Graph model development in the context of the grain cleaning machine

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Abstract. Schematic layout and graph model of seed-cleaning unit are introduced in the article. Input vector, vector of control factors and vector of output characteristics are mentioned. The general mathematical model of purification section process is given. This model together with an oriented graph allows to conduct a program forecast and to find out the rational directions of increasing the efficiency of the work of individual working bodies and the system as a whole.

1 Introduction

The development of agricultural areas is not possible without the introduction of modern means of mechanization aimed at increasing labor productivity. Post-harvest processing is an important stage in the harvesting system. This kind of work operates at the universal seed-cleaning units, able to function in the following modes: primary, preliminary and seed ones, representing a system of machines which use different principles of separation from the original clogged grain heap coming after combine cleaning, outside impurities with bringing the grain to basic conditions.

The analysis of the scientific researches [1-13] on increasing the efficiency of the functioning of individual elements of the system allowed to elicit the following problem - despite a significant increase in the efficiency of the operation of a single element of the system (working body that performs the technological process) its efficiency is leveled by work of other elements of the system and as a consequence, the efficiency of the entire system changes statistically insignificantly.

2 The goal setting and description of the research object

The goal is to introduce a seed-cleaning unit as a system of individual technological operations using a graph model. The obtained model will allow to carry out the program forecast and to reveal rational directions of increasing the efficiency of separate private technological operations.

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The research object is the seed-cleaning unit (Fig.1), the unit, which includes a grain cleaning machine and an indented cylinder. The conducted researches with the purpose of minimization of private technological operations have allowed to allocate a number of functional schemes of the grain cleaning units representing a system of interconnected particles of technological operations represented by a closed finite graph.

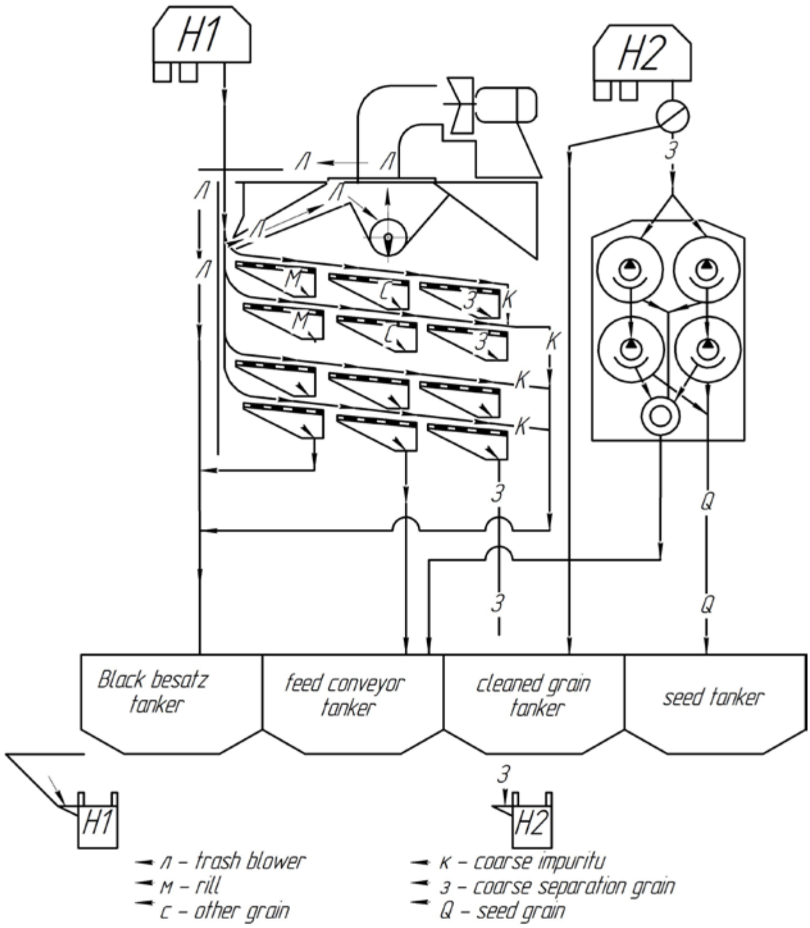

Fig. 1. Functional scheme of the grain cleaning unit.

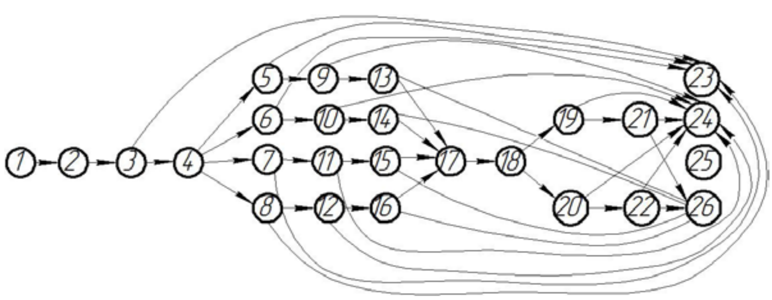

Fig. 2. Oriented graph of the functional scheme of the seed cleaning unit.

Each point X1 of a finite closed graph G(X,U) represents X1 particular technological operation of equation X={X1, X2, …, X26}. Here: X1 – is an accumulation of initial grain material, X2 is distribution of grain material along the width of the pneumatic duct, X3 is pneumatic separation of grain material in the aspiration duct of the air-grating machine at the input to the machine, X4 is the distribution of the flow of grain material to sieves, X5, X6, X7, X8 - separation of fine impurities from the grain material, X9, X10, X11, X12 - separation of impurities from the grain material, X13, X14, X15, X16 - sieving of the purified grain and the release of large impurities by descent, X17- pneumatic separation of the grain material in the aspiration channel of the VRM at the output of the machine, X18 - distribution of the flow of grain material; X19, X20 - separation of long - grain material components; X21, X22- isolation of short-grain material; X23, X24, X25, X26 - operation, accumulation and temporary storage respectively of weed and feed waste, the grain - food purposes and seeds.

3 The Description of mathematical model

For the model forecast, we used the generalized mathematical model of the functioning of the purification units of aggregates constructed as a system of interrelated assigned private technological operations. The mathematical model in general form with a partial disclosure of analytic constructions of its functionals is defined as follows.

The input effect on the system of operations with different structures is determined by the vector F whose independent arguments are random in the probabilistic-statistical sense of magnitude:

$$\vec{F} = \{Q, a_j, W, \gamma, M_{bj}, \sigma_{bj}, f_Q(B_i), f(L_i)\}. \tag{1}$$

The system functioning is provided by vector $\vec{A}$ of control factors

$$\vec{A} = \begin{Bmatrix} B_{ni}, h_{ni}, V_{bi}, f_V(B_{ni}), b_i, f_i(\Pi_i), \alpha_i, \beta_i, \\ n, R, T_i, L_i, B_i, C, K_\mu(x), T_{TOi}, T_{T\kappa i}, n_{Ti}, T_\delta(x) \end{Bmatrix} \tag{2}$$

Where Q, W, γ, a_j - is a grain supply, its wetness, bulk density and the content of j components.; M_{bj}, σ_{bj} - is a mathematical expectation and the standard deviation of the size of the separation characteristic of j component; $f_Q(B_i)$ - the probability density of the distribution of the supply of grain material over the width of B i sieve; $f(L_i)$ - is regularity of the receipt of grain material on i sieve; B_{ni}, h_{ni} - is a width and depth of i pneumatic duct of a separator; V_{bi}, $f_V(B_{ni})$ - is an average pace of air flow and probability density of its distribution along the width B Π_i-x of a pneumatic duct; $f_i(\Pi_i)$ - is a way of introducing the grain into *i*- *pneumatic* duct; T_{TOi}, $T_{T\kappa i}$ - is a working area of cockle and oat intended separator cylinder; n_{Ti} - is a rotation frequency of i - cylinder; $T_\delta(x)$ - is functional circuit of trier units.

The output characteristics of the system under consideration are determined by the vector

$$\vec{B} = \{E, \Xi, \varepsilon_{kj}, a_{no}, b_j, b_C, b_{\Pi 3}, a_1, a_4, Q_\Phi, Q_{OH}, Q_O\} \tag{3}$$

Here E, Ξ - is the criterion for the efficiency of grain cleaning and separation efficiency criterion; ε_{kj} - is the completeness of the output of the grain material of j-component in the purified grain; a_1 - is weight fraction of the yield of the screenings grains; a_4 - is weight fraction of the yield of the grain refined in the aggregate; a_{no}, b_j, b_C, $b_{\Pi 3}$ - is cleanliness of cleaned grain, the content of j-components in it, foreign material and grain impurity; Q_Φ, Q_{OH} - is forage unused waste; Q_O - is unit capacity.

Mathematical example of the performance of seed cleaning unit in general:

$$E = \{F_O, A_O, Q_\delta[K_\delta(x), T_\delta(x), M_\delta(x)]\} \quad (4)$$

$$E \to \max; \ A_O \subset \vec{A}; \ F_O \subset \vec{F}; \ x \in G(x,k)$$

$$\varepsilon = (1-(1-\varepsilon_{ПК1} \cdot k_{ПК1})(1-\varepsilon_{РМ1} \cdot k_{РМ1})(1-\varepsilon_{ПК2} \cdot k_{ПК2})(1-\varepsilon_{ТБ}))$$

Where $\varepsilon_{ПК1}$, $\varepsilon_{ПК2}$, $\varepsilon_{РМ}$, $\varepsilon_{ТБ}$ - is the completeness of the components of the grain heap in pneumatic duct on the input and output of the air-sieved machine, on the sieve unit and intended cylinder.

The received mathematical models (1)-(4) of the grain separation process in the considered structures of the purification section allow us to form the patterns, programs for computer, to have multivariate analysis, parametric synthesis of basic separators and the estimation of unit cleaning performance indicator at given levels of variation of the arguments of the input and control vectors.

The adequacy of description by analytical model of real processes is checked earlier with comparison of calculated and experimental data for separate working units and for system as a whole. The analysis of the accuracy of the estimation of separation indices and the results of comparative analysis has approved the opportunity of its using for parametric synthesis and multivariate analysis of regularities of functioning of modern grain cleaning aggregates. [13]

Taking into account that Q variations and technological properties a_j, W of grain material, feeding into the seed-cleaning unit influence the rational parameters of the arguments of the vector $\vec{A}$ of control factors using the developed set of programs(see the form.2), for each grain feeding and its discretely specified technological properties parametric optimization of grain cleaning separation was held. Taking into account the nonlinear nature of mathematical models (see form.(1)-(4)), the presence of limitations on the arguments of the vector $\vec{A}$ of control factor, nonlinearity of expressions describing the limitations on technological indicators of the process of separation of grain material, lack of confidence in the unimodality of the model, a scanning method with limitations is used as a method of nonlinear mathematical programming. Varying the initial data with forecast indicators of possible performance increasing of separate elements it is possible to find out more rational ways of increasing the efficiency of the system due to increasing the efficiency of particular technological operations.

4 Conclusion

The given methodology of the program forecast and identification of the rational directions of the increase of efficiency of separate private technological operations is recommended to apply at the initial stages of making decisions on the intensification of functioning of work of the separate working bodies and systems including them.

References

1. D.S. Tarabrin, Improving of the process of pneumocephaly grain heap in two suction cleaning machines: Dis. ... Ph.D. in Engineering Science, (Voronezh, 2018), 159 p.
2. A.M. Gievsky. Increasing the efficiency of universal air grating grain cleaning machines:D. in Engineering Science, (Voronezh, 2016), 364 p.
3. A.A. Doroshenko. Intensification of the process of pneumoseparation of grain material in the grain cleaning unit: Dis. ... Ph.D. in Engineering Science,

(Rostov-on-Don, 2015), 296 p.

4. S.V.Saitov. Improving the efficiency of grain cleaning machines by improving their main working units and pneumatic systems with fractional separation: Dis. ... Ph.D. in Engineering Science, (Cheboksary, 2014)
5. D.K. Muratov. The process intensification of separation of small grain heaps in air-screen cleaning of a combine harvester: Dis. ... Ph.D. in Engineering Science, (Rostov-on-Don, 2012), 220 p.
6. A.V. Butovchenko. The process intensification of separation of grain materials in the purification unit of a seed cleaner: Dis. ... Ph.D. in Engineering Science, (Rostov-on-Don, 2009), 235 p.
7. M.U. Kochkin. The process perfection of separation of grain material in the grain cleaning unit: Dis. ... Ph.D. in Engineering Science, (Rostov-on-Don, 2010), 328 p.
8. N.O. Kurinaya. Increasing the efficiency of grain separation by circular oscillations of sieves in the regime of self-cleaning of the holes from the stuck particles: Dis. ... Ph.D. in Engineering Science, (Kurgan, 2009), 174 p.
9. V.A. Khandrikov. The efficiency increase of the seed lines for processing small batches of wheat seeds by improving the technology and the final cleaning machine: Dis. ... Ph.D. in Engineering Science, (Perm, 2009), 197 p.
10. L.V. Borisova. The process intensification of grain heap separation with jet airflows enrichment: Dis. ... Ph.D. in Engineering Science, (Zernograd, 2001), 237 p.
11. A.V. Butovchenko, *High-tech seed cleaner*, Bull. DSTU, **3 (64)** pp. 16-21 (2012)
12. U.I. Ermoliev, A.V. Butovchenko, A.A. Doroshenko, S.V. Belov, *The process modeling of grain heap separation in a vertical pneumatic duct*, Bull. DSTU, **7(68)**, pp. 90-98 (2012)
13. U.I. Ermoliev, A.V. Butovchenko, M.N. Moskovsky, M.V. Shelkov, *The technological processes designing of air-grating and grating grain cleaning machines* (Publishing center DSTU, Rostov-on-Don, 2010)