UDC 633.63:631.35

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SIMULATION TECHNOLOGY OF SUGAR BEET

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Abstract. *The Article highlights specific features of process simulation and technical facilities related to sugar beet production. It reviews the literature sources and specifies distinctive properties of the created models . Basing upon the analysis conducted the main principles of process simulation of sugar beet growing and cropping are proposed.*

Keywords: modelling; root; sugar beet; technical means; technological process.

1. Introduction

Sugar production in Ukraine is one of the leading directions of private business which provides the importance of scientific research related to improvement of process simulation and technical facilities of sugar beet growing and cropping. Sugar industry requires its own raw materials and sugar which are a crucial condition for independence from the importers and world market price fluctuations. Most important of all is that effective sugar beet production is to be ensured by use of advanced technologies at all stages – from pre -sowing soil processing up to obtaining raw beet materials at the factory. Therefore, research of substantiation of parameters of technological processes, explore the facilities and production technologies, to examine patterns of efficient use of machinery and equipment , ensuring their reliability and prediction of their development. Therefore, research of determinant for this "demanding" specific culture (Pic. 1).

During the study of the literature and the requirement standards the following contradictions of the gathering of SB, which is the most significant in the structure of the direct operating costs of their production (37-42 %), were found. According to the State Standard of Ukraine contaminated piles delivered for the processing of roots should be no more than 7.0 %, while the number of damaged roots can be no more than 10%. As the research data and the results of years of state tests at UkrNDIPVT im. L.Pogorilogo and experience in the use of machines in beet cultivating households shows, these figures are greatly exceeded. For example, harvesting at weeded fields with absolute hardness of the soil more than 3,2 MPa leads to the loss of roots as not dug and damaged in an amount of 35-40 % of the cultivated roots and in a pile of harvested beet is a significant percentage (about 45 %), of lumps of soil. In this way, some of the fertile soil is transported from the fields to plants along with root vegetables and, of course, is not delivered back. Therefore, there is the problem of maintaining of the soil fertility.

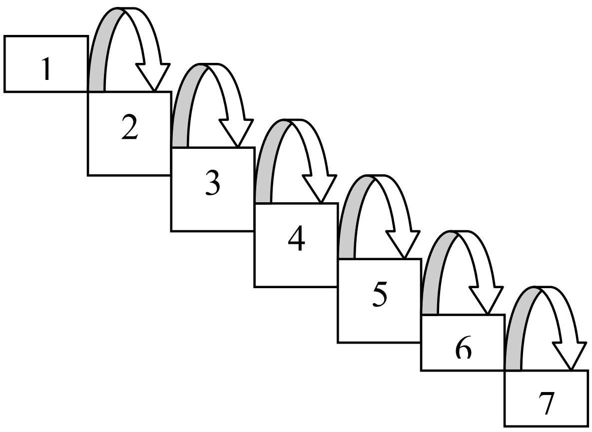

Fig. 1. Domestic technology of cultivation and harvesting of sugar beets:
1 – Chaict of sail and its predessors;
2 – Pre-fillage of the sail;
3 – Chaice of sart and hybrit;
4 – Preparation of seeds far saving;
5 – Taking of the craps;
6 – Harversting;
7 – Transportion of root craps.

Another equally important issue in the processing **of raw beet crop is pollution of the root heap with** the Institute of the sugar industry, with the increase of tops on the roots from 1,9 to 5,5 % juice quality is reduced from 89,3 to 85,1 % of heads above the ground. Harvest quality assurance significantly depends. Thus each percent of green weight on beet roots leads to the reduction of juice quality on 0,4–0,5 % and increase of sugar content in molasses on 0,1 %.

In general, during the long-term plant storage (more than 60 days) of severely damaged beet roots, contaminated with the soil and weed residues, the condition of raw materials significantly deteriorate due to the lesion by rot, and loss of sugar increases in 5 - 7 times.

The solution to this problem, obviously, is inextricably linked with the improvement of existing and creation of new working bodies of machines which would be technologically and technically reliable in difficult conditions of growing and harvesting of sugar beets.

The quality of harvested sugar beet raw materials depends on various parameters: humidity and hardness of the soil, uniformity of soil topography, crop infestation by weeds, the diameter of the roots and their location relatively to each other in a row, lateral deviation of the axis line of roots and protrusion bodies of machines, which are used at and working bodies of machines, which are used at all stages of sugar beet growing. This leads to the necessity of modeling and research on models of technological processes of growing and harvesting of root crops and sugar beet tops.

2. Literature Review on research

Works of many scientists are devoted to the research of the issues of effective beet complex functioning and development. Such authors as V.M. Bulgakov, P.F. Vovk, S.A. Toporovskyi and others review agrophysical properties of crops and mechanicaly-technological properties of roots in their works [1, 2, 3, 9, 13].

A lot of scientific literature sources are devoted to the issue of beet tops separation. For example, a study of the process of beet tops separation is reflected in the works V.M. Bulgakov, V.A. Shterenzon ,S.A. Toporovskyi , D.G Voytiuk. [1, 4, 8, 11].

Works of many scientists are devoted to design and creation of the ways of mechanization of sugar beet collection, in particular of the working bodies for the digging of roots, including such as V.M. Bulgakov, M.V. Royik , L.O. Vlasenko etc. [1, 3, 7, 10, 12].

Analysis of the famous researches shows that despite some results concerning the development of new working bodies and determination of their optimal structural, kinematic and dynamic parameters, in many cases, these devices do not provide a high technological reliability regardless of agronomic conditions, necessary versatility, intensification of sugar beet collection processes and high operating parameters.

Improvement of the technology of sugar beet growing and harvesting is an important problem of sugar beet industry. An integrated approach to improving the quality of processes of soil preparation, planting, growing and harvesting of beet should include both the search of new design solutions of working bodies and theoretical study of structural and technological parameters. This leads to the development of the modern theory of sugar beet growing for the synthesis of optimal technological parameters of machines and working bodies to provide high quality at all stages.

Thus, the theoretical generalization, simulation and research of the technical and technological processes of sugar beet production requires the development both of results of studying of the crop agrophysical properties, characteristics of growing and harvesting of root crops and of common approaches to the management of the complex systems and processes, to the class of which technological processes of SB production can be attributed.

The aim of this work is to determine the principles of modeling process of sugar beet production by the unifying of construction of complex system models procedures and development of the basic principles for improving of the methodology of technological processes modeling.

To achieve this goal it is necessary to investigate the general scheme of SB production technology, study the features of technological processes modeling, define the purpose of simulation and consider the possible criteria, summarize the theoretical basis of construction of complex system models and propose the principles of modeling of technological processes of sugar beet production.

3. Principles of modeling process of sugar beet

Production of sugar beet consists of a number of technological processes and operations, the main of which can be defined as following: soil preparation, sowing of seeds, growing of the crop and harvesting of the crop roots and tops. Harvesting of roots is recognized as one of the most labor-intensive and energy-intensive processes in the production of sugar beet. [1] The quality of harvest and providing sugar industry with the raw stuff of high standard depends on the proper and accurate process of crop harvesting, rational use of the collecting equipment and vehicles.

The quality and energy intensity of the process of excavation of roots depends on the properties of the digging working body (DWB). You can select the following general requirements for DWB of the beet harvesting machines. Firstly, they should provide the necessary degree of breach of the connection of root with the soil. Secondly, the DWB should not permit damage and loss of roots. Thirdly, it is necessary to lift the root from the soil with the help of digger on the height, suitable for the providing conditions for the functioning of other working bodies. Fourthly, to provide effective implementation of general agronomic requirements.

There is a large variety of working bodies for digging root crops of sugar beet, which differ not only by the schemes of performance and design parameters but also by the technological process [7, 11]. The problem is lack of technological reliability of existing working bodies in difficult agrotechnical conditions of harvesting. DWB of the beet harvesting machine must satisfy the requirements for the reliability of the process of excavation, the quality of raw beet, energy intensity of the process of root gathering. On the other hand we shouldn't rely only on the technological characteristics of the working bodies of the collecting machines, because long-term studies of the processes of mechanical SB harvesting show that the performance quality of roots and tops collection are largely dependent on technological, organizational factors and weather conditions; the state of plants' development; humidity and soil hardness: technical perfection of the working bodies; and most importantly – on the quality of performance of all previous operations of sugar beet growing(primary and pre-tillage of soil, seed preparation, sowing, growing).

Mathematical modeling is based on such general principles as informativity, feasibility, plurality, but during the construction of complex system models, including technological processes of SB production, it is necessary to consider some additional aspects. The authors proposed to consider the following principles of modeling of complex processes:

1. The expediency of modeling - a fundamental principle of building of any model. Modeling as a process of representation of the object, process or phenomenon must be focused, economically sound and the result (the model) should not increase the complexity.

2. Having enough information - a principle of availability of information means that to construct a model you need a priori information that allows you to build an adequate model. Completeness and uncertainty of information available determines appropriateness, adequacy and effectiveness of the simulation.

3. The multiplicity of modeling – a principle of representation of a real object or set of process models that reflect different aspects of its functioning. Selection of the type of modeling, detailed description of the process, the complexity of the model – all this must be consistent with the purposes and objectives of the modeling.

4. Agregativity of the model – a principle of modeling of complex systems as a combination of simpler components that are combined by the model of a higher level – a unit. Hierarchical representation of the process allows you to simplify a complex object model, focus on key aspects, detalization of which is studied on the lower level of abstraction.

5. Coordination – a principle of modeling of complex system through decomposition and taking into account the mutual influence of autonomous subsystems. Any technological process consists of a specific set of operations, which makes quite a natural decomposition and modeling of individual stages as autonomous subsystems that interact with each other. Consistency of parameters, information and material flows between individual subsystems and between levels of aggregation of the model can effectively solve complex management tasks.

Modern technological processes have a complex structure, which determines the decomposition into correlated subsystems through which the material and information flows pass. Improvement of the technical and economic indicators of the technological processes is possible if the tasks of the coordination of individual parts of the process are solved. There are three main variants of the task setting of technological process coordination [5]:

– Coordination of material flows between the subsystems under conditions of saving of technological regimes of the related subsystems;

– Coordination of technological regimes of related subsystems under conditions of improvement of general quality index of the technological process functioning;

– Determination of the parameters of material flows and technological modes of individual subsystems that provide the best technical and economic indexes of the process.

In general form the mathematical formulation of the problem of coordinating a complex process is formulated in such a way. It's necessary to find such indexes of process parameters $x_g = \{x_{gh}\}$ and vector of the controlling impact $u_g = \{u_{gh}\}$ for each g--th subsystem of

$$f_g = (x_g, u_g, S_g) \to \max$$

$$u_g \in u$$

$$x_g \in x,$$

where S_g is a fixed parameter of the technological process, which provides coordination of the g-th subsystem of the technological process.

Problem of the coordination is formalized in such a way: find such meanings of the parameters $S_g \in S$ which under the condition that specified parameter $S_g \in S$ meanings x_g and controlling impacts u_g for each subsystem will provide maximum effectiveness of the technological process, ie

$$F(S) = \sum_{g=1}^{N} \alpha_g f_g(\bar{x}_g, \bar{u}_g, S_g) \xrightarrow[S_g \in S]{} \max$$

where $\acute{\alpha}_g$ is a coefficient of the relative importance of g-th subsystem of the technological process, x_g, u_g – solution of the appropriate local problems for each subsystem, N – the total number of subsystems.

In order to have the formal presentation and study technical and technological base of sugar beet production authors suggest considering technological process of growing and processing of sugar beet in terms of the theory of complex systems. Technological processes can be seen as complex systems, which are characterized by the following features [12]:

– a large number of interrelated subsystems and components;

– a sufficient number of different connections and relations;

– a variety of goals and requirements of individual parts of the technological process;

– random nature of processes;

– structure invariance;

– heterogeneity of the physical nature.

The main goal of the complex technological processes managing is to increase the effectiveness. The concept of effectiveness as the ratio of costs and profits is very narrow in relation to the consideration of the complex systems functioning. Therefore, we distinguish the following types of the effectiveness of production and technological processes [4]:

1) by the level of production we can identify: the effectiveness of the country economy, the effectiveness of the agricultural sector, the effectiveness of sugar beet industry, the effectiveness of the SB production;

2) by the shape of the effect effectiveness can be total or partial;

3) by the organizational level we can distinguish effectiveness at the individual or team level, effectiveness at the enterprise level, effectiveness at the district level, effectiveness at region or state level;

4) by the functional impact we consider economic, technological, social, environmental, etc. effectiveness;

5) by the types of activities or technological processes the following types of effectiveness can be distinguished: the effectiveness of pre-tillage and sowing, harvesting beets effectiveness.

6) thus, this classification of types of effectiveness shows that general principles of formation of the evaluation models of efficiency regardless of its type are necessary. The most common approach to estimation involves the selection of estimation criteria and variables which affect the final index.

It is impossible to estimate the effectiveness of the SB production by the one criterion. This is due to the complexity of the production processes. For example, we can identify such criteria as loss of roots mass, total damage, pollution and so on for the estimation of the process of excavation. The indexes of these criteria are affected by a variety of factors, including, for example, soil moisture, type of DWB, the yield of sugar beet, the hardness of the soil, crop weediness and others. Therefore, you should use a multicriteria approach. Modeling of multicriteria estimation models and decision-making is the subject of a separate study. We shall consider only the basic principles of the formation of multicriteria estimation models. The author proposes us to use network model of the complex estimation as a basic model of multicriteria estimation process of sugar beet growing. As it's shown in the work [6], a model of complex network estimation gives us opportunity to obtain aggregated mark; to take into account different groups of indicators; compare alternatives for each other and choose the most advantageous in terms of overall effectiveness. We can use different types of rolls and weight coefficients in the model of complex network estimation for the convolution of indexes in groups [13]. And the weights are determined within each group separately, which facilitates the work of experts and makes estimation mechanism more flexible.

So, the estimation of the processes of SB production has two types of indicators: inputs and devices. Indicators of "inputs" describe some agronomic conditions and technological parameters of the working bodies. Indicators of "units" represent a group of the technological process characteristics. For example, we can consider groups of indexes by the stages of the technological process, or by the types of machines or working bodies, which are used. If the effectiveness indexes of the technological process of growing beets are heterogeneous in nature (eg , technical parameters of working bodies and agronomic properties of soil) and have different units of measure, it is impossible to make one by convolution aggregated indicator by convolution of their meanings, and it is more appropriate to form multiple levels of aggregated indicators, which will consistently be coagulated into one. On the other hand, the intermediate aggregated indicators estimate various aspects of the process and can be used in the estimation process as independent.

Formally, the results of grouping of characteristics of the technological renovation project can be represented as acyclic directed graph G = (K, A) [6, 13], where K is a set of elements (tops) of the graph; $A = \{a_{ij} : a_{ij} \in (0,1)\}$ – a set of directed arcs, that connect elements. Every element $k_i \in K$ reflects a certain index (primary or aggregated). Each directed arc (a_{ij} = 1) means that element k_j reflects a general characteristic of the project compared to element k_i. So, for all, $k_i, k_j \in K$ if $a_{ij} = 1$, then $a_{ij} = 0$, i.e. the direction of the arc determines the direction of mark aggregation.

The entire set of elements K can be divided into two subsets: $K°$ and $\tilde{K}$, where $K° \, U \, \tilde{K} = K$, $K° \cap K = ø$. $K°$ is a set of indicators – inputs. Indicators of the $K°$ set are directly estimated during the process of selection of the technology and machine working bodies. Formally K° is a set of elements, to which no arc (a set of indicators-inputs) leads, i.e. $k_j \in K$, $k_j \in K°$ shows $a_{ij} = 0$.

$\tilde{K}$ is a set of elements, which is represented by separate groups of indicators, i.e. $\tilde{K}$ determines aggregates (set of indicators – aggregates). There is at least one element for $k_j \in K$ each element, for which $a_{ij} = 1$.

Is true, in other words, the set $\tilde{K}$ brings together elements $k_j \in K$, to which at least one arc leads at least one arc.

When the network structure of complex estimation is determined, it is necessary to define the convolution Fl (·) functions for all elements $k_l \in \tilde{K}$, as there is quite a large number of indicators and it's necessary to bring them together to one aggregated, so it is advisable to choose appropriate rolls functions among existing. The most common are simple and weighted average methods [13].

All primary and aggregated indicators which describe the technological renovation project have a unit of measure and the range of possible meanings. In other words, all primary indicators are defined in their own units of measure, i.e., the absolute meanings of the indicators cannot be used for further aggregation. In order to collate and compare the indicators with different units of measure, they should be converted to relative with the help of normalization operation.

According to recommendations [13] the method of natural normalization is the most appropriate. It is necessary to define the reference and discarded meaning for each primary indicator to determine the relative meanings of the indicators. It is recommended to take a value that is the best in the world for this indicator at the time of estimation as a reference meaning of the index, and as discarded meaning – the closest, but worse than the worst of the indicators of the project.

Thus, the calculation of the relative meanings should be made as follows:

$$x_i = (y_i - \mathrm{Re}\, j_i)/(\mathrm{Re}\, f_i - \mathrm{Re}\, j_i)$$

where x_i – relative meanings of th j-th indicator;

y_i – absolute meaning of the i-th indicator;

Ref_i and Rej_i – reference and discarded meaning of the indicator respectively.

So, it is necessary to change the meaning of all primary indicators from the absolute to relative. Whatever type of convolution is used for aggregation, it is recommended to use expert method based on the determination of the meaning of eigenvectors of matrices of pairwise comparisons to determine the degree of importance of a particular parameter. Pairwise comparisons are carried out by experts for all indicators belonging to the same group of indicators, which are aggregated.

Simulation of digging of SB root crops takes into consideration a variety of factors – from agrophysical soil properties and dimensionally - mass characteristics of roots to technical and technological parameters of the DWB. This necessitates the use of various classes of models that need to be combined into a single complex. Full justification of technological regimes is impossible without the use of simulation tools, including computer modeling, solving of the coordination problems and multi-criteria estimation.

Summarizing the studies it can be concluded that the main goal of modeling of technological processes of the SB production is to increase effectiveness by identifying and reasoning of the technological processes parameters and technical units.

Research of the technological processes based on modeling helps us to determine the technological variables, their interaction and mutual influence, to identify technical and economic parameters, to estimate the impact on profitability, identify areas of development and ways of improvement of technical and technological base of SB production industry. To achieve this goal and solve the corresponding problem it is necessary to develop methodological principles of modeling and optimization of manufacturing processes on different operating conditions.

4. Conclusions

So, having considered the various aspects regarding modeling of the technological processes of sugar beet production, we can make the following conclusions:

– technological processes belong to the class of complex systems, which are characterized by a large number of parameters and variables, dynamics, incomplete information, the complexity of the structure, the heterogeneity of the physical nature, the mutual influence and presence of connections between the components;

– modeling of complex manufacturing processes of sugar beet production should be based on a set of principles that provides methodological principles for the construction of models by unifying modeling procedures, classification of estimation criteria and generalizing of process variables;

– the basic principles of modeling technology for growing and harvesting of sugar beet are:

a) the feasibility of modeling;
b) Having enough information;
c) plurality;
d) agregativity;
e) coordination.

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Received 10 July 2014.

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Технологія виробництва коренеплодів цукрових буряків є поєднання агротехнічних прийомів і технічних засобів, покликаних їх виконувати. Моделі таких технологічних процесів пропонується розглядати як складні системи, які характеризуються великою кількістю взаємопов'язаних між собою підсистем та елементів, різноманітністю вимог до окремих ланок технологічного процесу, випадковим характером, інваріантністю структури, неоднорідність фізичної природи і т.п. Тому моделювання таких технологічних процесів повинно базуватися на певному наборі принципів, що забезпечує методику побудови моделей шляхом уніфікації процедур моделювання, класифікації критеріїв оцінювання та узагальнення технологічних змінних, коли основними принципами моделювання технології вирощування і збирання цукрових буряків визначаються:
– доцільність моделювання;
– наявність достатньої інформації;
– множинність;
– агрегативність;
– координованість.
Ключові слова: коренеплід; моделювання; технічний засіб; технологічний процес; цукровий буряк.

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Технология производства корнеплодов сахарной свеклы объединяет несколько агротехнических приемов и технических средств, которые нужны для их работы. Модели таких технологических процессов предлагается рассмотреть как сложные системы, которые характеризируются большим количеством взаимосвязанных между собою подсистем та элементов, разнообразием требований к отдельным звеньям технологического процесса, случайным характером,, инвариантностью структуры, неоднородностью физической природы и т.п. Поэтому моделирование таких технологических процессов должно базироваться на определенном наборе принципов, что в свою очередь дает возможность методике построения моделей путем унификации процедур моделирования, класификации критериев оценивания и обьединения технологических значений, корда основними принципами моделирования технологи выращивания и сборки сахарной свеклы определяются :
– оптимальность моделирования;
– наявность нужной информации;
– агрегативность;
– множественность;
– координованость.
Ключевые слова: корнеплод; моделирование; сахарная свекла; технологический процесс; техническое средство.

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