The task of technological adjustment of an axial-rotor type grain combine

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Abstract. One of the promising approaches to improve the efficiency and effectiveness of the harvesting process of grain crops using a combine method is the use of an intelligent information system in the form of a decision support system. The expansion of the use of high-performance rotary-type combines in production conditions puts the task of optimal technological adjustment of the working bodies and the entire combine as a whole into the category of topical ones. When performing harvesting work with an axial-rotary threshing and separating device (ARTSD), as a result of continuously changing external harvesting factors, deviations in the values of work quality indicators from acceptable values are possible. For their timely elimination, it is important to know the relationships between the groups of signs: "environmental factors - parameters of the working bodies - indicators of the quality of work." The lack of knowledge leads to non-optimal decisions on the choice of specific values of the controlled parameters and, as a result, to the loss of grain and other resources. To select the optimal strategy for managing the technological process of harvesting using a rotary harvester, we propose a new approach based on the use of an intelligent information system (expert system), which corresponds to the concept of intellectualization of a new type of machine. The article presents the results of research into the process of technological adjustment of a rotary harvester, as well as an analysis of the empirical knowledge of experts with extensive production experience in operating combines of this type. The concepts of parameters, causes and methods for eliminating violations of the technological process are introduced. As a result of expert analysis, decision trees were formed for the first time, on the basis of which the rules of the knowledge base are formulated. To create a knowledge base, it is proposed to use a production model of knowledge. An example of constructing a decision tree when searching for the cause of the appearance of one of the external signs of a violation of the quality of the work of a rotary harvester is given. A fragment of the system of production rules for solving the problem of adjusting the values of control parameters is presented.

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1 Introduction

The priority task of ensuring the country's food security is the sustainable development of agricultural production, which largely depends on the improvement of processes and means of mechanizing technological processes, in particular harvesting. At present, the main trend is the creation of machines of a new type, in particular, the intellectualization of the control of these machines.

In the modern market of grain harvesting equipment, high-performance combine harvesters with an axial-rotary threshing and separating device are becoming more common in agriculture [1]. However, unlike grain combines with a classical threshing scheme, the optimal control of a rotary combine is difficult due to the lack of knowledge of the dependences of the quality indicators of the combine on external factors, which, due to the large variability, can lead to violations of the harvesting process and, as a result, the appearance of significant losses. product. When detecting changes in the values of harvesting factors (for example, moisture content of crops, lodging, weediness, etc.), it is necessary to adjust the values of the machine's adjustable parameters, that is, to solve a multifactorial decision-making problem. The solution of this problem is complicated by the presence of uncertainty in determining the specific values of factors and parameters of an agricultural machine.

Previously, from the standpoint of systems theory, we have shown that among several main tasks of managing the technological process of harvesting, the tasks of pre-setting the working bodies of the combine and adjusting technological adjustments are classic tasks of choice under uncertainty. Moreover, the solution of these problems in agricultural production is complicated by the fact that for the most part harvesting factors, performance indicators, and some parameters of the combine can be characterized as qualitative features (for example, grain losses are high, stalk moisture is average, rotor speed is significant, etc.).

Thus, the study of the characteristic features of the process of technological adjustment of high-performance rotary harvesters is relevant, since the formalization of these relationships will make it possible to implement in practice the design capabilities of agricultural harvesters.

An analysis of literary sources allows us to state that there is no adequate mathematical description of the decision-making process when implementing the processes of technological adjustment of the working bodies of a rotary harvester. The formal-logical approach currently used mainly consists in constructing regression dependences of the quality indicators of the harvesting process on input factors [2–6]. However, the use of such models in difficult field conditions is difficult, since only quantitative characteristics are taken into account during technological adjustment.

Currently, there is a growing number of publications that address the issues of modeling various problems of subject areas for agricultural purposes, based on the mathematical apparatus of fuzzy set theory. Among them, one can single out the tasks of assessing the yield of agricultural crops, the quality of tillage, the efficiency of fertilizer use, the identification of weeds, and much more [7-10]. The tasks of technological adjustment of combines of the classical type are also reflected [11-13].

The considered problem of technological adjustment, the choice of optimal (or rational) values of parameters is a rather difficult task. Its solution requires appropriate competencies from the personnel (operator). The severity of their absence can be neutralized through the use of intelligent information systems (expert systems) used as an adviser to the operator during combine harvesting [14-15].

The place of the task of adjusting the values of control parameters in the process control system is shown in Figure 1.

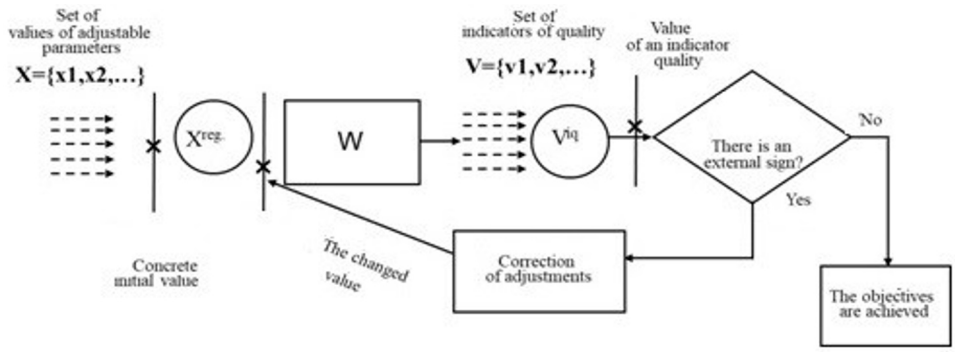

Fig. 1. The place of the task of adjusting the parameters of the combine $X^{reg.}$ - the specific value of the adjustable parameter; V^{iq} - specific value of the quality indicator.

2 Materials and methods

In the hierarchical scheme for solving the problem of correction in the field, the first step is to identify the causes of violations of the harvesting process. Identification of the subject area (technological adjustment) in order to identify the characteristic features of violations of the cleaning process made it possible to formulate 6 external signs of such violations. Moreover, these deviations of the performance indicators of the axial-rotary threshing-separating device can be due to the influence of 16 parameters (both adjustable and technical condition parameters). The presence of the second group of parameters greatly complicates the task of technological adjustment and increases the time spent on eliminating the cause of the violation of the quality of work.

The next step is to choose a strategy to search for a specific cause of the violation. Moreover, this choice is complicated by the presence of factors presented in Figure 2. Evaluation of the effectiveness of the chosen strategy can be based, for example, on the use of the criteria of "playing with nature".

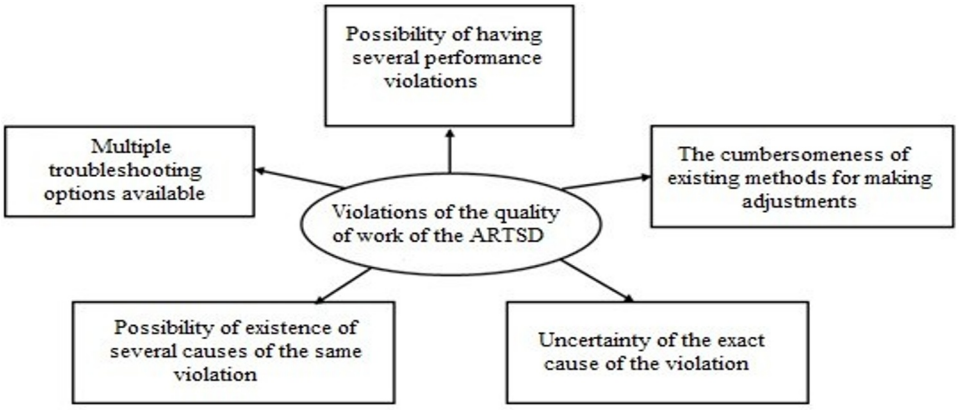

Fig. 2. Factors complicating the adjustment of technological adjustments.

3 Results and Discussion

The analysis of expert judgments of specialists of agricultural enterprises, as well as their own experience in harvesting grain crops using a rotary combine, made it possible to

structure the relationship between external signs of possible violations of the technological process and combine parameters (Figure 3 and Table1) [16].

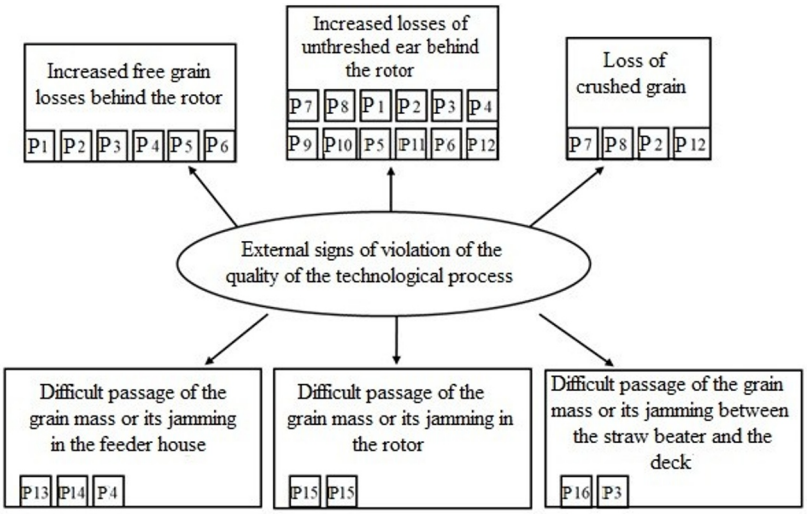

Fig. 3. External signs of possible violations of the technological process: P 12 - symbol of the parameter (Table 1).

The adjustable parameters presented in the table, as well as the parameters of the technical condition of the machine itself and its units, have a predominant effect on the values of the quality indicators of the technological process performed by the combine harvester. Exceeding the permissible values of harvesting quality indicators is due to incorrectly set operating parameters of the axial-rotary threshing-separating device.

Table 1. Adjustable parameters and technical condition parameters.

No. p/p	Parameter names	Symbol
1	Angle of attack of the turns of the separating part of the deck	P_1
2	Rotor speed	P_2
3	Gap between straw beater and deck	P_3
4	Combine speed	P_4
5	The state of the rotor turns	P_5
6	The state of the turns of the separating part of the deck	P_6
7	Gap between rotor scourges and deck scourges	P_7
8	Angle of attack of the turns of the threshing part of the deck	P_8
9	Condition of rotor scourges	P_9
10	The state of the deck scourges	P_{10}
11	The condition of the turns of the threshing part of the deck	P_{11}
12	Deck Roller Condition	P_{12}
13	Feeder House Drive (HK) Status	P_{13}
14	Condition of Feeder House Beater Drive Chain and Sprockets	P_{14}
15	The condition of the knives on the lead-in part of the rotor	P_{15}
16	Straw beater drive status	P_{16}

The success of the development and use of intelligent information systems in agriculture is largely due to the choice of an adequate model for the formal description of expert knowledge. In general, the solution of the knowledge processing problem is based on the transformation of the set of initial situations Astart (external signs of violation) into the set of final states Aend using transition operators:

$$A_{start} \text{->} A_1 \text{->} A_2 \ldots A_{k-1} \text{->} A_{end} \quad (1)$$

A set of rules-productions can serve as a form of implementation of the transition operator; If Aip, Then Ajn, that is, if there is a state A_i with the property 'p', then there is also a state A_j with the property 'n'.

The generalized form of the knowledge base rules is: rule number, list of pairs "parameter-value "; couple "cause-method loss".

As a formal model of the relationship between the features of the problem under consideration, the following model was used: [17]:

$$i: \ A \Rightarrow B; (F) \quad (2)$$

Where i - product name; $A \Rightarrow B$ - the core of the production, in which A - antecedent, including elementary sentences connected by logical connectives “and”, and B - consequent, expressing the conclusion; $\Rightarrow$ - logical consequence operator; F - product reliability coefficient.

The rule base must be complete, consistent, and continuous. Completeness means that at least one rule is activated for each value in the input space. A rule base is consistent if there are rules with the same antecedent but different consequences. And finally, the rule base is continuous if there are no neighboring rules for which the result of the intersection of sets in their consequents is the empty set.

In practice, there are three main methods for creating a rule base:

- Using the knowledge of a human expert or based on the physical laws describing the phenomenon (white box modeling).
- By automatically extracting rules based on numerical data representing the relationship between the inputs and outputs of the phenomenon (black box modeling).
- Mixed, where part of the knowledge is obtained from a human expert, and part is from automatic extraction (grey box modeling).

The solution to the problem of finding the cause of a violation of the quality of operation of an agricultural machine of this type is based on an approach that is based on a formalized description of expert knowledge and decision trees built on the basis of these formalisms.

Let us consider an example of a scheme for searching for the causes of a disruption in the functioning of an axial-rotary threshing and separating device for one of the external features (Figure 4). The essential features of the problem are shown in Figure 5.

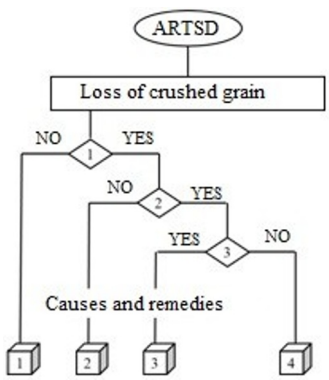

Fig. 4. Decision tree.

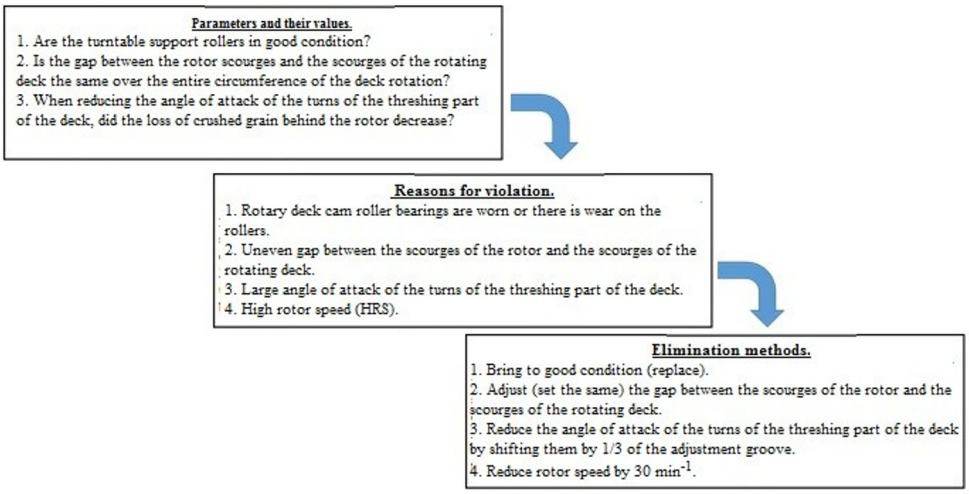

Fig. 5. The essential features of the knowledge base Fragment task are presented below.

IF < Loss of crushed grain behind the rotor is “increased” and Support rollers of the rotating deck are “in normal condition” and The gap between the rotor scourges and the scourges of the rotating deck is “same” along the entire circumference of rotation of the deck and When the angle of attack of the turns of the threshing part of the deck decreases “decreased” by the rotor, THEN The angle of attack of the turns of the threshing part of the deck is “large”: reduce the angle of attack of the turns of the threshing part of the deck by shifting them by 1/3 of the adjusting groove.

IF < Loss of crushed grain behind the rotor is “increased” and Support rollers of the rotating deck are “in normal condition” and The gap between the rotor scourges and the scourges of the rotating deck is “same” along the entire circumference of rotation of the deck and When the angle of attack of the turns of the threshing part of the deck decreases rotor “did not decrease, THEN the rotor speed is “high”. It is necessary to reduce the rotor speed by 30 min^{-1}>

4 Conclusion

The construction of a formal theory of technological adjustment of the combine requires the definition of initial and derivable formulas, their transformation and derivation rules. The construction of a formal theory can be based on the study of heuristics used by experts and the formalization of expert knowledge.

For the formalization of expert knowledge, a production model is proposed. Relationships of semantic spaces of attributes of the subject area are identified and described: parameters, causes and methods for eliminating violations of the technological process. The use of decision trees is proposed as the basis for formulating knowledge base rules. An example of building a decision tree is given when searching for the cause of the appearance of one of the external signs of the poor quality of the rotary harvester. A fragment of the knowledge base of the production type is presented for solving the problem of adjusting the adjustments of the axial-rotary threshing and separating device using the intelligent information system of the system.

The introduction of an expert system in the performance of harvesting grain crops with rotary combines will reduce the severity of the problem of transferring experience during the technological adjustment of the combine and, as a result, reduce the time to search for

the causes of the violation by 2–5 times. Reducing the time in practical conditions will increase the shift productivity of combines by 6 - 10% and reduce the level of grain losses.

The considered approach to modeling the knowledge of the specified subject area serves as a theoretical basis for the intellectualization of the control system of a rotary combine, which in the future will make it possible to implement a strategy for creating a new type of grain harvester. The implementation of this approach will ensure the sustainable development of agriculture.

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