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Hardware and information system for the recording of the working time of universal metal-working machines

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Abstract. The article is aimed at implementing the principles of lean manufacturing at machine-building enterprises. It considers the task of monitoring and analyzing the efficiency of using the machine time of the universal machine park, where CNC is not used. It also does not provide for the possibility to register information and promptly take into account the duration and modes of operation of the machine. The article proposes a software-hardware solution, in which the idea of machine loading in an automated mode is formed without the influence of the "human factor". The data are generated based on the registration of the current strength consumed by the machine. The developed information system allows us to generate a report and a load schedule for each piece of equipment for a selected period of time. The result is a reduction in downtime up to 2 times and an increase in output by 25%.

1. Introduction

The effect of the operative management decision-making largely determines the effectiveness of the head of a modern industrial enterprise. However, one's information support has a decisive role. The implementation of the information support system of the management decision-making is necessary to automate the data collection process. This allows you to timely analyze information for subsequent management decisions. Reducing the loss of working time equipment makes a significant reserve to increase productivity. Equipment diagnostics are closely related to monitoring. The data should be used to make appropriate management decisions that will lead to an increase in labor productivity [1].

Currently, there are several ways to improve the efficiency of production equipment. The remote monitoring of the action time, idle speed and machine downtime in real time allows the operator to collect and promptly provide management with information on the loading of the equipment fleet without operator intervention. The data are output to the computer after the statistical processing. The advantage of the considered systems is that it is rather difficult to deceive such systems. Statistics of worked programs, electric power, tool run time, etc. are saved in them. In this case, all data is obtained from the sensors of the machine with a period of the order of seconds. This eliminates the distortion of the monitoring results from the influence of the "human factor". However, all considered systems are limitedly distributed due to the fact that there is no direct interaction with CNC systems of different manufacturers. The possibility of applying known technical solutions to control the duration of operation of universal machines is also limited.

The results of our research have shown [1, 9] that one of the ways to solve this problem is to take into account working time, idling and machine downtime based on recording electricity consumption.

The scientific novelty of the work is the ability to make standard management decisions based on the consideration of the acting time of the process equipment, including universal equipment. This is achieved by installing a current sensor in the power supply circuit of the main drive of the machine. It is connected together with a programmable relay, which is responsible for transferring data to a personal computer under different engine operating conditions. In the future, they will be processed and visualized for ease of use.

2. The architecture of the hardware-software complex

The hardware-software complex for monitoring of the acting time of the industrial equipment is a multi-level system.

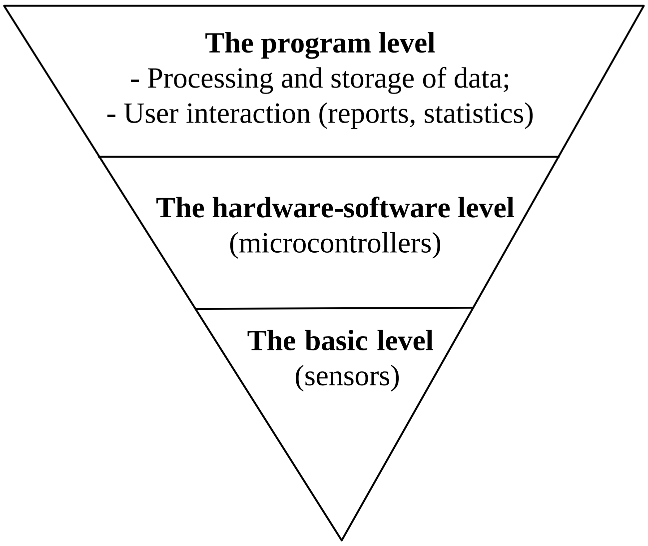

Figure 1. The structure of the hardware-software complex

- The base (hardware) level is represented by the developed current sensors that are connected directly to industrial equipment (machines, mechanisms, etc.).
- The intermediate (hardware and software) level represented by microcontrollers that receive analog signals from sensors. Their digitization and initial processing (for example, filtering and smoothing) is performed here. The data obtained at this level are transmitted to level 3 in digital form.
- The upper (software) level is presented by an automated information system that works on the PC-base. This level can be divided into two sublevels: the level of the data processing and the level of the user interaction. The data processing involves the obtaining data from the controllers (hardware-software level) in real time and saving them in a database (DB). The user interaction level is responsible for the user interface, which allows you to view statistics and generate reports based on database information.

The automated information data system (AIS) should provide the following properties for the quick access and usability of the management information:

- accuracy of the information. The level of accuracy should be sufficient for making management decisions, but excessive accuracy is also not required. For example, measuring the operating time or inactivity of the equipment during a working day with an accuracy of one minute seems sufficient. The same data with reductions in hundredths of a second is redundant, despite the

fact that the information system technically allows for such accuracy;
- reliability of the information (completeness and general accuracy). Reliability is ensured by the lower and intermediate levels of the system due to regular (several times per second) removal of data from equipment and processing. For this, verified algorithms are used;
- relevance of information (compliance with the current point in time). The system must operate in real or "almost real" time to meet this requirement;
- usefulness of the information. The data presented by the system will be valuable if it is used for management decisions. Therefore, of the variety of data, the user must receive exactly the data that will help analyze the current situation and make the right decisions.

In addition, there are a number of technical requirements which are made to the system:
- speed, which includes two aspects. This is an online recording of the information that comes from the sensors to the database. The speed of the database (and computer hardware) must be sufficient so that the data stream from the sensors does not have losses. This is especially important when working with a large number of sensors.. The second component of the system response speed is the ability to the quickly analyze of the accumulated in the database information over a long period of time (over months and even years) with the output of relevant statistics;
- scalability: the system has the ability to increase the number of the data highways (it can work with a large number of simultaneously connected sensors);
- convenient user interface;
- access to system data through communication channels, allowing to receive reports and statistics from any workplace within an enterprise or organization;
- protection against unauthorized access to data.

3. Software implementation
Embedded SQLite relational database is used to store information. This database does not require licensing and it is free, including for commercial use. SQLite does not use a client-server paradigm, and API functions are used to access the database. This approach allows for a rather low response time even with intensive work. According to the research, the power of this database is enough to process 10-20 sensors simultaneously. However, it is possible to use a powerful client-server database management system, for example, MS SQL Server. This is useful if the system needs to be scaled for solving problems of collecting information from physically separated objects and with a significant number of sensors (about hundreds)

The database is presented in two sections. Information about the monitored equipment (machines, machines, mechanisms, etc.) and their parameters is stored in the first section. This part of the database is filled and edited by the system administrator if it is necessary (for example, when a new device is connected). The second section stores information about the operation of the connected devices. It is automatically filled based on the information received from the sensors. Information about each device (sensor) is presented in a separate table. The data removal time is saved for the each value taken from the sensor. This eliminates the need to synchronize the signals from the sensors. It means that the different sensors can transmit data at different frequencies. In addition, controllers can independently reduce the frequency of the information output with its constant nature to reduce the size of the database. The time in the database is represented in the Unix time format (specified as the number of seconds elapsed from 0:00 on January 1, 1970). This allows you to work with time as a whole positive number, which is extremely convenient for data processing, calculation of intervals, etc. The information model of the system is shown in the Fig. 2

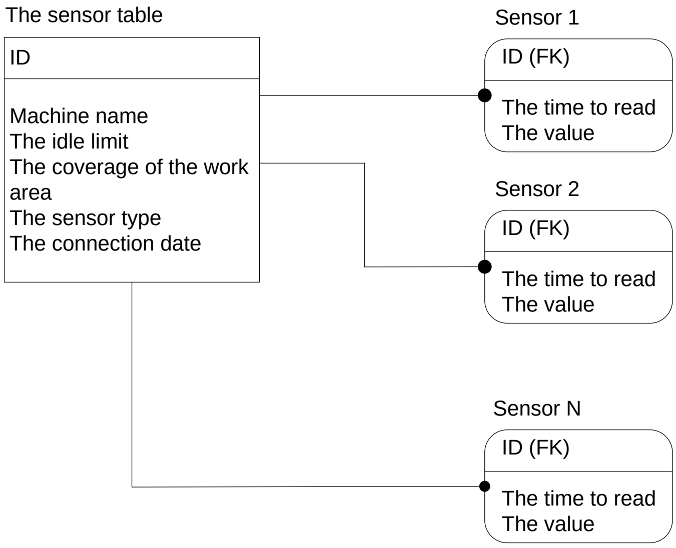

Figure 2. The database information model

The information processing system is implemented on the Node.js software platform. It is distributed under the X11 License (MIT), which allows the free use of software products implemented in Node.js, including for commercial purposes.

Node.js is an event-oriented programming language and is well suited for tasks related to streaming and processing data. The system uses a client-server architecture, all calls to the system are made through the web interface. It makes it possible to create an arbitrary number of workplaces with the ability to access data and reports from anywhere in the enterprise network, and if it is necessary, via the Internet, using a computer or smartphone. The installation of specialized software is not required (only the browser is used).

The automated system runs under the operating systems of the Windows family (XP and above) or Linux. The minimum system requirements are 2 GB of RAM, 250 MB of disk space for installing the system plus enough space to store the database, at least 1 GB is recommended.

The system has two modes of operation: administrative mode and user mode. The first mode provides the ability to connect and disconnect sensors (devices), control their parameters, and manage the database.

In user mode is available to obtain information about the equipment. To access the system, you need to enter the server address in the address bar of the browser in the same way as when you visit any website. The server address of the system is reported by the administrator. The screen displays the main AIS page. The devices (equipment) connected to the system and their current status (for example, “working” or “disabled”) are indicated on this page.

However, from the user's point of view, the main interest is to obtain statistics for past periods based on the information from the system database.

The user can receive a work statement of the equipment for fixed periods (day, week, month, year), as well as for a randomly selected time interval. The work statement can be presented in tabular form, in the form of a histogram or timeline (Fig. 3). On the histograms, color coding is used for clarity: red means the equipment is turned off (does not work), green means it is idling, blue means it is working under load, gray means no data.

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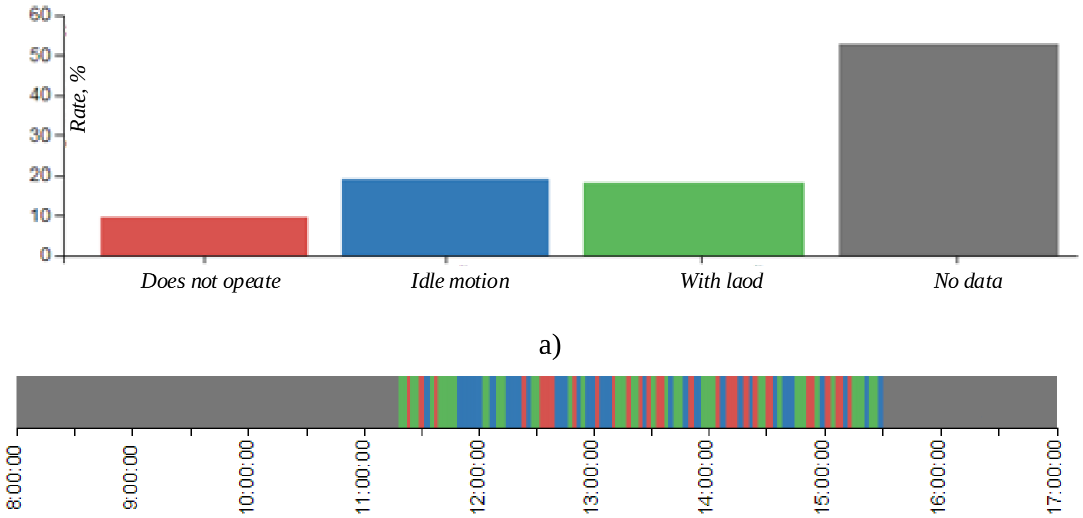

a)

b)

Figure 3. Presentation of the work statement in the form of: a) a histogram; b) a timeline

The information from the report can be exported in formats Excel, PDF for the convenience of the user. Such presentation of the information is typical in the development of bottom-up management decisions. This is typical for the conditions of a developing enterprise or its high stability. The process of setting goals and building an enterprise architecture begins with the standardization of technological processes (technological architecture). Then the process evolves towards solving problems of a higher level. Ultimately, it covers the entire spectrum of management problems related to business processes and business architecture.

It should be noted that the problems and shortcomings that are present when using these approaches can be overcome by an effective management system. In this case, the use of one or another approach is determined by the stage of the life cycle of the enterprise's development and the market situation.

Of course, the information must be coordinated with operational objectives set "from above". Such approach to decision-making allows harmonizing target installations and plans for their implementation, timely adjusting operational processes and the enterprise architecture, taking into account technological features. All this allows to increase the efficiency and effectiveness of the enterprise.

A common feature of all the above approaches is that the basic premise for making a management decision is the availability of operational information about the occurrence of the problem. The earlier the information arrives, the easier and faster it is solved. The ideal option is to monitor information "on-line".

In addition, it is important to determine the criteria and methods for evaluating the effectiveness of the model of supporting operational management decisions. Studies have shown that the system of local indicators does not objectively reflect the effectiveness of the system as a whole, since the indicators themselves may be contradictory in relation to each other. On this basis, you can use the total performance factor (Total Factor Productivity - TFP) [10], modified using the resource approach. In the development of this model, the theory of vital resources can be used [11], and it is proposed to use the theory of fuzzy sets [12] as a method for assessing the resources themselves.

4. Implementation of the protocol of the information exchange

During the experiments, it was found that the transfer of data from the controller to the computer may be unstable, especially at sufficiently large distances. This led to the need to develop a robust data transfer protocol based on the *Cyclic redundancy check, CRC.*

The controller does not just transmit the data, but calculates the checksum based on them:

```
// crc // (simple xor)
```

```
uint8_t crc = CNT ^ STX ^ ETX;
for (int i=0; i<sizeof(double); i++) {
  crc ^= data[i];
}
// crc //
```

The calculated CRC1 checksum is added to the transmission packet. The receiving party, having received the packet, calculates the CRC2 data obtained by a similar algorithm and compares it with the one that is in the packet. In the case of codes match (CRC1 == CRC2), the packet is considered delivered without damage and goes into processing. Otherwise (CRC1 <> CRC2) the packet is considered damaged and is destroyed. The algorithm running on the client side is shown below:

```
function parsePack(buf, callback) {
	var crc = buf[6];
	var calc_crc = 0;
	buf[6] = 0;
	for (var i=0; i<buf.length; i++) {
		calc_crc ^= buf[i];
	}
	if (crc == calc_crc) {
		var val = buf.readFloatLE(2);
		//console.log("PACKAGE CORRECT, value:", val);
		io.emit('data', { val: val });
		callback(val);
	}
	//else {
		//console.log("CRC INCORRECT!",buf, "crc:", crc, "calc_crc:", calc_crc);
	//}
}
```

It is possible to implement a protocol with guaranteed delivery, like TCP; however, practice shows that the proportion of corrupted packets is small, data is removed quite often (up to 60 times per second), so even the destruction of 1-2% of packets does not distort the statistical picture. At the same time, it would be necessary to store some sent packets in the controller, which would reduce the performance of the system as a whole.

5. Conclusion

The developed system was tested on the basis of Kovrov State Technological Academy named after V. A. Degtyarev, as well as at the All-Russian Research Institute «Signal». The software-developed hardware solution is aimed at reducing equipment downtime and will significantly improve staff productivity. It is shown that as a result of the implementation of the proposed information system, it is possible to reduce the machine downtime equipment up to 2 times. This will provide an opportunity to increase the volume of output by 25% while reducing the loss of working time by 20% to the level that is typical for the industry. Tests showed the efficiency of the principles underlying the system and the feasibility of using this system in the practice of enterprises.

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