АВТОМАТИЗАЦІЯ
ТА КОМП'ЮТЕРНО-ІНТЕГРОВАНІ ТЕХНОЛОГІЇ

УДК 681.5+631.354.2 DOI: https://doi.org/10.32515/2664-262X.2023.7(38).2.98-104

Sergey Osadchy, Prof., DSc.
Flight Academy of the National Aviation University, Kropyvnytskyi, Ukraine
Larisa Vikhrova, Prof., PhD tech. sci., **Mariya Miroshnichenko**, Assoc. Prof., PhD tech. sci., **Valentin Soldatenko,** Assoc. Prof., PhD tech. sci.
Central Ukrainian National Technical University, Kropyvnytskyi, Ukraine
e-mail: srg2005@ukr.net, vihrovalg@ukr.net, marymir@ukr.net

Information technology for Synthesizing a Grain Mass Flow Multidimensional Optimal Stabilization System with Perturbation Feedback

The article presents a new methodology for creating information technology for designing a combined system for stabilizing the flow of bread mass at the entrance to the thresher of the grain harvester. The characteristic features of this methodology are outlined.

This makes it possible to design control systems for technological processes on the harvester taking into account external influences that are stochastic in nature.

The stage of creation of the information technology of the synthesis of the optimal combined stabilization system with feedback on the deviation of the bread mass from the average value and correction on the yield change is substantiated.

stabilization of the flow of bread mass, optimal systems, synthesis of systems, information technologies, stages of research

Formulation of the problem. In recent years, a trend in the development of grain-harvesting equipment has emerged, which consists in its computerization and operation as part of a precision farming system, which allows optimizing the modes of operation of grain-harvesting equipment according to the criteria of minimum crop losses and maximum productivity.

The results of research by scientists in the field of designing grain harvesting equipment and creating systems for stabilizing the flow of bread mass in the combine thresher [1,2] show that it is advisable to maximize the quality of grain collection by creating optimal combined systems for stabilizing the flow of bread mass at the entrance to the thresher. The structure and parameters of the specified systems should be determined taking into account the dynamics models of the stabilization object (polynomials M1, P1, Fig. 1), sensors in the feedback circuits for the deviation K1 and in the correction circuit for the disturbance K2, disturbances $\psi 1$, $\psi 2$ and disturbances $\varphi 1$, $\varphi 2$, inherent in the real operating conditions of the harvester, based on modern effective methods of automated design of control systems.

The concept of such an approach to the creation of automatic control systems is [4, 6] that, as a result of solving the so-called analytical design problem, even before the start of the main design of the system, the boundary lines of improving its quality should be assessed, as well as the optimal structure should be synthesized, not only the parameters the regulator, but also to determine the expediency of starting work related to the creation of a new system. At the same time, the main material and time costs for the design, manufacture and testing of the product arise only after a positive decision has been made regarding the feasibility and quality of the system.

Analysis of recent research and publications. Studying the features of the procedures for the creation and construction of modern existing systems for stabilizing the flow of bread mass according to literary sources [1,2] allows us to identify a number of reasons that do not allow to dramatically increase the competitive capabilities of this agricultural technique. First, the differential equations of the grain harvester do not take into account the dynamic properties and design features of hydraulic transmissions operating in the mode of constant load changes. Secondly, traditional approaches to determining the structure and parameters, which are used for the development of control systems for technological processes on the harvester, are designed for the action of only regular external influences, while real disturbances and disturbances are of a stochastic nature. Thirdly, the existing methods of synthesis of optimal combined stabilization systems allow to successfully determine the structure and parameters of the two-channel controller, if the system has only one controlled source of disturbance at the input of the stabilization object.

Setting objectives. To overcome the identified shortcomings, we propose to spread the effect of the experimental and analytical method [4] of developing optimal stabilization systems in case of minimizing the fluctuations of the flow of bread mass at the entrance of the thresher of the grain harvester by developing information technology for the synthesis of the optimal combined stabilization system with feedback based on the deviation of the bread mass from average value and correction for changes in yield.

Presenting main material. Such an experimental and analytical approach allows you to drastically reduce the costs of creating an automatic control (stabilization) system due to the reduction of testing and debugging work, determining the possible limits of maximizing the quality of control even at the stage of creating a technical proposal, formalizing the procedures for synthesizing the stabilization system and analyzing its quality, bringing the final design to implementation of optimal control laws, which are found analytically.

On the other hand, the successful spread of such an approach to solving the problem of achieving objectively maximum efficiency of grain collection due to the development and implementation of an optimal combined system for stabilizing the flow of bread mass at the entrance of the thresher requires [3, 4, 6]:

1. Formulation of the task of synthesis of the combined system of stabilization of the flow of bread mass at the entrance to the thresher in terms of dynamic design [4, 5] of optimal systems of stochastic stabilization of dynamic objects.

2. The availability of information about the dynamics model of the generalized control object "the angle of inclination of the washer of the cylinder block - the flow of bread mass at the entrance to the thresher", in the form of a transfer function or a differential equation, which correspond to the work of the organizational and technical system of the grain harvester in real operating conditions.

3. Models of the dynamics of disturbance changes (field topography, crop yield), which accompany the grain collection process, and measurement noises acting on the outputs of sensors of the combined stabilization system.

4. The availability of algorithms for determining the dynamics models of the control object, sensors of measurement information, disturbances and interferences, as specified above, synthesis of optimal combined stabilization systems and analysis of their quality in real conditions of grain harvesting, appropriately adapted to the conditions of the given task.

5. Software and technical means of automated design of optimal control systems of the specified class.

Taking into account the requirements 1.-5., let's set the problem of synthesizing the optimal combined system of stabilization of the bread flow with feedback on the deviation of the bread mass from the average value and correction on the change in yield (Fig. 1) as follows.

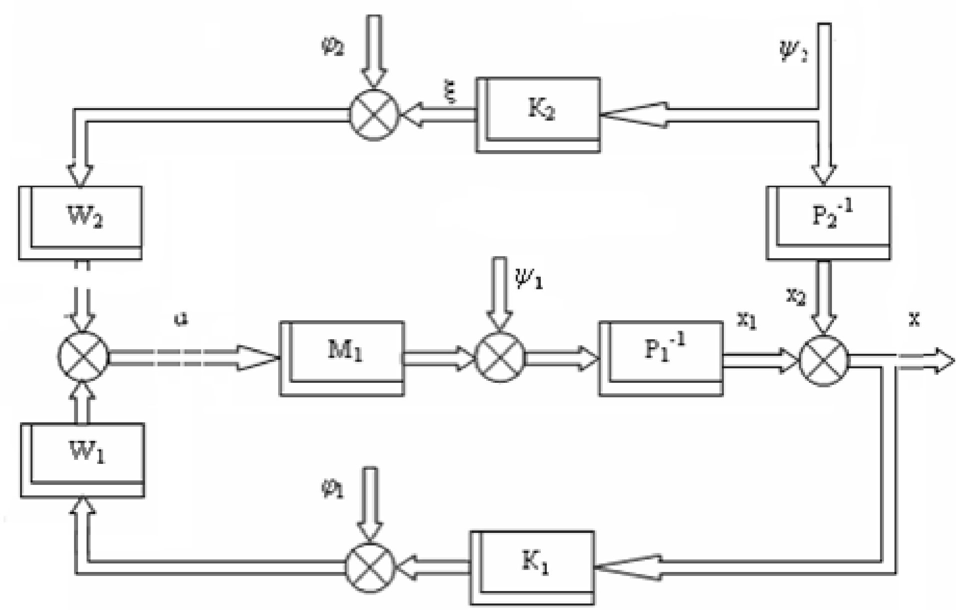

Figure 1 – Structural diagram of the combined stabilization system

Source: own research

Given:

• bread mass flow at the entrance to the thresher combine stabilization system structure;

• necessary geometric parameters of the combine;

• dynamics of bread mass flow sensors (matrix of transfer functions K_1) and yield change sensors (K_2);

• dynamics characteristics of changes in noise (errors) at the outputs of sensors, vectors φ_1 and φ_2;

• numerical characteristics of the change in the topography of the field ψ_1, as a stationary random process;

• field yield map;

• a differential equation that relates the change in torque on the wheels of the combine with the change in grain flow

$$\begin{cases} P_1 x_1 = M_1 u + \psi_1 \\ P_2 x_2 = \psi_2 \\ x = x_1 + x_2 \end{cases}, \quad (1)$$

where

x, x_1, x_2 – n-dimensional vectors of the initial coordinates of the control object;

u – m- dimensional vector of control signals;

P_1, P_2 - are polynomial matrices from the differentiation operator $s=d/dt$ of size $n \times n$, which determine the change in the initial coordinates of the object when the perturbation vectors ψ_1, ψ_2 change;

M_1 is a polynomial matrix from the differentiation operator s of size $n \times m$, which characterizes the sensitivity of the control object to changes in the components of the vector u.

It is necessary to determine:

• the spectral density of yield change (ψ_2) when the harvester moves at a given average speed;

• matrices P_1, P_2, M_1 of the generalized control object "the angle of inclination of the washer of the cylinder block – the flow of bread mass at the entrance to the thresher" operation under the grain harvesting conditions differential equations (1) system;

• regulator transfer functions matrices' W_1, W_2 structure and parameters , the inclusion of which in the feedback and correction circles ensures the stability of the closed-loop system "object-regulator" and minimizes the bread mass flow at the entrance to the thresher fluctuations with limited control resources in real conditions of changes in yield, field relief and measurement noise;

• the effect of using the optimal combined stabilization system and the ultimate possibilities of increasing stabilization accuracy with limited control resources in real conditions of changes in yield, field topography and noise;

• microprocessor controller functioning algorithm and structure, of the optimal combined stabilization system for bread mass flow at the entrance of the thresher.

The application of an experimental-analytical approach to the solution of the given task requires the implementation of a number of diverse but interconnected stages of scientific research, the sequence of which determines the information technology for solving the given task.

At the stage of preparation for carrying out research, it is necessary to study the features of the design of modern grain harvesters and the principles of creating models of the dynamics of the system of processing bread mass into grain. In addition, determine, if possible, models of dynamics or characteristics of changes in factors that make it difficult to achieve the maximum quality of stabilization of the flow of bread mass, and justify the choice of possible methods of automatic stabilization of such a flow. The results of experimental research conducted by us [7] showed that a sharp increase in the quality of stabilization of the flow of bread mass at the entrance to the thresher can be achieved due to the use of the combined principle of stabilization by mass deviation and yield change. However, the successful application of such a principle for the guaranteed minimization of grain mass flow fluctuations in real conditions of harvesting requires the development of new methods, techniques and means of developing optimal combined stabilization systems with correction for the disturbance acting on their output.

At the first stage of research, based on the study of methods of modern control theory and their comparison with information about the dynamics of the control object, controlled and uncontrolled disturbances and measurement disturbances, justify the choice of existing or develop new methods of synthesis of the optimal structure and parameters of combined stabilization systems, develop quality analysis algorithms such two-circuit closed systems, as well as to create a method of refining the dynamics model of the generalized control object "the angle of inclination of the washer of the cylinder block – the flow of bread mass at the entrance to the thresher".

The second stage of research completes the development of the methodology for designing an optimal combined stabilization system with deviation feedback and disturbance correction. At this stage, it is necessary to develop, based on the obtained methods of determining the dynamics of the control object, synthesis and analysis of optimal closed stabilization systems in the frequency domain: a method of determining the spectral density of yield fluctuations in the direction of movement of the grain harvester; structural identification of the transmission function of the hydrotransmission and the spectral density of disturbances acting on it during operation in a loaded mode; technologies for researching the quality of the synthesized combined system; as well as software for factorization and separation of fractional-rational functions in the MATLAB engineering calculation system.

The implementation of the third stage of research is devoted to the evaluation of dynamics models: a generalized control object and vectors of controlled and uncontrolled perturbations that operate under the conditions of movement of a combine harvester across a field, the terrain of which and yield change randomly. The initial data for this stage consists of a field yield map, records of laboratory bench tests of the hydraulic transmission, known models of the dynamics of the longitudinal movement of the harvester, characteristics of macro irregularities of the field, which are described by a system of equations of the type (1), metrological characteristics of sensors for the flow of grain mass and yield changes. The methodological basis consists of the relevant algorithms and methods of their application, determined at stages I, II.

The purpose of the fourth stage of research is to determine the structure and parameters of the matrix of the transfer functions of the two-channel controller of the optimal combined stabilization system and the matrix of the transfer functions of the single-channel controller of the conventional optimal stabilization system, which allow to evaluate the effect of the application of the combined principle of regulation to achieve the goal of the dissertation. The initial data for the execution of these studies are the corresponding results of stage III. As a result of the synthesis of the combined stabilization system at different levels of the average yield of the field, obtain nomograms of changes in the parameters of the matrix of optimal transfer functions.

The fifth stage of research consists of two stages. At this stage, based on the transfer functions of the two-channel controller, tactical and technical characteristics of microprocessors of different architectures, and the features of modeling the dynamics of control systems in the SIMULINK environment, it is necessary to develop and apply the methodology for developing a microprocessor control system that implements the matrices of the transfer functions of the two-channel controller, as well as to simulate the operation of the synthesized system in conditions of change in the average yield level.

Conclusions. Thus, the article substantiates the composition and defines the content of operations of the new information technology for designing a combined system for stabilizing the flow of bread mass at the entrance to the thresher of the grain harvester.

The new technology has several distinctive features. First, its implementation allows obtaining differential equations of the grain harvester, which take into account the dynamic properties and design features of hydrotransmissions operating in the mode of constant load changes.

Secondly, it allows designing control systems for technological processes on the harvester, designed for the action of external influences that have a stochastic nature.

Thirdly, the new technology allows for the synthesis of optimal combined stabilization systems under the conditions of action of two multidimensional independent sources of disturbances at the input and output of the stabilization object.

List of references

1. Сисолін П.В., Коваль С.М., Іваненко І.М. Машини для збирання зернових культур методом обчісування колосків . Кіровоград : КОД, 2010. 112 с.
2. Войтюк Д.Г., Яцун С.С., Довжик М.Я. Сільськогосподарські машини: основи теорії та розрахунку: навч. посібник ; за ред. : Д. Г. Войтюка. Суми : Університетська книга, 2008. 543 с.
3. Osadchy S., Zubenko V., Fedotova M. Synthesis of an optimal stochastic stabilization system for an unstable multivariable object with time delays in controls . *2018 IEEE 5th International Conference*

Methods and Systems of Navigation and Motion Control (MSNMC)», October 16-18, 2018 Kyiv, Ukraine IEEE Catalog Number CFP1852Y-RPT . Київ: НАУ, 2014. pp. 114-118.
4. Osadchy S., Zubenko V., Yakoreva M. Synthesis of an Optimal Combined Multivariable Stabilization System for Adsorption Process Control ; Kuntsevich, V.M., Gubarev, V.F., Kondratenko, Y.P., Lebedev, D.V., Lysenko, V.P. (Eds). Control Systems: Theory and Applications. Series in Automation, Control and Robotics, River Publishers, 2018, chapter 13. pp. 315-324
5. Методи сучасної теорії управління: навч. посіб. / А.П. Ладанюк, В.Д. Кишенько, Н.М. Луцька, В.В. Іващук. К.: НУХТ, 2010. 196с.
6. Осадчий С.І. Автоматизація динамічного проектування оптимальних багатовимірних робастних систем стохастичної стабілізації . *Конструювання, виробництво та експлуатація сількогоподарських машин: Загальнодержавний міжвідомчий науково-технічний збірник*, 2010. Вип. 40, ч.1 , С.25-34.
7. Дідик О.К., Мірошніченко М.С. Синтез оптимальної системи стабілізації потоку хлібної маси зернозбирального комбайну . *Вестник национального технического университета «ХПИ» : сб. наук. праць.* Тематический выпуск «Информатика и моделирование». 2011. №36. С.48-51.

References

1. Sysolin, P.V., Koval', S.M. & Ivanenko, I.M. (2010). *Mashyny dlia zbyrannia zernovykh kul'tur metodom obchisuvannia koloskiv* [M*achines for harvesting grain crops by combing ears*]. Kirovohrad : KOD [in Ukrainian].
2. Vojtiuk, D.H., Yatsun, S.S. & Dovzhyk, M.Ya. (2008). *Agricultural machines: basics of theory and calculation* . D. H. Vojtiuka (Ed.). Sumy : Universytets'ka knyha [in Ukrainian].
3. Osadchy, S., Zubenko, V., Fedotova, M. (2014). Synthesis of an optimal stochastic stabilization system for an unstable multivariable object with time delays in controls . Methods and Systems of Navigation and Motion Control (MSNMC)»: *IEEE 5th International Conference* (October 16-18, 2018 Kyiv, Ukraine). IEEE Catalog Number CFP1852Y-RPT . Kyiv: NAU, pp.114-118 [in English].
4. Osadchy, S., Zubenko, V. & Yakoreva, M. (2018). Synthesis of an Optimal Combined Multivariable Stabilization System for Adsorption Process Control . Kuntsevich, V.M., Gubarev, V.F., Kondratenko, Y.P., Lebedev, D.V., Lysenko, V.P. (Eds). *Control Systems: Theory and Applications. Series in Automation, Control and Robotics, River Publishers, 13*, 315-324 [in English].
5. Ladaniuk, A.P., Kyshen'ko, V.D., Luts'ka, N.M. & Ivaschuk, V.V. (2010). *Metody suchasnoi teorii upravlinnia* [*Methods of modern management theory*] . Kyiv: NUKhT [in Ukrainian].
6. Osadchyj, S.I. (2010). Avtomatyzatsiia dynamichnoho proektuvannia optymal'nykh bahatovymirnykh robastnykh system stokhastychnoi stabilizatsii [Automation of dynamic design of optimal multidimensional robust systems of stochastic stabilization] . *Konstruiuvannia, vyrobnytstvo ta ekspluatatsiia sil's'kohopodars'kykh mashyn: Zahal'noderzhavnyj mizhvidomchyj naukovo-tekhnichnyj zbirnyk – Design, production and operation of agricultural machinery: State-wide interdepartmental scientific and technical collection*, *Issue. 40, part.1* , 25-34 [in Ukrainian].
7. Didyk O.K., Miroshnichenko M.S. (2011). Syntez optymal'noi systemy stabilizatsii potoku khlibnoi masy zernozbyral'noho kombajnu [Synthesis of the optimal system for stabilizing the flow of bread mass of a grain harvester]. *Vestnyk natsyonal'noho tekhnycheskoho unyversyteta «KhPY» : sb. nauk. prats'. Tematycheskyj vypusk «Ynformatyka y modelyrovanye» – Bulletin of the National Technical University "Khpy": Sat. of science works Thematic issue "Informatics and modeling", 36*, 48-51 [in Ukrainian].

С.І. Осадчий, проф., д-р техн. наук
Льотна академія національного авіаційного університету, м. Кропивницький, Україна
Л.Г. Віхрова, проф., канд. тех.наук, **М.С. Мірошніченко**, доц., канд. тех.наук, **В.П.Солдатенко**, доц., канд. тех.наук
Центральноукраїнський національний технічний університет, м.Кропивницький, Україна

Інформаційна технологія проектування системи автоматичної стабілізації потоку хлібної маси на вході в молотарку комбайна

У статті представлено нову методику створення інформаційних технологій проектування комбінованої системи стабілізації потоку хлібної маси на вході в молотарку комбайна. Окреслено характерні риси такої методики. Це дозволяє проектувати системи керування технологічними процесами на комбайні з урахуванням зовнішніх впливів, які мають стохастичний характер.

Обґрунтовано етапи створення інформаційної технології для синтезу оптимальної комбінованої системи стабілізації зі зворотним зв’язком за відхиленням маси хліба від середнього значення та поправкою на зміни виходу.

У статті обґрунтовано склад та визначено зміст операцій нової інформаційної технології проектування комбінованої системи стабілізації потоку хлібної маси на вході в молотарку комбайна.

Нова технологія має кілька відмінних рис. По-перше, його впровадження дозволяє отримати диференціальні рівняння зернозбирального комбайна, які враховують динамічні властивості та конструктивні особливості гідропередач, що працюють в режимі постійної зміни навантаження.

По-друге, це дозволяє проектувати системи управління технологічними процесами на комбайні, розраховані на зовнішні впливи, що мають стохастичний характер.

По-третє, нова технологія дозволяє синтезувати оптимальні комбіновані системи стабілізації в умовах наявності двох багатовимірних незалежних джерел збурень на вході та виході об'єкта стабілізації.
стабілізація потоку зернової маси, оптимальні системи, системний синтез, інформаційні технології, етапи дослідження

Одержано (Received) 27.04.2023 *Прорецензовано (Reviewed) 05.05.2023*
Прийнято до друку (Approved) 29.05.2023

УДК 621.869 DOI: https://doi.org/10.32515/2664-262X.2023.7(38).2.104-112

О.В. Щербак, доц., канд. техн. наук, **А.В. Сумінов**
Харківський національний автомобільно-дорожній університет, м. Харків, Україна
С.Л. Хачатурян, доц., канд. техн. наук
Центральноукраїнський національний технічний університет, м. Кропивницький, Україна
e-mail: olegcherbak@gmail.com

Дослідження динамічних навантажень рами фронтального навантажувача з використанням комп'ютерних 3D моделей у середовищі Siemens NX

У статті запропоновано нове рішення з проведення аналізу міцності рами фронтального навантажувача на стадії проєктування за допомогою комп'ютерних 3D моделей у середовищі Siemens NX. Даний метод дозволяє не створювати нову модель рами в металі у натуральну величину для проведення випробувань. Відповідно до запропонованого методу достатньо виконати масштабовану спрощену модель майбутньої рами, провести випробування на міцність та запропонувати конструктивні зміни щодо розробки раціональних параметрів. Такий метод дозволяє суттєво скоротити витрати на матеріали, виробництво та час виготовлення нових виробів.
міцність, рама, навантаження, випробування, 3D модель, динаміка, тривимірне комп'ютерне моделювання, Siemens NX

Постановка проблеми. У ході проєктування нових будівельних та дорожніх машин використовують різноманітні комп'ютерні CAD та CAE програми. Конструктор має можливість задавати певні властивості міцності майбутній конструкції за допомогою розрахунків методом кінцевих елементів. Але вже після виготовлення першого дослідного зразка настає момент, коли для підтвердження попередніх розрахунків на міцність його потрібно випробувати на навантаження, що діють під час виконання технологічних операцій.

Аналіз останніх досліджень і публікацій. Дослідженням з визначення навантажень, які діють у рамах різноманітних транспортних засобів, було присвячено низку робіт: у [1] розглядається метод прогнозування життєвого циклу рами за