Technological bases of the improvement of agricultural transport-technological machines

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Abstract. Mechanical, electrical, hydraulic and pneumatic transmissions are used in transmissions of agricultural transport technology machines. Depending on the design tasks, the considered transmissions have different kinematic schemes, parameters and design solutions. At the same time, the number of possible options can be quite large; therefore, the determination of the preferred option is, as a rule, a multi-criteria task and often leads to a palliative or compromise choice. The main problem of their development is the adaptability of the design of the actuator to the requirements of the technological (working) process associated with the constant change in the state of the technological object. This paper presents the rationale for developing a theory of kinematic chains of positive orders (adaptive kinematic chains), creating a theory of the structure of adaptive kinematic and adaptive mechanisms in general, methods for static and dynamic analysis of adaptive mechanisms, as well as methods for calculating their basic parameters.

1. Introduction

Mechanical (gear, friction, flexible coupling, worm, roller and “screw-nut” gears), electric, hydraulic and pneumatic transmissions are used in transport-technological machines for agricultural purposes. Recently, there have been projects for the mechatronic solution of some design problems related to the problem of digitalization of agricultural equipment.

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In this regard, the problem of flexibility and adaptability of the design of the actuator to the requirements of the technological (working) process, associated with the constant change in the state of the technological object, is highlighted. The fulfillment of the required adaptation functions, if not to take into account the known methods and devices of automatic control systems, obviously should be associated with a special organization of the structure of the actuating mechanism, ensuring the restructuring of the law of movement of the driven units depending on the state of the technological process and external conditions, i.e. and completely depends on the inclusion in the structure of the mechanism of external relations characterizing the parameters of the technological process. A technological process in a general sense implies a complex of real technological operations or treatments in the technological environment of agricultural production, including this concept, along with the processes of conversion of agricultural raw materials into the final product at various stages of processing, as well as processes of other functional purposes, which include the processes of loading and transportation of both bulk cargo and agricultural objects, soil treatment processes as traditional
second plowing and rotary plows, disk activity, soil mills and harrow. This list can also include the
working processes of active attachments and trailing equipment, which include the drilling of holes for
fruit trees, their spraying, pruning of grape and the grinding of these scraps, etc. All these processes are
united by one common feature - a complex interaction of actuators with the technological environment.

The main technological operations of agricultural transport-technological machines, especially
energy-intensive ones, are characterized by large fluctuations in loads, due to the uncertainty of
numerous and heterogeneous external factors affecting the formation of the load on the executive bodies.
In general, this process is a multifactorial system, due to the high heterogeneity (variability) of the
environment. For example, the efficiency of the plowing processes is mainly influenced
by the physical mechanical and rheological properties of the soil; therefore, there is a need to create
devices that determine the hidden parameters of the treated soil during operation and react in a certain
way to their change. Technological operations of plowing, as a rule, are subject to random perturbations
due to the uncertainty of numerous and heterogeneous external factors that characterize large ranges of
changes in resistance to the working body, uneven ground surfaces, its physical and mechanical
properties, even weather conditions, etc.

The control of such machines at the present stage is still impossible without the participation of the
machinist-operator, since the creation of an automatic control system that would assume the functions
of control of the technological process, although it is possible in principle, however, is quite difficult
and not always justified for the usual conditions of use of agricultural machines. Managing such
machines manually does not allow efficient use of their power and traction qualities due to well-known
drawbacks peculiar to a human operator (subjective assessment of external factors depends on the
knowledge, experience and condition of the operator, inertia of actions, delay in making decisions, etc.).
Therefore, in conditions when the optimal control of the processes under consideration by the operator
is impossible, and the creation of a complete automatic control system for these machines is inexpedient,
obviously, the transition to automatic control of the most important operations should be used. At the
same time, in our opinion, there should be a reasonable compromise regarding the complexity of the
automated control system, the capabilities of the human operator and the use of the self-regulating
functional properties of a specially organized structure of such machines for the automatic execution of
a number of process control functions.

In this regard, the problem of flexibility, adaptability of the agricultural transport and technological
machinery to the current conditions of operation, i.e. requirements of the technological process in which
the machine itself participates. At the same time, it goes without saying that meeting the requirement of
constant adaptation to the changing conditions of the technological environment should lead to rational
(and, ideally, even optimal) operating modes of the machine.

Achieving these modes of operation is currently practically carried out by constructive solutions of
varying complexity [1-5] or the use of various automatic control and regulation devices [9-12].
However, there is another way this article is dedicated to.

2. Materials and methods
A typical technological process of agricultural transport-technological machines can be described by the
following generalized model. Such model (Figure 1) is a multidimensional object, exposed to random
influences with a complex interrelation of input and output parameters, which can be divided into the
following groups:

- a) the group of input parameters includes, firstly, unmanaged parameters \( x_1, \ldots, x_n \), which are
technological and structural parameters, determined by the working body and machine tool (type of the
working body, type and geometry of the tool, etc.), and secondly, adjustable operating parameters, which
act as regulatory influences. The latter include traction force, the speed of movement of the executive
body or tool, the speed of rotation of active disks or soil cutters, etc. They are denoted as \( y_1, \ldots, y_n \);

- b) the group of output parameters \( y_1, \ldots, y_n \) includes resistance forces, power (moment) consumed
by the engine, the speed of movement of the machine or the executive body, specific energy
consumption, tool durability or wear rate, productivity, specific cost, etc. It should be noted that the
parameters of the output group, in fact, they characterize the efficiency of the process, essentially depend
on the chosen variant of controlling the course of the technological process;
c) the group of disturbing influences $z_1, \ldots, z_m$ includes the effects of the external environment, depending on the physic mechanical properties of the treated array, including uneven ground surfaces, the presence of solid inclusions, soil sticking and other factors. A model of a typical process is shown in Figure 1.

![Figure 1. Model of a typical technological process.](image)

3. Results and discussions
The feedback of the process includes the properties and characteristics of the drive and transmissions of the machine, i.e., in the general case, the feedback is nonlinear and inertial with the supply of external energy. The feedback ratio, proportional to the energy intensity of the process, is due to the characteristics of the drive. The presence of feedback indicates that the process is self-regulating in its energy performance. In real conditions, the self-regulating ability of the process is limited to the adjustment range of the drives and the kinematic scheme of the machines. There are cross-links between all three groups of parameters, as a result of which a change in one of the input parameters causes a corresponding change in one or more of both the output and the input parameters.

In the most general form, the relationship between input and output parameters can be expressed by the functional dependence $v = v(x_1, \ldots, x_i; y_1, \ldots, y_j; z_1, \ldots, z_m)$. This dependence, as a rule, for many typical working processes, for example, for the ones mentioned above, is a substantially nonlinear randomly determined multidimensional function. The view of this function is changed in an unknown manner in advance. This function can have a natural extremum, and an artificial extremum can be formed in most cases. Thus, the characteristic features of the considered typical workflows are:

1) non-stationarity, since the parameters characterizing the basic properties of the process depend on time;
2) multidimensionality, that is, the presence in them of a large number of parameters that are significant for the course of the process, which change with changes in the coordinates of the working body;
3) multi-factorial nature, since these parameters, as a rule, depend not only on the above-mentioned factors (time and spatial coordinates), but also for fixed values of the latter, they are functions of other factors (geometric, power, thermal, etc.);
4) the interconnectedness of the majority of input and output parameters among themselves.

From this it follows that the effective work of the technological machine is attainable only by optimizing its modes, taking into account all the existing factors of the interaction of the machine with the working processes under conditions of its constant change. These operations are very often combined
in time, and sometimes even belong to the same technological process, which outlines a certain relationship between the parameters of these operations.

For agricultural machines, in addition to the well-known requirements of efficiency, reliability, manufacturability, efficiency and ergonomics, it is possible and necessary to apply the requirement of "merging" of the transmission itself with the automatic control system of the operating mode.

4. Conclusion

In papers [6–8], it is proposed to entrust some automatic control functions directly to the mechanism by means of a properly organized structure. The structural basis of such mechanisms should be “nonassour kinematic chains of positive orders”. Since prior to our work, such mechanisms had not been practically investigated, the objectives of the research that we conducted were:
- the theory of nonassour kinematic chains of positive orders, which we called adaptive kinematic chains;
- creating a theory of the structure of adaptive kinematic and adaptive mechanisms in general;
- methods of static and dynamic analysis of adaptive mechanisms, as well as in the development of methods for calculating their basic parameters.

References

[1] Drownikow A, Bulgaqkowa I, Schindler J 1995 Adaptive Greifer and Hubgerate fur Bau- montagprozesse In Das Manuskript ist fur furVeroffentlicihe im Wissenschaft Zeitschr. Dresden im Marz angenommen.
[2] Chistyakov A D 2003 Forecasting the need for agricultural mechanization for the future at 20 years In Proc. of Conf. on Scientific bases for solving problems of agricultural engineering (Tula: TSU) pp. 111-119.
[3] Rusanov A I, Zhuravleva G. M. 1997 Engineering method for predicting the development of combine harvesters Tractors and agricultural machines 1 5-7.
[4] Ivanov K S 2004 Discovery of the Force Adaptation Effect In Proc. of the 11th World Congress in Mechanism and Machine Science April 1-4 2004 (Tianjin, China) vol. 2. pp. 581-585.
[5] Shugayev G A 2009 Development of a gear box with a clutch of ganging In Proc. of the 3rd International conference “Power transmissions 2009” (Kallithea, Greece) pp. 579-584.
[6] Drovnikov A N 1984 Adaptive structures of mechanisms and machines (Rostov–on-Don, Publishing house of Rostov University).
[7] Chistyakov A D, Ermoliev Yu I 2012 Schemes and design solutions of simplified grain-harvesting units based on universal and row-crop tractors Vestnik DGTU 2(63) pp. 5-7.
[8] Chistyakov A D 2003 Prediction of the structure of agricultural (Rostov-on-Don, DGTU).
[9] Buryanov A I, Dmitrenko A I, Goryachev Yu I, et al 2016 Modular grain-harvesting units based on universal energy means Herald of Agrarian Science of the Don 3(35) 14 - 30.
[10] Chistyakov A D 2003 Prediction of the structure. The application of agricultural machinery (Rostov-on-Don, DGTU).