UDC 621. 87 DOI: 10.30977/AT.2219-8342.2025.57.0.03

Operational features and reliability of drill rods during controlled trenchless laying of underground utilities

Suponyev V.[1], Ragulin V.[1], Kravets S.[2], Lemets O.[1], Barskiy A.[1]

[1]Kharkiv National Automobile and Highway University, Ukraine
[2]National University of Water and Environmental Engineering, Ukraine

Abstract. Problem*. When laying distribution networks in densely built-up cities, significant difficulties arise due to the need to cross roads, tram and railway tracks. In such cases, installations for trenchless laying of engineering networks are widely used. At the same time, a well with a complex trajectory is formed in the soil with the help of soil-piercing equipment. The efficiency of the operation of machines and installations is ensured by the reliability of the operation of the drill rods, which transmit the force pressure from the installation to the piercing head. Exaggerated bending of the rods in curved sections can lead to their breakage and loss of working equipment in the soil.* ***Goal****. The object of the study is the process of the effect of bending of drill rods on their operational reliability when creating a communication cavity in the soil on curved sections of the route.* ***Methodology****. The work uses mathematical calculation methods to determine the permissible radius of bending of the pipeline whip, taking into account profile and the physical and mechanical properties of the material from which the pipe is made.* ***Results****. The work establishes the conditions for the reliable use of drill rods, taking into account the curvature of the puncture trajectory and the critical bending radius of the rods. The resulting calculation dependencies account for the geometric parameters of the rods and the mechanical properties of the material from which they are made. The permissible deviations of the soil puncture trajectory from the axis of movement and the length of the span when correcting the movement of the equipment and the soil are also determined.* ***Originality****. An approach to well design based on permissible bending radii of drill rods is substantiated.* ***Practical Value****. The results of the work are of great practical importance, which is to increase the operational reliability of drill rods during trenchless laying of engineering communications.*

Keywords: *soil penetration, drill rods, earthmoving equipment, engineering communications, trenchless technologies, motion correction, penetration trajectory, operation, reliability.*

Introduction

When laying distribution networks with relatively small diameter pipelines and cables for various purposes in densely built-up cities, significant difficulties arise due to the need to cross roads, tram and railway tracks. In such cases, installations for trenchless laying of engineering networks are widely used. In this case, a horizontal well is formed in the soil by static puncture, through which a protective casing in the form of a pipeline is pulled, the diameter of which is larger than the diameter of the communication that runs through it. The operational reliability of the machine or installation is ensured by various factors. Among them, the most important are the durability and reliability of the drill rods used in this case. Considering that this is expensive equipment, their breakdown or loss can lead to significant economic losses, as well as loss of working time to eliminate the consequences. Therefore, the task of choosing the conditions for reliable operation of the drill rod is an urgent issue

Citation: Suponyev, V., Ragulin, V., Kravets S, Lemets O**.,** (2025) Navolokov V. Operational features and reliability of drill rods during controlled trenchless laying of underground utilities. Automobile Transport, 2025. 57, 23–30. https://doi.org/10.30977/AT.2219-8342.2025.57.0.03

Received (надійшла) 02.10.2025
Revised (рецензована) 12.11.2025
Accepted (прийнята до друку) 12.12.2025
Published (опублікована) 30.12.2025

Analysis of publications

For laying linearly extended objects, namely cables, drainage systems and pipelines of various purposes, when creating trenches, highly efficient chain multi-scraper excavators of continuous action are used [1, 2]. But more effective are knife machines for deep cutting of soil [3, 4]. The improvement of their working equipment is described in studies [5].

The technology of guided trenchless laying of underground communications has been widely implemented since the beginning of the 2000s and belongs to modern construction technologies [6]. Their development is associated with the active development of large cities, which required comprehensive provision of the population with energy carriers, water supply, waste disposal, etc. [7-9]. The use of trenchless machines and installations in the difficult, cramped conditions of cities required constant development of navigation devices and search devices [10-13]. The improvement of ground-penetrating equipment followed the path of increasing the intensification of the process of creating communication wells in the soil [14-16]. The issues of reliability of construction equipment and diagnostics of working equipment are considered in the works [17-19].

The static processes that occur during soil penetration, as the main stage of well formation with a curvilinear trajectory, were investigated in [20]. Based on the obtained understanding of the processes, a mathematical modeling of the interaction of working equipment with the soil was obtained, which is presented in such works as [4-6]. The asymmetric designs of soil penetration tips proposed in [6-9] provide control of the trajectory of movement. Also, works [1-3] consider the influence of the angle of inclination of the beveled asymmetric cylindrical tip of the soil penetration head on the magnitude of the deviation of the working body from the trajectory of soil penetration. However, the analysis of the technological process and operating conditions of the rods that occur during controlled soil penetration was not carried out in these works.

Purpose and Tasks

The purpose of the study is to develop scientifically based recommendations for determining the permissible value of rod bending during controlled soil penetration.

To achieve the goal, it is necessary to solve the following problems. First: determine the permissible value of the force that the bar can withstand depending on its design parameters and the mechanical properties of its material. Second: establish the minimum bending radius and the minimum length of the trajectory correction section

Formation of a well in the ground with a complex trajectory

It has been established that if the tip shape and head rotation are changed quickly, it will be possible to control the trajectory of its movement in the soil (Fig. 1). Since the task of small-sized installations for static soil penetration is to form a well with the greatest approximation of its trajectory to a straight line, then by correcting the guidance of the soil penetration head, the problem of increasing the duration of underground puncture sections several times is overcome, namely from 15–20 m with a certain accuracy to 50–100 m. From this distance, the effective use of more complex and expensive horizontal directional drilling machines begins. Thus, the issue of increasing the distance of soil penetration by static action installations by correcting the movement of the soil penetration installation in the soil is relevant, both from a scientific and practical point of view.

Factors influencing this process are shown in the diagram in Fig. 1. First of all, it is necessary to establish a critical deviation of the working body from the initial trajectory, at which further movement becomes impossible due to the critical bending of the pipe or push rod, when its deformation can take a critical state from the strength condition.

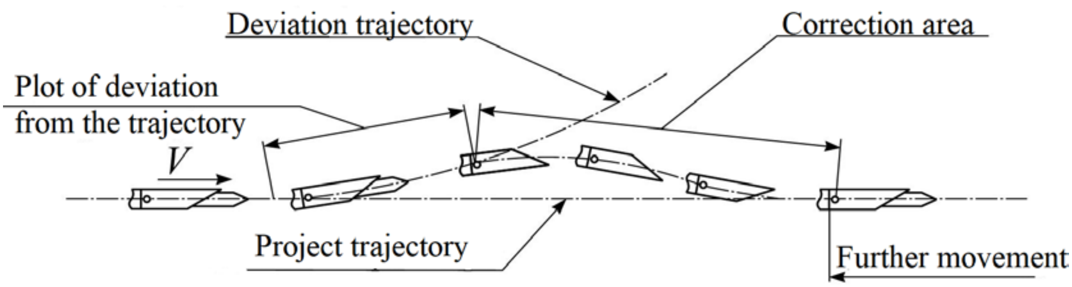

Fig. 1. Principle of correction of the trajectory of the piercing head

Secondly, it is known that the transverse force that deflects the movement of the head in the soil depends on the angle of inclination of the cut plane of the tip. This determines the total deviation of the movement from the initial axis and the length of the puncture correction section. Thirdly, the deviation of the movement is influenced by the physical and mechanical properties of the soil. Fourthly, when determining the trajectory of movement, it is necessary to take into account the stiffness of the rod, the elasticity of which is determined by the properties of the rod material and the shape of its cross section.

To solve the first issue, there are modern navigation technologies that allow you to determine the coordinates of the head's location in the soil with a sufficiently high accuracy. When controlling the drilling of a well by GSB machines, electromagnetic, laser and cable location methods from such well-known manufacturers as Digi Trax, Spot-d-Nek, Pipe Hawk GPR and others are used [3, 4]. But these are quite complex and expensive devices. To correct the movement of the piercing head at relatively shallow depths, you can use the domestic search device SPRUT - 5 of the Dnipro company "KROM", which has a sufficiently high accuracy of determining its location, which is up to 2 cm at a depth of up to 3 m. The transverse deviation at the first stage is determined by the requirements for the accuracy of the puncture. A deviation from the design exit point of the piercing head in the receiving pit is allowed horizontally within ±40 cm, and vertically within ±20 cm. If the deviation occurred during the piercing process, and the distance to the receiving pit is still sufficient, then it is possible to correct the piercing.

To establish the conditions for effective control of the trajectory of the piercing head, let us consider the technological scheme of its advancement in the soil (Fig. 2), from which it can be seen that the process of correcting the movement of the piercing head does not occur simultaneously, but in stages.

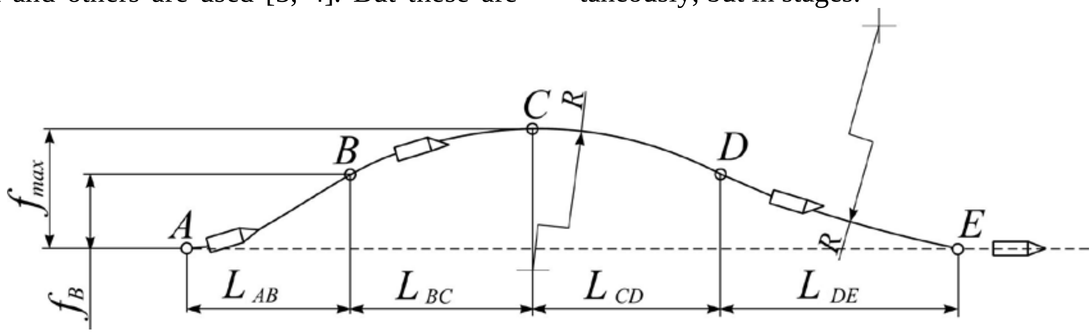

Fig. 2. Scheme for calculating the trajectory of soil puncture

At the first stage, when an unexpected deviation occurs in the *AB* section, the tip has the shape of a symmetrical cone. For the correction process, it is necessary to change it to an asymmetrical, for example, beveled frontal surface. Its position should be oriented towards the axis of the trajectory of movement. With further advancement of the head, due to the force of transverse action from the soil reaction, its movement will occur from the starting point *B* to the maximum deviation from the trajectory at point *C*. This must be taken into account when setting the critical deviation point. After the working body reaches point *D*, further movement of the head requires changing the position of the asymmetric head by 180° until the trajectory of the head movement reaches the design direction at point *E*. Then the tip head must change the asymmetric shape of the front surface to a symmetrical one and move further in a straight line. If the deviation again reaches its critical value, the correction process must be repeated.

Determination of permissible deflection force of drill rods

The main issue in soil penetration is determining the permissible deflection force of the drill rods. To do this, we first determine the critical deviation from the design trajectory and the distance at which the trajectory correction can occur with a known width of the obstacle to be overcome [21, 22].

To do this, we assume that the trajectory of the puncture must correspond to the line corresponding to the permissible deflection of the pipe from which protective cases or drill rods are made. The problem is complex. To solve it, it is proposed to accept the condition that the rod is made of a solid pipe, and its internal and external bends are equal to each other, which are described by the radii of curvature *R* (1), and the point of contact of the two circles *D* is located at a distance from the initial axis equal to half the permissible value of the rod deflection fmax at point *C*. The place of contact with the axis is assumed to be the contact point *E*.

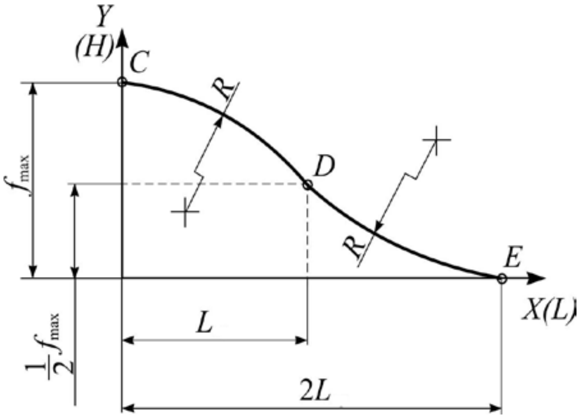

Fig. 3. Scheme for calculating pipe deflection using the radius method

Taking into account the above, the minimum radius of curvature is determined from the condition of the pipe material strength for bending. As a result, the dependence (1) is obtained. Having determined the limiting bend of the pipeline in the section *AB* (see Fig. 2) according to the specified dependence, it is possible to obtain the limiting value of the deviation of the rod tip from the puncture axis. This case corresponds to the minimum length of the rod deflection line Lmin, and accordingly the minimum length of the trajectory correction section:

$$L_{\min} = 2\sqrt{R_{\min} \cdot f_{\max} - \frac{1}{4} f_{\max}^2} \qquad (1)$$

Knowing the minimum length of the rod deflection, it is easy to determine at what depth the force $P_{\max}$ it is achieved. To do this, we will write an equation to determine the maximum allowable moment from the action of the transverse force applied to the end of the cantilever beam (Fig. 4)

$$M(x) = \frac{qL_{\min}^2}{8} + P_{\max}\frac{L_{\min}}{2} = W[\sigma_{ben}] \qquad (2)$$

where q – the driving force of gravity of the pipe.

Where:

$$P_{\max} = \frac{W[\sigma_{ben}]}{L_{\min}} - \frac{qL_{\min}}{4} \qquad (3)$$

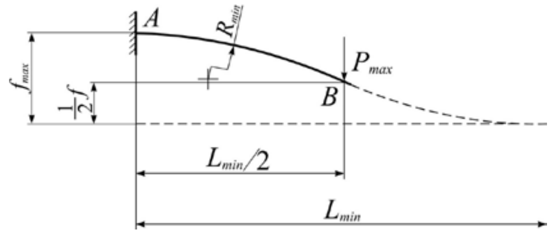

Fig. 4. Calculation scheme for determining the permissible crushing force of the pipeline

According to the obtained ideas about the stressed state of pipes or rods, we will obtain the permissible deviation from the puncture axis. If we imagine that the trajectory of the head movement relative to this line can pass with a different radius, then it is possible to determine the zone of effectiveness of the correction of the trajectory of movement (Fig. 5), that is, the trajectory, the radius of which is as close as possible to the permissible bending line of the rod. If the radius of the rod deflection is significantly larger, then this leads to an increase in the value of the deviation fmax beyond the permissible limits and an increase in the length of the correction section L, at which it is possible not to have time to bring the head to the primary axis.

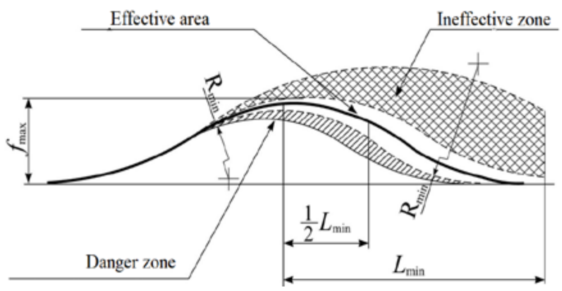

Fig. 5. Zones that may occur when correcting the trajectory of soil puncture

The desire to reduce the deviation values and the length of the correction section can lead the operation of the rods or pipes being pulled into the dangerous correction zone, when they cannot withstand bending stresses.

From the above it is clear that by comparing the maximum permissible crushing force of drill rods or pipelines with the transverse force that occurs on a head with an asymmetric tip, in which the front surface is a beveled plane, it is possible to obtain a calculated dependence for determining the critical angle of inclination of this surface, which has the form

$$\beta_{cr} = arcctg\left(f_{ter} + \frac{8W[\sigma_{ben}] - qL_{\min}^2}{1.44 \cdot E_{sd} \cdot D^2 \cdot L_{\min}}\right) \qquad (4)$$

where f_{ter} - friction force of steel on the soil; W - static moment of the pipe section

$$W = \frac{\pi \cdot D^3 \cdot \left(1-\alpha^4\right)}{32} \quad (5)$$

where α is the coefficient of the internal ratio pipeline diameter d to the outside D, $[\sigma_{ben}]$ - bending strength of the rod material, N/m^2; q - linear weight of the rod, kg/m^2; E_{sd} - soil deformation modulus, N/m^2; D - outer diameter of the tip; $L_{\min}$ - minimum length of the rod deflection line, m (dependence 1)

The value $R_{\min}$ presented in dependence (1) is the minimum bending radius and is determined by the dependence

$$R_{\min} = \frac{E \cdot D}{2 \cdot [\sigma_u]} \quad (6)$$

where E is the modulus of elasticity of the rod material, N/m^2.

Table 1. Input data on soil properties for determining the critical tip inclination angle

Soil properties included in calculations	Units of measurement,	Common soil types		
		Tugoplastic clay	Semi-hard loam	Firm sandy soil
Deformation modulus, Egr	N/m^2	63.1·104	89.2·104	139.0·104
Friction coefficient, fter	-	0.325	0.424	0.532

To calculate the critical angle of inclination of the frontal surface according to formula (4), we will assume the following initial data: outer diameter of the rod D = 0.0635 m, inner d = 0.040 m, length l = 0.5 m. Rod material – steel 45, unit weight: q=140 N/m^2; bending strength limit of steel $[\sigma_{ben}]$ = 250…340 106 N/m^2; modulus of elasticity of steel E_{sd} = 211010 N/m^2.

Input calculation data for typical soils common in Ukraine are given in Table 1.

The minimum bending radius of the drill rod will be 22.4 m. The minimum length of the deflection line under the action of force with a deviation from the axis of 0.3 m will be 8.2 m.

The static moment of the rod profile will be 0.0022 m^3.

The maximum permissible (or critical) angle of inclination of the front surface of the working body for different types of soils will be:

- for rigid plastic clay – 79.24°;
- for semi-hard loam – 71.84°;
- for semi-hard loam – 64.7°.

The industry produces a variety of different rods for drilling oil wells, which can be used when creating wells with machines using various methods of soil development (Fig. 6).

Table 2 Characteristics and dimensions of typical drill rods for GNB rigs

Drilling rig type, (traction force)	Outer diameter of the lock part, mm	Outer diameter of the rod body, mm	Rod body wall thickness, mm	Length, mm	Bending radius, m	Strength grade
From 150 kN to 200 kN	68	60.3	7.2	3000, 4570	45	G105, S135
From 200 kN to 320 kN	79	73	8	3000	60	G105, S135
	82	73	08-10	3000, 4570	65-70	G105, S135
From 320 kN to 450 kN	92	88.9	10	4570	80	G105, S135
	105	88.9	10	4570, 6000	85-90	G105, S135
From 450 kN to 600 kN	127	102	10	6000	95	G105, S135
More than 600 kN	127	114.3	11.5	6000	98	G105, S135

Table 2 presents the main characteristics and geometric dimensions of standard drill rods used in GNB rigs. These parameters are directly related to the calculated minimum bending radii of the drill rods, which are determined based on the maximum critical angle of inclination of the flat front surface on the working body. The presented data allow for a clearer understanding of how the structural features of the drill rods influence their operational limits and bending capabilities under working conditions.

Fig. 6. Typical drill rods for drilling oil wells

Drill rods as a factor in the reliability of the process of forming wells in soil with a complex trajectory

Increasing the operational efficiency of trenchless laying of underground utilities is a modern direction of scientific research development.

The process of developing horizontal wells is a complex process in which drill rods are subjected to complex tensile, compressive and bending loads. The curvature of the soil penetration trajectory is an important condition for rationally overcoming obstacles on the route, which cannot be created without a drill rod of the appropriate design and material from which it is made.

A method for calculating the minimum angle of inclination of the flat front surface of the piercing working body, taking into account the maximum possible bending of the drill rod and the physical and mechanical properties of the soil, was obtained. From the review of previous studies, no detailed analysis of the operating conditions of drill rods when forming wells in the soil was found. The analysis of the process made it possible to determine its main regularities and choose an approach for scientific substantiation of the conditions under which reliable operation of the rod is guaranteed, taking into account the rational trajectory that must be maintained when overcoming obstacles that arise on the route. For this, calculation dependencies were created to determine the minimum permissible radius of curvature of the puncture trajectory, which is tied in accordance with the minimum radius of bending of the drill rod. Thus, the goal of rationally laying the well trajectory was achieved, taking into account the design of the drill rods and the physical and mechanical properties of their materials.

Achieving the goal set in the conducted research has important practical significance, which contributes to increasing the efficiency of drill rods by creating recommended conditions for their reliable operation.

Conclusions

The results obtained allow to increase the operational reliability of drill rods during controlled soil penetration and to improve the efficiency of the process by reducing the radius of the trajectory of the head movement in the soil with an asymmetric tip shape in the form of a beveled frontal surface. Calculation dependencies were obtained that make it possible to determine the permissible minimum bending radius of the rod and the length of the correction section span and which take into account both the parameters of the drill rods and their materials, and the bevel angle of the asymmetric tip of the soil-piercing head depending on the type of soil.

The results of the work have important practical significance, which lies in increasing the operational reliability of drill rods and the efficiency of trenchless laying of engineering communications, which can be used at the design stage of future routes.

Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

1 Wang, Z., & Hu, C. (2024). Examining Pipe–Borehole Wall Contact and Pullback Loads for Horizontal Directional Drilling. *Applied Sciences*, **14(19),** 8841. https://doi.org/10.3390/app14198841

2 Коваль, А. (2022). Забезпечення керованості гусеничних землерийних машин безперервної дії за умови монтажу їх робочого обладнання збоку від базового шасі. *Automobile Roads and Road Construction*. Koval, A. (2022). Zabezpechennia kerovanosti husenychykh zemleriiinykh mashyn bezperervnoi dii za umovy montazhu yikh robochoho obladnannia zboku vid bazovoho shasi (Ensuring controllability of continuous-action crawler earthmoving machines when mounting equipment beside the base chassis). *Automobile Roads and Road Construction*. https://doi.org/10.33744/0365-8171-2022-112-287-294

3 Ткачук, М. М., Филипчук, В. Л., & Якимчук, Б. Н. (2013). *Будівництво зовнішніх мереж і монтаж санітарно-технічного обладнання будівель: навчальний посібник*. НУВГП. Tkachuk, M. M., Fylypchuk, V. L., & Yakymchuk, B. N. (2013). *Budivnytstvo zovnishnikh merezh i montazh sanitarno-tekhnichnoho obladnannia budivel: navchalnyi posibnyk* (Construction of external networks and installation of sanitary engineering equipment of buildings: textbook). NUVGP.

4 Кравець, С. В. (1999). *Грунтозахисні та енергозберігаючі машини (Основи теорії, проектування та створення)*. Рівне: РДТУ. Kravets, S. V. (1999). *Hruntozakhysni ta enerhozberehaiuchi mashyny (Osnovy teorii, proektuvannia ta stvorennia)* (Soil-protective and energy-saving machines: theory, design, and creation). Rivne: RDTU.

5 Кравець, С. В., Скоблюк, М. П., Стіньо, О. В., Зоря, Р. В. (2018). *Критичноглибинні двоярусні грунторозпушувачі: монографія*. Kravets, S. V., Skobliuk, M. P., Stin'io, O. V., & Zoria, R. V. (2018). *Krytychnohlybynni dvoiarusni hruntorozpushuvachi: monografiia* (Critical-depth two-level soil looseners: monograph).

6 Tong, H., & Shao, Y. (2022). Mechanical Analysis of DS in Horizontal Directional Drilling. *Applied Sciences*, **12(6),** 3145. https://doi.org/10.3390/app12103145

7 Najafi, M. (2010). *Trenchless Technology Piping: Installation and Inspection*. Alexandria, VA: ASCE Press, WEF Press Water Environment Federation

8 Jian Xin. (2014). Application of Trenchless Pipeline Rehabilitation Technology. *International Conference on Pipelines and Trenchless Technology*. https://doi.org/10.1061/9780784413821.051

9 Allouche, E. N., & Ariaratnam, S. T. (2012). State-Of-The-Art Review of No-Dig Technologies for New Installations. https://doi.org/10.1061/40641(2002)55.

10 Gunsaulis, F. R., & Levings, R. (2008). Installation of Gravity Sewers Using Horizontal Directional Drilling (HDD). *Proceedings of Pipelines Congress*, July 22–27, Atlanta, GA.

11 Bennett, R. D., & Ariaratnam, S. T. (2008). *Horizontal Directional Drilling Good Practices Guidelines, Third Edition*. HDD Consortium

12 Kruse, G. (2009). The Trenchless Technique Horizontal Directional Drilling: Soil Related Risk and Risk Mitigation. *4th Pipeline Technology Conference*, 134–156.

13 Asperger, M., & Jeremic, B. (2012). Examination of the Cavity Expansion Model: Predicting Hydrofracture During Horizontal Directional Drilling. *ECI* **284***: Theoretical Geomechanics*, 256–267.

14 Кравець, С. В., Кованько, В. В., Лук'янчук, О. П. (2015). *Наукові основи створення землерійно-ярусних машин і підземно рухомих пристроїв: монографія*. Kravets, S. V., Kovan'ko, V. V., Luk'ianchuk, O. P. (2015). *Naukovi osnovy stvorennia zemleriiyno-iarusnykh mashyn i pidzemno rukhomykh prystroiv: monografiia* (Scientific foundations for the creation of earthmoving multi-level machines and underground moving devices: monograph).

15 Wang, Z., & Hu, C. (2024). Examining Pipe–Borehole Wall Contact and Pullback Loads for Horizontal Directional Drilling. *Applied Sciences,* **14(19)**, 8841. https://doi.org/10.3390/app14198841

16 Najafi, M. (2012). *Trenchless Technology: Planning, Equipment, and Methods*. New York: McGraw-Hill.

17 Penkina, N., Saliy, Y., Petrushev, N., & Pimonov, I. (2025). Practice of Visual Diagnostics Using Endoscopes. *Annali d'Italia*, **63**, 72–76. https://doi.org/10.5281/zenodo.14726829

18 Пімонов, І. Г., & Керницький, Я. (2023). Дослідження системи діагностичних параметрів гідропривода з урахуванням похибки вимірювань. *Вісник ХНАДУ,* **1(101)**, 86–91. Pimonov, I. H., & Kernitskyi, Ya. (2023). Doslidzhennia systemy diagnostychnykh parametruhidropryvod (Study of diagnostic system parameters of hydraulic drives considering measurement errors). *Visnyk KhNAHU*, **1(101)**, 86–91. https://doi.org/10.30977/BUL.2219-5548.2023.101.0.86

19 Аврунін, Г. А., Пімонов, І. Г., Щербак, О. В., Ярижко, О. В., Мороз, І. І. (2022). Аналіз сучасних технічних засобів для обслуговування аеродромів і літаків. *Вісник ХНАДУ,* **99**, 34–41. Avrunin, H. A., Pimonov, I. H., Shcherbak, O. V., Yaryzhko, O. V., & Moroz, I. I. (2022). Analiz suchasnykh tekhnichnykh zasobiv dlia obsluhovuvannia aerodromiv i litakiv (Analysis of modern technical means for servicing airfields and aircraft). *Visnyk KhNAHU*, **99**, 34–41. https://doi.org/10.30977/BUL.2219-5548.2022.99.0.34

20 Кравець, С. П., Супонєв, В. М., & Балесний, С. П. (2017). Встановлення реакцій грунту і величини відхилення від осьового руху при його проколі асиметричним наконечником. *Автомобільний транспорт,* **41**, 155–163. Kravets, S. P., Suponiev, V. M., & Balesnyi, S. P. (2017). Vstanovlennia reaktsii grunty i velychyny vidkhylennia vid os'ovoho rukhu pry yoho prokoli asimetrychnym nakonechnyk (Determination of soil reactions and deviation from axial movement using asymmetric tip). *Avtomobilnyi transport*, **41**, 155–163. https://doi.org/10.30977/AT.2219-8342.2017.41.0.155

21 Kravets, S., Suponyev, V., Shevchenko, V., Yefymenko, A., & Ragulin, V. (2021). Determination of the Regularities of the Soil Punching Process by the Working Body with the Asymmetric Tip. *Eastern-European Journal of Enterprise Technologies,* **2/1(110),** 44–51. https://doi.org/10.15587/1729-4061.2021.230256

22 Рагулін, В. М., Супонєв, В. М., & Ковалевський, С. Г. (2022). Дослідження навантаження робочого обладнання ножового трубозаглиблювача для безтраншейного прокладання інженерних комунікацій методом протягування. *Автомобіль і електроніка. Сучасні технології,* **22**, 104–111. Ragulin, V. M., Suponiev, V. M., & Kovalevskyi, S. H. (2022). Doslidzhennia navantazhennia robochoho obladnannia nozhovoho trubozahlybliuvalcha dlia beztransheinoho prokladannia inzhenernykh komunikatsii metodom protiahuvannia (Study of working equipment load of knife pipe pusher for trenchless installation of utilities by pull-through method). *Avtomobil i elektronika. Suchasni tekhnolohii*, **22**, 104–111.

Suponyev Vladimir[1], DSc (Eng.), Professor of the Department of Operation, Testing, and Service of Commercial Vehicles and Road Vehicles,
Phone.: +38 (098) 078-67-58
e-mail: v-suponev@ukr.net,
ORCID: http://orcid.org/0000-0001-7404-6691
Ragulin Vitaliy[1], CSc (Eng.), Assoc. Prof. Department of Construction and Road-Building Machinery,
Phone: +38 (097) 29-57-392,
e-mail: ragulinrvn@ukr.net,
ORCID:https://orcid.org/0000-0003-2083-4937
Kravets Svyatoslav[2], DSc (Eng.), Professor Department of building, road, melioration, agricultural machinery and equipment,
Phone. +38 (097) 28-915-89
e-mail: s.v.kravets@nuwm.edu.ua,
ORCID https://orcid.org/0000-0003-4063-1942
Lemets Oleg[1], post graduate student, Department of Construction and Road-Building Machinery,
Phone: +38 (095) 414-43-17
e-mail: m1a24loo@stud.khadi.kharkov.ua
ORCID: https://orcid.org/0000-0002-0433-9736
Barskiy Anatoliy[1], post graduate student, Department of Operation, Testing, and Service of Commercial Vehicles and Road Vehicles,
Phone: +38 (050) 410-45-04,
e-mail: abarskiy.ua@gmail.com
ORCID: https://orcid.org/0009-0008-7433-048X

[1]Kharkov National Automobile and Highway University, 25, Yaroslava Mudrogo str., Kharkiv, 61002, Ukraine.
[2]National University of Water and Environmental Engineering, Soborna str., 11, Rivne, 33000, Ukraine.

Експлуатаційні особливості та надійність роботи бурових штанґ при керованому безтраншейному прокладанні підземних комунікацій

Анотація. Проблема. *При прокладанні розподільних мереж в умовах щільної забудови міст виникають значні трудноші у зв'язку з необхідністю перетинання доріг, трамвайних та залізничних колій. В таких випадках широко використовуються установки для безтраншейного прокладання інженерних мереж. При цьому за допомогою ґрунтопроколюючого обладнання в ґрунті формується свердловина із складною траєкторією. Ефективність роботи машин і установок при цьому забезпечується надійністю роботи його бурових штанґ, що передають силовий натиск від установки на проколюючу головку. Перебільшений перегин штанґ на криволінійних ділянках може привести до їх поламки та втрати робочого обладнання в ґрунті.* ***Мета.*** *Об'єктом дослідження є процес дії перегину бурових штанґ на їх експлуатаційну надійність при створенні комунікаційної порожнини в ґрунті на криволінійних ділянках траси.* ***Методологія.*** *В роботі використані математичні методи розрахунку для визначення допустимого радіусу прогину трубопровідного батогу з урахуванням їх профілю та фізико-механічних властивостей матеріалу з якого зроблена труба.* ***Результати.*** *В роботі були встановлені умови надійного використання бурових штанґ з урахуванням кривизни траєкторії проколу та критичного радіусу вигину штанґ. Отримані розрахункові залежності враховують геометричні параметри штанґ та механічні властивості матеріалу з якого вони зроблені. Також визначаються допустимі розміри відхилень траєкторії проколу ґрунту від осі руху та довжини прольоту при корекції руху обладнання і ґрунті.* ***Оригінальність.*** *Обґрунтовано підхід до проектування свердловини, який оснований на допустимих радіусах згину бурових штанґ.* ***Практична цінність.*** *Результати роботи мають важливе практичне значення, яке полягає у підвищенні експлуатаційної надійності бурових штанґ при безтраншейному прокладанні інженерних комунікацій.*

Ключові слова: *прокол ґрунту, бурові штанґи, землерийне робоче обладнання, інженерні комунікації, безтраншейні технології, корекція руху, траєкторія проколу, експлуатація, надійність.*

Супонєв Володимир Миколайович[1], д.т.н., професор кафедри експлуатації, випробувань, сервісу будівельних і дорожніх машин,
тел.: +38 (050) 30-199-58,
e-mail: v-suponev@ukr.net,
ORCID: http://orcid.org/0000-0001-7404-6691
Рагулін Віталій Миколайович[1], к.т.н., доцент кафедри будівельних і дорожніх машин ім. А.М. Холодова,
тел: +38 (097) 29-57-392,
e-mail: ragulinrvn@ukr.net,
ORCID:https://orcid.org/0000-0003-2083-4937
Кравець Святослав Володимирович[2], д.т.н., професор кафедри будівельних, дорожніх та меліоративних машин,
тел. +38 (097) 28-915-89
e-mail: s.v.kravets@nuwm.edu.ua,
ORCID https://orcid.org/0000-0003-4063-1942
Лемець Олег Олександрович[1], аспірант будівельних і дорожніх машин ім. А.М. Холодова,
тел: +38 (095) 414-43-17
e-mail: m1a24loo@stud.khadi.kharkov.ua
ORCID: https://orcid.org/0000-0002-0433-9736
Барський Анатолій Якович[1], аспірант експлуатації, випробувань, сервісу будівельних і дорожніх машин, тел: +38 (050) 410-45-04,
e-mail: abarskiy.ua@gmail.com
ORCID: https://orcid.org/0009-0008-7433-048X

[1]Харківський національний автомобільно-дорожній університет, 61002, Україна, м. Харків, вул. Ярослава Мудрого, 25.
[2]Національний університет водного господарства та природокористування. 33000, Україна, м. Рівне, Рівненська область, вул. Соборна, 11