UDC 621.9.0255

RESULTS OF EXPERIMENTAL RESEARCH ON THE CUTTING OF HIGHLY ABRASIVE MATERIALS WITH ABRASIVE REINFORCED CIRCLES

Yu.V. Maksimyuk,
Doctor of Science (Engineering), Professor

K.I. Pochka,
Doctor of Science (Engineering), Professor

Yu.D. Abrashkevych,
Doctor of Science (Engineering), Professor

M.O. Prystailo,
Candidate of Science (Engineering), Associate Professor

A.G. Polishchuk

Kyiv National University of Construction and Architecture

DOI: 10.32347/2410-2547.2023.110.361-374

In order to carry out experimental studies of the process of cutting highly abrasive materials with abrasive reinforced wheels, a dynamometer stand for registering the force load of the author's design of the KNUCA was modified, which made it possible to conduct full-fledged experimental studies taking into account all the valid factors of the interaction of the working environment and the working body during cutting with the supply of water to the cutting zone to dedust the working process As a working environment, it is proposed to use refractory bricks, and as a working body - an abrasive reinforced wheel for cutting highly abrasive materials with a strength of up to 60 MPa. As a result of the research conducted for the dynamometric stand for force load registration during the study of the process of cutting highly abrasive materials with an abrasive reinforced wheel, the tangential forces that perform the work of destruction and overcoming friction between the side surfaces of the wheel and the material were analytically determined. According to the results of theoretical studies, it was established that the limits of the change in the resistance to cutting, determined for a natural installation for cutting highly abrasive materials (refractories) with an abrasive reinforced wheel and for a laboratory stand, are the same, and the nature of their change is also similar and related by a similarity coefficient.

In order to check the adequacy of theoretical calculations, experimental studies of cutting refractory bricks with temporary resistance to uniaxial compression of the rock $\sigma_в$=60 MPa were carried out on a dynamometric stand. When conducting experimental studies, normal and tangential forces were simultaneously measured, which perform the work of destruction and overcoming friction between the side surfaces of the circle and the material. The main attention was paid to oscillograms of tangential (directed tangentially to the working body) forces. The conducted experimental studies fully confirm the adequacy of the theoretical calculations, and the comparison of the theoretical and experimental results of determining the tangential cutting forces showed their sufficient convergence and, accordingly, the legitimacy of using analytical expressions when calculating the power parameters of machines with an abrasive tool. The values of the tangential cutting forces that perform the work of destroying and overcoming the frictional forces between the side surfaces of the wheel and the material, which were determined theoretically taking into account the similarity coefficients used in physical modeling for the given laboratory bench for recording the cutting forces of highly abrasive materials by abrasive reinforced wheels, compared with the results tangential cutting forces determined experimentally on this stand. The maximum value of the error in determining the tangential cutting forces theoretically and experimentally on the laboratory bench for recording the cutting forces of highly abrasive materials with abrasive reinforced wheels is Δ_δ=13,8%.

Keywords: laboratory stand, experimental studies, abrasive wheel, forces, cutting speed, feed speed.

Introduction. Construction and assembly works are characterized by the fact that they are performed in purely specific conditions, which differ from the conditions of factory production. These works can be performed in limited conditions, in places difficult to access, in open areas, etc. [1]. Cutting machines, the working body of which are abrasive reinforced wheels, were especially widely used during construction and assembly works [1, 2]. For the successful operation of cutting machines with abrasive reinforced wheels, strict conditions are imposed on the processing method and the design of the corresponding mechanisms, on their working tools, which, in turn, affects economic efficiency, high energy performance, and ease of use [1-5].

Despite the indicated advantages and great interest in abrasive processing of materials for construction, assembly and repair works, its possibilities have not yet been fully revealed [6]. This is mainly due to the fact that not enough attention is paid to the study of the peculiarities of work in such conditions, which occur in the process of abrasive processing of various materials, as well as to its practical implementation. The mass (industrial) use of this method of processing is connected with the solution of a number of problems to increase the efficiency of their use: optimization of cutting modes and heating of the processing material, improvement of accuracy, increase of indicators of stability of the abrasive tool, reduction of time for further processing, improvement of ergonomic indicators of the operator's work at mechanization of production processes. Therefore, the issue of the theory and practice of abrasive wheel processing processes, the disclosure of its physical mechanism requires further in-depth study.

Analysis of publications. In order to check the adequacy of theoretical studies, experimental studies are conducted followed by a comparative analysis of the results obtained in the process of theoretical and experimental studies. In works [1-7] equipment for assembly work, the working body of which is abrasive reinforced wheels, is considered, calculations of their operational indicators, power parameters are given, the influence of thermal processes on the performance of cutting tools, features and operating conditions of the specified machines are investigated. The work [8] presents the development of a device for cutting highly abrasive materials with diamond discs and abrasive reinforced circles. In works [9-11], a method of non-parametric construction of the dynamics of abrasive wear of working surfaces is proposed and the factors affecting abrasive wear resistance are considered, the differences in the calculations of high-speed working bodies depending on the kinematics of their work processes are given. The works [12-17] present mathematical models for technical systems with different intensity of movement of working (executive) bodies, give their detailed description with working conditions, and provide a solution that makes it possible to evaluate the dynamics of such systems taking into account the connections between the source energy, intermediate elements, transmission mechanism and working body. The conducted analysis of literary sources allows us to create an idea of the dependence of power parameters of working bodies of technical systems on their kinematic characteristics.

Purpose of the paper. The purpose of this work is to present the results of experimental studies of cutting highly abrasive materials with abrasive reinforced wheels, followed by a comparative analysis of the results obtained in the course of theoretical studies.

Research results. As a rule, natural research objects and their models are used for conducting experimental research [18]. In a natural experiment, means of experimental research interact directly with the object of research, and in a model experiment - with its simulated prototype. When conducting model experimental research, the model acts as a means of experimental research and a direct object of research. Nowadays, the creation of a natural installation for cutting highly abrasive materials (refractories) with an abrasive reinforced wheel for the purpose of conducting experimental research would lead to a significant expenditure of time and money. Taking this into account, a physical model of an installation for cutting highly abrasive materials with abrasive reinforced circles [19]. was built, which is similar to a full-scale installation for cutting highly abrasive materials [8]. As a physical model of the installation, taking into account the similarity coefficients and the intended research tasks, a dynamometer stand [20-23] for registering the force load (Fig. 1) of the author's design of the KNUCA for researching the process of cutting highly abrasive materials with an abrasive reinforced wheel was refined, which allowed to conduct full-fledged experimental studies with taking into account all valid factors of the interaction of the working environment and the working body during cutting with the supply of water to the cutting zone for dedusting the work process.

Fig. 1. Dynamometric bench for registering force load

The laboratory stand, which allows you to perform dynamometric measurements, has the following structure: a frame on which a trolley is mounted on guide beams with the help of rollers, a holder is attached to it through tensometric beams, in which the mechanism for driving the rotation of the working body - an abrasive reinforced wheel - is fixed through an adapter. The trolley of the laboratory stand is equipped with a lifting and lowering mechanism with a handle that allows you to adjust the cutting depth. The possibility of horizontal movement of the cart is realized by means of a screw-nut transmission, a V-belt transmission with a gear ratio $u = 2{,}5$ and an electric motor with power $N = 2{,}5\,\mathrm{kW}$ and frequency of rotation of the rotor $n = 980\,\mathrm{rot/min}$ with a control panel and limit switches.

The trolley is equipped with a tare mechanism for a horizontal beam and a tare mechanism for a vertical beam. The test material is rigidly fixed on the mounting surface with the help of a mechanical vice. As a mechanism for driving the rotation of the working body $N = 2{,}2\,\mathrm{kW}$, a manual angle grinder with a capacity of an abrasive reinforced circle with a diameter $d = 125\,\mathrm{mm}$ and frequency of rotation $n = 3000...11000\ \mathrm{rot/min}$ was used. A refractory brick with temporary resistance $\sigma_в = 60\,\mathrm{MPa}$ to uniaxial rock compression was used as the experimental material.

The speed of the horizontal movement of the carriage with the angle grinder in the cutting zone was ensured by connecting the drive electric motor through the frequency converter "Frecon" FR150A. Thanks to the frequency converter, it is possible to change the current frequency of the drive electric motor, which in turn leads to a change in the speed of the horizontal movement of the cart with the angle grinder in the cutting zone. The frequency of rotation of the abrasive reinforced wheel was set using the regulator of the manual angle grinder. The number of revolutions was measured using a digital phototachometer.

For the given laboratory stand for recording the cutting forces of highly abrasive materials with abrasive reinforced wheels with the equipment described above, taking into account the similarity coefficients used in physical modeling, the tangential forces that perform the work of destruction and overcoming friction between the side surfaces of the wheel and the material were determined [5, 8, 24, 25]:

$$P_z = K_z \cdot \frac{V_n^x}{V_p^y} \cdot \sigma_в \cdot H^{z_1} + K_n \cdot \sigma_в \cdot H^{y_1}, \qquad (1)$$

where K_z – is a coefficient that depends on the composition of the abrasive mass of the wheel, m; V_n – feed speed – horizontal movement of the cart with the angle grinder in the cutting zone, $\mathrm{m/s}$; V_p – circular cutting speed, $\mathrm{m/s}$; $\sigma_в$ – temporary resistance to uniaxial compression of the rock, Pa; H – cutting depth, m; K_n – coefficient depending on the design of the circle, m;

x, y, y_1, z_1 – degree indicators that depend on the conditions of interaction of the working body with the working environment.

For the laboratory bench, taking into account the similarity coefficients used in physical modeling [19], the parameters included in equality (1) have the following values: $K_z = 35,5 \cdot 10^{-2}$ m; $K_n = 5,35 \cdot 10^{-5}$ m; $\sigma_в = 60$ MPa; $H = 0,028$ m; $x = 0,75$; $y = 0,75$; $y_1 = 0,75$; $z_1 = 0,7$.

Substituting into equation (1) the feed rate of the working body within the range of $V_n = 0,0005$ m/s to $V_n = 0,02$ m/s with a step $\Delta V_n = 0,001$ m/s, was calculated tangential cutting forces at values of circular cutting speed $V_p = 20, 30, 40, 50, 60, 70, 80, 90$ m/s. The results of the calculations are given in the table. 1. Based on the data in table. 1 graphs of changes in the tangential cutting force depending on the feed rate at different values of the circular cutting speed are plotted (Fig. 2).

Analysis of graphs in fig. 2 shows that at all values of the circular cutting speed, the dependence of the tangential cutting force on the feed rate in the range from $V_n = 0,0005$ m/s to $V_n = 0,005$ m/s has a curve that turns into a linear dependence after the value of the feed rate $V_n = 0,005$ m/s.

Table 1

Results of tangential cutting force calculations P_z, N

V_p, m/s	Feed speed V_n, m/s										
	0,0005	0,001	0,002	0,003	0,004	0,005	0,006	0,007	0,008	0,009	0,01
20	1319	1949	3009	3938	4792	5593	6355	7086	7791	8474	9138
30	1076	1541	2323	3009	3639	4230	4792	5331	5851	6355	6845
40	944	1319	1949	2502	3009	3485	3939	4373	4792	5198	5593
50	859	1176	1709	2177	2606	3009	3392	3760	4114	4458	4792
60	799	1076	1541	1949	2323	2675	3009	3330	3639	3939	4230
70	755	1002	1416	1779	2113	2426	2724	3009	3285	3552	3811
80	721	944	1319	1647	1949	2232	2502	2760	3009	3251	3486
90	693	897	1240	1541	1818	2077	2323	2560	2788	3009	3224
V_p, m/s	Feed speed V_n, m/s										
	0,011	0,012	0,013	0,014	0,015	0,016	0,017	0,018	0,019	0,02	
20	9786	10419	11040	11648	12246	12833	13412	13982	14545	15100	
30	7323	7791	8248	8697	9138	9572	9999	10419	10834	11244	
40	5979	6355	6724	7086	7441	7791	8135	8474	8808	9138	
50	5118	5437	5749	6055	6355	6651	6942	7229	7511	7791	
60	4514	4792	5064	5331	5593	5851	6105	6355	6602	6845	
70	4064	4312	4554	4792	5026	5255	5481	5704	5924	6141	
80	3715	3939	4158	4373	4584	4792	4997	5198	5397	5593	
90	3434	3639	3840	4037	4230	4420	4608	4792	4974	5154	

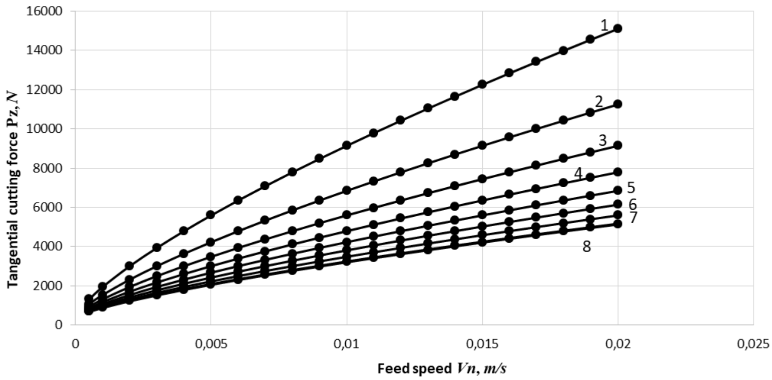

Fig. 2. The graph of changes in the tangential cutting force depending on the feed rate:
1 – $V_p = 20\,\mathrm{m/s}$; 2 – $V_p = 30\,\mathrm{m/s}$; 3 – $V_p = 40\,\mathrm{m/s}$; 4 – $V_p = 50\,\mathrm{m/s}$;
5 – $V_p = 60\,\mathrm{m/s}$; 6 – $V_p = 70\,\mathrm{m/s}$; 7 – $V_p = 80\,\mathrm{m/s}$; 8 – $V_p = 90\,\mathrm{m/s}$

The limits of the change in the resistance to cutting, determined for a natural installation when cutting highly abrasive materials (refractories) with an abrasive reinforced wheel and for a laboratory stand, are the same, and the nature of their change is also similar and related by a similarity coefficient [19].

In order to check the adequacy of theoretical calculations on a dynamometric stand (Fig. 3), experimental studies of cutting refractory bricks with temporary resistance to uniaxial compression of the rock $\sigma_в = 60\,\mathrm{MPa}$ were carried out.

Fig. 3. Cutting refractory bricks on a dynamometric stand

A refractory brick was fixed in the clamp, and the cutting depth was set using the deepening mechanism, the value of which, according to the similarity coefficient, is equal to $H = 0,028\,\mathrm{m}$ [19]. For each cut, using a frequency converter, the feed speed of the working body was ensured within the range from $V_n = 0,005\,\mathrm{m/s}$ to $V_n = 0,009\,\mathrm{m/s}$ with a step $\Delta V_n = 0,001\,\mathrm{m/s}$. The value of the circular cutting speed $V_p = 40\,\mathrm{m/s}$, $V_p = 60\,\mathrm{m/s}$, $V_p = 80\,\mathrm{m/s}$ was provided by the speed controller of the angle grinder.

When conducting experimental studies, normal and tangential forces were simultaneously measured, which perform the work of destruction and overcoming friction between the side surfaces of the circle and the material [26]. The strain gauge effect is the basis of resistance measurement methods [26] – a change in the electrical (i.e., ohmic) resistance of the metal wire of the sensor during its elastic deformation with the help of strain gauge beams. The signal was amplified by modern instrumental amplifiers manufactured by Analog Devices. A 10-bit module is used as an analog-to-digital converter (ADC), which is part of the PIC (Peripheral Interface Controller) microcontroller family. Therefore, the measurement data was recorded with the help of high-tech measuring and recording equipment, which made it possible to quickly and without repetitions from primary data to obtain sufficiently accurate estimates of the interaction of highly abrasive materials with an abrasive reinforced wheel. The obtained results in the form of an array of points are recorded in real time (oscillograms) (Fig. 4).

In the future, the oscillograms were processed using modern software called "Tenzo Cut", which eliminated the time-consuming process of data processing. Thanks to this, the number of measurements of the cutting force was minimized with the specified accuracy and reliability of the results of the experiment with the probability of the obtained data from 0.90 to 0.95.

The main attention was paid to the oscillograms of tangential (directed tangentially to the working body) forces that perform the work of destruction and overcoming friction between the side surfaces of the circle and the material. The obtained oscillograms were brought to the beginning of the horizontal axis of coordinates, shifting the smallest value to the level of the zero mark and programmatically converted into power values *H* (carried out calibration).

After calibrating the oscillograms using the software calculation module, the average value of the tangential forces at the established mode of cutting refractory bricks on the dynamometer bench was determined (fig. 4, c,d). Having previously set the range on the calibrated oscillogram, the initial and final marks on the horizontal coordinate axis are set. The results of the calculations are given in the table. 2.

Based on the data in the table 2 graphs of changes in the tangential cutting force depending on the feed rate at the values of the circular cutting speed are plotted $V_p = 40\,\mathrm{m/s}$, $V_p = 60\,\mathrm{m/s}$ and $V_p = 80\,\mathrm{m/s}$ (fig. 5).

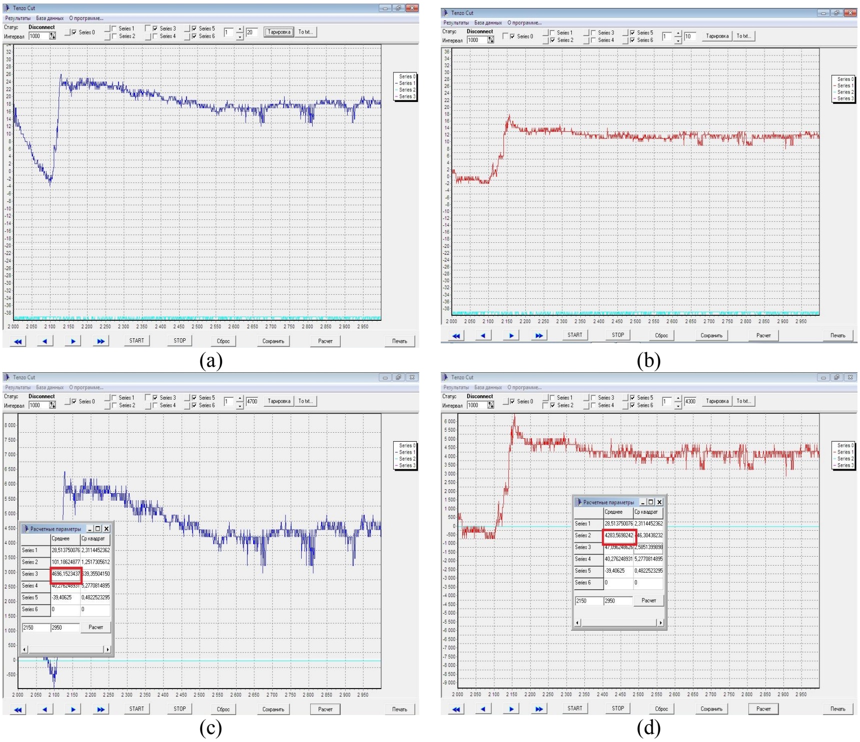

Fig. 4. Oscillograms of tangential refractory brick cutting forces on dynamometer stand at $V_p = 40\,\mathrm{m/s}$, $V_n = 0.007\,\mathrm{m/s}$ ((a), (c)) and $V_p = 40\,\mathrm{m/s}$, $V_n = 0.008\,\mathrm{m/s}$ ((b), (d)):
(a), (b) – results as an array of points recorded in real time (oscillogram);
(c), (d) – waveforms are reduced to the beginning of the horizontal axis of coordinates and programmatically converted into force values (tare performed)

Table 2

Value of tangential cutting force P_z (N) obtained experimentally

V_p, m/s	Feed speed V_n, m/s				
	0,005	0,006	0,007	0,008	0,009
40	3411	3903	4320	4714	5113
60	2611	3013	3306	3618	3921
80	2215	2508	2713	3007	3206

Analyzing the graphs in fig. 5, it can be seen that at all values of the circular cutting speed, the dependence of the tangential cutting force on the feed rate has a linear relationship.

To check the adequacy of the results of theoretical calculations, a comparative analysis of similar parameters determined experimentally was carried out. The values of the tangential cutting forces that perform the work of destroying and overcoming the frictional forces between the side surfaces of the wheel and the material, which were determined theoretically taking into account the similarity coefficients used in physical modeling for the given laboratory bench for recording the cutting forces of highly abrasive materials by abrasive reinforced wheels, compared with the results tangential cutting forces determined experimentally on this stand (Fig. 6).

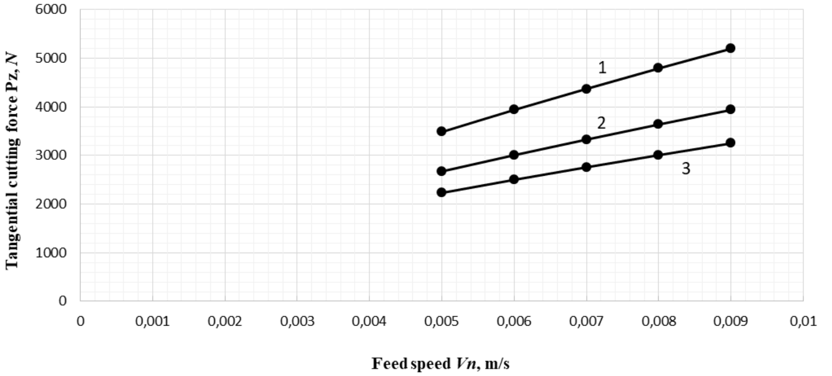

Fig. 5. Graphs of changes in the tangential cutting force obtained experimentally, depending on the feed rate: 1 – $V_p = 40\,\mathrm{m/s}$; 2 – $V_p = 60\,\mathrm{m/s}$; 3 – $V_p = 80\,\mathrm{m/s}$

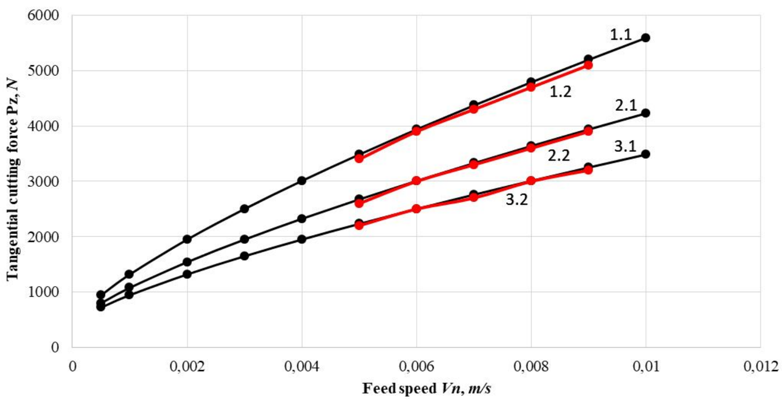

Fig. 6. Comparative analysis of theoretical and experimental results of tangential cutting forces: 1.1, 2.1, 3.1 – theoretical data at $V_p = 40\,\mathrm{m/s}$, $V_p = 60\,\mathrm{m/s}$ and $V_p = 80\,\mathrm{m/s}$;
1.2, 2.2, 3.2 – experimental data at $V_p = 40\,\mathrm{m/s}$, $V_p = 60\,\mathrm{m/s}$ and $V_p = 80\,\mathrm{m/s}$

The error of determining the tangential cutting forces, obtained theoretically and experimentally, is determined by the dependence:

$$\Delta_\delta = \frac{|\delta_E - \delta_T|}{\delta_E} \cdot 100\,, \tag{2}$$

where δ_E – is the value from the graph obtained experimentally; δ_T – the value from the graph obtained theoretically.

The maximum value of the error in determining the tangential cutting forces theoretically and experimentally on the laboratory stand for recording the cutting forces of highly abrasive materials with abrasive reinforced circles is $\Delta_{\delta} = 13,8\%$.

Thus, as a result of the experimental studies, the value of the tangential cutting force at different values of the feed speed of the working body was determined. A comparison of the theoretical and experimental results of determining the tangential cutting forces showed their sufficient convergence and, accordingly, the legality of using analytical expressions when calculating the power parameters of machines with an abrasive tool.

Conclusions. As a result of the research conducted for the dynamometric stand for force load registration during the study of the process of cutting highly abrasive materials with an abrasive reinforced wheel, the tangential forces that perform the work of destruction and overcoming friction between the side surfaces of the wheel and the material were analytically determined. According to the results of theoretical studies, it was established that the limits of the change in the resistance to cutting, determined for a natural installation for cutting highly abrasive materials (refractories) with an abrasive reinforced wheel and for a laboratory stand, are the same, and the nature of their change is also similar and related by a similarity coefficient.

In order to check the adequacy of theoretical calculations, experimental studies of cutting refractory bricks with temporary resistance to uniaxial compression of the rock $\sigma_{в} = 60\,\text{MPa}$ were carried out on a dynamometric stand. The conducted experimental studies fully confirm the adequacy of the theoretical calculations, and the comparison of the theoretical and experimental results of determining the tangential cutting forces showed their sufficient convergence and, accordingly, the legitimacy of using analytical expressions when calculating the power parameters of machines with an abrasive tool.

The maximum value of the error in determining the tangential cutting forces theoretically and experimentally on the laboratory stand for recording the cutting forces of highly abrasive materials with abrasive reinforced circles is $\Delta_{\delta} = 13,8\%$.

REFERENCES

1. *Abrashkevych Yu. D., Pelevin L. Ye., Rashkivskiy V. P.* Obladnannya dlya montazhnykh robit (Equipment for assembly work). Kyiv: KNUBA Publ. 2016. 238 p. (in Ukrainian).
2. *Machyshyn H. M.* Robochi orhany mashyn ta mekhanizmiv dlya ochyshchennya poverkhon′ budivel′noyi tekhniky (Working bodies of machines and mechanisms for cleaning surfaces of construction equipment). Mining, Constructional, Road and Melioration Machines. 2014. No. 83. P. 69-79. (in Ukrainian).
3. *Abrashkevych Y. D., Pelevin L. Ye., Polishchuk A. G.* Pidvyshchennya ekspluatatsiynykh pokaznykiv abrazyvnoho instrumentu (Increasing the operational performance of an abrasive tool). Mining, Constructional, Road and Melioration Machines. 2012. No. 80. P. 30-37. (in Ukrainian).
4. *Abrashkevych Y., Polishchuk A.* Doslidzhennya vplyvu teplovykh protsesiv na robotozdatnist vidriznykh instrumentiv (Study of the influence of thermal processes on the performance of cutting tools). Mining, Constructional, Road and Melioration Machines. 2013. No. 81. P. 39-44. (in Ukrainian).

5. *Abrashkevych Y., Rashkivskyi V., Polishchuk A., Chovnyuk O.* Sylovi parametry mashyn z abrazyvnym instrumentom (Power parameters of machines with an abrasive tool). Mining, Constructional, Road and Melioration Machines. 2015. No. 85. P. 67-71. (in Ukrainian).
6. *Pelevin L. Ye., Machyshyn H. M.,* Kuz′minets′ M. P. Tekhnolohichni umovy roboty abrazyvnoho instrumentu (Technological conditions of operation of an abrasive tool). Mining, Constructional, Road and Melioration Machines. 2019. No. 93. P. 27-34. (in Ukrainian).
7. *Abrashkevych Yu. D., Machyshyn H. M., Marchenko O. A., Balaka M. M., Zhukova O. H.* Mechanical strength increasing of abrasive reinforced wheel. Strength of Materials and Theory of Structures: Scientific-and-technical collected articles. 2022. Issue 108. P. 295-308. DOI: 10.32347/2410-2547.2022.108.295-308.
8. *Abrashkevych Yu. D., Pochka K. I., Prystailo M. O., Polishchuk A. G.* Rozrobka ustanovky dlya rizannya vysokoabrazyvnykh materialiv almaznymy dyskamy ta abrazyvnymy armovanymy kruhamy (Development of an installation for cutting highly abrasive materials with diamond discs and abrasive reinforced wheels). Current issues of science and integrated technologies: Proceedings of the I International Scientific and Practical Conference. Milan, Italy. January 10-13, 2023. P. 656-663. (in Ukrainian).
9. *Rohovskyy I. L., Kalinichenko D. Yu.* Metodyka neparametrychnoyi pobudovy dynamiky abrazyvnoho znoshuvannya robochykh poverkhon′ detaley budivel′nykh mashyn (Methodology of non-parametric construction of the dynamics of abrasive wear of working surfaces of parts of construction machines). Scientific Bulletin of the National University of Bioresources and Nature Management of Ukraine. 2018. №. 298. P. 137-147. (in Ukrainian).
10. *Rogovskyi I. L., Vygovskyi S. M.* Faktory vplyvu na abrazyvnu znosostiykikst′ detaley budivel′nykh mashyn naplavlenykh tytanoazotovmisnym bilym chavunom (Factors affecting the abrasive wear resistance of construction machine parts welded with titanium-nitrogen-containing white cast iron). Machinery & Energetics. Journal of Rural Production Research. 2019. Vol. 10, No. 1. P. 189-194. (in Ukrainian).
11. *Teteriatnyk O., Rashkivskiy V.* Calculations difference of hight-speed working units depending on the kinematics of their working processes. Mining, Constructional, Road and Melioration Machines. 2021. No. 98. P. 5-10. DOI: 10.32347/gbdmm2021.98.0101.
12. *Loveikin V. S., Pochka K. I., Romasevych Yu. O., Pochka O. B.* Dynamichnyi analiz rolykovoi formuvalnoi ustanovky z kryvoshypno-shatunnym pryvidnym mekhanizmom (Dynamic analysis of a roller forming unit with a crank-rod drive mechanism). Strength of Materials and Theory of Structure: Scientific and technical collected articles. 2019. Issue 102. P. 91-108. DOI: 10.32347/2410-2547.2019.102.91-108. (in Ukrainian).
13. *Loveikin V. S., Pochka K. I., Prystailo M. O., Pochka O. B.* Dynamichne zrivnovazhennya pryvidnoho mekhanizmu rolykovoyi formuval′noyi ustanovky z enerhetychno vrivnovazhenym pryvodom (Dynamic balancing of drive mechanism of roller forming installation with energy balanced drive). Strength of Materials and Theory of Structure: Scientific and technical collected articles. 2019. Issue 103. P. 112-130. DOI: 10.32347/2410-2547.2019.103.112-130. (in Ukrainian).
14. *Loveikin V. S., Pochka K. I., Prystailo M. O., Balaka M. M., Pochka O. B.* Impact of cranks displacement angle on the motion non-uniformity of roller forming unit with energybalanced drive. Strength of Materials and Theory of Structure: Scientific and technical collected articles. 2021. Issue 106. P. 141-155. DOI: 10.32347/2410-2547.2021.106.141-155.
15. *Loveikin V. S., Pochka K. I., Prystailo M. O., Balaka M. M., Pochka O. B.* Dynamic balancing of roller forming unit drive. Strength of Materials and Theory of Structure: Scientific and technical collected articles. 2021. Issue 107. P. 140-158. DOI: 10.32347/2410-2547.2021.107.140-158.
16. *Loveikin V. S., Romasevich Yu. O., Shymko L. S., Loveikin Yu. V., Pochka K. I.* The dynamic analysis of the joint trolley movement and hoisting mechanism in the tower crane. Strength of Materials and Theory of Structure: Scientific and technical collected articles. 2022. Issue 108. P. 267-282. DOI: 10.32347/2410-2547.2022.108.267-282.
17. *Loveikin V. S., Romasevych Yu. O., Loveikin A. V., Liashko A. P., Pochka K. I., Balaka M. M.* Drive power minimization of outreach change mechanism of tower crane during steady-state slewing mode. Strength of Materials and Theory of Structure: Scientific and technical collected articles. 2022. Issue 109. P. 317-330. DOI: 10.32347/2410-2547.2022.109.317-330.
18. *Loveikin V. S., Nazarenko I. I., Onyshchenko O. H.* Teoriya tekhnichnykh system [Theory of technical systems]: navchalnyi posibnyk [study guide]. Kyiv-Poltava, IZMN-PDTU [Institute of the content of teaching methods. Poltava State Technical University]. 1998. 175 p. (in Ukrainian).

19. *Pochka K. I., Abrashkevych Yu. D., Prystailo M. O., Polishchuk A. G.* Pobudova fizychnoyi modeli ustanovky dlya rizannya vysokoabrazyvnykh materialiv abrazyvnymy armovanymy kruhamy (Construction of a physical model of an installation for cutting highly abrasive materials with abrasive reinforced wheels). Visnyk of Kherson National Technical University. 2022. Issue 3 (82). P. 30-36. DOI: 10.35546/kntu2078-4481.2022.3.4. (in Ukrainian).
20. *Smirnov V. M.* Osnovy teoriyi rizannya hruntiv prostorovo oriyentovanymy nozhamy robochykh orhaniv zemleryynykh mashyn: Monohrafiya (Basics of the theory of soil cutting with spatially oriented knives of the working bodies of earthmoving machines: Monograph). Kyiv: "MP Lesya" Publ. 2009. 260 p. (in Ukrainian).
21. *Pelevin L. Ye., Balaka M. M., Prystailo M. O., Machyshyn H. M., Arzhayev H. O.* Teoretychni osnovy vzayemodiyi pruzhno-deformovanykh vykonavchykh elementiv budivel′noyi tekhniky i robochoho seredovyshcha z vrakhuvannyam termoreolohinykh protsesiv: monohrafiya (Theoretical foundations of the interaction of elastic-deformable actuators elements of construction equipment and the working environment, taking into account of thermorheological processes: monograph). Kyiv: Interservis Publ. 2015. 232 p. (in Ukrainian).
22. *Pelevin L. Ye., Prystailo M. O., Prystaylo T. Yu.* Udoskonalennya reyestratsiyi skladovykh syl rizannya v laboratornykh umovakh (Improvement of registration components of cutting forces in laboratory conditions). Mining, Constructional, Road and Melioration Machines. 2005. No. 65. P. 58-62. (in Ukrainian).
23. *Patent* of Ukraine for an invention 13846, IPC G 01 L 5/16, G 01 N 3/58 (2006.01). Stand for registration of cutting efforts / L. Ye. Pelevin, M. O. Prystailo, T. Yu. Prystailo (Ukraine); applicant and patentee Research Institute of Construction, Road and Engineering Technology, № u 2005 10393; stated 03.11.2005; published 17.04.2006, Bulletin № 4.
24. *Abrashkevich Yu., Pochka K., Prystailo M., Polishchuk A.* Technologies installation for cutting stone with abrasive and diamond tool. TEKA. Semi-Annual Journal of Agri-Food Industry. 2022. No. 22 (1). P. 33-39. DOI: 10.12912/27197050/139346.
25. *Abrashkevich Yu., Prystailo M., Polishchuk A.* Mathematical model of heat distribution in an abrasive wheel. Mining, Constructional, Road and Melioration Machines. 2022. No. 100. P. 5-11. DOI: 10.32347/gbdmm.2022.100.0101.
26. *Pochka K. I., Abrashkevych Yu. D., Prystailo M. O., Polishchuk A. G.* Metodyka provedennya eksperymental′nykh doslidzhen′ rizannya vysokoabrazyvnykh materialiv abrazyvnymy armovanymy kruhamy (Method of experimental research of cutting highly abrasive materials with abrasive reinforced circles). Modern Engineering and Innovative Technologies. 2023. Issue 25, Part 1. P. 3-16. DOI: 10.30890/2567-5273.2023-25-01-016. (in Ukrainian).

Стаття надійшла 12.04.2023

Максим'юк Ю.В., Почка К.І., Абрашкевич Ю.Д., Пристайло М.О., Поліщук А.Г.

РЕЗУЛЬТАТИ ЕКСПЕРИМЕНТАЛЬНИХ ДОСЛІДЖЕНЬ РІЗАННЯ ВИСОКОАБРАЗИВНИХ МАТЕРІАЛІВ АБРАЗИВНИМИ АРМОВАНИМИ КРУГАМИ

Для проведення експериментальних досліджень процесу різання високоабразивних матеріалів абразивними армованими кругами доопрацьовано динамометричний стенд реєстрації силового навантаження авторської конструкції КНУБА, що дозволило провести повноцінні експериментальні дослідження з врахуванням всіх чинних факторів взаємодії робочого середовища та робочого органу під час різання з подачею води в зону різання для обезпилення робочого процесу. В якості робочого середовища запропоновано використання вогнетривкої цегли, а в якості робочого органу – абразивний армований круг для різання високоабразивних матеріалів міцністю до 60 МПа. В результаті проведених досліджень для динамометричного стенда реєстрації силового навантаження при дослідженні процесу різання високоабразивних матеріалів абразивним армованим кругом аналітично визначено тангенціальні зусилля, які виконують роботу по руйнуванню і подоланню тертя між бічними поверхнями круга і матеріалом. За результатами теоретичних досліджень встановлено, що межі зміни сили опору різанню, визначеної для натуральної установки для різання високоабразивних матеріалів (вогнетривів) абразивним армованим кругом та для лабораторного стенду, однакові, а характер їх зміни також подібний і пов'язані між собою коефіцієнтом подібності.

З метою перевірки адекватності теоретичних розрахунків на динамометричному стенді проведено експериментальні дослідження різання вогнетривкої цегли з тимчасовим опором одноосному стисканню породи $\sigma_в$=60МПа. Проведені експеременталні дослідження в повній мірі підтверджують адекватність теоретичних розрахунків, а порівняння теоретичних та експериментальних результатів визначення тангенціальних зусиль різання показало їх достатню збіжність і, відповідно, правомірність використання аналітичних виразів при розрахунку силових параметрів машин з абразивним інструментом. Максимальне значення похибки визначення тангенціальних зусиль різання теоретичним та експериментальним шляхом на лабораторному стенді реєстрації сил різання високоабразивних матеріалів абразивними армованими кругами становить Δ_δ=13,8%.

Ключові слова: лабораторний стенд, експериментальні дослідження, абразивний круг, зусилля, швидкість різання, швидкість подачі.

Maksimyuk Yu. V., Pochka K. I., Abrashkevych Yu. D., Prystailo M. O., Polishchuk A. G.

RESULTS OF EXPERIMENTAL RESEARCH ON THE CUTTING OF HIGHLY ABRASIVE MATERIALS WITH ABRASIVE REINFORCED CIRCLES

In order to carry out experimental studies of the process of cutting highly abrasive materials with abrasive reinforced wheels, a dynamometer stand for registering the force load of the author's design of the KNUCA was modified, which made it possible to conduct full-fledged experimental studies taking into account all the valid factors of the interaction of the working environment and the working body during cutting with the supply of water to the cutting zone to dedust the working process The use of refractory bricks is proposed as the working environment, and the abrasive reinforced wheel for cutting highly abrasive materials with a strength of up to 60MPa is used as the working body. As a result of the research conducted for the dynamometric stand for force load registration during the study of the process of cutting highly abrasive materials with an abrasive reinforced wheel, the tangential forces that perform the work of destruction and overcoming friction between the side surfaces of the wheel and the material were analytically determined. According to the results of theoretical studies, it was established that the limits of the change in the resistance to cutting, determined for a natural installation for cutting highly abrasive materials (refractories) with an abrasive reinforced wheel and for a laboratory stand, are the same, and the nature of their change is also similar and related by a similarity coefficient.

In order to check the adequacy of theoretical calculations, experimental studies of cutting refractory bricks with temporary resistance to uniaxial compression of the rock $\sigma_в$=60 MPa were carried out on a dynamometric stand. The conducted experimental studies fully confirm the adequacy of the theoretical calculations, and the comparison of the theoretical and experimental results of determining the tangential cutting forces showed their sufficient convergence and, accordingly, the legitimacy of using analytical expressions when calculating the power parameters of machines with an abrasive tool. The maximum value of the error in determining the tangential cutting forces theoretically and experimentally on the laboratory bench for recording the cutting forces of highly abrasive materials with abrasive reinforced wheels is Δ_δ=13,8%.

Keywords: laboratory stand, experimental studies, abrasive wheel, forces, cutting speed, feed speed.

УДК 621.9.0255
Максим'юк Ю.В., Почка К.І., Абрашкевич Ю.Д., Пристайло М.О., Поліщук А.Г. **Результати експериментальних досліджень різання високоабразивних матеріалів абразивними армованими кругами** // Опір матеріалів і теорія споруд: наук.-техн. збірник. – К.: КНУБА, 2023. – Вип. 110. – С. 361-374.

Для проведення експериментальних досліджень процесу різання високоабразивних матеріалів абразивним армованим кругом використано динамометричний стенд реєстрації силового навантаження авторської конструкції КНУБА. Експериментально визначено тангенціальні зусилля взаємодії робочого органу з дослідним матеріалом, які виконують роботу по руйнуванню і подоланню тертя між бічними поверхнями круга і матеріалом. Експериментальні дані проаналізовані та порівняні з результатами, отриманими в процесі теоретичних досліджень.

Табл. 2. Іл. 6. Бібліогр. 26 назв.

UDC 621.9.0255
Maksimyuk Yu.V., Pochka K.I., Abrashkevych Yu.D., Prystailo M.O., Polishchuk A.G. **Results of experimental research on the cutting of highly abrasive materials with abrasive reinforced circles** // Strength of Materials and Theory of Structure: Scientific and technical collected articles. – K.: KNUBA, 2023. – Issue 110. – P. 361–374.
To carry out experimental studies of the process of cutting highly abrasive materials with an abrasive reinforced wheel, a dynamometer stand for registering the force load of the author's design of KNUCA was used. Experimentally determined tangential forces of interaction of the working body with the test material, which perform the work of destruction and overcoming friction between the side surfaces of the circle and the material. Experimental data are analyzed and compared with the results obtained in the course of theoretical research.
Table 2. Fig. 6. Ref. 26.

Автор (вчена ступень, вчене звання, посада): *доктор технічних наук, професор, професор кафедри будівельної механіки КНУБА МАКСИМ'ЮК Юрій Всеволодович*
Адреса робоча: *03037, Україна, м. Київ, Повітрофлотський проспект 31, Київський національний університет будівництва і архітектури, кафедра будівельної механіки, МАКСИМ'ЮКУ Юрію Всеволодовичу*
Мобільний тел.: +38(067) 230-94-72
E-mail: maksymiuk.iuv@knuba.edu.ua
ORCID ID: https://orcid.org/0000-0002-5814-6227

Автор (вчена ступень, вчене звання, посада): *доктор технічних наук, професор, завідувач кафедри професійної освіти КНУБА ПОЧКА Костянтин Іванович*
Адреса робоча: *03037, Україна, м. Київ, Повітрофлотський проспект 31, Київський національний університет будівництва і архітектури, кафедра професійної освіти, ПОЧЦІ Костянтину Івановичу*
Мобільний тел.: +38(097) 212-86-29
E-mail: pochka.ki@knuba.edu.ua
ORCID ID: https://orcid.org/0000-0002-0355-002X

Автор (вчена ступень, вчене звання, посада): *доктор технічних наук, професор, професор кафедри будівельних машин КНУБА АБРАШКЕВИЧ Юрій Давидович*
Адреса робоча: *03037, Україна, м. Київ, Повітрофлотський проспект 31, Київський національний університет будівництва і архітектури, кафедра будівельних машин, АБРАШКЕВИЧУ Юрію Давидовичу*
Мобільний тел.: +38(067) 401-59-54
E-mail: abrashkevych.iud@knuba.edu.ua
ORCID ID: https://orcid.org/0000-0001-8396-7812

Автор (вчена ступень, вчене звання, посада): *кандидат технічних наук, доцент, доцент кафедри будівельних машин КНУБА ПРИСТАЙЛО Микола Олексійович*
Адреса робоча: *03037, Україна, м. Київ, Повітрофлотський проспект 31, Київський національний університет будівництва і архітектури, кафедра будівельних машин, ПРИСТАЙЛУ Миколі Олексійовичу*
Мобільний тел.: +38(097) 495-07-50
E-mail: prystailo.mo@knuba.edu.ua
ORCID ID: https://orcid.org/0000-0003-3151-4680

Автор (вчена ступень, вчене звання, посада): *здобувач кафедри будівельних машин КНУБА ПОЛІЩУК Андрій Григорович*
Адреса робоча: *03037, Україна, м. Київ, Повітрофлотський проспект 31, Київський національний університет будівництва і архітектури, кафедра будівельних машин, ПОЛІЩУКУ Андрію Григоровичу*
Мобільний тел.: +38(093) 719-27-38
E-mail: p.a.g.19.05@gmail.com
ORCID ID: https://orcid.org/0000-0003-4808-9932