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УДК 621.18:66.096:502.33

THE CONCEPT OF EXTRUDATE PROCESS AUTOMATIC CONTROL SYSTEMS EFFICIENCY INCREASE

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Аннотация: Обоснованы общие понятия синтеза эффективный САУ экструдирования биополимеров, включая концептуальную модель объекта, разновидности функциональной структуры его устройства, косвенные показатели качества продукта, доступные для квази непрерывного измерения.

Abstract: There was proved the general concept of construction effective SAC by biopolymers extrudate process, including conceptual model of steering object, variants of functional structure of its actuation device, indicators extrudate product, characterizing its quality indirectly, but accessible to quasi continuous measurement it is direct during process. For concept realization are developed imitating mathematical model of process biopolymers extrudating, describing dynamics of ports of regulation, special cross and cascade structures of subsystems of automatic regulation of a temperature mode of thermal processing of raw materials with several zones of heating, a subsystem of guaranteeing steering of loading the extruder electric motor, including regulations of its current of loading in cascade engaged circuit and the thermal condition, providing minimization of specific power inputs on process conducting. For increase SAC quality, in algorithm of current regulation of loading the extruder electric motor, forecasting of change of a current at change of giving of a product for the period of delay forward is applied. Efficiency developed the concept and algorithms of steering are confirmed by computer experiments on imitating models and laboratory researches of model sample SAC.

Key words: biopolymers, effective SAC, extrudate, indicators extrudate product.

Introduction

Processes extrudating phytogenesis biopolymers (EBP) are realized in manufacture of foodstuff and mixed fodders, thus the orb of their application extends. It is promoted by unique association of various factors of action on a yield which is processed: various aspects of plastic strains, intermixing, high temperature and pressure, its sharp collapse to

atmospheric, modifications of a modular condition of the water deeply integrated into a yield. At the expense of it there are radical changes as a part of nutrients of end-products – starch is partially split to dextrin and sugars, proteins give in denaturation therefore nutrients are better acquired both people and animals. Besides, after extrudating mechanical and flavouring qualities of yields essentially improve, there is a neutralization of toxins and an erasure of their producers that ensures sanitary safety extrudate.

Existing systems of automatic control (SAC) processes EBP, realize, at the best, only functions of regulating (stabilization) of a current loading of the electric engine drive (EED) extruder and a temperature condition of handling of raw materials. Practice shows that such SAC cannot ensure stable functioning extruder in energetically effective conditions and high indicators of quality of a ready yield. Principal reasons of they are dynamically varying performances of components of raw materials, their structure in a compounding of the made yields, deterioration of working organs, oscillations of voltage of a power line, presence of restrictions which are superimposed by regulations of conducting process EBP on ranges of modifications of its parameters which violations leads to origin of emergencies.

The carried out analysis of a content of researches and workings out in the field of a raise of efficiency SAC processes EBP and the conclusions drawn on them allow to state that, despite a considerable quantity of scientific workings out in this area, the urgency of a problem of a raise of efficiency such SAC remains.

The purpose of researchers

The purpose of researches – automatic control means to guarantee observance of regulations of technological process (TP) EBP to raise quality extrudate, to ensure a stability and high efficiency of process, to lower specific expenditures of energy.

Unlike extrudating synthetic polymers when structure and raw materials performances are stable, at extrudating vegetative raw materials (biopolymers), in particular food and mixed feed mixtures, a compounding, structure and raw materials performances vary. Raw materials performances, even within the limits of one compounding, always differ from each other and dynamically vary in time. It essentially complicates managerial process EBP as these perturbations «on raw materials» reduce not only in modifications of values of regime (procedural) variables which are eliminated within the limits of regulating function, but also to modifications of dynamic properties of channels of regulating, best values of the governed variables, ranges of their is boundary-admissible modifications. In such conditions efficient control processes EBP forces to use SAC with more developed functional organization and more perfect algorithms, than for processes extrudating synthetic polymers.

Working out such SAC assumes presence of MM of process EBP as control object (OC). The analysis of existing models has shown the following. The models received on the basis of analytical exposition which are potentially capable at substantial level to map all singularities OC, have appeared almost inapplicable, as a basis for working out effective SAC (do not describe dynamics of processes), as a component most SAC (describe processes approximately enough, including do not consider many factors). The principal reason of it is complexity and a small level of scrutiny of physical properties fusions biopolymers as nonlinear viscoelastic liquids. The models received on the basis of handling of outcomes of complicated multifactorial experiments, initially oriented on working out SAC, also cannot be applied. Such models are received for small (two, a maximum of three) amounts of factors which vary in small ranges. They are adequate only for that equipment, those conditions of conducting process and aspects of raw materials which have been enveloped by these experiments. Important, as those and other models are considered by their authors as determined and, in particular, do not consider uncertainty of values of parameters and casual character of perturbations.

Body

Variants SAC process EBP presented in publications and theses, are rather various. At the same time, in them some can be selected only, it is a lot of in what the general and in essence important, lines. Functions of regulating of a temperature condition of thermal handling of raw materials and loading extruder it is realized, as a rule, everywhere, and basically with application of PID-regulators. In cases when temperature and loading governors are interconnected, SAC becomes much more sensitive to variations of parameters OC, up to instability. Some authors SAC suggest to realize functions of observance of a field of tolerances of indicators of quality extrudate (guaranteeing control) or process optimization. However, as means of automatic measurement of these indicators does not exist, by default it is supposed that the quality analysis is made in laboratory. As the alternative is offered to make a quality estimation of extrudate on MM, using models as component SAC. Thus arguments of such models are performances of raw materials and current values of parameters of process extrudating. Problems of practical application of such MM it is connected with labour input of their deriving, inevitably low level of their adequacy, necessity of measurement of performances of raw materials for real time.

The essence of the concept of construction effective SAC consists, at first, in introduction of new functions SAC in real time: measurements of indirect indicators of quality extrudate; process optimization by the chosen criteria; the guaranteed prevention of events *S1* (violation of indicators of quality of a yield) and *S2* (an electric drive overheat);

secondly, in improving of realization of traditional functions, namely regulating functions. The accepted concept of control is rendered concrete by alternative variants of structures such SAC.

Regulating functions realize on the basis of the closed principle of control of governors which stabilize controlled variables in proximity of preset values accordingly.

$I_{неод}^{зодо+*}(t)$ − Set, taking into account prevention of event *S1* and process optimization by criteria of a minimum η_e, values for *Ineод* (t); $\theta_i^{зо}(t)$ −set, under condition of security of demanded quality extrudate, values for θ_i (t); $\theta_{г}^{зодо+}(t)$ −set, taking into account prevention of event *S2*, value for $\theta_г$ (t).

Function of optimization of power efficiency are realized as a problem of conditional optimization:

$$I_{неод}^{зодо+*} = \arg\min\left\{\eta_e(I_{неод}^{зодо+}, t)\right\}, \quad (1)$$

$$\text{with } \theta_{неод}^{зодо+} = \arg\left\{\hat{P}_{\underline{s}_1}\left(\theta_{неод}^{гр+}(\theta_{неод}^{зо}), T\right) = P_{\underline{s}_1}^{г}\right\},$$

Where $\eta_e(t) = \int_t^{t+\tau_{оср}} P_{неод}(t)dt \Big/ \int_t^{t+\tau_{оср}} Q_м(t)dt$ −criterion of optimization which pays off on a sliding interval of time $\tau_{оср}$;

$\hat{P}_{\underline{s}_1}\left(\theta_{неод}^{гр+}(\theta_{неод}^{зо}), T\right)$ − Estimation of probability of lack of event *S1* on *T*;

$P_{\underline{s}_1}^{г} \equiv P_{\underline{s}_1}^{г}\left(\theta_{неод}^{гр+}, T\right)$ − The set probability of lack of event *S1* on *T*.

Function of optimization of quality dares by means of laboratory measurements of direct indicators of quality extrudate on which foundation the laboratory personnel periodically sets (corrects) $\theta_i^{зо}\ i = \overline{1;3}$, and is boundary-admissible values $\alpha_e^{гр+}\ C_e^{гр+}\ D_e^{гр+}$. During process quality indicators are stabilized at an optimum level by a modification $\theta_{г}^{зодо+}$.

Functions of warranting of prevention of events *S1* and *S2* are realized on the basis of two different principles. For prevention *S1* the preset value to a governor of temperature EED $\theta_{неод}^{зодо+}$ pays off in MCPA (the module of calculation of an admissible preset value) on the basis of the information which turns out with MEPC (the module of an estimation of probabilistic characteristics).

For prevention of events *S2* boundary-admissible preset value $\theta_{г}^{зодо+}$ calculating in a closed loop of regulating of frequency n_{s_2} of this event. As in the given problem we interest the frequency estimation n_{s_2} "from above" it is considered variable α_e (t), *Ce* (t), *De* (t) the poorly correlated, and simultaneous violations by two and three these variables in the account of frequency of violations is not considered as improbable.

The set (admissible) value n_{s_2}, namely value $n_{s_2}^{п+}$, calculating in MCAFV (the module of calculation of admissible frequency of violations) on the basis of a preset value of the guaranteed probability $P_{\underline{s}_2}^{г}$(Ткст) lack of event *S2* on time interval *T*:

For deriving of mathematical exposition OC the experimentally-heuristic approach has been chosen. It unites objective knowledge about performances of process which receive during natural experiments, with subjective knowledge (understanding) the developer of a physical essence of these processes. Its principal advantage - he allows to receive on the basis of the limited amount of experimental data physically justified and adequate (at qualitative level) model OC for wide ranges of modifications of conditions of conducting process EBP.

Model realization was spent in the environment of simulation modelling Simulink of package MATLAB (1-4 AE К761327 ВД, № 308918). The structure of model OC maps natural decomposition of process and design features concrete extruder. It includes model vibrating feeder, models of processes of heating of zones of pressing and a head extruder, processes of movement of a material, which extrudating, model EED extruder. Processes of heating and movement of a material which extrudating, objectively are processes with the distributed parameters. In models this distribution is mapped simply, in the form of cellular model. The amount of the meshes, which parameters are considered concentrated, corresponds to an amount of zones extruder.

Models of heating of each mesh map change θ_i for the account *ині*, heat exchange with a yield, which extrudating, with the next meshes and environment. Movement models consider a yield response time in zones, modifications of its expense and a moisture, transformation of mechanical energy (a radiant of this energy is EED) to heating of a yield at the expense of an interior friction at its strain and an exterior friction about walls and a screw surface extruder screw.

Outcomes of all-round testing of model during specially organized computer experiments have shown good correspondence of outcomes of natural and imitative experiments for identical conditions extrudating and its physical

consistency in wide ranges of a modification *иж*, *ие*, *ин1*, *ин2*, *ин3* that $\vec{f}$. It has allowed to accept a hypothesis about adequacy of model and to use it for working out SAC by process EBP.

In work from alternative variants of structure for realization has been chosen base (with the limited gang of functions) variant SAC process EBP and problems of its parametrical synthesis and the analysis, including a subsystem of guaranteeing control by loading EED extruder, and also problems of realization and researches are considered.

Base variant SAC oriented on a solution of the most dynamical problems of control, keeping behind an operator and laboratory quality management extrudate.

For all alternative variants three-dimensional CAP θ_1, θ_2, θ_3, $\theta_г$ structural and parametrical synthesis with typical PID-algorithms has been spent. The subsequent analysis of these CAP for a wide spectrum of conditions of conducting process has shown their high enough dynamic accuracy. It has removed a problem on necessity of refinement of structure SAR and-or its algorithms. It is important that all variants have the advantages, and a choice concrete it is reasonable to lay to an operator which can consider specific singularities of process thus.

The analysis of outcomes of synthesis SAR *Iпедсз* typical algorithms in conditions which vary, has shown to operation expediency of refinement of its algorithms for expansion of stores of a stability at the expense of input of forecasting of modification *Iпед* on a delay time forward at a modification *иж*. Synthesis of a subsystem of guaranteeing control $\theta_{пед}$ has led to two-contour system when the contour of regulating *Iпед* has appeared is enveloped by a regulating contour $\theta_{ноед}$. The Present value $\theta_{пед}$, namely $\theta_{пед}^{здд+}$, pays off on the basis of guaranteeing, with the set probability $P_{s_1}^{г} \equiv P_{s_1}^{г}(\theta_{пед}^{гр+}, T)$, not violations $\theta_{пед}^{гр+}$.

The analysis shows that at realization of guaranteeing control by degree of heat EED extruder, its efficiency can be raised to 30 % in comparison with a variant of typical system. Thus, simultaneously, specific expenditures of the electric power it is direct on extrudating decreases to 5 %. It is very important that for working conditions extruder which vary, such system itself, in real time, defines current admissible value of degree of loading extruder, solving simultaneously both a problem of optimization of process and a problem of warranting of observance of service conditions EED extruder.

Let's notice that SAC has allowed to deduce extruder from an idling condition in a condition of working loading in an automatic condition. It was spent at the disconnected algorithm of optimization – algorithm of warranting. At its inclusion the current of loading EED and its productivity noticeably raised, and its thermal condition comes nearer to boundary admissible, remaining below the heating defined before a limit.

Trials of the model sample base SAC have confirmed the conclusions made at a stage of its modelling. Certainly, they cannot give a definitive conclusion about high efficiency SAC which should remain in the widest series of conditions, characteristic for industrial use. It would demand creation of the scientific-industrial sample of system and its long operation. At the same time, the conducted trials show that the chosen directions of a solution of a problem of a raise of efficiency of process extrudating biopolymers automatic control means give expected effect.

Conclusions

In work the substantiation and a new solution of a scientific and technical problem of a raise of efficiency of systems of automatic control by process extrudating biopolymers is presented. Its purpose – automatic control means to guarantee observance of regulations of technological process extrudating biopolymers to raise quality extrudate, to ensure a stability and high efficiency of process, to lower specific expenditures of energy.

The basic outcomes of work consist in the following.

1. It is justified the general concept of construction effective SAC by process extrudating biopolymers, including conceptual model of plant of control and variants of functional structure of its actuation device. The choice concrete of these variants is defined by structure of the information which receives SAC about a current condition of process, and structure accessible to a modification during process of operating actions. This concept allows to develop purposefully effective SAC for different types extruder, including such which have a miscellaneous is informational-hardware.
2. It is justified, in technological and informational-technical aspects, the enumeration of indicators extrudate biopolymers which characterize their quality indirectly, but accessible thus for quasi continuous measurement it is direct during process. The technological aspect causes correlations between direct and indirect indicators of extrudate quality, and informational-technical aspect – a variant of program-technical realization of measuring channels of indirect indicators of quality. Use of such indirect indicators which are measured almost continuously, allows to stabilize better actual quality extrudate and to conduct process more close to boundary admissible, to the most effective, technological conditions.
3. It is developed imitative mathematical model of process extrudating biopolymers on concrete extruder

which adequately describes dynamics of channels of regulating. She allows to formalize basic singularities of process as control plant, purposefully and effectively to transform the formulated conceptual approaches to working out SAC in robust quasi optimum algorithms of control of process. In the long term its application will allow to raise functional integrity of system, completing on this model complicated algorithms of new functions of control.

4. Variants of cross and cascade structures of subsystems of automatic control of a temperature condition of thermal handling of raw materials with several interdependent heating zones alternative to traditional structure are developed. The possibility of a choice an operator-technologist concrete of variants will allow to have to it an additional resource of the accented quality management extrudate in constantly varying conditions.
5. It is developed a subsystem of guaranteeing control by loading drive the electric engine of extruder which comprises in cascade included contours regulating by its current of loading and a thermal condition. Such system ensures high dynamic accuracy stabilization of a thermal condition of the electric motor at level of boundary admissible value, guarantees avoidance of its emergency cut-off by a thermal guard, and, eventually, ensures minimization of specific power inputs on process conducting extrudating.
6. Necessity is revealed, and the algorithm of control by a loading current drive the electric engine of extruder in a raise direction robustness of this subsystem is improved at preservation of its dynamic accuracy. Such refinement is spent on the basis of principles of forecasting of free movement of a contour for delay forward and has allowed to ensure stability SAC at a modification of conditions of conducting process extrudating in a wide range.
7. Laboratory and industrial trials of the model sample developed SAC are conducted have confirmed its efficiency and, thereby, practical value of the scientific outcomes received in work.

УДК (66.046:637.52)

ДОСЛІДЖЕННЯ ДОЦІЛЬНОСТІ ВИКОРИСТАННЯ РЕГУЛЯТОРА ЗІ ШТУЧНО - НЕЙРОННО МЕРЕЖЕВИМ РЕГУЛЯТОРОМ ДЛЯ УПРАВЛІННЯ ПРОЦЕСОМ ТЕРМІСНОЇ ОБРОБКИ М'ЯСНИХ ВИРОБІВ

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Анотація: Процес термічної обробки м'ясних виробів на підприємствах м'ясопереробної промисловості є кінцевим енерговитрат ним етапом та багато в чому визначає якість та собівартість готового продукту. Для дослідження шляхів підвищення ефективності управління термічною обробкою м'ясних виробів був використаний метод цифрового імітаційного моделювання, зокрема, була розроблена модель об'єкту управління, що враховує статичні та динамічні характеристики реального об'єкту. Були також отримані формалізовані моделі виконавчих механізмів та регулюючих органів.

Abstract: Process of thermal processing of meat products at the enterprises of the meat processing industry is final stage and much in what defines quality and the cost price of a ready product. For research of ways to increase the management efficiency by thermal processing of meat products the method of digital imitating modeling has been used the model of object of management which considers static and dynamic characteristics of real object, in particular, has been developed. Also the formalized models of executive mechanisms and regulating bodies have been received.

Ключові слова: імітаційне моделювання, нейронна мережа, моделювання.

Термічна обробка, в нашому випадку, представляє собою технологічний процес варіння та обжарювання котлетних виробів за допомогою машини для термічної обробки м'ясних напівфабрикатів. Режим термічної