Formulation of Design Concepts of Complex Technical Tools and Technological Processes of Plant Cultivation

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Abstract: Nowadays both agricultural science and practice possess a great amount of experimental data that should be taken into account during the process of development of new technological procedures and working tools. Consequently, the necessity of designing of technical processes appears in order to identify their effectiveness. That is why appliance of methods of synthesis of technological processes is of immediate interests. These methods of synthesis of technological processes should be based on the characteristics of tillage, seeding and production systems of the economy and latter should define the realization of projected technological processes. The design of technological processes is one of the complex problems with its characteristic feature – the lack of knowledge about the methods of designing, suitable for system and structural modeling and algorithmization of design processes. To overcome this incompleteness, a systematic approach is needed. The system approach underlines that specificity of complex objects lies in the nature of their constituent parts and elements as well as in their interrelationships. This article presents the design methodology that is based on the formulated fundamental assumptions and principles of the system including more specific statements, revealing the structure and content of the design operations, the synthesis of the solutions choice. The article also deals with the designed principles of technological compatibility and emergence suitability for system-structural analysis of complex technical means and technological processes, consisting of statements having a hierarchical structure, where the degree of the goals specification increases from level to level, and the approval of the last level determines the direction of the search for the optimal solution of the problem.

Keywords: Technical Tools and Technologies, The System Approach, Design Methodology, Principles and Statements, Efficiency

1. Introduction

Both agricultural science and practice have accumulated a great number of experimental factors that are taken into account in the design of new technological processes and working bodies [1, 2, 4, 5, 11, 14] Constant improvement of technologies, agricultural machinery construction, intensification of modes of its work with simultaneous improvement of quality of performance of working processes complicate methods of calculation of structure and parameters of machines at their design. At the same time, methods of experimental designing and testing of prototypes of agricultural machines in the real-life conditions are of the great importance. However, such kind of a strategy is ineffective, as during the process of the agricultural machinery constructing there is a necessity to experiment from season to season, which in its turn is connected with high labor costs, time and money expenditures [6].

The goal of this research is to develop the principles of designing of complex technical tools and technological processes of plant cultivation.

The objective of this work is to determine the system characteristics of a technical tool and the technological process, providing agro technical requirements of soil treatment and sowing with the lowest costs, taking into consideration given restrictions.

2. Materials and Methods

Design is a complex issue where processes of synthesis, modeling, analysis, evaluation, optimization and selection of options are intersected. To solve such complex problems, a methodology of systematic approach is necessary. At the same time, the specificity of complex objects and processes is not limited by the distinct features of its constituent parts and elements, but lies in the nature of relations and relationships between them [3, 9, 10, 15].

The technology of cultivation of agricultural crops and lack of some technical means that help to perform certain operations require the modernization of suggested methodology. Among technical limitations that determine the permissible variants of the technological process are progressive methods of soil cultivation and sowing, the construction of a machine and its technical characteristics, a set of general and special working tools as well as the variety of basic and auxiliary materials. It is also necessary to take into account changes in the production environment in the economy. Such changes include modification of the structure of the cultivated area, replacement of out-of-date machines, ongoing replenishment of technological equipment and working tools, updating of basic materials and technological standards.

3. Results and Discussion

Methodological basis of formation and choice of rational technological processes will be built by deductive generalization of the received results, that is "from top downward" using the formulated principles of the whole system and specific statements revealing the structure and the content of design decisions. [7, 8, 12, 13]

In the terms of pointed principles, a system of more specific statements is deductively employed and these specific statements present the basis for building algorithms and programs of technological design. Thus, the constructed system of statements has a hierarchical structure. The upper (initial) level creates a set of principles (P_1, P_2,…, P_n). On their basis, a number of intermediate statements of the first level appear (UT_1, UT_2,..., UTn.) Later, using the principles and statements of the first level, more specific statements of the second level are built. This process continues until the approvals defining the function, structure and parameters of the elements of the designed process will be obtained. Statements of the last level represent mathematical models of construction of variants of options that are admitted by technical restrictions and serve as a basis for construction of algorithms and programs of technological design, see the Figure 1.
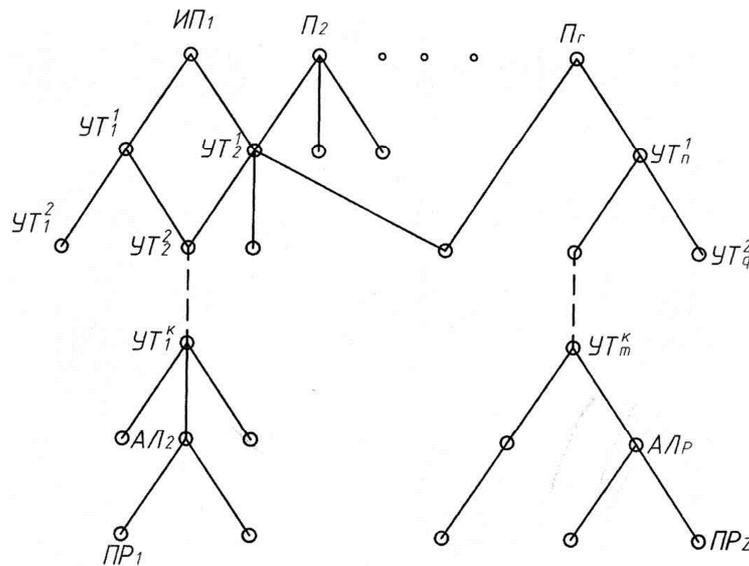

Figure 1. *The structure of the designing process model: IP$_1$, P$_2$-initial assumptions and principles; UT^k-statements of the k level; AL, PR-algorithms and design programs.*

According to this structure, we have developed the principles and their approval for the design of complex technical means and technological processes of crop production.

Principle of technological compatibility. A set of objects, if they have a property of compatibility, can be combined into a system, that is, in such an entity which functions, structural and functional properties, thanks to which their joint functioning as a whole is ensured in accordance with the specified agrotechnical requirements. Thus, tillage and sowing are compatible if the shape and size of a piped coulter with a cultivator-type hoe correspond to the shape and size of

the sowing tube of the sowing complex. The operations of the technological process are compatible if the soil quality after performing one procedure is appropriate for further procedures.

Statement 1. Assembling elements that are incompatible because of one or more types of connections to the system is allowed only by introducing special intermediary units that perform the compatibility functions by inconsistent types of connections between interacting elements. For example, a blower is an intermediate element between the trailer hopper and the cultivator of the sowing complex, it is designed for forced transportation of seeds through the seed pipeline from

the hopper to the coulter hoes. Besides, one or two distribution devices can be installed along the transport path to distribute the seeds evenly when approaching the coulters.

Statement 2. The cost efficient technological process in terms of expenditures on technological compatibility will be such its variant that provides planned productivity, agrotechnical requirements for soil treatment and sowing, with the minimum cost of special devices that perform the functions of compatibility.

The concept of "the optimality of the system" should be used now. The optimality of the system being in the contrast with traditional ideas, connects the system characteristics of the object with the costs for their implementation. Firstly, this concept provides the measurability of the efficiency level of a rational variant of the technology and the complex of machines, and in certain conditions reflects the advantages of new developing technologies, the effectiveness of which is confirmed in the production environment. In this regard, this statement defines only one side of the optimality of the system - the minimum costs (Z_c) spent for the compatibility of the system with the environment, that is, the cost of the design of the blower, its drive and switchgear is taken into account.

Secondly, the optimality of the system – minimum costs $Z_{f,z}$ for the implementation of a given function of the system F and a set of specified parameters Z, that is the cost of the hopper, cultivator, rollers, management and control systems, as well as the reliability and durability of their working bodies is taken into account.

Thirdly, the optimality of the system is the cost Z_m connected with the improvement and modernization of the technical system for the operation period. Based on this, a statement about the optimality of the system as a whole is formulated.

Statement 3. The optimal variant Q from a number of options of designing objects will be the one that provides the minimum total costs on compatibility of the system with the environment, on the performance of specified functions and expenditures for improvement and modernization during the period of operation:

$$Q = (Z_c + Z_{f,z} + Z_m) \rightarrow \min$$

The principle of emergence points on the system integrity, that is when a system possesses such properties that every separate element of a system does not have if it is on a standalone basis. Below are statements provided that determine the conditions for the appearance of this principle.

Statement 1. The system category includes only those objects and processes that consist of separate parts, elements and have an integral nature of functioning.

Statement 2. The properties and functions of system objects are not reduced directly to the sum of the properties and functions of their constituent elements. They have new properties and functions that separate elements of a system may not have. Thus, a unit made from separate parts is a technical system characterized by new properties and functions that separate parts do not possess. Thus, several lower-level system parameters are combined into higher-level system parameters.

Statement 3. As a result of several system elements combining the so-called synergistic effect appeared. The synergistic effect is greater than the sum of the effects of the elements of the system acting. The main reason for this effect is either the creation of more efficient systems and technologies, or creativity in building operations with known systems or technologies.

4. Conclusion

The developed set of design principles, technical means and technological processes consists of statements having a hierarchical structure, where the granularity of goals from level to level increases, and the approval of the final level determines the direction of search of the optimal variant of solving the problem.

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