Mining of Mineral Deposits
Volume 19 (2025), Issue 4, 147-157

https://doi.org/10.33271/mining19.04.147

Threshold vibration metrics of drilling tools as indicators of bit wear and rate of penetration decline: Field trials and data interpretation

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Abstract

Purpose. Vibrations during deep drilling may lead to detrimental energy dissipation, reduced rate of penetration, and accelerated tool wear. The objective of this study is to conduct field trials of a budget-friendly downhole vibration controller with a novel mounting assembly for installation in the bottom-hole assembly, and to assess the relationship between vibration loading levels and drilling performance indicators, as well as bit damage, quantitatively.

Methods. The methodology is based on synchronized recordings of lateral and axial root-mean-square vibrations, as well as the stick-slip index, along with drilling parameters and gamma-ray logging. Comparisons were made between two adjacent wells in the same field, spanning identical geological intervals. These comparisons were supplemented by photographic documentation and analysis of the bit condition before and after each run.

Findings. Empirical evidence was obtained demonstrating that elevated vibration levels consistently correlate with decreased mechanical rate of penetration and bit wear. In the well with elevated vibration loading, the mechanical rate of penetration was approximately 7.3 m/h. In the adjacent well, where the dynamic regime remained within acceptable limits, it reached 11.9 m/h – approximately 40% higher than the other well.

Originality. The originality of this work lies in combining field tests of a low-cost downhole vibration controller with a novel mounting assembly for its installation in the lower part of the drill string, together with a quantitative assessment of the relationship between vibration loading levels, drilling efficiency, and bit damage. An additional original result is the identification of indicative threshold vibration levels for timely decision-making aimed at preserving the drilling tool and optimizing the rate of penetration.

Practical implications. The feasibility of applying a budget-friendly downhole controller and the proposed mounting assembly as accessible tools for adjusting drilling parameters and making informed bit selections to prevent abnormal dynamic loading is demonstrated.

Keywords: *vibration protection, drill string vibrations, vibration sensor, drill bit, drill string, controller, strengthening*

1. Introduction

Over the past three years, hydrocarbon production volumes in Ukraine have been increasing in both the public and private sectors [1]-[3]. This is associated with the intensification of drilling operations, commissioning of new wells, and restoration of existing well stock through sidetrack drilling. Consequently, operators are facing increasing demands to maintain drilling efficiency while controlling operational risks. These challenges amplify the importance of managing dynamic loading and vibration-related complications during well construction. Simultaneously, well trajectories and geological conditions are becoming more complex; in particular, productive horizons are located at greater depths, and terrain often does not permit rig placement directly above the geological target [4]-[6]. The rapid development of drilling technologies makes such complex projects feasible; however, despite increasing complexity, project organizations have not significantly extended planned well construction timelines [7].

The most significant potential for reducing overall well construction cycle duration lies in the drilling phase. In addition to bit design, drilling performance is also affected by hydraulic and thermal conditions at the bottomhole, including flushing regimes that can alter rock weakening and drilling efficiency [8]. The key objectives are clear: reduce the number of trips and tripping operations, increase the duration of continuous drilling per run, and improve footage per bit. Rock-breaking tool manufacturers continuously improve the

Received: 3 October 2025. Accepted: 22 December 2025. Available online: 30 December 2025

Mining of Mineral Deposits. ISSN 2415-3443 (Online) | ISSN 2415-3435 (Print)

cutting structure design, wear resistance, and overall configuration of polycrystalline diamond compact (PDC) bits [9]. This enables longer preservation of bit aggressiveness at the bottomhole, maintenance of higher average mechanical drilling rates per run, and reduced frequency of additional tripping operations. At the same time, selecting the optimal bit type remains challenging, as results are influenced by factors such as cutter diameter and rake angle, body profile, gauge length, blade count and layout, and other design features [10]. The same bit type may yield substantially different results across different fields. Relying solely on prior experience and general guidelines for bit selection does not guarantee maximum productivity, as conceptually similar designs respond differently to rock type, hardness, and interbedding, which directly affects drilling technical and economic performance [11].

To ensure the reliable operation of the drill string, contemporary research examines its interaction with the wellbore [12], performs calculations of tool joint threaded connections [13]-[15], develops materials and technologies for hardfacing-based strengthening [16]-[18], designs specialized tools for thread cutting [19], [20], and improves balancing methods [21], among other measures. An essential theoretical basis for analyzing drill string vibrations is provided by studies on the dynamics of elastic rods with elastic-plastic and viscoplastic external resistance, particularly in the context of shock and torsional wave propagation [22]-[25]. The relevance of such analyses extends beyond conventional drilling, as ensuring wellbore stability and controlling deformation processes is also important for technologies that rely on directional boreholes – most notably underground coal gasification [26], [27], the development of gas-hydrate deposits [28], [29], and borehole-based mining technologies such as horizon-oriented in-situ leaching, where maintaining stable wellbore operation is also actively significant [30]-[32].

Equally important is considering the dynamics of bit-rock interaction. During drilling, the bit excites a broad spectrum of tool vibrations [33], [34]. A long tubular string behaves as an elastic rod capable of localized buckling, helical deformations, and longitudinal, lateral, and torsional oscillations. Under certain conditions, these modes interact and mutually amplify, forming complex dynamic states in the elongated body [35], [36]. Vibrational behavior is influenced by bit aggressiveness, its lateral and torsional stability, and propensity for side cutting. These properties are determined by cutter size and arrangement, gauge length, profile shape, and the number and positioning of blades.

In general, vibrations of the drill bit and the lower portion of the bottomhole assembly (BHA) are inherent to the drilling process [37]. Exceeding acceptable threshold vibration levels leads to accelerated wear of the bit, downhole tools, and drill string, as well as detrimental energy dissipation and loss of mechanical rate of penetration [38], [39]. The typical intuitive response is to reduce rotary speed and weight on the bit. This indeed lowers vibration levels but simultaneously decreases the mechanical rate of penetration. A more effective approach is targeted vibration protection within the BHA configuration. In practice, drilling shock absorbers [40], [41], vibration dampeners [42], and dampers with high load-bearing capacity [43], [44] are employed, as well as other vibration protection approaches for drilling equipment [45]. The goal is not to completely suppress oscillations but to achieve a rational balance between rock destruction dynamics and equipment vibration protection levels. Such a balance increases mechanical drilling rates while improving operating conditions for drill string components.

The motivation for this research was shaped by actual field complications and failures in which the authors were involved. Under conditions typical of Dnieper-Donets Basin fields, "aggressive" design PDC bits and forced drilling parameters are often employed to achieve high well construction performance [46]. Field observations demonstrated that uncontrolled depth of cut in interbedded formations with sharply varying properties frequently causes instantaneous stops and bit stalling. When a PDC bit stalls, the external torque begins to increase until the bit suddenly breaks free, accelerates, and torsional oscillations develop. It should be noted that the technical capabilities of modern drilling rigs permit implementation of forced drilling parameters in practice; however, dynamic loads and drill string oscillation magnitudes sometimes cause back-off and failures of BHA components, damage to downhole motors and bits, and other complications. This necessitates the implementation of instrumentally verified means for monitoring dynamic loads on BHA components to maintain drilling process efficiency and ensure safety [47]-[49]. It should be noted that similar problems of stress-strain state and operational reliability also arise in casing strings and main transmission pipelines operating in zones of ground movement, discontinuities, or landslides, where string curvature, local stress concentrations, and strict limits on admissible loads are observed [50]-[52].

Improving drilling process controllability requires reliable measurements that provide a reproducible picture of dynamic processes at the wellbore bottom. Modern engineering systems in the oil and gas industry are extensively equipped with sensors, which is particularly important for critical infrastructure [53], [54]. Currently, downhole vibrations are recorded by independent sensors [55], [56] that either store data in onboard memory or transmit them to the surface in real time [57]. Real-time monitoring during drilling [58], [59] is the most operationally responsive approach for decision-making, as it allows parameter adjustment without stopping operations. However, widespread implementation of such systems is limited by high service costs and communication channel difficulties (signal stability, bandwidth, equipment compatibility), requiring a balanced choice of measurement architecture and a compromise between responsiveness and cost. Given this, it is advisable to use sensors with memory storage, whereby the acquired data arrays can be readily correlated with events and productivity indicators. This enables informed parameter adjustments, improved drilling efficiency, and reduced risk of complications.

The objectives of this study are as follows: to present the field application of a budget-friendly downhole vibration controller and an original mounting assembly for installation in the lower part of the drill string; to synchronously record and correlate downhole vibration data with drilling parameters and gamma-ray logging over matched intervals of a single field; to demonstrate the relationship between elevated vibration levels and reduced mechanical rate of penetration as well as signs of bit damage; and to establish practical threshold vibration levels for making operational decisions regarding drilling tool preservation and drilling rate stabilization.

2. Materials and methods

In our study, an autonomous Smart controller manufactured by Innova Power Solutions (Calgary, Canada) was used to record oscillations in the lower part of the drill string. The device contains an integrated triaxial accelerometer, from which the controller records shock events (short-duration peak overloads) and calculates vibration levels along each of the three axes. The vibration level is defined as the root-mean-square (RMS) value – the square root of the mean of squared instantaneous accelerations over a specified time interval. This metric is convenient because it summarizes the "energy" of oscillations into a single number and is independent of signal polarity. The controller stores all vibration loading data, and the interval between successive recordings (accumulation interval) is user-configurable – from half a second to one day, depending on the experimental objective. For extended campaigns, 16 MB of non-volatile memory is provided, divided into two logical sections: a "session" area for high-speed detailed recording and an "integrated" memory that functions as a "black box" throughout the tool's lifecycle. The upper limit of the controller's operating temperature range is 180°C, which corresponds to high-temperature drilling conditions.

For real-time telemetry data transmission, an optional telemetry module can be installed to establish an uplink data channel (and, if required, a downlink command channel) between the tool and the surface station. In our work, a budget version of the controller was used, operating in autonomous mode with data readout after retrieval. Figure 1 shows a general view of the controller circuit board (diameter approximately 35 mm). On the front side of the board (Fig. 1a), a reference quartz resonator, a triaxial accelerometer and angular rate sensor, a 0.018-ohm shunt resistor, and a 3.3-volt linear voltage regulator are located. Their stable operation is ensured by carefully selected resistor-capacitor network circuitry that provides clean power and filters signals. On the reverse side of the board (Fig. 1b), a microcontroller (Microchip PIC24FJ32KA) and non-volatile memory for data storage are located, along with an analog signal conditioning module (eight-pin IC) and a filtering assembly with a ferrite filter and resistor-capacitor networks that suppress interference in power and signal traces and ensure stable operation of the measurement channel. The controller's non-volatile memory is organized as a session area and an integrated "black box". The session area is created at the beginning of each measurement cycle and stores continuous time-series data, along with metadata, in sequential write mode. The "black box" is a protected, append-only partition that is locked against editing.

Before field measurements, the board was pre-mounted on a test bench and connected to a stabilized DC power source and a serial interface service line (Fig. 1c). This connection scheme enabled initialization, zero-setting of the triaxial sensor, test recording, and verification of time synchronization against the reference quartz resonator. After function validation, the controller was integrated into the drill string assembly, where it was placed inside the composite housing of the battery module. High-temperature lithium-thionyl chloride cells rated for operation up to 175°C were used as the power source. The entire assembly was potted with a thermally resistant compound that provided rigid component fixation, vibration resistance, sealing, and electrical insulation within the composite housing.

(a) (b) (c)

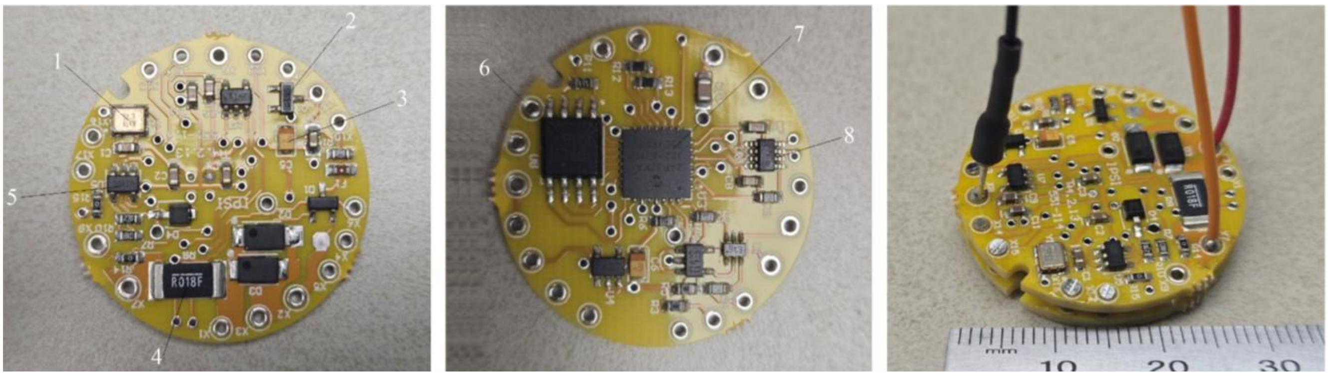

Figure 1. Controller board for recording vibration loads: (a) front side of the board; (b) bottom side of the board; (c) controller board mounting before testing; 1 – quartz resonator; 2 – triaxial accelerometer and angular rate sensor (accelerometer and gyroscope); 3 – chip capacitor; 4 – shunt resistor; 5 – linear voltage regulator; 6 – microcontroller (sensor data acquisition, processing control, and recording); 7 – non-volatile memory; 8 – analog signal conditioning module

A significant problem requiring a rational solution is the method of placing the vibration recording controller board and power battery in the drill string. Limited diametral space and extreme operating conditions substantially complicate this task. In this study, the installation of the vibration controller board with a power battery in the lower part of the drill string was accomplished using a specialized module (Fig. 2a, b). Structurally, this is a cylindrical housing with threaded connections, inside which an inner cartridge containing electronics and a serially connected battery compartment is coaxially positioned. A guide nose is threaded onto the left end of the housing; a fishing neck is attached to the right end. After assembly, the module is installed into the BHA through a landing sub (Fig. 2b). A guide sleeve is mounted in the sub, into which the lower end of the module (the guide nose) enters. The protruding portion of the module is placed in a specially fabricated pup joint or heavyweight drill pipe, using an internal rubber centralizer to ensure coaxiality.

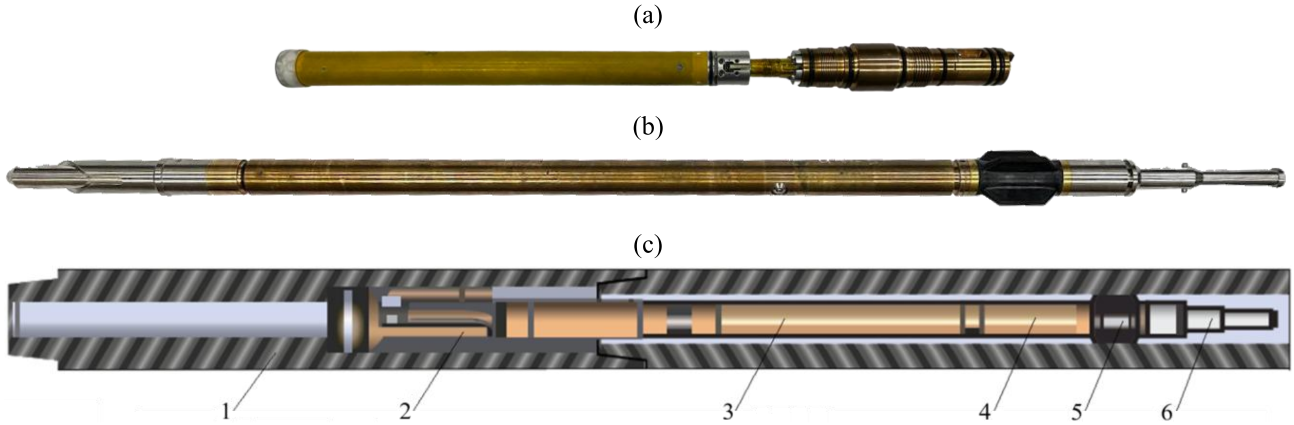

Figure 2. Module for housing the vibration controller board and power battery in the BHA: (a) vibration controller with power battery before installation in the module; (b) sample of assembled module; (c) schematic of module installation in the drill string; 1 – landing sub; 2 – guide sleeve; 3 – main housing with vibration controller; 4 – contact group housing; 5 – centralizer; 6 – fishing neck

Since magnetic interference does not affect Smart-4 controller operation, housing components may be manufactured from alloy steel that complies with current industry standards for strength and durability.

Data retrieval is accomplished without disassembling the electronics. After pulling the drill string, the fishing neck of the module is unscrewed, one end of a USB data transfer cable with a special connector is attached to the contact group, and the other end is connected to a laptop. The proposed solution ensures reliable installation of the vibration sensor module in the drill string and stable collection of information about the dynamic operating regime of the drilling tool.

Field trials were conducted at a Dnieper-Donets Basin field during the drilling of two adjacent wells. In both cases, the downhole vibration controller was installed in the lower part of the BHA, directly above the bit. On the first well, intervals of elevated drill string vibration were identified from the recorded data. For the same geological intervals on the second well, a different bit type was purposefully selected, and an identical recording protocol was followed. Both datasets were depth-aligned and synchronized with logging and drilling parameters. Time correlation was based not on calendar time, but rather on relative to interval penetration (events of "interval entry and exit" and parameter changes), ensuring a valid comparison. These comparisons were supplemented by photographic documentation and analysis of the bit's technical condition before and after each run. The results obtained are presented and analyzed in the following section.

3. Results and discussion

3.1. General overview of field studies

Within a single field, we purposefully compared downhole vibration and drilling parameters by recording both downhole dynamics and surface parameters (weight on bit, rotary speed, torque, etc.) on two closely spaced wells. Hereafter, we use the designations: well No. 1 – reference, i.e., the baseline run with the PDC bit TD505KSX, and well No. 2 – with a modified bit design, where an alternative PDC bit T505KS was configured for higher torsional stability and improved bottomhole cleaning.

In both cases, a unified methodology for monitoring BHA dynamics was applied. A downhole oscillation recorder was included in the BHA, which logged RMS values of lateral (LRMS) and axial (ARMS) vibrations, as well as the torsional stick-slip index (Slip/SSI). The recorded downhole signals were synchronized with surface drilling parameters – weight on bit (WOB), rotary speed (RPM), torque, flow rate (Flow), standpipe pressure (SPP), and mechanical rate of penetration (ROP). Time and depth were aligned to a standard scale. This enables a valid comparison of drilling parameters, vibrational events, and rock destruction efficiency between wells. Summary drilling parameters, bit designs, and final cutting structure condition are presented in Table 1. Threshold levels for evaluating "exceedances" were established based on stable (reference) operating intervals and remained unchanged for both wells, ensuring a valid comparison.

Table 1. Summary comparison of main drilling parameters for two wells

Well	Well 1 (reference)	Well 2 (alternative bit design)
Interval, m	1931-2750	1715-2650
Bit (type Ø), mm	Baker Hughes TD505KSX, Ø311.1 mm	Baker Hughes T505KS (S223), Ø311.1 mm
ROP, m/h	7.3	11.9
RPM, min^{-1}	110	60-95
WOB, t	5-12	6-12
Flow (Q), l/s	52	46-57
SPP, atm	160	130-185
Torque, kN·m	6.8-24.4	up to ~20

The key experimental difference between the two field observations – well No. 1 and well No. 2 – concerns bit type and design, and this difference is not coincidental. After the baseline run on well No. 1, we analyzed integral characteristics of downhole dynamics – the percentage of time when LRMS, ARMS, or Slip exceeded agreed-upon thresholds, as well as the count of recurring events (stick-slip series). It was precisely the threshold exceedances and event recurrence within characteristic depth "windows" that indicated cumulative energy losses to self-excited oscillations, accompanied by localized rate of penetration declines and signs of cutting structure degradation. Based on these findings, for well No. 2, the bit design was purposefully changed at analogous intervals. Instead of the PDC bit TD505KSX (Ø311 mm) used in the reference case, T505KS (Ø311 mm) was employed, configured for enhanced torsional stability and more efficient nose cleaning. Continuous recording by the downhole logger enabled assessment not only of peak LRMS/ARMS/Slip amplitudes but also intensity (percentage of time above thresholds) and recurrence (cycle count). These integral metrics reflect the portion of input power the system expends on sustaining oscillations versus the portion that goes directly to rock cutting. These metrics formed the basis for the informed bit change and subsequent field verification of the hypothesis regarding stick-slip suppression.

From the summary indicators, it is evident that well No. 2 provides a higher average ROP and exhibits no critical cutting structure damage at the conclusion of the run. In contrast, well No. 1 showed signs of cutting element degradation (nose chipping and ring-out wear) in zones of active vibration events.

3.2. Comparison of drilling tool vibrations over characteristic drilling intervals

To demonstrate that differences in system behavior are primarily attributable to bit design rather than geological variability, we consider two representative interval pairs with identical depth correlation in both wells. This approach enables "fixing the geology" and focusing on BHA dynamics, while also addressing energy balance. Note that downhole dynamics and surface parameters were recorded over the full length of both wells; however, their complete reproduction would occupy several pages of tables and graphs, which exceeds the scope of the substantive content of this paper; therefore, only the most characteristic segments are presented here.

The first pair of drilling intervals (2280-2380 m) represents a reference section of stable drilling tool operation (Fig. 3 and 4). Within this interval, stable, controlled dynamics are observed in both wells, characterized by isolated and brief stick-slip episodes (slip channel), low lateral (LRMS) and axial (ARMS) vibration levels, the absence of a pronounced torque "sawtooth" pattern, and a stable mechanical rate of penetration. This section is appropriate for use as a reference for subsequent calibration. It is here that baseline thresholds for LRMS, ARMS, and Slip are established, along with background values for percentage of time above threshold and recurring event counts. In other words, this is a state where the predominant portion of input energy is directed toward rock cutting rather than sustaining oscillations.

Further deepening is accompanied by an increase in rock hardness and a higher risk of stick-slip development, as confirmed by gamma-ray log trends. At the transition boundary to a more challenging interval, bit design and hydraulic regime become determinative. If they do not smooth peak torsional moments and do not ensure effective nose zone cleaning, the "string–BHA–bit" system may enter a limit cycle of self-excited oscillations. In the recordings, this manifests as event series in the Slip channel, increases in LRMS and ARMS, and characteristic "sawtooth" torque graph patterns. The operator is consequently forced to limit the WOB, leading to localized declines in ROP.

The second pair of drilling intervals, 2425-2525 m, represents a transition into a formation of increased rock strength. In this interval on well No. 1, series (clusters) of stick-slip with synchronous LRMS/ARMS increases and a torque "sawtooth" pattern are recorded, with localized ROP decreases correlating with phases of torsional strain accumulation and release in the drill string (Fig. 5). Thus, a significant portion of input power is expended on sustaining oscillations rather than proper cutting.

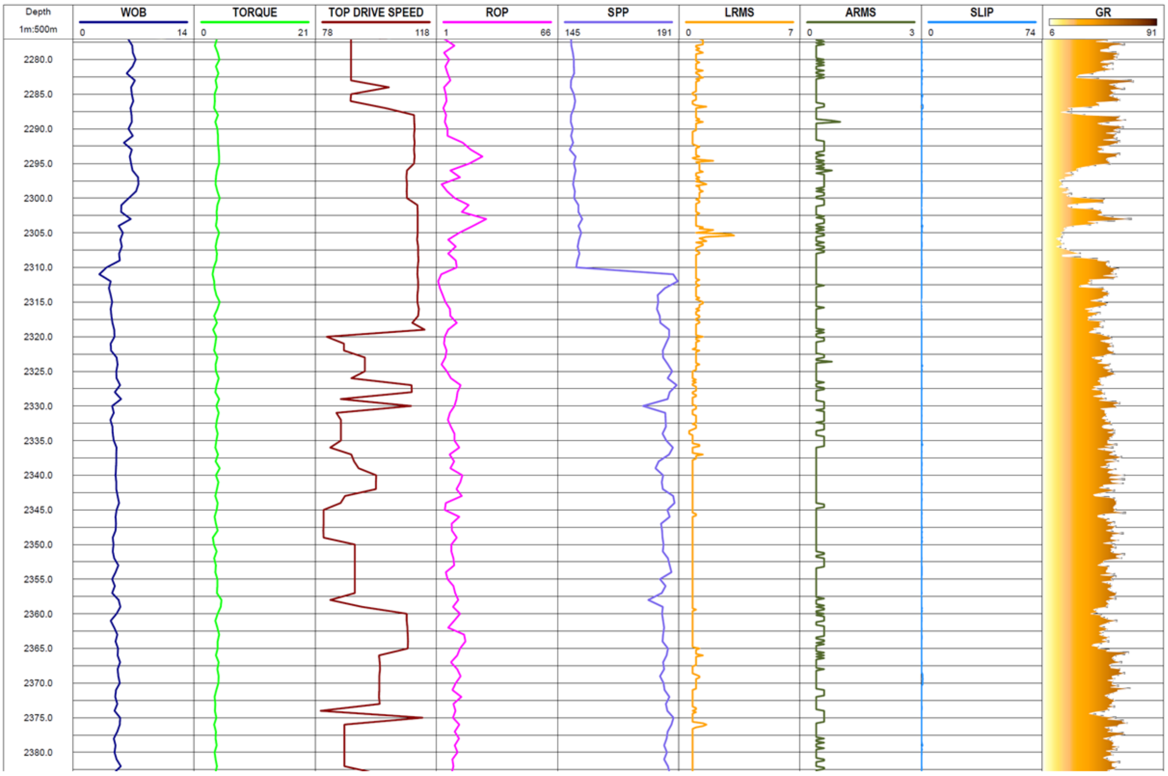

Figure 3. Depth profiles of downhole vibration metrics (LRMS, ARMS, Slip) and drilling parameters for well No. 1 over the 2280-2380 m interval (reference stable interval)

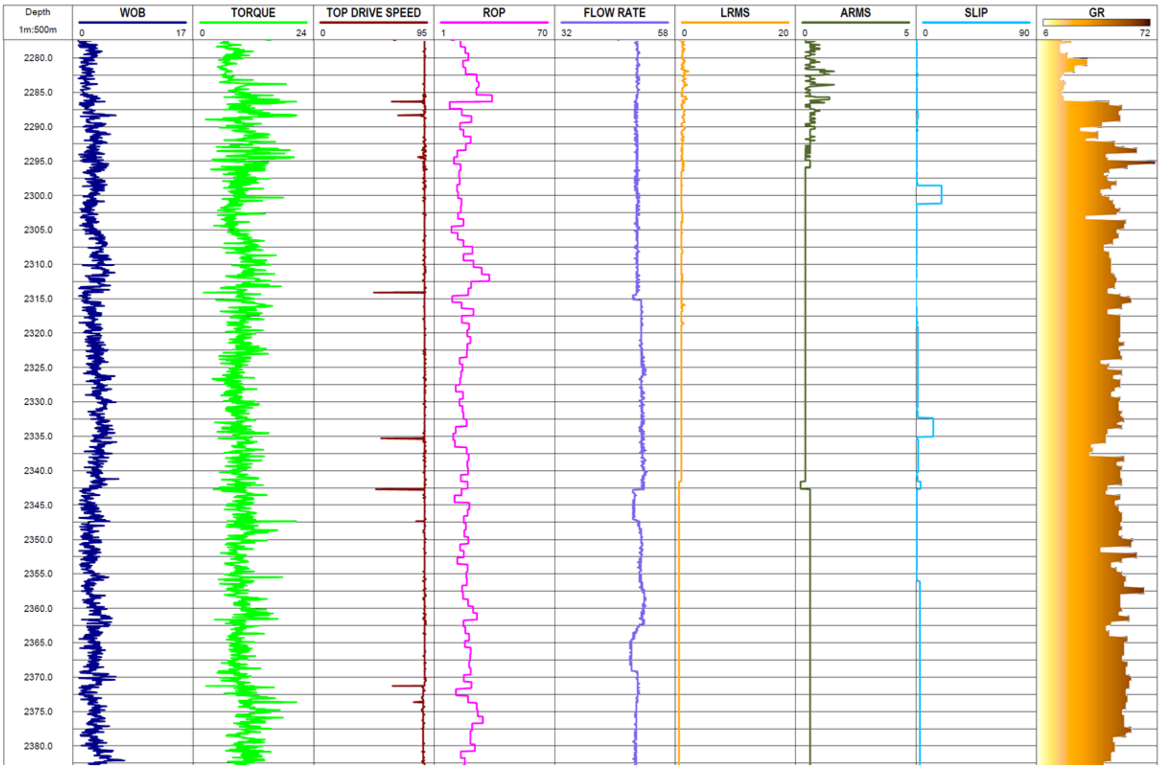

Figure 4. Depth profiles of downhole vibration metrics (LRMS, ARMS, Slip) and drilling parameters for well No. 2 over the 2280-2380 m interval (stable regime with alternative bit design)

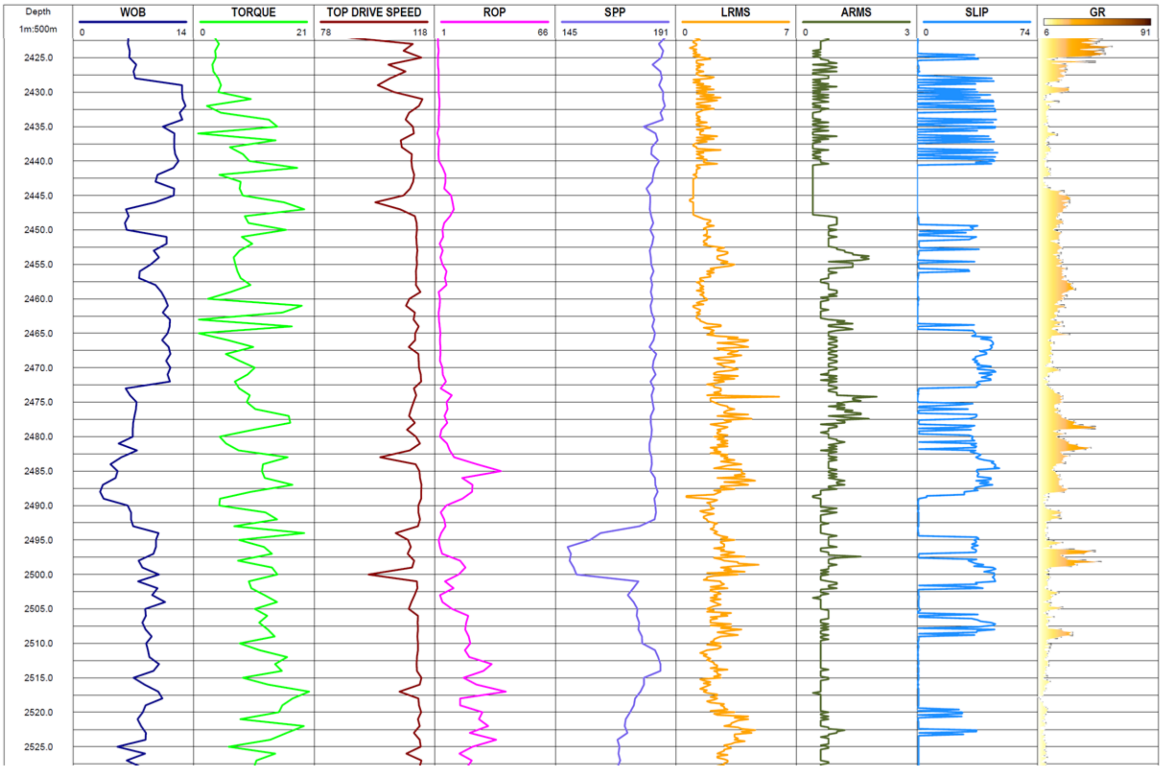

Figure 5. Depth profiles of downhole vibration metrics (LRMS, ARMS, Slip) and drilling parameters for well No. 1 over the 2425-2525 m interval (development of intense stick-slip vibrations)

During drilling of well No. 2, at the same depth, torsional events are typically isolated and brief, LRMS/ARMS remain within the operating range, and ROP shows no systematic declines (Fig. 6). This indicates higher torsional stability of the alternative bit design: incipient disturbances do not "spin up" into a cascade, the percentage of time above thresholds for LRMS/ARMS/Slip is lower, as is event recurrence. Correspondingly, a greater portion of energy is allocated to cutting, which is consistent with both the higher average ROP and the absence of cutting structure damage at the end of the run.

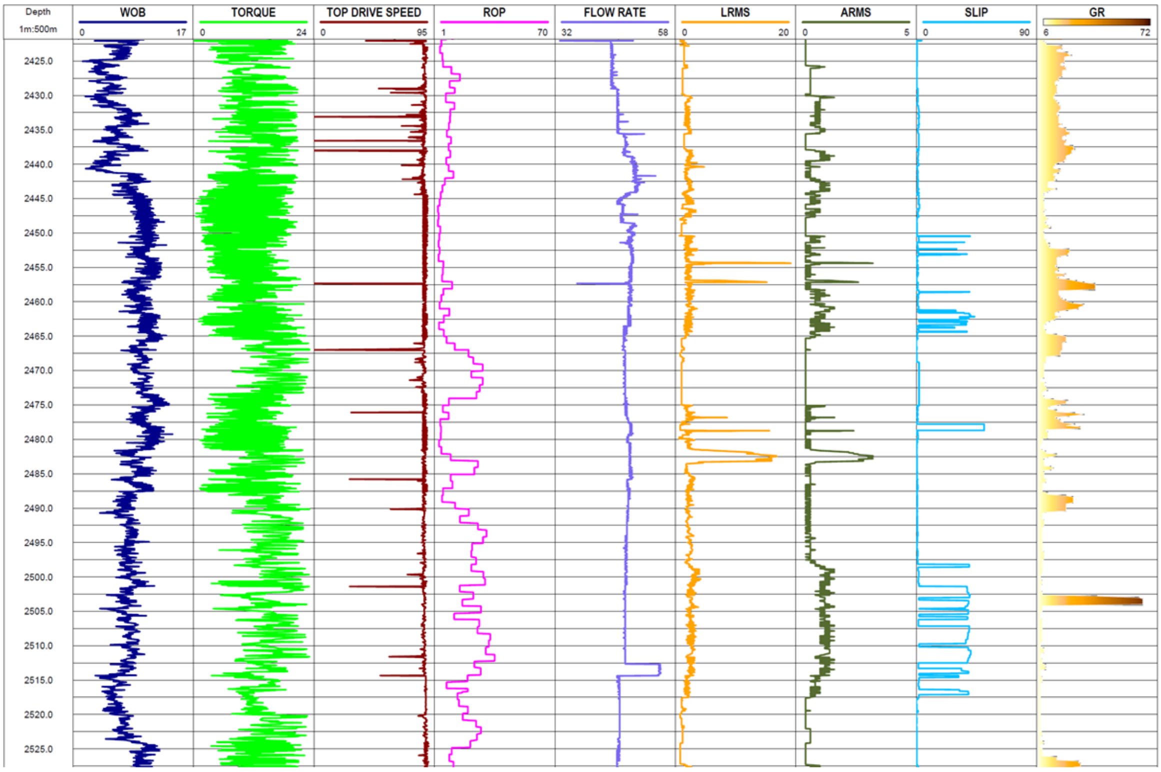

Figure 6. Depth profiles of downhole vibration metrics (LRMS, ARMS, Slip) and drilling parameters for well No. 2 over the 2425-2525 m interval (suppression of stick-slip vibrations by the alternative bit design)

Thus, in relatively homogeneous rocks of moderate hardness, both bits perform similarly. In contrast, in the transitional interval of increased hardness, the alternative bit design systematically reduces the duration of dynamic indicators above threshold values. It decreases event recurrence, directly improving drilling efficiency (ROP) and promoting the preservation of cutting structures. Within the scope of this pilot study, these conclusions are confirmed by quantitative metrics, including the percentage of time above threshold, the 95th percentile of LRMS/ARMS/Slip (the value that exceeds 95% of all observations and is robust to isolated outliers), and event series counts.

3.3. Photographic documentation of the bit condition

Photographic documentation of bit condition supplements downhole dynamics recordings, allowing for a substantive correlation of oscillatory process behavior with actual wear patterns. For well No. 1, in the "before run" photo panel (Fig. 7), the original, correct geometric profile and undamaged cutting structure of the drill bit are documented – this serves as a valid "zero" reference point.

After the run, the general view reveals incipient ring-out wear on the body and blades, without gauge loss, and locally visible areas of more intensive surface polishing. Close-ups of the nose zone document PDC cutter chipping and, in places, diamond table delamination from the carbide substrate. On the periphery, edge chipping and minor cracking are observed, along with a typical "slip" abrasive wear pattern. Together, this forms a characteristic "signature" of impact-oscillatory loading. Under such loading, nose cutters experience impulsive contacts during stick-slip breakout phases, explaining the chipping and delamination. At the same time, the periphery accumulates abrasive wear against a background of periodic cutting instability.

(a)

(b)

Figure 7. Photographic documentation of bit condition on well No. 1: (a) before run; (b) after run

Junk slots and blade edges exhibit localized wear marks in the direction of cuttings evacuation, consistent with deterioration during dynamic peaks. Despite this, the gauge is preserved; however, the aggregate defects indicate substantial energy losses due to oscillations and an increased risk of progressive damage with continued operation.

For well No. 2, it is appropriate to consider the design differences of the T505KS bit, which is oriented toward higher torsional stability and improved cleaning (Fig. 8).

(a)

(b)

Figure 8. Photographic documentation of bit condition on well No. 2: (a) before run; (b) after run

Instead of a second row of cutting elements, spherical tungsten carbide inserts are employed, which reduce "catching" on rock in transitional formations; narrower blades increase inter-blade space, and an additional hydraulic nozzle enhances hydraulic cleaning in the nose zone. Post-run photographs document the absence of critical cutting structure damage, uniform moderate "working" wear without signs of impact destruction, clean junk slots, preserved gauge, and intact nose cutters without chipping or delamination. This picture is consistent with brief and infrequent torsional instability episodes, i.e., incipient disturbances do not transition into a cascade; energy is expended on cutting rather than sustaining self-excited oscillations, which manifests in a more stable mechanical rate of penetration and, correspondingly, a "calm" wear profile. Thus, comparison of drill bit condition "before and after run" on two wells demonstrates a consistent cause-and-effect relationship. Where torsional instability becomes serial in nature, the PDC bit nose zone experiences impact loading and rapidly degrades. Conversely, a design aimed at stick-slip suppression shifts the operation to an energy-efficient regime, leaving the bit with only normal abrasive wear without critical defects. This visual "imprint" correlates well with the difference in productivity and parameter controllability, supporting the decision to change bit type on problematic intervals.

The authors associate the prospects for further research with the stepwise expansion and deepening of the proposed approach. Primarily, it is advisable to conduct a series of field trials on a larger sample of wells with different profile geometries, diameters, and lithological conditions to statistically refine the threshold values of LRMS, ARMS, and Slip for various drilling regimes. An important task is also to verify the applicability of these thresholds for alternative types of PDC bits, different BHA configurations, and options for using downhole shock absorbers, including the assessment of their influence on bit wear and mechanical rate of penetration. Special attention should be paid to the development of simple algorithms for real-time adjustment of weight on bit, rotary speed, and hydraulic parameters based on metrics recorded by the downhole vibration controller, followed by the integration of such algorithms into a drilling support system. Finally, an important direction is the techno-economic assessment of the effect of using threshold metrics (reduced bit wear, shorter run duration, lower risk of failures), which will provide a quantitative justification for the widespread implementation of low-cost downhole vibration controllers in deep drilling practice.

4. Conclusions

Within the framework of a pilot project aimed at improving vibration protection during drilling in Dnieper-Donets Basin fields, the application of a budget-friendly controller for recording drilling tool vibrations was initiated. Furthermore, an improved module for installing the vibration controller in the BHA was developed and tested, which ensures reliable coaxial placement, compatibility with standard BHA configurations, and stable recording of downhole oscillations under actual operating conditions.

Within the field study framework, a sequential "measurement – interpretation – tool design change – repeat measurements" cycle was implemented. Runs on adjacent wells were compared, where identical depth intervals were drilled with different PDC bits. This comparison demonstrated that cutting structure wear and efficiency loss are determined not so much by LRMS/ARMS/Slip amplitude as by vibration "exposure" – the duration of indicator values above threshold levels and the recurrence of stick-slip events. In the reference well No. 1, it was precisely the cumulative effect of such exposure that explains localized ROP declines and the documented dull condition. In contrast, the alternative bit design in well No. 2 redirects energy from self-excited oscillations to cutting, suppresses torsional "sawtooth" patterns, and provides higher and more stable ROP while preserving the cutting element. Comparison of downhole recordings with "before and after run" photographic documentation of bit condition demonstrates a consistent picture. Intervals in which LRMS/ARMS/Slip indicators systematically exceed threshold levels and exhibit serial character clearly correlate with diamond table chipping and delamination in the nose zone, ring-out wear, and localized polishing on blades.

The results obtained demonstrate that smoothing torsional dynamics expands the operating WOB-RPM parameter window. The operator can maintain forced drilling parameters without a decline in rate of penetration and without an excessive increase in vibration risks. The proposed interpretation, utilizing integral indicators (time above thresholds and event recurrence), shifts bit selection, BHA configuration, and parameter optimization from the domain of intuitive approaches to that of quantitatively justified decisions. A budget-friendly autonomous controller, combined with this methodology, creates a practical foundation for scaling the monitoring system and further optimizing drill string vibration protection under challenging engineering-geological conditions.

Author contributions

Conceptualization: SL, AV; Data curation: VV, LR; Formal analysis: SL, AV; Funding acquisition: VV, LR; Investigation: SL, AV; Methodology: SL; Project administration: VV, LR; Supervision: SL; Validation: SL; Visualization: SL, AV; Writing – original draft: SL, AV; Writing – review & editing: SL, VV, LR. All authors have read and agreed to the published version of the manuscript.

Funding

The authors express their sincere gratitude to the Ministry of Education and Science of Ukraine for providing funding for the implementation of projects 0124U000473 and 0124U000668.

Acknowledgements

The authors express their sincere gratitude and deep respect to the Armed Forces of Ukraine, whose dedication made it possible to complete this article and prepare it for publication.

Conflicts of interest

The authors declare no conflict of interest.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

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Порогові метрики вібрацій бурильного інструмента як індикатори зносу доліт і зниження швидкості проходки: польові випробування та інтерпретація даних

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Мета. Вібрації під час глибокого буріння можуть призводити до непродуктивних втрат енергії, зниження швидкості проходки та прискореного зносу інструмента. Метою роботи є польові випробування бюджетного вибійного контролера вібрацій з оригінальним вузлом для його встановлення в нижній частині бурильної колони та кількісна оцінка взаємозв’язку рівнів вібраційних навантажень з показниками ефективності буріння та пошкоджуваністю долота.

Методика. Методика базується на синхронізованих записах поперечних і осьових середньоквадратичних вібрацій та індексу прилипання-ковзання, разом з режимами буріння і гамма-каротажем. Порівняння виконано для двох сусідніх свердловин одного родовища на однакових геологічних інтервалах та доповнене фотодокументуванням і аналізом стану доліт до та після рейсу.

Результати. Отримано емпіричні докази, що підвищені рівні вібрацій стабільно супроводжуються падінням механічної швидкості буріння та зносом доліт. На свердловині з підвищеними вібраційними навантаженнями механічна швидкість становила близько 7.3 м/год. У сусідній свердловині, де динамічний режим залишався в межах допустимого, – 11.9 м/год, тобто приблизно на 40% вище.

Наукова новизна. Оригінальність роботи полягає в поєднанні польових випробувань бюджетного вибійного віброконтролера з новим монтажним вузлом для його встановлення в нижній частині бурильної колони, а також у кількісній оцінці взаємозв'язку між рівнями вібраційного навантаження, ефективністю буріння та пошкодженням долота. Додатковим оригінальним результатом є визначення індикативних порогових рівнів вібрацій для своєчасного прийняття рішень, спрямованих на збереження бурильного інструмента й оптимізацію механічної швидкості проходки.

Практична значимість. Продемонстровано доцільність застосування бюджетного вибійного контролера і запропонованого вузла його монтажу як доступних інструментів для коригування параметрів буріння та обґрунтованого вибору доліт з метою запобігання нештатним динамічним навантаженням.

Ключові слова: *віброзахист, вібрації бурильної колони, вібродатчик, бурове долото, бурильна колона, контролер, зміцнення*

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