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MODERNIZATION OF AN OBSOLETE FP-17SMN4 MILLING MACHINE BASED ON A MODERN MONITORING AND ENERGY MANAGEMENT SYSTEM

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Abstract

This article discusses the modernization of an obsolete FP-17SMN4 milling machine by introducing a modern technical monitoring and energy management system instead of completely replacing the machine with a new one. The research was carried out using the FP-17SMN4 milling machine installed at "Fergana Mechanical Plant" LLC as the main experimental object. The purpose of the study was to improve the technical condition of the machine, reduce energy consumption, detect possible faults at an early stage, and increase production efficiency.

The proposed system is based on the continuous monitoring of the main operating parameters of the milling machine, including vibration, temperature, current, voltage, torque, and load. The data obtained from sensors are processed by a control algorithm, which makes it possible to assess the technical condition of the machine in real time and select an energy-saving operating mode. Experimental results showed that the modernization reduced energy consumption by 10%, increased fault detection accuracy to more than 90%, and improved production productivity by 12–15%. In addition, maintenance costs decreased by 15%, and losses caused by unplanned downtime decreased by 18%. According to the economic calculations, the annual economic benefit from implementing the proposed modernization system amounted to 2,739,000 UZS.

Keywords

milling machine, modernization, FP-17SMN4, technical monitoring, energy management, sensor-based control, fault diagnosis, productivity, economic efficiency.

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INTRODUCTION

In modern mechanical engineering enterprises, increasing production efficiency, reducing energy consumption, and extending the service life of existing technological equipment are among the most important practical tasks. Many industrial enterprises still use machine tools that have been in operation for a long time. As a result of long-term use, such equipment becomes physically and morally obsolete. This leads to a decrease in machining accuracy, an increase in energy consumption, higher maintenance costs, and more frequent unplanned downtime.

Milling machines are one of the most widely used types of technological equipment in mechanical engineering. They are used for machining metal parts, forming surfaces, and performing various technological operations. However, when milling machines become obsolete, their technical condition deteriorates, and their reliability decreases. In such cases, enterprises often face two options: to purchase a new machine or to modernize the existing one.

Buying a new milling machine requires significant capital investment. For many enterprises, especially those operating with limited financial resources, this option may not be economically convenient. Therefore, modernization of existing machines using modern monitoring, diagnostic, and energy management systems is considered a more practical and cost-effective solution.

The object of this study is the FP-17SMN4 milling machine used in the production workshop of “Fergana Mechanical Plant” LLC. Instead of completely replacing this machine, a modernization method based on a technical monitoring and energy management system was developed. The system was designed to monitor the technical condition of the machine in real time, optimize energy consumption, identify possible faults in advance, and improve overall production efficiency.

The main aim of this research is to increase the reliability and efficiency of an obsolete milling machine by equipping it with a modern sensor-based monitoring system. The practical significance of the research lies in the fact that the proposed solution can be applied to other similar milling machines used in industrial enterprises..

1. Integrated monitoring model

Formula:

$$M\_\{FP-17SMN4\} = f(V, T, I, P, L)$$

This formula represents the general monitoring model of the modernized FP-17SMN4 milling machine. The technical condition of the machine depends on

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vibration, temperature, current, power consumption, and load condition. Where:

V — vibration level;

T — temperature;

I — current;

P — power consumption;

L — load condition.

2. Real-time sensor data model

Formula:

$$S(t) = \{V(t), T(t), I(t), P(t)\}$$

This formula shows the set of sensor data collected from the machine in real time. The system continuously receives vibration, temperature, current, and power values during operation.

Where:

S(t) — sensor data at time t;

V(t) — vibration at time t;

T(t) — temperature at time t;

I(t) — current at time t;

P(t) — power at time t.

The modernization system of the FP-17SMN4 milling machine consists of an ESP32 controller, vibration sensor, temperature sensor, current sensor, Wi-Fi dashboard module, DC power supply, and wiring accessories. The ESP32 controller collects and processes data from the sensors. The MPU6050 vibration sensor is installed near the spindle bearing to detect abnormal vibration. The DHT22 temperature sensor is placed near the motor to monitor overheating. The current sensor is used to evaluate energy consumption and load condition.

The collected data are transmitted to the ESP32 through I2C and digital input interfaces. Then, the controller sends the processed information to the dashboard via Wi-Fi. The dashboard displays vibration, temperature, current, and machine status in real time. This system helps detect faults earlier, reduce downtime, improve energy efficiency, and increase the reliability of the FP-17SMN4 milling machine.

METHODS

The FP-17SMN4 milling machine was selected as the experimental object of the research. This machine had been used for a long period in the production

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workshop of "Fergana Mechanical Plant" LLC. Due to long-term operation, some of its technical characteristics had deteriorated. Instead of replacing the machine completely, it was proposed to modernize it with a technical monitoring and energy management system.

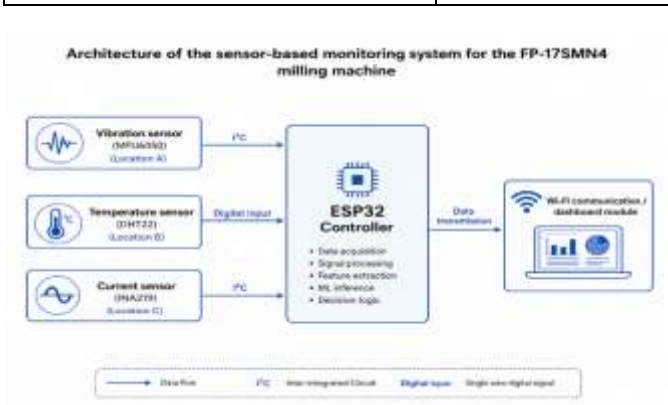
The modernization system was developed to monitor the main operating parameters of the milling machine. These parameters are important because changes in them can indicate the technical condition of the machine and possible faults during operation.

The monitored parameters included:

- vibration level;
- operating temperature;
- current and voltage;
- torque;
- mechanical load;
- energy consumption;
- general technical condition of the machine.

The proposed system consists of several main components:

Component	**Function**
Microcontroller	Receives and processes data from sensors
Current and voltage sensor	Measures electrical parameters and energy consumption
Temperature sensor	Monitors overheating of machine components
Vibration sensor	Detects mechanical vibrations and abnormal oscillations
Load or torque sensor	Evaluates mechanical load during machining
Software algorithm	Analyzes collected data and evaluates machine condition
User interface	Displays monitoring results and warning signals



The operating principle of the system is based on real-time data collection. Sensors

are installed on the main working parts of the milling machine. They continuously measure vibration, temperature, current, voltage, torque, and load. The collected data are sent to the microcontroller, where they are processed using a diagnostic algorithm.

If any monitored parameter exceeds the allowed limit, the system gives a warning to the operator. For example, an increase in vibration may indicate problems in the spindle, bearings, or transmission elements. A rise in temperature may show excessive friction or insufficient cooling. An increase in current and load may indicate mechanical overload or inefficient operation.

The experimental tests were carried out by comparing the machine's performance before and after modernization. The following indicators were evaluated:

- energy consumption;
- maintenance and repair costs;
- fault detection accuracy;
- production productivity;
- losses caused by unplanned downtime;
- annual economic efficiency.

This comparison made it possible to determine the practical effect of the proposed modernization system.

RESULTS

The experimental results showed that the modernization of the FP-17SMN4 milling machine with a modern monitoring and energy management system had a positive effect on its technical and economic performance.

First, energy consumption decreased. Before modernization, the machine operated in a traditional mode without continuous monitoring of energy use. After modernization, energy consumption was controlled using sensors and an energy management algorithm. This helped reduce unnecessary energy losses and improve the operating mode of the machine.

According to the test results, energy consumption decreased by approximately 10%. This result is important for industrial enterprises because milling machines usually operate for many hours, and electricity costs make up a significant part of total operating expenses.

Second, the accuracy of fault detection increased. The monitoring system made it possible to continuously observe the technical condition of the machine. As a result, possible faults could be detected at an early stage. The fault detection accuracy exceeded 90%, which confirms the effectiveness of the diagnostic system.

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Third, production productivity improved. Due to better technical control, fewer unplanned stops, and more stable operation, the productivity of the milling machine increased by 12–15%.

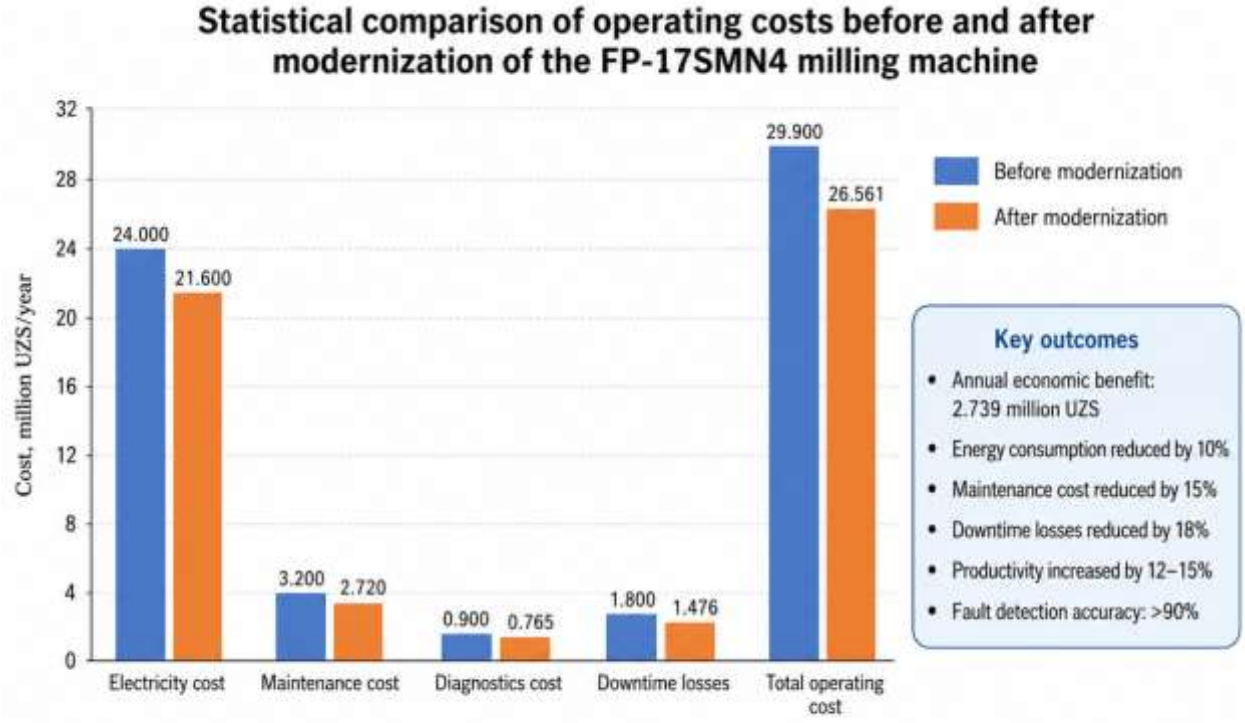

Figure. Statistical summary of the technical and economic effects of modernization.

The results show that the use of a sensor-based monitoring system improves the reliability of the milling machine and reduces operational costs. The system allows the operator to receive real-time information about the machine condition and take preventive measures before serious failures occur.

The reduction in maintenance costs was also significant. Because the system helps detect faults earlier, the need for emergency repair decreases. According to the calculations, maintenance and repair costs decreased by 15%.

Unplanned downtime was also reduced. Since the technical condition of the machine was monitored continuously, unexpected failures and production interruptions became less frequent. As a result, losses caused by downtime decreased by 18%.

DISCUSSION

The obtained results confirm that modernization of obsolete milling machines using a modern monitoring and energy management system is technically and economically effective. The FP-17SMN4 milling machine example shows that it is possible to improve the performance of old equipment without purchasing a completely new machine.

Before modernization, the technical condition of the machine was mainly assessed through periodic inspections and the operator's experience. This approach is not always accurate because faults may develop between inspections and remain unnoticed until they cause serious problems. After modernization, the technical condition of the machine was monitored continuously using sensors. This made the diagnostic process more reliable and objective.

The 10% reduction in energy consumption demonstrates the effectiveness of the energy management function. Although this percentage may seem moderate, it can produce considerable savings in industrial production, especially when several machines operate continuously.

The fault detection accuracy of more than 90% is another important result. Early detection of faults allows the enterprise to prevent serious failures, reduce emergency repairs, and plan maintenance more effectively. This contributes to increasing the service life of the machine.

The increase in production productivity by 12–15% shows that modernization has not only technical but also economic importance. Higher productivity means that the enterprise can produce more products in the same amount of time, reduce delays, and use production capacity more efficiently.

Another important advantage of modernization is the extension of the service life of existing equipment. Instead of buying expensive new machines, enterprises can improve the performance of available machines by installing relatively low-cost monitoring and control systems. This approach is especially useful for small and medium-sized industrial enterprises.

The economic analysis also supports the practical value of the modernization. The annual economic benefit was calculated as 2,739,000 UZS. This result shows

that the proposed system can reduce operating expenses and improve the economic efficiency of production.

CONCLUSION

The research results show that modernization of the obsolete FP-17SMN4 milling machine using a modern technical monitoring and energy management system is an effective solution from both technical and economic points of view.

The experimental tests confirmed that the proposed system reduced energy consumption by 10%, increased fault detection accuracy to more than 90%, and improved production productivity by 12–15%. In addition, maintenance and repair costs decreased by 15%, and losses caused by unplanned downtime decreased by 18%.

The annual economic benefit obtained from the modernization was calculated as 2,739,000 UZS. This confirms that the proposed system is economically efficient and suitable for practical implementation in industrial enterprises.

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