agrarian University, Engineering Institute-Novosibirsk: Zolotoy kolos. - 2016. - pp. 74-78.
8. Startsev A S, Protasov A A 2015 *Theory of sunflower heapse parationprocess by a sieve with adjustable outlets in harvester cleaning*. *The Agrarian Scientific Journal.* **10** 52–54, (2015).
9. V. Safonov, M. Lapa, D. Bordan, E. Zhalnin, *Use of vortex flows for aerodynamic threshing of agricultural crops.* Proceedings of International conference «International conference on modern trends in manufacturing technologies and equipment, ICMTMTE 2019», September 09-13, Sevastopol, Source: E3S WEB OF CONFERENCES, Publisher: EDP Sciences, P. 00004, (2019).
10. Startsev A S, Makarov S A, Nesterov E S, Kazakov Yu F and Terentyev A G 2020 *Comparative evaluation of the operation of a combine harvester with an additional sieve with adjustable holes for sunflower harvesting*. IOP Conf. Ser.: Earth Environ. Sci. **433** 012007, (2020).
11. Startsev A S *Mathematical expression for determining the loss of sunflower seeds from air flow using a sieve with adjustable holes*. Izvestia Orenburg State Agrarian University. Theoretical and Scientific-Practical Journal. **4(78)** 119–122, (2019).