Paper No.344/2021

THEORETICAL STUDIES OF THE VELOCITIES OF THE VIBRATIONS OF DRILL BITS WOODWORKING DRILLING MACHINES

[a)]Dmitry Ruslyakov

[a)]Don State Technical University, Rostov-on-Don, Russia, ruslyakof@yandex.ru

***Abstract**: On woodworking machines of the drilling group, drill bits of the following diameters (mm) are used at rotation speeds: SvP2 and SvA-2-ø 50 mm, n = 3000 rpm 4500 rpm; Sv8, Sv12-ø 10-16 mm, n = 2800 rpm; SGVP-ø up to 35 mm, n = 2800 rpm.*
Acoustic models are described in detail in [1] as can be seen from the analytical dependences of sound pressure levels to calculate the noise spectra, it is necessary to determine the oscillation velocities of the drill bit at their natural frequencies.

***Keywords:** Woodworking machines, drill bit, noise, sound pressure*

***DOI:** 10.36336/akustika202139124*

1. INTRODUCTION

The 'spindle-drill bit' system is a rod system in which the drill bit is a cantilever part, and the spindle is a two-support beam. Bending stiffness of the drill bits of all diameters used in the range of single-and multi-spindle woodworking machines is much less than bending stiffness of the spindle. In addition, the sound energy of the spindle is radiated into the internal air volume of the spindle unit housing, which has significant sound insulation. Therefore, the contribution of the sound radiation of the spindle to the sound field at the operator's workplace can be ignored. Drill bits are also an open source of sound energy radiation, located in the immediate vicinity of the operators' workplaces. In this connection, the drill bits are approximated using a cylindrical radiator with a cantilever attachment [1-3].

2. THEORETICAL JUSTIFICATION OF CUTTING PARAMETERS

The force effect for drilling machines is determined according to the cutting mode standards for wood processing [4]. Drilling modes are shown in Tab. 1.

Wood species	Cutting speed, m/s	Feed, mm/rev
Soft wood	0.8 – 4	0.6 – 0.7
Hard wood	0.2 – 0.5	0.1 – 0.5

Tab.1: Drilling modes

The cutting power (***W***) is determined using the formula:

$$N_p = \frac{KPD^2 u_0 n}{4 \cdot 60 \cdot 120} = 1,3 \cdot 10^{-4} D^2 u_0 n K_t \alpha_t \alpha_b \qquad (1)$$

where
D is the drill bit diameter, mm;
n is the rotation speed, rpm;
u_0 is the feed, mm / rev;
K_t is the specific cutting work, kg*m/cm³, set according to the table;
α_t is the coefficient that takes into account the type of wood;
α_b is a coefficient that takes into account the bluntness.

The average K_t value when drilling pine across the fibers is shown in Tab. 2.

Drilling diameter, mm	K_t at the drill bit feed rate u_0, mm/rev					
	1	0,7	0,4	0,3	0,2	0,1
5	8	8,5	8,8	9,6	12,4	20
10	4	4,2	4,4	4,8	6,2	10
15	3	3,2	3,4	3,6	4,2	7,5
20	2,4	2,5	2,6	2,9	3,6	6
25	2	2,1	2,2	2,4	3,1	5

Tab.2: Specific cutting work K_t (approximate) when drilling pine across the fibers with center drill bits with pruners

The value of the coefficient α_t for different species: alder-0.9; beech-1.8; birch-1.2-1.5; oak-2.2.

The value of the coefficient α_b for blunting the tool: the working time of the tool after sharpening

h	1	2	3	4	5	6
α_b	1.2	1.3	1.35	1.4	1.45	1.5

The correction factor for the wood species is determined according to Tab. 3 (for pine, α_r = 1).

Linden, aspen	0.8	**Birch**	1.2-1.3
Spruce	0.9-1	**Beech**	1.3-1.5
Alder	1-1.05	**Oak**	1.5-1.6
Larch	1.1	**Ash**	1.5-2

Tab.3: The correction factor for the wood species

The specific cutting work is defined as the product of: $K = K_t \cdot \alpha_t \cdot \alpha_b$

Cutting speed when drilling is determined using the dependence (m/s):

$$V_c = \frac{\pi d_d n}{2 \cdot 1000 \cdot 60}$$

where
$\boldsymbol{d_d}$ is the drill diameter, m;

The amplitude of the cutting force when drilling is (n):

$$P = \frac{N}{V} = 3,8\, K_t \cdot d_d \cdot u_0 \cdot \alpha_t \cdot \alpha_b$$

and the cutting force as a function of time $P(t) = Psin0,2nt$.

The oscillation velocities of the drill bit are determined from the differential equation.

$$EI\frac{\partial^4 Y}{\partial x^4} + m_0\frac{\partial^2 Y}{\partial t^2} = P(t)\delta(x - x_0) \tag{1}$$

where $\boldsymbol{E}$ is the elastic modulus, Pa;
$\boldsymbol{I}$ is the moment of inertia, m^4;
$\boldsymbol{m_0}$ is the distributed mass, kg/m;
$\boldsymbol{\delta\ (x\text{-}x_0)}$ is the delta function centralized in the coordinate $\boldsymbol{X_0}$.

Taking into account the elastic modulus and density of the drill bit material, the differential equation will take the form:

$$\frac{\partial^2 Y}{\partial t^2} + 2,7 \cdot 10^7\frac{I}{F}\frac{\partial^4 Y}{\partial x^4} = \frac{P(t)}{7,8 \cdot 10^3 F}\delta(x - x_0) \tag{2}$$

where
$\boldsymbol{F}$ is the cross-sectional area, m^2.

3. THE MEASUREMENTS OF THE VELOCITY FLUCTUATIONS DRILLS

A comparison of the calculated values of the ratios of the values $2,7 \cdot 10^7\frac{I}{F}$ and $1,7 \cdot 10^6 dc^2$ showed that for drill bits of different diameters, the difference does not exceed 10-12%. Therefore, for technical calculations of the sound pressure level spectra of drill bits, taking into account the setting of the function for the cantilever attachment:

$$\varphi(x) = cos\frac{4\pi kx}{l_d}cos\frac{2k-1}{2l_d}\pi x$$

the oscillation rates are determined from the system of differential equations:

$$\begin{aligned}
&\frac{d^2Y_1}{dt^2} + 10^7 d_d^2\left(\frac{10k-1}{l_d}\right)^4_{I_1} = \frac{2 \cdot 10^{-5}}{d_d^2 l_d}P\,sin\,0,2nt\\
&\frac{d^2Y_2}{dt^2} + 10^7 d_d^2\left(\frac{6k+1}{l_d}\right)^4_{I_2} = \frac{2 \cdot 10^{-5}}{d_d^2 l_d}P\,sin\,0,2nt\\
&\frac{d^2Y_3}{dt^2} + 10^7 d_d^2\left(\frac{6k-1}{l_d}\right)^4_{I_3} = \frac{3 \cdot 10^{-5}}{d_d^2 l_d}P\,sin\,0,2nt\\
&\frac{d^2Y_4}{dt^2} + 10^7 d_d^2\left(\frac{2k+1}{l_d}\right)^4_{I_4} = \frac{3 \cdot 10^{-5}}{d_d^2 l_d}P\,sin\,0,2nt\\
&\frac{d^2Y_5}{dt^2} + 10^7 d_d^2\left(\frac{2k-1}{l_d}\right)^4_{I_5} = \frac{6 \cdot 10^{-5}}{d_d^2 l_d}P\,sin\,0,2nt
\end{aligned} \tag{3}$$

where
$\boldsymbol{d_d}$ is the drill diameter, m;
$\boldsymbol{l_d}$ is the drill length, m;
$\boldsymbol{n}$ is speed of rotation, rpm.

The solutions of the equations with respect to the real part of the oscillation velocities are obtained in the following form:

$$\begin{aligned}
&V_{k1} = Re\left\{\frac{\partial Y_1}{\partial t}\right\} = \frac{4 \cdot 10^{-6}Pn}{d_d^2 l_d}\sum_{k=1}^{k^*}\left[10^7 d_d^2\left(\frac{10k-1}{l_d}\right)^4 - (0,2n)^2\right] \times\\
&\times\left\{\left[10^7 d_d^2\left(\frac{10k-1}{l_d}\right)^4 - (0,2n)^2\right]^2 + 10^{14}d_d^2\eta^2\left(\frac{10k-1}{l_d}\right)^8\right\}^{-1} cos\,0,2nt\\
&V_{k2} = Re\left\{\frac{\partial Y_2}{\partial t}\right\} = \frac{4 \cdot 10^{-6}Pn}{d_d^2 l_d}\sum_{k=1}^{k^*}\left[10^7 d_d^2\left(\frac{6k+1}{l_d}\right)^4 - (0,2n)^2\right] \times\\
&\times\left\{\left[10^7 d_d^2\left(\frac{6k+1}{l_d}\right)^4 - (0,2n)^2\right]^2 + 10^{14}d_d^2\eta^2\left(\frac{6k+1}{l_d}\right)^8\right\}^{-1} cos\,0,2nt\\
&V_{k3} = Re\left\{\frac{\partial Y_3}{\partial t}\right\} = \frac{1,6 \cdot 10^{-5}Pn}{d_d^2 l_d}\sum_{k=1}^{k^*}\left[10^7 d_d^2\left(\frac{6k-1}{l_d}\right)^4 - (0,2n)^2\right] \times\\
&\times\left\{\left[10^7 d_d^2\left(\frac{6k-1}{l_d}\right)^4 - (0,2n)^2\right]^2 + 10^{14}d_d^2\eta^2\left(\frac{6k-1}{l_d}\right)^8\right\}^{-1} cos\,0,2nt\\
&V_{k4} = Re\left\{\frac{\partial Y_4}{\partial t}\right\} = \frac{1,6 \cdot 10^{-5}Pn}{d_d^2 l_d}\sum_{k=1}^{k^*}\left[10^7 d_d^2\left(\frac{2k-1}{l_d}\right)^4 - (0,2n)^2\right] \times\\
&\times\left\{\left[10^7 d_d^2\left(\frac{2k-1}{l_d}\right)^4 - (0,2n)^2\right]^2 + 10^{14}d_d^2\eta^2\left(\frac{2k-1}{l_d}\right)^8\right\}^{-1} cos\,0,2nt\\
&V_{k5} = Re\left\{\frac{\partial Y_5}{\partial t}\right\} = \frac{1,2 \cdot 10^{-5}Pn}{d_d^2 l_d}\sum_{k=1}^{k^*}\left[10^7 d_d^2\left(\frac{2k-1}{l_d}\right)^4 - (0,2n)^2\right] \times\\
&\times\left\{\left[10^7 d_d^2\left(\frac{2k-1}{l_c}\right)^4 - (0,2n)^2\right]^2 + 10^{14}d_d^2\eta^2\left(\frac{2k-1}{l_d}\right)^8\right\}^{-1} cos\,0,2nt
\end{aligned} \tag{4}$$

The maximum values of the oscillation velocity, i.e. [5-8], are used to calculate the sound pressure levels.

$$V_k = \sum_1^5 V_{k_i}$$

4. CONCLUSION

In this way, the parameters of the cutting speed and the vibration of the drills during drilling were theoretically justified. The obtained dependences take into account the geometric dimensions of the cutting tool, the physical and mechanical properties and, most importantly, the parameters of the technological process when drilling workpieces from various types of wood.

REFERENCES

[1] Ruslyakov D. V., Motrenko D. V., Chukarin A. N.: Specific features of vibroacoustic dynamics of spindle butterflies of the multi--spindle and milling-grooving woodworking machines // Izvestiya Tul'skogo gosudarstvennogo universiteta. Tekhnicheskie nauki. № 7. P. 91-98, 2020

[2] Ruslyakov, D. V., Motrenko, D. V., Chukarin, A. N.: Influence of the production environment factors on operators of the woodworking machines // Nauchno-tekhnicheskij zhurnal: Trudy RGUPS. – Rostov n/D: 2020, № 2 (51). P.106-109, 2020

[3] Bezopasnost' zhiznedeyatel'nosti: ucheb. posobie / I.G. Pereverzev, T.A. Finochenko, I.A. YAickov [i dr.]; FGBOU VO RGUPS. – 2nd ed., reprint. and additional Rostov n/D : 2019. – 308 p.

[4] Chukarin, A.N.: Teoriya i metody akusticheskih raschetov i proektirovaniya tekhnologicheskih mashin dlya mekhanicheskoj obrabotki. – Rostov n/D: Izdatel'skij centr DGTU, 152 p., 2004

[5] Meskhi, B.CH.: Uluchshenie uslovij truda operatorov metallorezhushchih i derevoobrabatyvayushchih stankov za schet snizheniya shuma v rabochej zone (teoriya i praktika). – Rostov n/D: Izdatel'skij centr DGTU, 131 p., 2003

[6] Theoretical research of noise and vibration spectra in cabins of locomotive and diesel shunting locomotive Yaitskov I.A., Chukarin A.N., Finochenko T.A. International Journal of Applied Engineering Research. 2017. T. 12. № 21. C. 10724-10730

[7] Yaitskov, I.A., Chukarin, A.N.: The efficiency of the noise reduction levels of the locomotives and diesel locomotives, AKUSTIKA, ISSN 1801-9064, Studio D – Akustika s.r.o., České Budějovice, VOLUME 32, p. 92-96, 2019

[8] Saw Frame in a Metal-Cutting Band Saw with Increased Rigidity and Vibrational Stability / A.E. Litvinov, V.V. Novikov, A.N. CHukarin // Russian Engineering Research, Vol. 38, No. 3, pp. 218-219, 2018

Dmitry Ruslyakov *is Candidate of Technical Sciences, Associate Professor, Dean of the Faculty of Engineering and Technology, Associate Professor of the Department of Automobile Transport and Technological Equipment of the Institute of Service and Business (branch) of the Don State Technical University in Shakhty, the Rostov region. Dmitry Ruslyakov is a specialist in the field of noise generation and dustiness in the woodworking industry, calculation and design of noise barriers of woodworking machines, noise and dust absorption in working areas of production facilities. He is a member of the Association of Engineering Education of Russia, as well as a member of the organizing committees of conferences and seminars on topical issues of engineering and technology. Dmitry Ruslyakov is the author of more than 70 scientific papers, the co-author of textbooks and patents. He presented the main results of his research at international conferences in Moscow, Rostov-on-Don, Tula, Novocherkassk, Sofia (Bulgaria).*