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Energy Planning in Production Shops with Numerically Controlled Machine Tools

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Abstract—A method is proposed for planning the energy expenditures in production buildings with numerically controlled machine tools. The calculations take account of the individual production operations, as well as the actual state of the machine-tool drives.

Keywords: energy expenditures, preproduction, production operations, production specifications, machine-tool drives

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For purposes of import substitution, it is important to organize the preproduction of new products at manufacturing enterprises. Typically, machine parts are produced by cutting on numerically controlled machine tools. By that means, a single part may be subjected to numerous operations.

Existing CAD software permits the generation of trajectories and program code for the control of machine-tool drives and preliminary assessment of the machining time. To minimize machining expenditures, we need to assess the cost of manufacturing options on the machine tools available at the enterprise. In the present work, we consider a method of planning and reducing energy expenditures.

Existing energy planning methods have numerous deficiencies. In economic analysis, the energy consumption is determined approximately, as the product of the rated power of the electric motor and the duration of the process. In such calculations, the power consumption does not depend on the actual production operations.

In manufacturing design, the maximum cutting forces and torques are only determined to verify that the drives are of sufficient power. This method does not permit calculation of the overall power consumption for each operation and for the production shop.

Thus, these two approaches do not consider the shaping operations in sufficient detail.

In cutting, power is mainly consumed in overcoming the resistance to the cutting forces and the frictional forces in the moving components (guides, bearings, screw–ball pairs) and is also associated with the conversion of current to heat in the electric motors. In addition, power is consumed in assorted equipment required for the machining process. Pumps supplying the machining fluid are switched on; electric motors operate to lubricate the mobile parts of the machine tool, to remove the chip, and in loading and transport mechanisms.

In the Russian literature, empirical models in the form of formulas or tables are recommended to calculate the cutting force [1]. These models lack information regarding the range in which they operate. In practice, therefore, the use of empirical models is difficult. However, even when the parameters are within the specified range, the models take no account of many factors operating within the system.

Major manufacturers of cutting tools (Sandvik Coromant, Iscar, and Mitsubishi) determine the components of the cutting force in each operation, for the specific tool material and specific form of the cutting insert (in terms of the force per mm^2 of chip cross section) in their handbooks and on-line references (for example, Sandvik Coromant's application for calculating the cutting conditions [2]).

In contrast to Russian handbooks, they contain exhaustive information regarding the parameter ranges in which the given model is applicable. That permits more satisfactory determination of the cutting force, but only in the case of complete compliance with the drawings and specifications for a particular machine tool, workpiece, and tool.

By means of dynamometers, the actual cutting forces and their variation over time may be determined, and the mathematical models required may be formulated, on the assumption of an ideal solution. In reality, however, the use of dynamometers is limited by the high cost of the measuring equipment, the impairment of the machine tool's rigidity (which affects the machining precision), and in some cases the impossi-