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THE INVESTIGATION OF SPEED ON IDLING POWER OF A DRIVE OF CUTTING MACHINE UNIMAT 23 EL

Experimental values of capacity at idling of a quadrilateral milling machine Unimat 23 EL cutting drive are defined at various tool rotation speed and various tool types. It is experimentally established that dependence of cutting drive idling capacity on tool rotation speed has curvilinear character, and dependence of cutting drive idling capacity on tool rotation speed square is close to the linear. It contradicts the theoretical data received by a way of calculations by a technique for metalcutting machines. Accordingly, the idling capacity calculating technique is inapplicable to woodcutting machines not only owing to big divergence of calculated and experimental values, but also because of character discrepancy of experimental and settlement dependences.

Introduction. Modern wood processing machines are a high-performance equipment. Increased productivity of woodworking machinery and high quality processing requirements determine the use of high frequency of the instrument, especially for milling tool. However, increasing the speed of the instrument and intermediates of kinematic chain leads to the growth of power cost which is not connected with cutting.

Power consumed by drive includes the power for cutting as well as the power of idling. The idle power is power expended by energy source for the rotation of the drive in case of a payload. This power is expended on the work of friction in the bearings and seals of drive mechanisms, aerodynamic losses ect. [1, p. 133–136].

The influence of rotation speed of the right vertical spindle of the machine Unimat 23 EL was tested for idle power in the literature [2, p. 241–244].

The experimental results were compared with calculated values. In addition, method of determining the idle power for metal-cutting machine tools was used for the theoretical calculations as there is no appropriate method for wood-cutting machine tools. It was found the technique of calculating the capacity of idling was not applicable to the drive of the machine Unimat 23 EL due to the large discrepancy between the calculated and experimental values of idle power (200–525%).

The influence of spindle rotation frequency on the idle speed of cutting drive is examined in this paper.

Main part. Description of the experimental setup is given in the paper [2, p. 241–242]. For experimental studies three types of cutters were used:

– Cutter with fastening PowerLock (which was used for the experiments [2, p. 241–244]);

– Aluminum cutter with direct mounting to fit on the spindle (via adapter HSK) with a lot of knife elements along the full length of the cutters;

– A set of four cutters mounted with direct fit on the spindle (via adapter HSK).

Cutters parameters (cutting diameter *d*, cutter length or total length of the cutters with a set of cutters *b*, type of mounting, material frame) are shown in Table 1. Photos of the cutters are shown in Fig. 1, *c*; 2, *c*; 3, *c*.

The researches were conducted from 1000 min^{-1} to 9000 min^{-1} instrumental frequency.

As a result of the experiments values of power idle P_{xx} were received depending on the frequency of the instrument *n* for each instrument (Table 2).

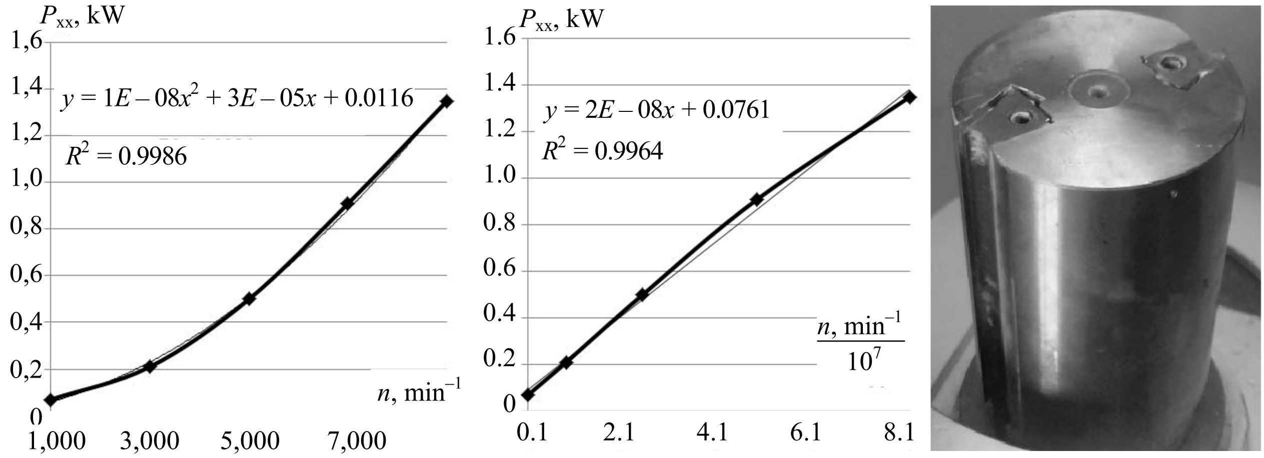
According to Table 2 let's draw diagrams of correlation of idle power from rotation frequency for each cutter constructions and get their approximation (Fig. 1, *a*; 2, *a*; 3, *a*).

It is obvious the type of the dependencies for different cutters is identical in these speed ranges (all curves are described by second-degree polynomial). In Fig. 1, *b*; 2, *b*; 3, *b* there are diagrams for the construction of which the same data of the idle power were used but these diagrams are constructed according to the square rotation frequency of the cutting tool. The resulting diagrams are close to linear. The latter indicates that the idle power is in direct proportion to the square of the rotation frequency. In accordance with the calculated data [2, p. 241–244] the idle power of the spindle is predominant in the overall balance of idle power of the cutting drive. In accordance with formulae (1) [1, p. 135] and (2) [3, p. 194] its value is in direct proportion to the rotation frequency.

Table 1

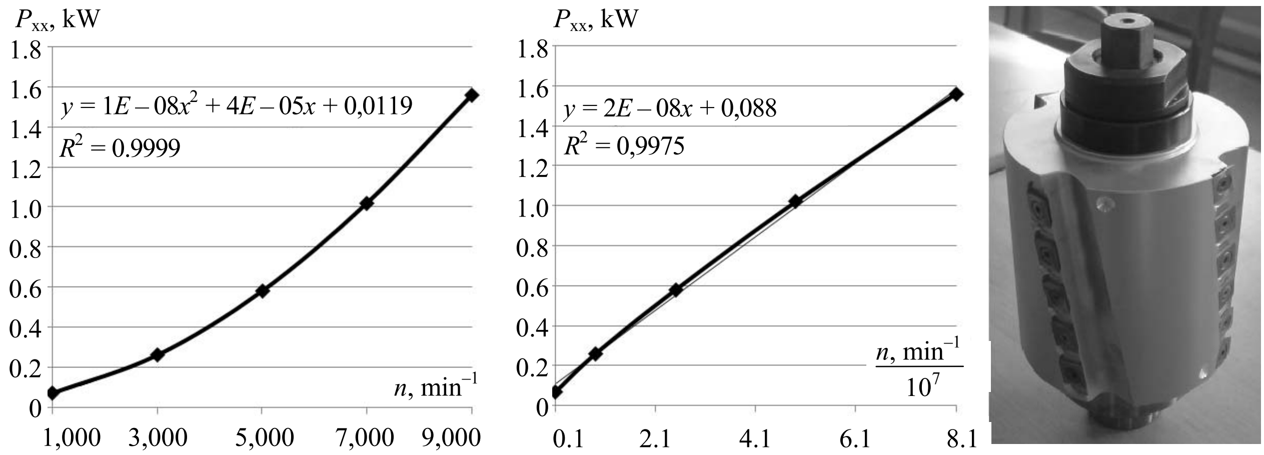
Cutters parameters

Parameter	Cutter		
	1	2	3
Cutting diameter *d*, mm	93	130	125
Length of the cutter frame *b*, mm	100	140	148
Material	Steel	Aluminum	Steel
Mount type	Power-Lock	With direct fit on the spindle (via adapter HSK)	



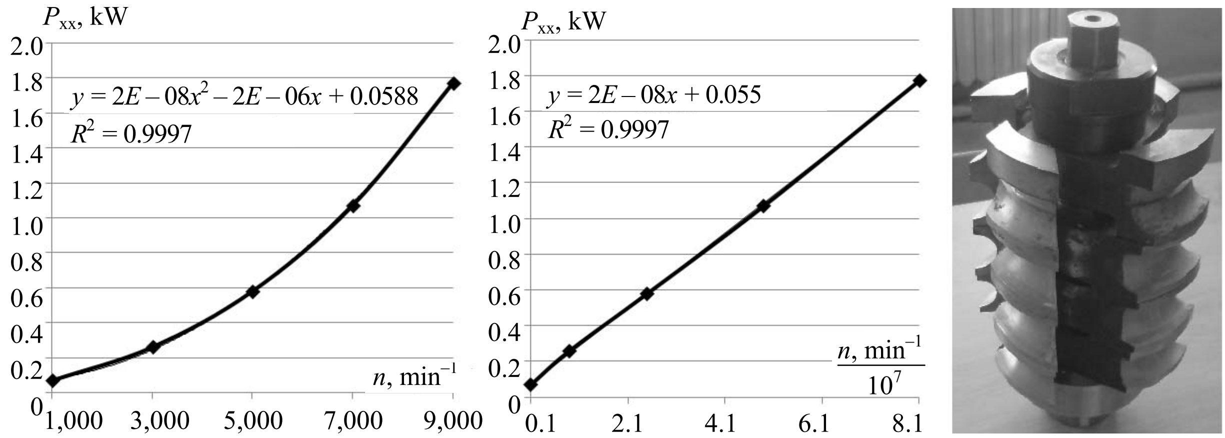
a *b* *c*

Fig. 1. The diagram of dependency of idle power while using cutters 1:
a – from the rotation frequency of the instrument and the approximation of the curve of the diagram;
b – from the square frequency of the instrument and the approximation of the rve of the diagram; *c* – photo of the cutter



a *b* *c*

Fig. 2. The diagram of dependency of idle power while using cutters 2:
a – from the rotation frequency of the instrument and the approximation of the curve of the diagram;
b – from the square frequency of the instrument and the approximation of the curve of the diagram; *c* – photo of the second cutter



a *b* *c*

Fig. 3. The diagram of dependency of idle power while using cutters 2:
a – from the rotation frequency of the instrument and the approximation of the curve of the diagram;
b – from the square frequency of the instrument and the approximation of the curve of the diagram; *c* – photo of the third cutter

The idle power of the spindle is determined by the formula

$$P_{is} = k_m k_{sp} n \frac{d_{sp}}{10^6}, \quad (1)$$

where k_m is a coefficient characterizing the complexity of the design of drive components and workmanship; k_{sp} – a coefficient reflecting friction losses in spindle drive unit; d_{sp} – a spindle diameter of cutting mechanism in front bearings, mm.

Table 2

Results of the experiment

n, min^{-1}	P_{xx}, kW		
	Cutter 1	Cutter 2	Cutter 3
1,000	0.07	0.07	0.07
3,000	0.21	0.26	0.26
5,000	0.50	0.58	0.58
7,000	0.91	1.02	1.07
9,000	1.35	1.56	1.77

The idle power of the cutting drive is determined by the formula

$$P_{is} = \frac{d_1}{10^6}(\sum n + k_1 \frac{d_0}{d_1} n_0) k_2, \quad (2)$$

where d_1 – the average diameter of bearing journal of all the intermediate shafts, мм; $\sum n$ – the sum of rotation frequency of all the intermediate shaft, min^{-1}; n_0 – spindle speed, min^{-1}; k_1 – a coefficient reflecting the increased losses in the spindle drive unit due to the preload; d_0 – diameter of the spindle journal, mm; k_2 – a coefficient reflecting the perfection of lubrication.

The idle power for the entire drive is not constant. A number of no-load losses increase as the square of speed, for example, losses to overcome the frictional forces generated by centrifugal force, aerodynamic losses. While operating the machine tools low rotation frequency of the instrument is used (usually up to 3000 min^{-1}). As the frequency range is low the dependency of the idle power of the frequency of the instrument can be considered linear. High speed tool are used for wood-cutting machines.

But the cost of power increases substantially and the dependence can not be considered as the linear. Consequently, the linear dependence of the idle power from the drive speed can not be used for the calculation of woodworking machines, working in a wider range of speeds.

Conclusion. After the experiments it was established that the dependence of the idle power of the cutting drive from the rotation frequency is curvilinear and from the rotation frequency of the square is close to linear. This is contrary to the theoretical data obtained by calculation in accordance with the machine tools method. Consequently, the method of calculating of the idle power given in the literature [1, p. 133–136] is not applicable to wood-cutting machines. Not only because of the large discrepancy between the calculated and experimental values but also because of the nature of non-compliance of the experimental and calculated dependences.

References

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