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Installation Diagram for Research of Energy Consumption Parameters during Process of Surface Shaping

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ABSTRACT: Article presents the scheme of experimental installation for research the characteristics of energy capacity of technological processes of shaping in machine-building production

KEYWORDS: energy efficiency, metal-cutting equipment, cutting process, Mercury-230 three-phase meter, active/reactive counter, interface converter, active (P), reactive (Q) and total (S) power, control device, current sensor.

1.INTRODUCTION

Processing industries of Republic remain the most power-consuming complex, and retain their demand properties for many decades. Expansion of energy conservation efforts covering the whole country almost had not affected the industry. This is primarily due to the exploitation of the accumulated fleet of technological machines designed in the era of cheap energy and continuing their technological life now. Moreover, new technological lines are also designed based on accepted standards.

Imperfection of many technological processes and machines in terms of energy saving for many years "was not noticed" by domestic designers and technologists. The unshakable confidence of our specialists in the infinity of energy resources did not contribute to the modernization of processes and equipment and survival in strong competition.

Reducing energy costs when processing work-pieces by cutting is urgent problem of modern mechanical engineering. Creation of new and increasing energy efficiency of existing metal-cutting equipment should be based on methods of reducing energy losses along the circuit: *currrent network* $\Rightarrow$ *converter of electrical energy into mechanical energy* $\Rightarrow$ *transmission* $\Rightarrow$ *cutting zone*. Considering the different nature of the phenomena occurring in links of chain, it is advisable to solve the problem of increasing energy efficiency in three successive stages:

- Introduction of saving methods of converting electrical energy into mechanical energy;
- Introduction of saving methods of transportation of mechanical energy to the cutting zone;
- Introduction of saving conditions and parameters for implementation of cutting process.

II. MATERIALS AND METHODS

The third part is of interest for cutting theory. It is the work of cutting that ultimately determines the amount of energy consumed by the motors of the machine from the electrical network, as well as the load losses in the transmission. Therefore, the solution to the problem should begin from final link –from determination of optimal conditions for implementation of cutting process [2].

Cutting is the main technological method in the manufacture of machine parts and mechanisms. Its labor intensity in most branches of mechanical engineering significantly exceeds the labor intensity of foundry, forging and stamping processes taken together.

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Calculation of cutting modes and the choice of rational one are the key links in the development of technological processes for the formation of specified configurations of parts, and the quality (and, accordingly, the performance) of the product, labor and money costs for its manufacture largely depend on this.

Cutting conditions are influenced by many factors that should be taken into account in calculation. These include, for example, the micro and macrostructure of the work-piece material, its physical and mechanical properties; condition of the treated surface; material and geometric parameters of the cutting tool; mechanical characteristics of equipment, etc. [4].

A number of experimental studies of the energy intensity of machine-building technological processes were carried out using the example of cutting.

Technological process of lathe machininga shaft-type part on lathe of 16K20 model is taken as object of experimental research. In the course of the experiment, a shaft made of Steel-45 material with tensile strength of 700 MPa was lathed. Measurements are carried out for various process characteristics, which include the processing mode, spindle rotationrate, feed rate and depth of cut. During the experiment, the modes were selected in such a way that the cutting power was constantly increasing.

Various cutting modes are required to obtain the relationship between the cutting force and the characteristics of energy consumption of technological processes of shaping [7].

During the measurement process, the following energy consumption characteristics are measured:

- The value of consumed current.
- The value of active component of consumed power.
- The value of reactive component of consumed power.
- The value of the total consumed power.
- The value of power coefficient.

Scheme of experimental installation and its general appearance are shown in Fig. 1.

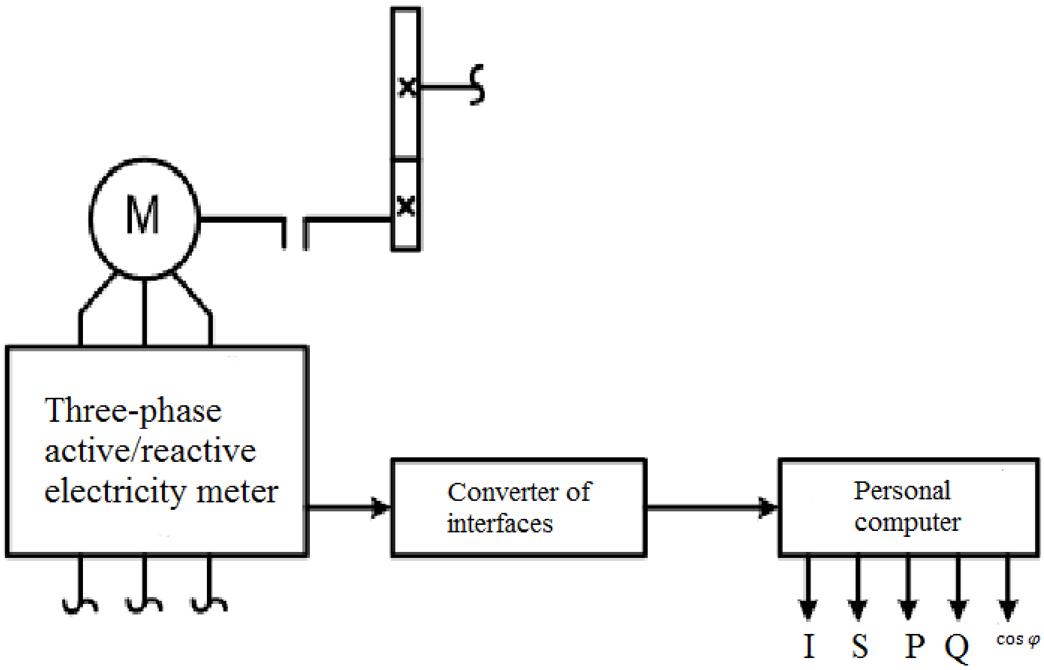

Fig. 1. Scheme of experimental installation

Experimental installation was developedto conduct experimental studies of the characteristics of energy consumption of technological processes of shaping, which consists of the following components:

- Screw-cutting lathe model 16K20.
- Three-phase active/reactive electricity meter Mercury 230 AR-01.
- Converter of interfaces Mercury 221.
- Personal computer with installed software “Mercury-Energy account LIGHT”

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Lathes make 70 - 80% of the total volume of lathing work. These machines are designed for smoothing and semi-smoothing, as well as for cutting various types of threads and are characterized by high rigidity, sufficient power and wide range of spindle rotation speeds and tool feeds, which allows to machine parts in economical modes using modern progressive tools made of carbide and super-hard materials.

Lathes are equipped with various devices that expand their technological capabilities, facilitate the work of the worker and improve the quality of processing, and have a high level of automation.

Technical characteristics allow to fully using the capabilities of advanced tools when processing various materials. Lathe 16K20 is designed for the needs of enterprises in all industries.

The key point to energy saving is correct energy metering.

Mercury 230 AR meters are designed to account for active and reactive electrical energy, power in one direction in three-phase 3- and 4-wire alternating current networks with a frequency of 50 Hz through measuring current transformers or directly with the possibility of transmitting measurements and accumulated information about energy consumption by digital interface channels [3].

They are operated autonomously or as part of any information and measurement systems for technical and commercial accounting.

Meters provide:

- Account of active and reactive electricity in one tariff mode in total for all phases or account of active energy in each phase separately (optional).
- Also possible multiple tariff account, differentiated by zones of the day when switching tariff zones in the meter with external device via RS-485 or CAN interface (up to four tariffs).
- Measurement of instantaneous values of active (P), reactive (Q) and total (S) power for each phase and for the sum of phases. Determination of the direction of the full power vector;
- Measurement by phase: current (I), voltage (U), frequency (F), $cosf_i$, angles between phase voltages;
- Possible to control external devices for switching off/on the load of consumer through programmable pulse output;
- Transfer of measurement results via 220/380V power network (only consumed energy), CAN, RS-485 interfaces (all available data);
- Programming of meters in the phase summation mode “on module” to prevent theft of electricity in case of violation of the phasing of connection of current circuits of the meter.

The control, measurement and indication device (hereinafter referred to as CMID) together with the terminal block is installed in the base of the frame

Indication control buttons are installed in frame cover and connected mechanically to the CID.

Current transformers are used as current sensors in the meter. Resistive dividers are used as voltage sensors. The signals from the current and voltage sensors are fed to the corresponding inputs of the analog-to-digital converter (ADC) of the microprocessor.

The ADC of the microprocessor converts the signals coming from the current and voltage sensors into digital codes proportional to the current and voltage.

Microprocessor multiplying the digital codes obtains value proportional to the instantaneous active power. Integration of power over time provides information on the amount of active energy. Using the appropriate algorithms, the counter also calculates all the required parameters.

Microprocessor (MC) controls all meter nodes and implements measurement algorithms in accordance with specialized program placed in the internal program memory. The meter nodes are controlled through software interfaces implemented on the MC input/output ports:

- 2-wire UART interface for communication with external device,
- 5-wire SPI interface for communication with non-volatile memory,
- 3-wire I2C interface for communication with non-volatile memory,
- 3-wire interface for communication with the LCD driver.

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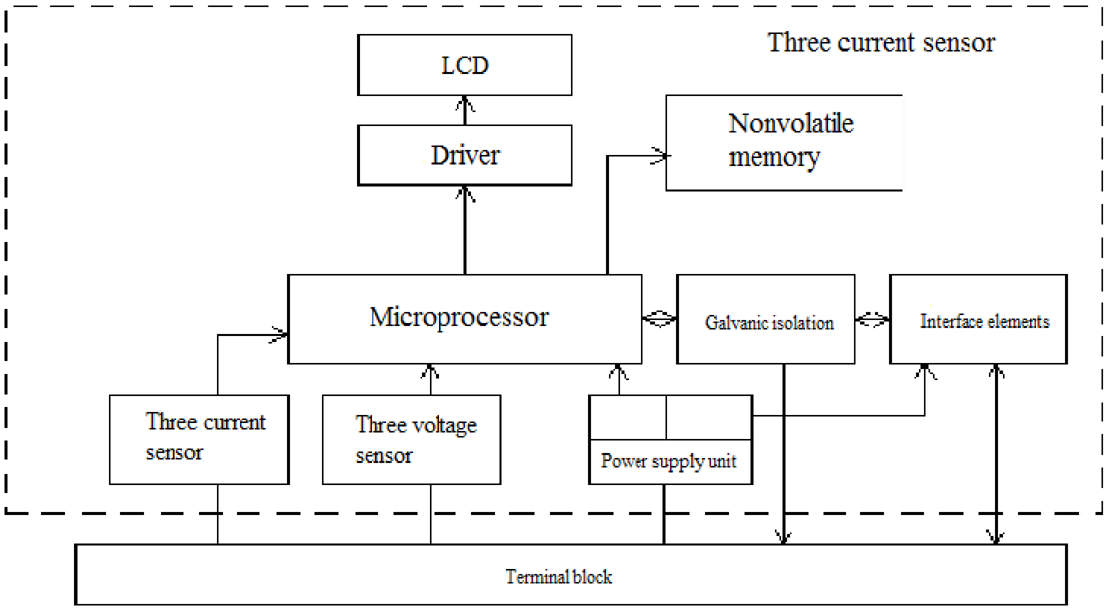

Fig. 2. The structure of meter Mercury 230 AR-01

MC sets the current tariff zone depending on the command received via the interface or from the timer, generates telemetry pulses, keeps track of energy at the included tariff, processes the commands received via the interface, and, if necessary, generates a response. In addition to the data on the recorded electricity, the non-volatile memory stores calibration coefficients, serial number, software version of the meter, etc. The calibration coefficients are stored in memory at the factory and are protected by removing the write permission jumper. Changing the calibration coefficients at the meter operation stage is possible only after opening the meter and installing a technological jumper.

MC is synchronized with an external quartz resonator operating at frequency of 6000 kHz.

MC controls the operation of the LCD driver via 3-wire serial interface in order to display the measured data. The display mode can be changed using the display control buttons.

LCD driver has built-in serial interface for communication with control device and memory for storing segment information. The control unit via the serial interface writes the information necessary for indication into the driver's memory, and the driver dynamically outputs information, placed in its memory, to the corresponding LCD segments.

The block of optronisolating devices is made on optically coupled device light-emitting diode-phototransistor and is designed to provide galvanic isolation of internal and external circuits of the meter.

Interface signals and telemetering pulses (pulse outputs of meter) pass through the block of optronisolating devices.

CMID includes non-volatile memory microcircuit (FRAM). The microcircuit is intended for periodic storage of MC data. In the event of emergency mode ("freezing" of the MC), the MC restores data from FRAM.

If the meter keeps record of average power at given integration period, the power data array is stored in another non-volatile memory microcircuit (EEPROM).

Power supply unit generates the voltages required for the CMID to operate. All connections and meter units are made on a modern element base and have a micro-powerful consumption, which allows building a meter power supply unit using a capacitor network.

As a result, a meter was developed and created, which has no analogues in Russia in terms of simplicity of circuit design, and, at the same time, has the necessary functional saturation.

This became possible due to the use of imported components with micro-powerful consumption from leading world manufacturers such as Texas Instruments, STMicroelectronics, Holtek, etc. Low power consumption of all parts of the meter allows using simple and reliable power supply that does not contain high-voltage elements operating in pulse modes, typical for power supplies for meters from other manufacturers. In addition to reliability, this also resulted in a significant reduction in the cost of the meter.

The meter contains only one microcontroller, which, due to its unique characteristics, solves all the necessary tasks: measuring all the parameters of the power network, metering the consumed energy, controlling the display unit, managing the exchange on all types of interfaces, maintaining the real time clock and calendar, etc. This also allows to significantly reducing the cost of the meter with higher reliability, since it is known that increase in the number of elements used in the device leads to decrease in the reliability of the entire device.

III. RESULTS AND DISCUSSION

Measurement of all parameters is carried out using digital signal processing principles. The increase in the functional properties of the meter, according to the wishes of customers from various power systems of Russia, was mainly due to the use of software resources without increasing the hardware. This allows to largely unifying the model range of Mercury 230 meters, which also has a beneficial effect on the characteristics of the meter. In the production of meters, unified printed circuit board is used. This allows the manufacturer to have a basic stock of elements in storehouse, which enables the production of all possible variants of meters, from household to industrial. Upon receipt and execution of order, specific version of the meter is made by installing/ not installing elements on the printed circuit board and correspondingly setting the meter software. The manufacturer no longer needs to purchase a complete set for a specific version of the meter and for a specific order, as a rule, with tight deadlines, change suppliers on the go, etc.

In addition, much attention was given to the manufacturability of the created meter. The Mercury 230 meter does not contain any adjustment position. The meter is calibrated and configured electronically via the interface, by storing the necessary information in the meter's memory. The production process of meters is largely automated, which helps to reduce the influence of the “human factor” on the quality of products. Installation of more than 95% of elements on the printed circuit board is carried out on automatic SMD-assembly lines of foreign manufacturers. Calibration, adjustment and verification of meters are also carried out automatically using special equipment. This significantly reduces the overhead costs included in the cost of the meter, and at the same time, again increases its reliability [5].

Due to the functional richness of the counter, special requirements were imposed on the interfaces. Mercury 230 can be composed of any type of interface: wired CAN or RS-485, optical IrDA interface, interface providing exchange via cellular systems (using GSM technology) or power network. Despite the differences inherent in different types of interfaces, it is possible for all types of interface to use the same command set. Depending on the purpose and use of the meter, the list of interfaces may vary, but as part of any Mercury 230 meter there is always a wired interface, which allows at any time to include the operated meter in the AMR system. During the installation of the meter at the facility, the correct connection of the meter can be checked by the readings of the auxiliary parameters read from the LCD or via the interface. With a laptop and IrDA as part of the meter, phase-by-phase vector diagram of voltages, currents and powers can be seen right at the facility in real time.

Interface converter “Mercury 221” is a USB interface to CAN/RS-232/RS485 converter, and is designed to connect one or several “Mercury” electricity meters with built-in CAN/RS-485 interfaces, or devices with an RS-232 interface (which only use RX, TX) to personal computer. After installing the USB driver, the device is detected as a virtual COM port. The driver installation manual and the drivers themselves are included on the CDROM. The diagram of connection of electricity meters to a personal computer is given in the operation manual for electricity meters.

There is an X4 jumper on the converter board to set the converter-operating mode. CAN functions with the jumper installed, and RS-485with the jumper removed.

All interface leads of the converter are galvanic isolated from the USB interface of the computer.

Interface converter (adapter) USB-CAN/RS232 “Mercury 221”. Automated information and measuring systems (AIMS) of “Mercury-Energy account” family are designed to automate the process of collecting, storing, processing and analyzing information required for commercial and technical metering of electricity. The main functions of AIMS are reading information from metering devices via the communication channels supported by these devices and storing the received information in the database (DB) of the systems for subsequent analysis and generation of reports.

AIMS “Mercury-Energy account LIGHT” is a light version of AIIS AIMS “Mercury-Energy account”, and is designed to work with a small (about 500) number of meters in a single-user environment. Compared to the full version, AIMS “Mercury-Energy account LIGHT” puts lower requirements for the hardware and operating system of the computer. The main differences in the functionality of the light version are the work in a single-user non-client-

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server mode and the absence of differentiation of access rights. At the same time, the light version, in contrast to the full version, is a regular MS Windows application that does not have a web interface and is unable to function in the absence of an interactive user login to MS Windows. From a licensing point of view, AIMS “Mercury-Energy account LIGHT” is fully compatible with the full-featured version. This means that the purchased license for the full-featured version gives you the right and ability to work with the light version – the electronic key of the full version will be correctly recognized and connected by the light version. In turn, the license (and, accordingly, the electronic security key) of the light version permits operation only in the AIMS “Mercury-Energy account LIGHT” without the possibility of working in the full-featured version.

IV. CONCLUSION

This installation allows carrying out the necessary research of characteristics of energy consumption of technological processes of shaping

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