TELEMATIC SYSTEM FOR MONITORING THE CONDITION OF ASSEMBLIES AND UNITS OF AGRICULTURAL MACHINERY

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This paper presents a sophisticated telematics system designed to monitor the condition of agricultural machinery in real time, with particular emphasis on predictive maintenance and operational efficiency. The system architecture consists of several key components, including a data acquisition, storage and processing unit, a data transmission module and a specialized set of sensors for analyzing particulate matter in lubricating fluids. The main sensor of the system is a particle counter in the fluid stream, which serves as the primary detection mechanism for monitoring the level of solid contaminants in the lubricating fluid. In addition, data is supplied from the engine control unit via a K-Line communication bus, which allows the monitoring data set to be extended to include key operating parameters. Mobile wireless networks are used for data transmission, providing remote, continuous access to equipment status data, allowing operators and maintenance teams to analyze equipment status regardless of geographic location. This enables early assessment of machine health based on real-time analysis of lubricating fluid. The system monitors key parameters such as particle count, fluid pressure and viscosity, providing valuable insights into wear status and contamination levels that directly affect component longevity. The proposed system is characterized by its ability to anticipate the need for maintenance by evaluating metrics in real time, which enables the identification of preliminary signs of wear or failure. Using anomaly detection algorithms, the system evaluates deviations from established performance standards and generates alerts to notify operators of impending problems. This proactive approach minimizes the occurrence of unexpected equipment failures, thereby reducing downtime. In addition, these systems help optimize equipment performance and improve overall operational efficiency, thereby supporting the long-term sustainability of agricultural equipment in challenging field conditions.

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Introduction

Modern agriculture is facing complex challenges provoked by a significant decrease in the number of agricultural machinery with virtually unchanged crop area. According to various estimates, the average age of agricultural machinery is up to 19.5 years, which is almost double the service life. In this regard, agricultural enterprises are experiencing difficulties in maintaining the performance of machinery, which leads to increased downtime, lower productivity and higher financial costs of enterprises.

To address these challenges, farmers are increasingly using technology solutions designed to optimise processes, reduce costs and increase productivity. One of the key elements of this transformation is agricultural machinery monitoring, which provides valuable information to make informed decisions and improve machine utilisation.

Telematics systems collect information on machinery status, location, load, travelling speed and many other metrics, transmitting it to the operator in the cab and to the chief mechanic at the plant in real time.

Paper [1] presents an overview of telemetry systems used for monitoring mobile energy facilities (MEFs). The paper emphasises benefits such as reduced maintenance costs, increased uptime and improved condition management. The study focuses on the use of machine learning and artificial intelligence to predict maintenance and optimise agricultural processes. However, the author lacks specific data or case studies to support his claims and focuses solely on technical aspects, neglecting human factors and safety risks. The monitoring method itself offers advantages such as remote maintenance and early fault detection, but faces challenges such as dependence on digital infrastructure and communication networks, security issues and cost factors. Overall, the study provides valuable information on telemetry-based IOE monitoring systems but needs further refinement to include more in-depth analyses, addressing security and human factors issues for successful implementation.

The study [2] examines the use of a non-contact diagnostic system (GALILEOSKY 7.0) for high power agricultural machinery, demonstrating its ability to collect data, analyse and perform diagnostics. Despite the potential advantages of non-invasiveness and remote access, the study lacks wider comparison with other methods, deeper analysis and qualitative evaluation. The system's dependence on technology, safety concerns, implementation costs and limited technical knowledge require further study to validate its practical utility in modern agriculture.

The study [3] highlights the need for innovative technologies to improve the performance of agricultural machinery and the need for training programmes to train professionals in the use of these technologies. The paper proposes a training simulator that incorporates real world objects and a virtual control centre, but it lacks specific technical details and empirical evidence to support its effectiveness. While monitoring technologies offer potential benefits such as increased efficiency and real-time data, they also raise concerns about technology dependency, data security, implementation costs, and technical skill requirements. Further research is needed to address these concerns and validate the effectiveness of the proposed monitoring system and methods under real agricultural conditions.

When looking at existing products in the field of telematics systems, it can be noted that only a few leading companies and manufacturers are actively involved in the development and implementation of telematics systems for agribusinesses. These companies offer a wide range of solutions from precision farming tools to advanced data management platforms:

1. John Deere, a major manufacturer of agricultural equipment, has integrated telematics into its equipment with the JDLink system, which enables remote monitoring and diagnostics of tractors, combines and other machinery. The StarFire system offers high-precision GPS for precision farming, including guidance systems for automatic steering and yield mapping.
2. Trimble, known for its leadership in GPS technology, offers advanced telematics solutions for agriculture through its Trimble Ag software. The platform integrates precision farming tools such as flow control, GPS navigation and remote sensing to make it easier for farmers to manage operations based on real-time data.
3. AGCO offers a range of precision farming solutions through its FUSE technologies, which combine technology, telematics and data management. AGCO's telematics platform, AgCommand, monitors equipment performance and helps optimise machinery use and reduce downtime.
4. CNH Industrial: The parent company of brands such as New Holland and Case IH, CNH Industrial uses its AFS Connect telematics platform to support precision farming with features such as vehicle tracking, preventive maintenance and crop data analysis. The platform integrates seamlessly with equipment to optimise operations.
5. Topcon: Topcon, a company specialising in precision positioning technology, offers solutions such as the Topcon Agriculture Platform (TAP), which uses real-time field data to improve decision-making in crop production. Their systems also support automated control and precise application of fertilisers and pesticides.
6. Raven Industries: Raven Industries, a leader in precision agriculture, offers Slingshot, a comprehensive telematics and logistics platform that connects field operations to the back office. The system supports machine-to-machine communication and data-driven decision making for precision agriculture.
7. Yara International: although primarily known for fertiliser, Yara has expanded into precision farming with its Atfarm platform, which combines satellite imagery and plant data to optimise nutrient application. This helps farmers utilise resources more efficiently and increase yields.

These companies play a key role in the development of agro-industrial technologies, and the telematics systems they have developed are improving operational efficiency and sustainability across the entire agricultural value chain.

Most telematics systems collect a wide range of information that provides a comprehensive view of machinery performance and condition. Table 1 summarises the types of data that can be monitored.

Summarising the above, it can be noted that existing products in the field of telematic systems and existing research do not imply installation of additional equipment for diagnostics of agricultural machinery, but are only a superstructure over basic control units and carry out collection, storage, processing and transmission of information of those values, which are received from standard systems.

Table 1

Types of telematics monitoring data

Data Area:	Data type:	Description:
Location	GPS coordinates	The exact location of the technique on the map
	Travelling speed	The speed of the machine at a given time
	Direction of movement	Direction of machine movement
	Movement history	Trajectory of machinery movement over a certain period of time
Operation of machinery	Engine hours	Total motor running time over a certain period of time
	Fuel consumption	Volume of fuel consumed
	Engine speed	Engine revolutions per minute
	Engine temperature	Temperature reading in the motor cooling system
	Oil pressure	Supply of oil to engine parts at a certain pressure
State of the art	Error code	Error codes that occur in the operation of the equipment
	System boot	Percentage of utilisation of various machinery systems
	Oil level	Engine oil level
	Fuel level	Fuel level in the tank
Additional features:	Geo-fences	Setting the geo-fences in which the equipment should be located or from which it should not leave.
	Alerts	Set up alerts for various events, e.g. speeding, machinery stoppage, fuel consumption, faults.

This study proposes to develop a telematics-like system equipped with an additional sensor to determine the amount of solid particles in the lubricant composition. Many studies show that some amount of small solid particles characterised by oil properties are present in the oil of an internal combustion engine from the moment of operation. In the process of internal combustion engine operation, the oil wears out, losing its lubricating properties, which leads to an increase in the rate of wear of friction pairs and a sharp increase in the number of solid particles (Fig. 1).

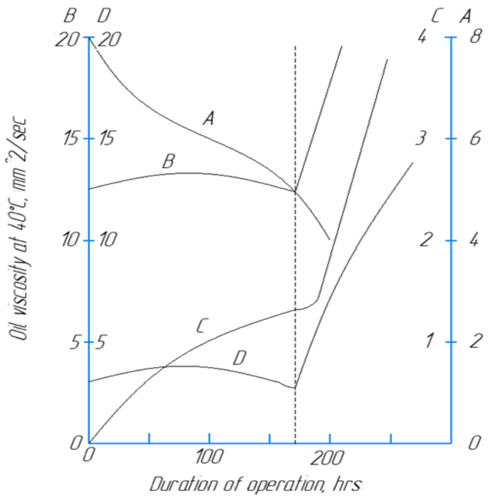

Fig. 1. Dependence of the main characteristics of oil in the process of running time, where: A – total alkalinity; B – oil viscosity; C – amount of insoluble products; D – total acidity

The development of an intelligent telematics system capable of determining the amount of solid particles in the lubricant composition will allow real-time assessment of the oil condition, indicate the need for its replacement, and based on the large data on the oil condition of a particular power unit for the previous period will allow to preventively determine the need for maintenance. Also, untimely and peak growth of solid particles can indicate critical wear of friction pairs and the need for technical repair of the power plant before its failure.

The purpose of this paper is to present the results of the research devoted to the development of an intelligent telematic system, which includes a unit for collecting, storing and processing information, a unit for transmitting information and a sensor (sensor) for determining the amount of solid particles in the oil. The proposed monitoring system is considered as a potential key element of smart agriculture combining efficiency, sustainability and innovation.

Materials and methods

Two systems for monitoring the oil condition of the power unit and drive system components can be applied to agricultural machinery:

1. Telematic system. Allows real-time assessment of lubricant condition and transmission to image output devices and the enterprise server.

2. Manual method. Allows to collect and store information about the state of the lubricant on a carrier inside the technique, and the information is collected and transmitted manually with the help of additional devices or a personal computer. Data processing can be carried out either on the capacity of the unit of collection, processing and storage of information, or on the enterprise server or personal computer.

Both methods require installation of an additional sensor, data collection, processing and storage unit and differ only in the method of data transmission. The most promising for large enterprises is a telematic system that meets the requirements of operational control over the condition of a large fleet of rolling stock.

PC-M600, which is a flow counter of particles in oils and technical liquids, designed for flow measurements under conditions of high pressure and temperature, as well as its analogues, is considered as the main sensor.

The rest of the information required by the telematics system for a more complete assessment of the state of agricultural machinery is proposed to be collected from the control unit of the power plant directly from the single-wire bidirectional bus (K-Line), designed to connect the control units of the vehicle among themselves.

Information on the condition of agricultural machinery can be transmitted for further analysis in several ways:

Mobile communication (GSM/LTE). This type of communication is the most common way of data transmission. The built-in GSM/LTE modem in the machinery is connected to the network of the mobile operator and transmits the information to the server. The scheme of signal transmission from the technique is shown in Figure 2.

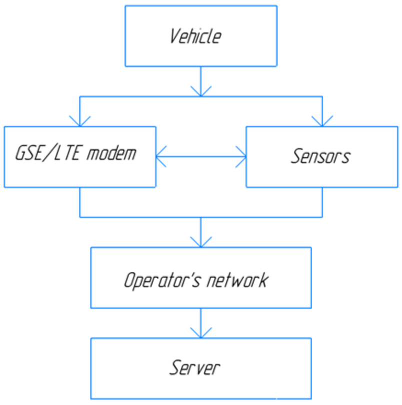

Fig. 2. Mobile phone monitoring scheme

The scheme reflects the standard scheme of data collection via mobile communication when monitoring agricultural machinery and functions as follows:

1. The machinery is equipped with sensors that collect information about the machinery operation (speed, fuel consumption, engine temperature, geolocation, etc.).

2. The sensors transmit the information to a GSM/LTE modem. A modem is a device that allows you to transmit data over a cellular network.

3. GSM/LTE modem transmits data to the operator's network. The operator's network provides communication between the modem and the server.

4. The rver receives data from the modem and processes it.

Satellite communication. This type of data transmission is used mainly in remote areas where mobile phone coverage is not available. The satellite modem in the technique establishes a connection with the satellite, which transmits data to the ground station and then to the server. The scheme of signal transmission from the technique to the server is shown in Figure 3.

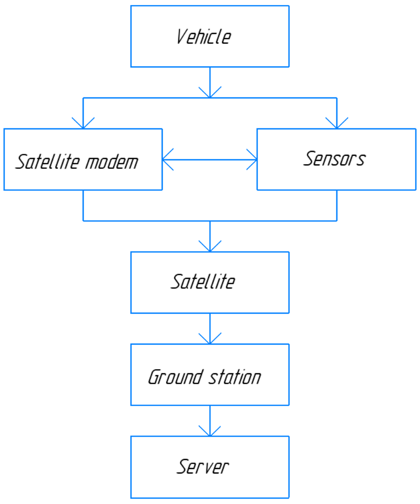

Fig. 3. Satellite-based monitoring scheme

The operation of the system looks like this:

1. the technique is equipped with sensors that collect information about the operation of the technique (speed, fuel consumption, engine temperature, geolocation, etc.).

2. T e sensors transmit the information to a satellite modem.

3. The satellite modem receives data from the sensors and transmits it to a satellite in space.

4. The satellite receives data from the modem and transmits it to a ground station.

5. The ground station receives data from the satellite and transmits it to the server.

6. The server processes the data received from the technique, stores it in its database and provides access to it to the user.

Wireless networks (Wi-Fi, Bluetooth). This type of data transmission is used within a short range. The Wi-Fi module in the technique is connected to the wireless network, and the Bluetooth module is connected to the operator's mobile device. The scheme of signal transmission from the equipment to the server is shown in Figure 4.

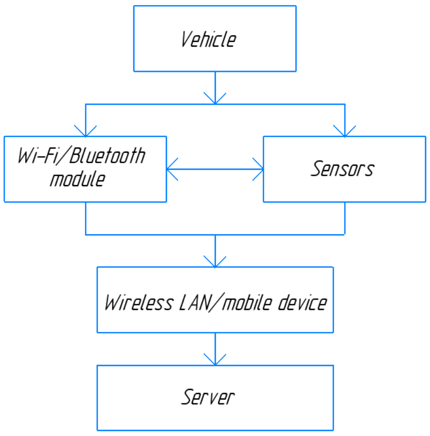

Fig. 4. Monitoring scheme with wireless network

The operation of the system looks like this:

1. The technique is equipped with sensors that collect information about the operation of the technique (speed, fuel consumption, engine temperature, geolocation, etc.).

2. The sensors transmit the information to the Wi-Fi/Bluetooth module installed on the equipment. 3.

3. The Wi-Fi/Bluetooth module receives the data from the sensors and transmits it to the wireless network / mobile device.

4. The wireless network / mobile device receives data from the module and transmits it to the server.

5. The server processes the received data, stores it in a database and provides access to the data to the user.

Table 2 summarises all the advantages and disadvantages of the above methods of transmitting data from agricultural machinery systems to the server for further analysis.

Table 2

Types of telematics monitoring data

Type of communication	Advantages	Disadvantages
Mobile communication	– broad network coverage; – availability; – low cost	– dependence on signal quality; – possible delays in data transmission
Satellite communication	– the largest coverage area; – Independence from terrestrial infrastructure	– high cost of equipment and services; – long data transmission time
Wireless networks	– high data transmission speed; – low cost	– limited range

In any case, all analysed methods of data transfer have a common essence - it is the process of data transfer to the storage, which is the server. First of all, data preprocessing takes place. This is the process of data cleaning from 'noise' and errors, where they are also brought to a single format and scale for further convenience of processing and analysis. The direct storage of information itself takes place in a relational database, which provides structured storage and quick access to materials.

The software part of the intelligent telematics system developed in one of our previous studies with the above set of sensors (sensors) and blocks allows collecting, storing, processing and presenting numerous parameters in various dependencies. Thus, the system is able to collect information passing through the K-Line technique, as well as information from an additional flow-through particulate counter. The main difference of the presented telematic system from the existing ones is the precise determination of lubricant indicators of the power plant and elements of the vehicle drive system, which in combination with self-learning software is able to preventively indicate the need for maintenance and technical repair.

Thus, for example, the system is able to determine the amount of solid particles depending on the oil operating time in motor-hours and to determine the moment of optimal maintenance before a significant change in the oil performance indicators and reduction of lubricating properties. Figure 5 shows an example of data output of the intelligent telematics system, which is programmed in such a way that when approaching 200 motor-hours, the system sends a notification to the image output device and to the server part of the hardware and software complex, and a notification of an imminent need for maintenance.

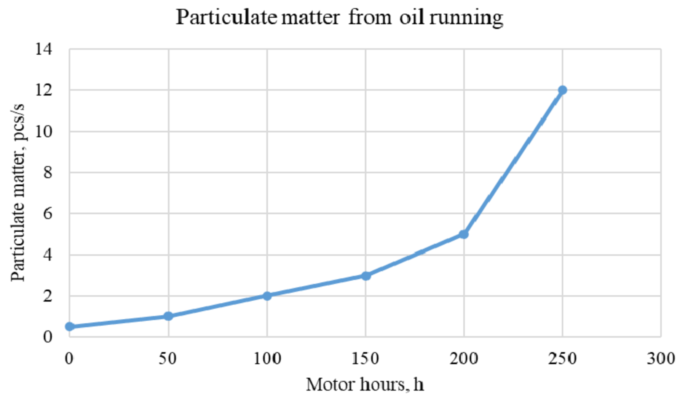

Fig. 5. Example of plotting the dependence of the number of solid particles on the operating time of the lubricant

The telematics system under development is also capable of collecting, storing and processing dozens of other parameters collected via K-Line when vehicle units communicate with each other and present them in a convenient and useful form for operators and chief engineer. Thus, Figure 6 shows the dependence of oil pressure on oil operating hours.

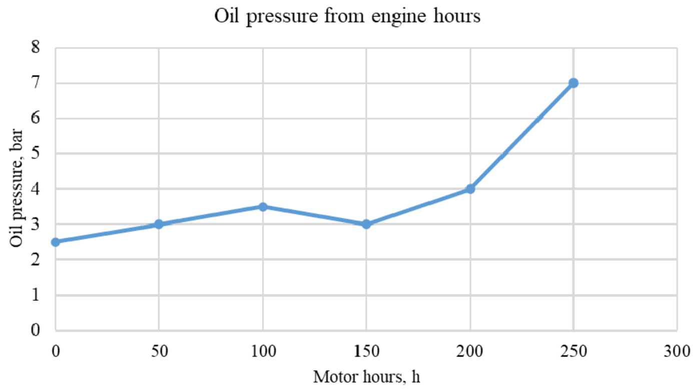

Fig. 6. Example of plotting the dependence of oil pressure in the oil system of the power unit of agricultural machinery on the lubricant runtime

An increase in oil pressure in the oil system of the power plant normally has a positive effect on the service life of the unit, but with oil wear, additive depletion and deterioration of lubricating properties, all the benefits are levelled out and, on the contrary, have a negative effect due to the increased load on the lubrication system of the combustion engine.

These are not the only dependencies and recorded indicators of the telematics system being developed. Complex analysis of the data received by the system due to self-learning intelligent software can significantly improve the operational performance of agricultural machinery, extending the service life, reducing the flow of failures, preventive decision on maintenance and repair work, as well as reducing the financial costs of downtime.

Correct training of programme training on reaction of changes of parameters of machinery in the process of operation, which are of peak character and their change from standard indicators, can be defined as a failure of this or that unit and assembly. For example, an increase in the temperature of exhaust gases with atypical changes in the ignition advance angle and accelerated ageing of the lubricant of the power plant with unchanged environmental parameters and air temperature at the inlet may indicate a malfunction of the fuel system, which is practically impossible to determine by conventional diagnostic equipment before failure, as changes in the nature of the equipment operation may not be noticed.

Results and discussion

Based on the analysis of all the presented types of monitoring, we can conclude that in the agricultural industry, where we are talking about large scale production and where it is necessary to control various types of machinery, the most promising will be the use of telematic type of monitoring with the installation of additional sensors (sensors) and built on intelligent software. In addition to the obvious advantages in the form of modern technology and increased productivity of work when used, the telematic method has the possibility of integration with other types of monitoring, which will allow a more comprehensive approach to the issue of maintenance and control of machinery.

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Conclusion

Telematic monitoring of machinery allows you to manage the operation of machinery more efficiently, reduce the cost of its operation and increase labour productivity. Thus, based on research, the use of telematics monitoring leads to changes in the following indicators:

– Reduction in downtime. Thanks to timely detection of malfunctions, it is possible to reduce downtime by 20-30%.

– Route optimisation. Analysis of data on the movement of equipment allows you to optimise routes, which can reduce travel time by 10-15%.

– Reducing fuel consumption. Monitoring fuel consumption and optimising engine performance can reduce fuel consumption by 5-10%.

Improved harvesting efficiency. Tracking harvesting equipment can optimise the harvesting process and increase harvesting efficiency by 5-10%.

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ТЕЛЕМАТИЧЕСКАЯ СИСТЕМА МОНИТОРИНГА СОСТОЯНИЯ УЗЛОВ И АГРЕГАТОВ СЕЛЬСКОХОЗЯЙСТВЕННОЙ ТЕХНИКИ

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Аннотация
В данной статье представлена сложная телематическая система, предназначенная для мониторинга состояния сельскохозяйственной техники в режиме реального времени, с особым акцентом на предиктивное обслуживание и эффективность эксплуатации. Архитектура системы состоит из нескольких ключевых компонентов, включая блок сбора, хранения и обработки данных, модуль передачи данных и специализированный набор датчиков для анализа содержания твердых частиц в смазочных жидкостях. Основным датчиком системы является счетчик частиц в потоке жидкости, который служит основным механизмом обнаружения для контроля уровня твердых загрязняющих веществ в смазочной жидкости. Кроме того, данные поступают от блока управления двигателем по коммуникационной шине K-Line, что позволяет расширить набор данных мониторинга за счет основных эксплуатационных параметров. Для передачи данных используются мобильные беспроводные сети, обеспечивающие удаленный непрерывный доступ к данным о состоянии оборудования, что позволяет операторам и группам технического обслуживания анализировать состояние оборудования независимо от географического положения. Это позволяет заблаговременно оценить состояние машины на основе анализа смазочной жидкости в режиме реального времени. Система отслеживает такие ключевые параметры, как количество частиц, давление жидкости и вязкость, предоставляя ценные сведения о состоянии износа и уровне загрязнения, которые непосредственно влияют на долговечность компонентов. Предложенная система отличается способностью предвидеть необходимость технического обслуживания путем оценки показателей в режиме реального времени, что позволяет выявлять предварительные признаки износа или отказа. Используя алгоритмы обнаружения аномалий, система оценивает отклонения от установленных норм производительности и генерирует предупреждения для оповещения операторов о надвигающихся проблемах. Такой превентивный подход позволяет свести к минимуму возникновение непредвиденных отказов оборудования, тем самым сокращая время простоя. Кроме того, данные системы способствуют оптимизации производительности техники и повышению общей эффективности работы, тем самым поддерживая долгосрочную устойчивость сельскохозяйственной техники в сложных полевых условиях.

Ключевые слова: *мониторинг, сельскохозяйственная техника, анализ неисправностей, Интернет вещей, беспроводная связь, повышение эффективности.*

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