Control of the Process of Cutting Metals by the Power Consumption of the Electric Motor of the Metal-Cutting Machine

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ABSTRACT

The article deals with the issues of control of the metal cutting process by the power consumption of the electric motor of the machine tool and its use as an informative parameter in the creation of high-performance technologies for processing machine parts in automated production.

Keywords: cutting process, cutting power, control system, cutting force, machine drive, cutting tool, signal level, transient process, cutting mode.

Cutting forces, cutting power and temperature are informative parameters of the cutting process. The power supplied from the outside to the process system is also a reliable source of information. However, the input power is spent not only on the cutting process, but is spent on heat losses, magnetization reversal and overcoming friction forces in the engine itself.

The solution of the problem of automatic control of the process of cutting metals in terms of power consumption would be facilitated if the power losses in the engine and transmission systems of the machine remained constant. In this case, the losses inherent in the motor and the kinematics of the machine could be attributed to idle losses. But idle power can vary for many reasons. For example, due to the change in friction forces in the machine as it heats up. Sometimes these variations turn out to be quite commensurate with those changes in cutting power, which are caused by changes in the allowance, hardness of the workpiece, and tool wear.

The foregoing does not exclude the creation of control systems for the used cutting power. Especially in those cases when the installation of primary converters directly in the processing system is difficult for design reasons. And also because of a slight change in the controlled parameter, as a result of which the system may turn out to be insensitive.

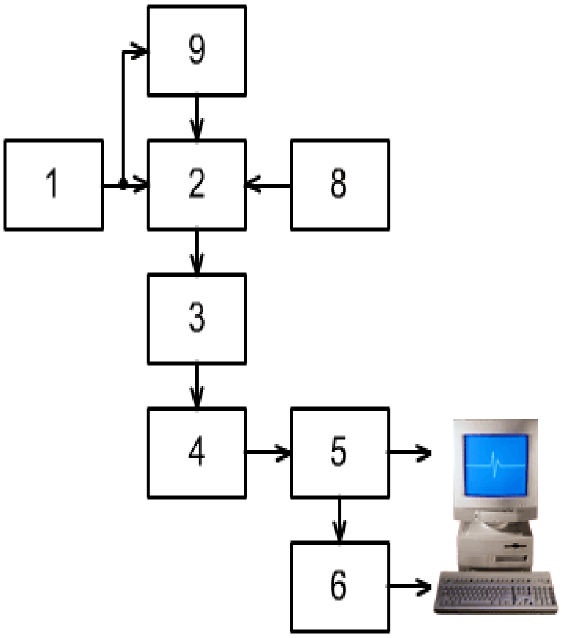

Fig. 1. Block diagram for measuring and processing power indicators.

1-main drive motor, 2-current sensor, 3-detector, 4-limiter, 5-integrator, 6-differentiator, 7-computer, 8-thyristor drive, 9-wattmeter

In order to develop a system for controlling the turning process, experimental studies were carried out using the developed installation, mounted on the basis of a CNC lathe model 16A20F3 (Fig. 1). The measuring installation consists of a set of instruments and devices. They allow directly in the cutting process to measure and record the constant and variable components of the power consumed by the electric motor of the main drive of the machine. The DC signal level corresponds to the absolute value of the power consumed by the electric motor at a given time. The variable component of the signal reflects any deviations in power consumption caused by changes in cutting conditions. As the main drive motor, a thyristor-controlled electromagnetically excited DC motor is used. These electric motors are characterized by a reduction in the moment of inertia of the rotor and an increased overload capacity. Thyristor control allows you to increase the speed, controllability and efficiency of the electric motor.

The installation works as follows. The measurement of the power consumed by the main drive motor I is carried out using a current sensor 2. The current sensor is a transformer in which the primary winding is connected in series to the motor armature circuit. From the secondary winding of the transformer, we remove the voltage proportional to the armature current of the main drive motor. In thyristor-controlled DC motors, the voltage is constant and equal to 380 V. Thus, the change in power consumed by the motors of the main wire is proportional to the change in armature current. From the current sensor 2, the signal enters the input of the detector 3, where the useful signal is rectified, and then to the limiter 4. The task of the limiter 4 is to protect the input circuits of the integrator 5 and limit the peak voltages when the machine drive is turned on and off. The integrator 4 performs filtering and smoothing of the signals coming from the detector 3 and extracts a constant component proportional to the power consumed by the main drive motor of the machine. In order to isolate the variable component of the signal, the integrated power characteristic is additionally differentiated in block 6. The recording of signals of variable and constant (integral) power components is carried out using a computer. In parallel with the recording of signals, the absolute value of the power consumed by the main drive motor of the machine is measured using a wattmeter.

During the experiments, the cutting conditions varied within the following limits: cutting speed $V \in [0.8;4.1]$ m/s; feed $S \in [0.025;0.135]$ mm/rev, cutting depth $t \in [0.05;0.5]$ mm. As a cutting tool, turning cutters with cutting plates made of T15K6 hard alloy were used. Geometry of the cutting part of the tool:: $\gamma = 8^0$, $\alpha = 9^0$, $\varphi = \varphi_л = 45^0$, $\lambda = 0^0$. Steel 45, 40Kh, 35KhGSA, St20, aluminum alloy D16, brass L60 were used as the processed material.

To accurately determine the number of revolutions of the machine spindle, a speed sensor has been developed, the main part of which is a reed switch installed in the machine body, next to the spindle. The pulses generated by the sensor with a duration of one revolution are fed to the frequency meter. The used setup allows to measure revolutions with an accuracy of 0.2 r/s.

On fig. 2. shows the nature of the change in the level of the signals of the variable (curve 1) and constant (curve 2) power components, when the tool enters and exits the part. Sections I and V of the curves correspond to the operation of the machine at idle. Sections II and IV reflect the change in the signal level, respectively, when the tool plunges into the part and the tool exits the part. Section III corresponds to the operation of the machine during cutting. The time T_K corresponds to the moment when the tool touches the workpiece and is the beginning of the plunge. Time T_B corresponds to the exit of the tool from the part, i.e. determines the moment of completion of the cutting of the workpiece.

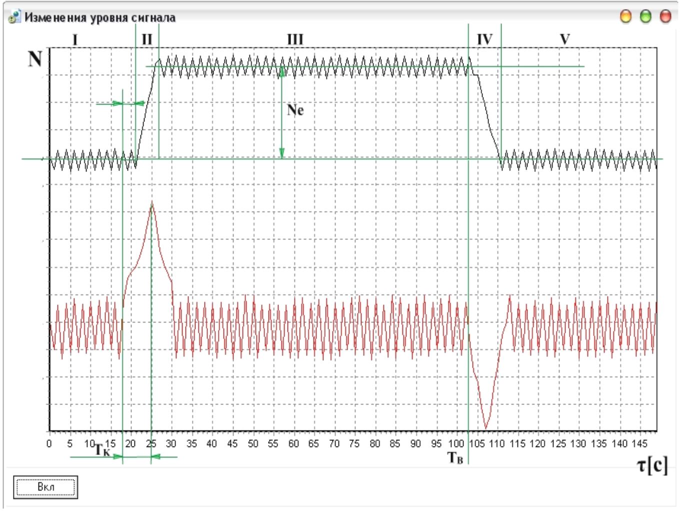

Fig. 2. The nature of the change in the level of signals of variable and constant power components in the process of turning

From the analysis of the curves (Fig. 2) it can be seen that the moment of cutting the tool into the part is very clearly reflected in the change in the level of signals, both variable and constant power components. The signal level of the variable power component during 0.5-0.7 s deviates by 6-8 times more compared to the zero level, i.e. level when the machine is idling, and then returns to its original position. Thus, there is a strong signal spike. During further processing, the variable power component signal stabilizes.

The level of the DC signal during the plunge also rises sharply. During 0.6-0.8 s it reaches its maximum value, and after the completion of the transient process, which lasts 1.5-2 s, the signal level stabilizes at a value corresponding to the power consumed by the main drive motor at given cutting conditions. The difference between the DC signal levels before and after the plunge corresponds to the effective cutting power.

It should be noted that the change in the level of the signal of the constant component of power, reflecting the moment of contact between the tool and the workpiece, is delayed by 0.2 s compared to the signal of the variable component which is explained by the delay of the signal during integration.

When the tool exits the part, the power consumption of the main drive motor is reduced to a value corresponding to the idling of the machine. The signal level of the constant power component returns to its original position in 1.5 s. In turn, the signal level of the variable component deviates sharply from the zero position and for 0.5-0.7s. reaches a maximum and then returns to zero. The amplitude and shape of the bursts of the signal of the variable power component during the insertion and exit of the tool from the part are almost similar, with the only difference being that they deviate from the zero level in opposite directions.

From the above, it follows that by the nature of the change in the signals, both variable and constant components of the power of the electric motor of the main drive of the machine, it is possible to determine changes in the cutting process. This allows you to control the technological processing system, as well control as overloading the metal-cutting machine, which confirms the suitability of this signal for creating high-performance technologies for processing machine parts.

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