Online monitoring of the technical condition of energy saturated agricultural equipment using neural networks

Yuri Kataev¹*, Igor Tishaninov¹, Evgeniy Gradov¹, and Margarita Mordasova¹

¹Federal Scientific Agro-Engineering Center VIM, 109428, Moscow, Russia

Abstract. The article presents a technique for continuous monitoring of the technical condition of energy-saturated agricultural machinery (SHT) using digital technologies, aimed at introducing new intelligent methods for diagnosing machines in the agro-industrial complex. It is noted that the main task of the digital monitoring system is to analyze the effective operation of equipment. The proposed neural network can continuously receive data on the technical condition of agricultural machinery in real time, analyzes and structures input values, such as engine speed, hourly fuel consumption, coolant temperature, which depend on the load and operating modes of the machine engine. The advantage of the digital method of monitoring the parameters of the technical condition is its assessment in the process of diagnosing in real time. The method allows to determine not only the cause of engine failure, but also to evaluate the efficiency of complex energy-saturated agricultural machinery in general.

The developed architecture of the neural network is capable of analyzing and transmitting data obtained during the diagnostic process to a special server for storing information. The proposed method for continuous monitoring of the technical condition of complex energy-saturated equipment according to controlled parameters, based on the use of neural networks, can be quickly adapted to different brands of equipment when diagnosing.

1 Introduction

Digital technologies and innovative intelligent systems in the standard process of diagnosing energy-saturated agricultural machinery, taking into account the continuous receipt of parameters about its technical condition, will reduce the labor intensity of the following operations: every shift (ETO); first TO-1; second TO-2; third TO-3; seasonal during the transition to the spring-summer period (STO-L); seasonal during the transition to the autumn-winter period (STO-Z); in preparation for long-term and short-term storage; current repair (TR) [1-8].

The main base of the proposed method for monitoring the technical condition of equipment is the architecture of artificial intelligence (AI) and a neural network.

*Corresponding author: ykataev@mail.ru

E3S Web of Conferences 402, 03026 (2023)  
TransSiberia 2023

https://doi.org/10.1051/e3sconf/202340203026

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).
The neural network with continuous monitoring of the technical condition provides for the possibility of its further machine learning through a large flow of diagnostic parameters that characterize the operation of the engine of agricultural machinery. As a result, a data bank (BigData) is formed, containing within itself examples of reference values of engine operation under various loads.

2 Purpose of research

The purpose of the research is to increase the efficiency of the diagnostic process due to the rapid transmission of data in the form of diagnostic parameters about the technical condition of the object under study using a neural network.

3 Materials and methods

The development of digital technologies in diagnosing agricultural tractors and predicting the occurrence of malfunctions or the onset of failures makes it possible to maintain agricultural machinery in working condition.

The analysis of digital methods for monitoring agricultural machinery was carried out on the basis of the studied materials of dealer services on leading manufacturers of machinery, online platforms, regulatory documents, remote diagnostics, as well as scientific papers in this area of research.

Depending on the nature of the tasks set, a graphical research method, methods of mathematical analysis using software, methods of system and statistical analysis using Python packages, Microsoft Office Excel 2020, etc. were used.

4 Results and discussion

Online monitoring of the parameters of the technical condition of energy-saturated agricultural machinery will allow you to analyze the information received online and process it using a trained neural network. The neural network identifies certain failures in the object, provided that it has been previously trained to recognize the failure. For machine learning, classical mathematical principles of neural networks are used.

With continuous monitoring of the technical condition of energy-saturated equipment, diagnostic information is collected. These processes include: failures; malfunctions; anomalies in the data. All these processes form a data bank for a specific controlled parameter. At this stage, on the basis of the obtained experimental values about the technical condition, the opinions of experts and the recommendations of manufacturers, a knowledge base (BigData) is formed. This is a set of training samples (data) that characterize the signs and manifestations of malfunctions during the operation of complex agricultural machinery; these samples are fed to the input of the neural network for further structuring and analysis.

The list of diagnostic parameters of the engine operation obtained as a result of continuous monitoring is presented in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Scale data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption fuel instant, l/h</td>
<td></td>
</tr>
<tr>
<td>Temperature coolant, °C</td>
<td></td>
</tr>
<tr>
<td>Engine shaft speed, rpm</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Diagnostic parameters of the engine operation obtained as a result of continuous monitoring.
To obtain a complete picture of the technical condition of the object under study (tractor), a special trained neural network is used, the input of which receives information from the tractor engine that characterizes real operational processes. The data obtained as a result of monitoring can be continuously monitored online via the Internet using special software. The software allows you to display the necessary parameters on the screen of a smartphone or tablet. The amount of data is unlimited. Based on the received diagnostic information, it is possible to obtain reports and graphs of events during the operation of the engine of energy-saturated equipment. Software interfaces are shown in Figure 1.
The implementation of the continuous monitoring method is as follows: diagnostic data is read from the diagnostic object (tractor) via the CAN bus by a special device; information is transmitted via GSM and GPS channels to a special server (storage) of big computing data (BigData); on the server, information is structured into groups (selections) according to controlled parameters; further, a signal is formed from the data, which is fed to the input of the neural network input values $x_1, x_2, x_3$; a decision tree or a descriptive model based on an information base of reference values recommended by the manufacturer analyzes the incoming information from the server and issues a prediction about the occurrence of a possible failure in the engine.

As a result, a number of conclusions can be drawn about the need for timely maintenance, which minimizes equipment downtime during field work. The model of the digital platform for continuous monitoring of the technical condition of energy-saturated agricultural machinery is shown in Figure 2.
In the neural network, the input layers $x_1, x_2, x_3$ (neurons) from the data bank (storage) receive the following controlled parameters: instantaneous fuel consumption $l/h$; engine temperature °C; engine speed rpm. All these parameters depend on the initial power of the engine. For example, engine rpm is used as one of the engine diagnostic parameters.

It should be noted that the developed neural network conducts self-learning on a constant stream of received data, based on a probabilistic method for detecting engine failures in energy-saturated equipment [12-16].

The architecture of the developed multilayer neural network for three controlled diagnostic parameters: instantaneous fuel consumption $l/h$ $x_1$; motor temperature °C $x_2$; engine rpm $x_3$ is shown in figure 3.

Fig. 3. The structure of a multilayer neural network, where $x_1, x_2, x_3$ are input signals.

As an example, the engine coolant temperature is predicted to be 6 hours in the future. This forecast is made on the basis of available data for a certain period of time, if we compare 5 days of observations, then a time interval is created for training the mathematical model, containing the last 720 (5x144) observations (due to the fact that different configurations are possible, this data set is a good basis for future experiments). An example of a time interval is shown in Figure 4.

Fig. 4. Dependence of temperature on the time interval.
5 Conclusions

The proposed method for continuous monitoring of the technical condition of a complex energy-saturated SHS according to controlled parameters, based on the use of neural networks, will be adapted to the tasks of diagnosing diesel engines, which will increase the service life of an energy-saturated SHS and their efficiency by 10-12%. It will make it possible to promptly carry out all types of technical support of the SHT due to timely notification.

The method of continuous monitoring based on a constant stream of diagnostic information about the technical condition of the equipment will increase the technical readiness factor by 5-8%, minimize the cost of spare parts and downtime of an energy-saturated SHT during ordinary operation.

References


2. V.F. Fedorenko, Information technologies in agricultural production: Scientific analytical review. (Moscow: FGBNU Rosinformagrotech, 2014)


6. M.N. Kostomakhin, Yu.V. Kataev, N.A. Petrishchev et al., Agroengineering 6(106), 4-10 (2021)


10. N.M. Tien, Young scientist 26(264), 76-81 (2019)

11. Yu.V. Kataev et al., Agrarian scientific journal 2, 79-82 (2022)


13. V. Chernoivanov et al., Equipment and equipment for the village 9(291), 33-36 (2021)

14. V. Denisov et al., IOP Conference Series: Earth and Environmental Science 981(3), 032003 (2022)

15. M. Kostomakhin et al., Russian Engineering Research 42(4), 360-364 (2022)