



## **ANALYSIS OF APPROACHES TO CONSTRUCTION OF DIAGNOSTIC MODELS FOR CONTROL OF PARAMETERS OF TECHNICAL CONDITION OF SELF-PROPELLED SPRAYERS**

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### **Abstract**

The diagnostic model of control of parameters of technical condition of self-propelled sprayers is intended for representation with necessary accuracy (measure of adequacy) of diagnostic objects (OD) for the purpose of further diagnosing of a condition of its elements, and also correct assessment of correctness of its functioning. There are 4 types of properties to describe the object of diagnosis: logical parameters; electrical indicators; temporary parameters; indicators of structure (topology). For the purpose of checking the serviceability (operability), the logical model of defects completely defines the object of diagnosis. A discrete (two-level – "correct"/"faulty" or multi-level scale) or continuous scale (for example, element readiness factor, flow error rate, etc.) can be used for the description. In addition to the logical one, a logical-parametric model of defects can be used for the tasks of checking the correctness of functioning. When considering the logical-dynamic model to the events of violation of the correctness or conditions of execution of functions is added a temporary description of the procedures for its execution, such as increasing execution time or delay in performing the function above the allowable value. In order to effectively and adequately solve each diagnostic task – to check the serviceability (operability) and correct operation of self-propelled sprayers, it is necessary to develop and study your own diagnostic model. They allow to present the object of diagnostics of self-propelled sprayers by the most adequately solved task of control of a technical condition of self-propelled sprayers.

### **Key words:**

analyse, diagnostic model, object, technical condition parameter, self-propelled sprayer.

### **Introduction**

Logical parameters describe the operation of OD self-propelled sprayers using a given alphabet – the rules of transformation of values of input variables values of output variables and internal state variables (Xi & Songlin, 2019). Electrical characteristics describe, for example, the shape of signals (Rogovskii, 2020), tolerances on deviations of their parameters (Erokhin *et al.* 2019), limit values, methods of connecting elements (Pisarenko *et al.* 2019), and so on. Temporary parameters describe the dynamics of OD behavior of self-propelled sprayers – characteristics of transients (Corinne & José, 2017), delays (Nykyforchyn *et al.* 2019), frequency of change of parameters jitter

and vander (Novotny, 2016). The structure (topology) forms the functional representation of the elements determines the nature of their interaction (Rogovskii & Titova, 2021). Analytical, structural, structural-analytical, behavioural (automatic) models for describing the OD of self-propelled sprayers are used to describe the OD of self-propelled sprayers (Sergejeva *et al.* 2018). In the analytical description of the topology, a system of equations is used (Voinalovych *et al.* 2019), in which the dependence of the output variables on the values of the input and internal variables is determined (Luo & Guo, 2013). In the structural form of the topology description, a graphic representation of the OD of self-propelled sprayers is performed in the form of a set of elements and between connections (Khamidullina *et al.* 2017). The

structural-analytical model of the description of OD of self-propelled sprayers is a combination of the two models considered above as it uses both system of equations (Astashev & Krupenin, 2017), and structure of OD of self-propelled sprayers at element level (Shih-Heng *et al.* 2018). The automatic (behavioural) model is designed to formally describe the OD of self-propelled sprayers using tables of transitions and outputs (Kypris *et al.* 2016). They are filled with values of input, output and internal variables, which are calculated according to certain rules of transformation (Zagurskiy *et al.* 2018).

## Formulation of problem

One of the main stages of building a diagnostic model of the object of diagnosis self-propelled sprayers is the choice and justification of the type of model of faults that are characteristic of the objects under consideration (Gyansah & Ansah, 2020). Consider the main types of fault models: logical; logical-parametric; logical-dynamic (Tyutrin, 2019).

The logic model takes into account only the defects that lead to improper operation of the object of diagnosis of self-propelled sprayers, i.e. violation of the logic of functions (Gurcanli *et al.* 2015). At the component level, this can lead to, for example, changes in the logical function, the emergence of new or removal of existing relationships between elements, etc. (Aven, 2016). This model is adequately and reliably described by the apparatus of mathematical logic (Kuzmich *et al.* 2021). Its disadvantage is the limited range of defects and the fact that the complication of the object of diagnosis self-propelled sprayers has led to an expansion of the class of faults (both logical and parametric) (Yata *et al.* 2018).

The logical-parametric model, together with the logical manifestations of defects, takes into account the change in the quantitative (in particular, electrical) characteristics of the object of diagnosis elements of self-propelled sprayers (Najafi *et al.* 2015). This model is quite voluminous due to the need for a more complete and detailed description of not only logical but also parametric properties and characteristics but covers a wider range of faults (Zou *et al.* 2017).

The logic-dynamic model describes the behavior of a faulty object of diagnosis of self-propelled sprayers in time due to additional accounting of time characteristics - delays, transients, jitter, etc. (Dubbini *et al.* 2017) This further complicates the description of the object of diagnosis of self-propelled sprayers (Sánchez-Hermosilla *et al.* 2021), as logical defects are supplemented by faults that describe the dynamic properties of elements and signals (Nazarenko *et al.* 2021), but expand the possibilities of diagnosis (Rogovskii *et al.* 2019).

Therefore, it is disappointing to conclude that the diagnostic model for monitoring the technical condition of self-propelled sprayers is characterized by a set of parameters (logical, electrical, temporal, etc.) of its components and interconnections (Kalinichenko &

Rogovskii, 2017), as well as the selected fault model (Duan *et al.* 2016), which is most appropriate for a particular object being diagnosed (Rogovskii, 2020).

Due to the change and complexity of the technological base of the studied multifunctional facilities for diagnosing self-propelled sprayers (Palamarchuk *et al.* 2021), as well as changes in the nature of defects (Rejovitzky & Altus), to assess the performance of functions (Pinzi *et al.* 2016), it is proposed to introduce such events and assessments not previously considered in the literature:

- failure to perform a function (Masek *et al.* 2017);
- incomplete (partial) performance of the function (Chen *et al.* 2020);
- the values of some parameters of the function are outside the allowable ranges (Viba & Lavendelis, 2006);
- erroneous execution of a function (execution of another function, ie transformation), etc. (Drga *et al.* 2016).

## Purpose of research

The purpose of research is to increase the efficiency of the process of technical maintenance and repair of combine harvesters to provide required level of technical reliability of combine harvesters in modern conditions.

## Research results and discussion

When considering the logical-dynamic model to the events of violation of the correctness or conditions of execution of functions is added a temporary description of the procedures for its execution, such as increasing execution time or delay in performing the function above the allowable value. For effective and adequate solution of each diagnostic task – checking the serviceability (efficiency) and correct operation, it is necessary to develop and research your own diagnostic model. They allow you to present the object of diagnosis of the most adequately solved control tasks. Construction and research of diagnostic models is carried out further.

Presentation of the object of diagnosing self-propelled sprayers. To solve various problems of monitoring the technical condition of self-propelled sprayers, it is proposed to build generalized or detailed diagnostic models. The generalized diagnostic model of control of a technical condition of self-propelled sprayers allows to receive the aggregated information on object and its elements for receiving information on their technical condition as a whole. For this purpose, the following variants of the status of object are allocated:

- serviceable: the object is available for control, there are no reports of malfunctions of its components;
- accident: shows the inconsistency of the parameter with the specified limit values (for example, "error rate greater than  $10^{-3}$ "), failure of the element ("does not correspond to microcontrollers"), etc.;
- condition (non-urgent accident): possible occurrence of an accident ("increased laser pump current") or message ("handset raised");

- no connection: the object is not available for control, the interface between the object and the manager of the management system is broken.

The following hierarchical structure of components of diagnostic model is offered:

- module (elementary structure, atomic object of control: physical device (processor, controller, node, port, etc.) or virtual structure (flow, channel, joint, etc.));
- board (a set of modules, but may be an atomic object of control);
- block (functional device consisting of boards);
- node (concentrated structure containing several blocks);
- subnet (distributed structure containing several nodes)
- network (distributed structure, contains several subnets).

The object of each level of hierarchy can have the above status.

Methods and algorithms for determining the status of objects will be proposed below.

The detailed diagnostic model of control of a technical condition of self-propelled sprayers allows to define the reason of occurrence of this or that status of object on the reports on malfunctions formed by objects

of level of hierarchy below. Such messages are usually tied to atomic objects of control (modules (flows, joints) or boards). For example, in the plesiochronous digital hierarchy (PDH) technology, the following types of fault messages are distinguished for the digital stream: LOS: signal loss; LOF: loss of cyclic synchronization; LOM: loss of over-cycle synchronization; AIS: alarm indication signal; RDI: remote end alarm indication (message), etc.

Each fault report can be classified as an accident or condition, depending on the nature, significance, consequences, etc.

The following examples are available as illustrations for board failure reports: configuration error; inclusion of a loop; laser warning; battery operation; transition to the backup source of the clock signal; service call, etc.

When analyzing objects of the highest level of the hierarchy, detailed information on the components of their atomic objects of control is provided, for example, in the form of a report.

Each physical object (board or unit) is described by a structure that displays technical information about it. At the request of the manager or on its own initiative, the object generates information about its technical status (we will use this term instead of the term "technical condition"), for example, in the following format:

| START | ADDRESS | Control field | Message 1 | Message 2 | ... | Message N | END |
|-------|---------|---------------|-----------|-----------|-----|-----------|-----|
|-------|---------|---------------|-----------|-----------|-----|-----------|-----|

Message structure (example block):

| № boards | Board type | Message type | Message code |
|----------|------------|--------------|--------------|
|----------|------------|--------------|--------------|

Information can be used:

- for indication on the unit itself (for example, in the board (status of the components of the board or the board itself) or in a special control and signaling board (status of the unit));
- for indication in a special device (banner);
- for transmission, processing and submission to the management system manager.

For the mathematical description of the diagnostic model of control of a technical condition of self-propelled sprayers it is most adequate to use binary logic. This is due to the fact that the elementary event is processed - the presence or absence of a specific fault message or a specific status of the unit. Thus according to the accepted hierarchy after establishment of the status of objects of the  $i$ -th level the process of processing and decision-making concerning the status of objects ( $i+1$ )-th level begins.

To determine and indicate the technical status of objects at the level of physical elements and devices (module, board and unit), the following possible options are identified (dimension of the model is 3, which emphasizes its compactness, but low illustrativeness):

**A:** serviceable - no accidents and conditions (no component no reports of accidents or conditions);

**B:** accident (at least one of their components is recorded at least one accident);

**C:** state (at least one of their components has at least one state, but no accident).

To process, display, store and present information in the manager, the list of technical conditions is

expanded due to the fact that received, viewed and analyzed by the operator messages can be *acknowledged (delayed, taken into account)* so that they can identify new communications is equal to 9):

- no information;
- no answer (D);
- acknowledged (deferred) status "no answer" (E);
- no accidents and conditions (F);
- state (there are new or new states) (G, fl\_dG)
- acknowledged status (status) (all states viewed and acknowledged) (H, fl\_dH);
- accident (there are new or new accidents) (K, fl\_dK);
- acknowledged status of "accident" status "all accidents viewed and acknowledged" (L, fl\_dL);
- new state against the background of delayed accidents (BDA).

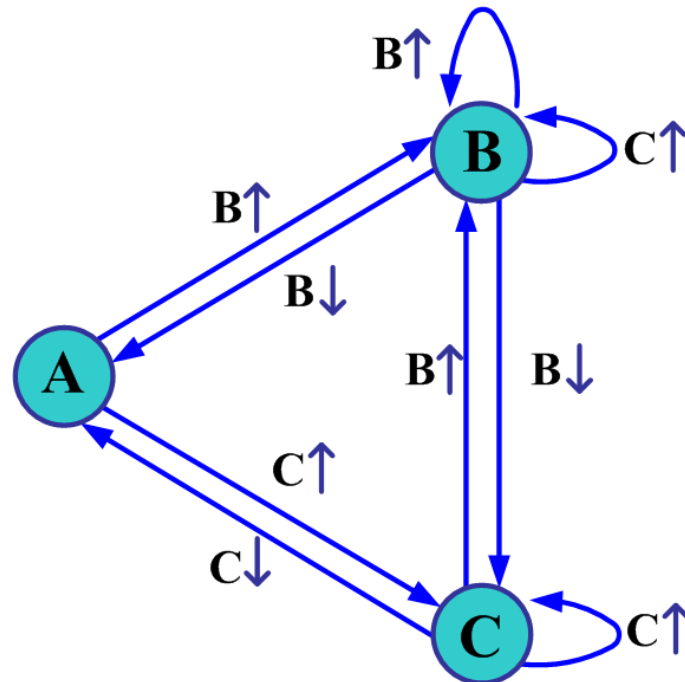
Transitions between different variants of the technical status of diagnostics are usually described using graphs. For example, let's build a graph of transitions to analyze the operation of the control board and signaling of one unit, which on its means of visual indication shows its status (Fig. 1).

For the process of information processing in the manager of the control system, the transition graph is complicated by expanding the list of possible states associated with the flowering of information, lack of communication with the object and so on. An example of a fragment of such a graph is shown in Fig. 2.

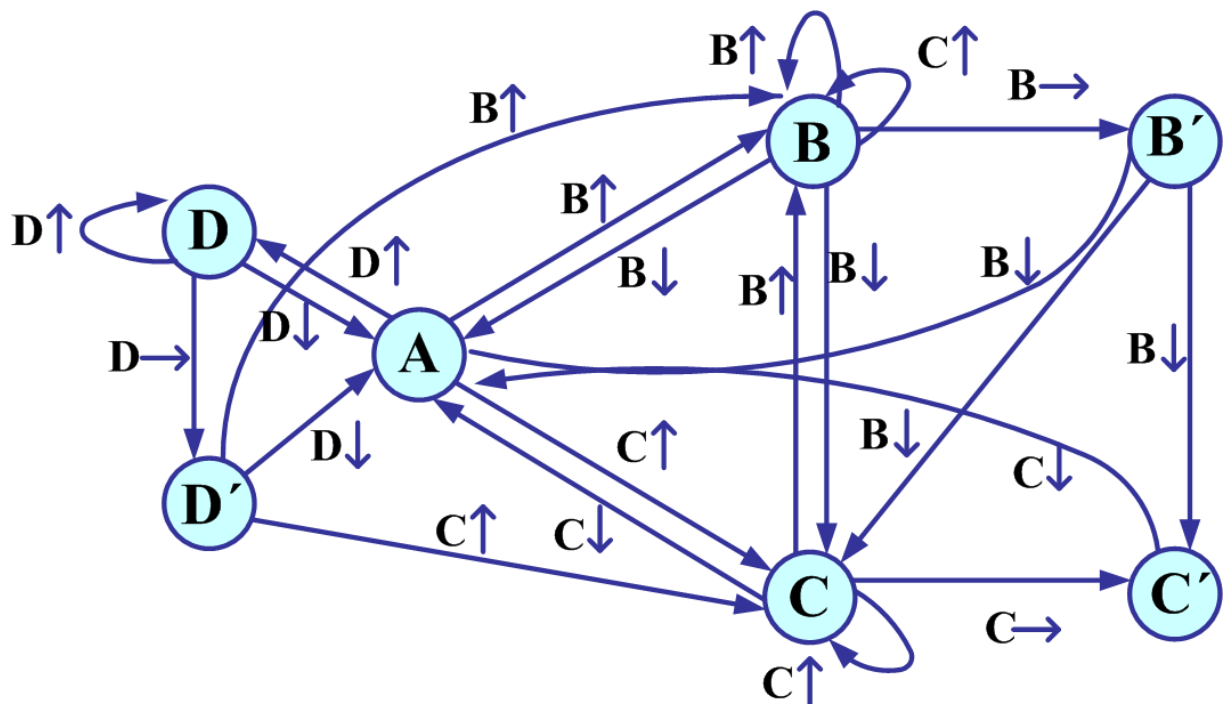
Based on the analysis of transition graphs for the processes of determining the technical status of objects of

all levels of the hierarchy, decision-making algorithms in the relevant software functions of the management system manager have been developed and implemented. Algorithms for determining the status of the board, block, node, subnet and all networks in general were

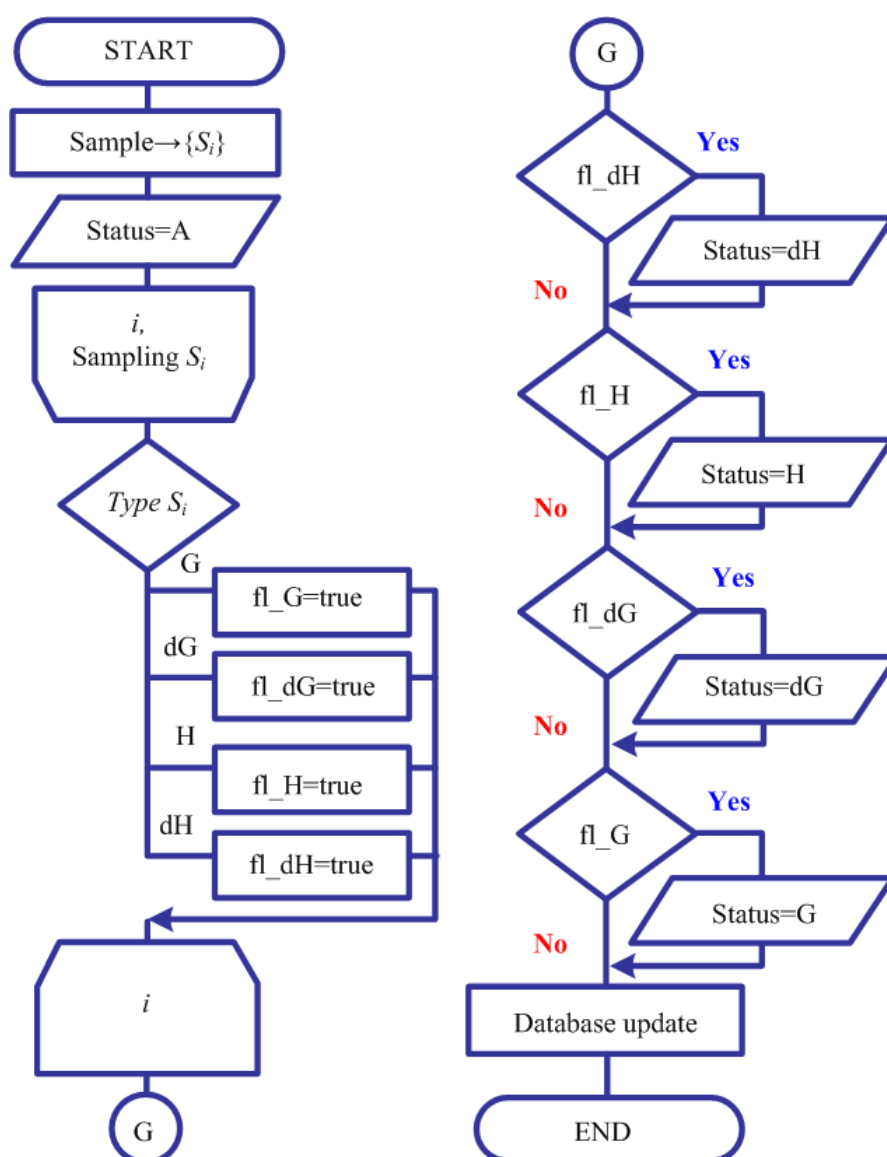
built and implemented. For this purpose, the expanded list of technical statuses (taking into account acknowledgment) was used. To illustrate the algorithm for determining the status of the board (Fig. 3).



**Figure 1.** Transition graph of the block status determination process (↑ – occurrence of an accident or condition; ↓ – elimination of an accident or condition).



**Figure 2.** The graph of transitions of process of definition of the status of the block (↑ – occurrence of accident or a condition; ↓ – elimination of an accident or a condition; → – acknowledgment of an accident or a condition).



**Figure 3.** Scheme of the algorithm for deciding on the status of the board.

To implement the algorithm, a table of conditions was constructed (Table 1) depending on the status of the flags (fl) of the appearance of a message. Symbol: "1" – true; "0" – false; "-" – does not matter.

**Table 1.** Table of formation of conditions

| № | Status flag values |       |       |       | Status devices |
|---|--------------------|-------|-------|-------|----------------|
|   | fl_K               | fl_dK | fl_dG | fl_dL |                |
| 1 | 0                  | 0     | 0     | 0     | D              |
| 2 | 1                  | -     | -     | -     | K              |
| 3 | 0                  | 1     | 0     | -     | dK             |
| 4 | 0                  | 1     | 1     | -     | BDA            |
| 5 | 0                  | 0     | 1     | -     | F              |
| 6 | 0                  | 0     | 0     | 1     | dF             |

For higher levels of the hierarchy, algorithms and decision tables are built similarly, given that the number of states expands by adding "no connection" events and its acknowledgment.

Graphic interpretation of various technical states of self-propelled sprayers is used to increase the illustrativeness in the manager's software (network map).

## Conclusions

Peculiarities of construction of diagnostic models of complex distributed objects of self – propelled sprayers are considered and analyzed. The classification is performed and the peculiarities of the application of logical, logical-parametric and logical-dynamic models in relation to the objects of the considered class are shown.

A diagnostic model for monitoring the technical condition of elements and devices of self-propelled sprayers was built and studied, which allowed to perform a hierarchical representation of the structure of the diagnostic object at the level of components of different levels, to introduce and analyze the defect model. The method of formal description of states of diagnostic model on the basis of graphs of transitions of technical



states for objects of different level is offered. Based on the constructed graphs, algorithms for processing and presenting diagnostic information are designed and implemented in the specific software of elements and devices of self-propelled sprayers.

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