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Features of fretting corrosion damage drilling lines of hoisting mechanisms of mobile drilling rigs

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Abstract. Downhole drilling, production, and servicing equipment is lowered, raised, and held in the well using the drilling system, the primary working element of which is the drilling line. During long-term operation, drilling lines undergo fretting corrosion damage, the mechanisms of action and development of which require additional research. The purpose of this study was to analyse the degradation processes by evaluating the features of fretting wear and fretting corrosion of wires, rods, and cores of drilling lines of lifting mechanisms of drilling rigs and their impact on the occurrence and development of damage. The analysis of publications on the selected topic in the research cycle, problem statement, collection of primary data on visual and non-destructive testing of lines from literature sources and examination data to assess their technical condition and study the impact of fretting corrosion damage was carried out. The methodology of research of drilling lines covered a complex of theoretical and practical approaches aimed at studying their characteristics,

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assessing their technical condition, predicting durability and ensuring operational safety. It was established considering the relevance and practical necessity based on data from literature sources characterised by high citation, the requirements of international standards for the study of line damage in conditions of corrosion and wear effects. Some features of the abrasive effect of oxides on the condition of wires, rods, and cores of drilling lines were revealed. The residual stress-strain state of conjugated surfaces in lines due to the kinematics features of multilayer line winding on the drum was analysed. The analysis of external and internal fretting wear and fretting corrosion damage for drilling lines of lifting mechanisms of the UPA-60x mobile drilling rig was carried out. The prerequisites for the occurrence of a critical condition of the surfaces of drilling line elements due to fretting and corrosion damage were established. Considering the features and potential hazards of damage and destruction of elements of drilling lines due to fretting corrosion phenomena, practical recommendations for the use of lines with polymer-coated cores were given for further operation. The use of these lines in the oil and gas industry will help to: prevent water and dust from entering the cores, reduce the friction forces of the rods to the core and internal stresses, improve the stability of the line shape; absorb fluctuations in dynamic loads

Keywords: fretting wear; fretting corrosion; fatigue damage; drilling system; descent and lifting operations; friction

Introduction

Drilling and operation of new wells, and repair of existing ones, is impossible without a large number of lifting operations and intensive operation of drilling systems. During operation, the drilling lines of the hoisting mechanisms of drilling rigs are damaged due to wear and corrosion. Operation of drilling lines in an aggressive environment, in a wide range of loads, amplitudes, and frequencies of forced vibrations creates strict requirements for lines of drilling systems. This is explained by the fact that drilling systems are critical components of drilling, production, and well servicing installations, and their reliability directly affects both the safety of operating personnel and the technical and economic performance of the equipment.

X. Chang *et al.* (2022) experimentally investigated the degree of line wear as a function of the relative sliding speed on pulleys, the temperature of lines and pulleys, the level of vibration, and the nature of the load. It was found that the temperature of the steel line increased in proportion to the increase in the sliding speed, from approximately 52.7°C to 116.2°C. The maximum diametric value of wear was lowest (approximately 1.5 mm) when the sliding speed was 1.2 m/s. The line wear mechanisms were mainly adhesive and abrasive, and surface wear changed the morphology of steel line destruction and accelerated its destruction rate. X. Chang *et al.* (2022), based on a tribological test unit, investigated the amount of wear in the contact zone of the drilling line and pulleys. The effect of surface wear on fatigue life during bending of line samples was analysed. It was found that the coefficient of friction decreases with increasing sliding distance and reaches a minimum value (approximately 0.52) when the contact load was 700 N. The maximum temperature increase ranged from 50°C to 60°C when the contact load increased. The nature of line wear was uneven, the maximum wear width increased from 1.94 mm to 2.45 mm with contact load.

Deterioration of the mechanical properties of a drilling lines caused by different wear evolution was investigated by L. Guerra-Fuentes *et al.* (2020). The change in the wear rate of lines depending on the load was studied by X. Chang *et al.* (2025). S. Senyk *et al.* (2025) investigated that line wear leads to nonlinear degradation of tensile strength and bending fatigue. C. Debeleac *et al.* (2020) found that when the sliding distance between the cable and the pulley increases, the breaking force decreases from about 48 kN to 23 kN, and the number of fatigue bends of the line before disposal decreases from about 6,200 times to 200 times. The study by A. Mohamed *et al.* (2019) proposed a hybrid visual control method for detecting defects in drilling lines. P. Zhou *et al.* (2020) developed special equipment for visual inspection of lines. E. Kuhn *et al.* (2024) established a number of key empirical dependencies using such equipment. M. Heldin *et al*. (2021) found that this method was based on comparing and analysing the internal and external stresses of the line layers. By combined strain gauges, H. Karasu *et al*. (2024) established destructive stress levels and stages of line damage. K. Huang *et al*. (2025) made generalisations regarding the level of damage, destruction of wires and rods, and subsequent disposal of a drilling line.

To ensure trouble-free operation of drilling lines, methods based on increasing the safety margin and reducing the intended life of the line were used. In addition, the condition of the line must be constantly monitored, including with the help of non-destructive testing tools and methods. Therefore, a comprehensive analysis of the processes of loading, wear, and degradation that occur in the line will allow determining and scientifically substantiating the influence of various external and internal factors on its durability. The very existence of such a scientific concept is of important national economic and strategic importance for the domestic oil and gas industry. That is why the purpose of this study was to carry out an additional analysis of the processes of corrosion degradation, local wear of line elements, and their impact on the occurrence and development of damage. To achieve this goal, this study used general scientific methods, such as analysis, synthesis, comparison, abstraction and generalisation, and a systematic approach. The study of the state of drilling lines was carried out based on the analysis of fretting corrosion damage and comparison of their degradation parameters. The literature review, as the main method, included the collection, critical evaluation, and analysis of already published studies.

The literature for this analysis was selected based on criteria such as relevance and practical necessity. The search was carried out in international scientific databases, such as Scopus, Web of Science, Index Copernicus, and in electronic libraries of universities and specialised oil and gas publications. Keywords such as drilling lines, corrosion, wear, damage, and combined queries that include these terms together with the specification of operating conditions in aggressive environments were used for selection. Irrelevant papers were eliminated at the stage of initial revision based on the results of checking the completeness of the study, the method of analysis, and its correlation with the topic. The selected sources were characterised by high citation, compliance with the requirements of international standards, and relevance for studying the damage of lines under conditions of corrosion and wear effects.

Design features and performance characteristics

Drilling lines are flexible elements of the hoisting system that connect the travelling block with the crown block and ensure the execution of hoisting and lowering operations during drilling and well operation (Kryzhanivskyi *et al.*, 2003; Borysevych *et al.*, 2004; Kryzhanivskyi *et al.*, 2007). The drilling line is made of steel wire (crucible steel), which is tied into strands of single, double, or triple weaving. Lines are shifted from strands that are wound on the core, which gives the line a round shape and flexibility (Fig. 1). In the lines of drilling rigs, steel lines of round cross-section, single-layer, 6-strand double twisting are used, the wires of which are twisted into strands, and the strands into lines. Drilling lines for operational and deep exploration drilling are manufactured in three versions, which differ in the type of cores used.

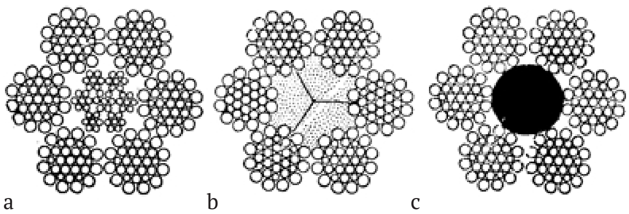

Figure 1. LK-DS type drilling lines with cores
Note: a – steel core; b – organic three-strand core; c – plastic core
Source: Ye. Kryzhanivskyi *et al*. (2007)

In lines with an organic core, lubrication is improved due to the impregnation of the fibrous core with a lubricant. Depending on the relative position of the wires in the strands, lines with point and linear contact of the wires are distinguished. Lines with a linear contact of wires are more durable. Tests show that their operating time is 1.5-2 times higher than that of lines with a point touch (Kryzhanivskyi *et al.*, 2003; Kryzhanivskyi *et al.*, 2007). Drilling lines belonging to the LK-DS type differ in that wires of different (D) and the same (S) diameters are used in separate layers of the strand. Line wires are made of steels (steel 50, 55, 60, 70) with heat treatment and a tensile strength of 1,700-2,000 MPa. In the direction of twisting, drilling lines of the following designs are made: cross right twist – Z; cross left twist – S. In the right Z twisting, the strands are placed from left to right, and in the left S – from right to left. Z-type lines are more common in operational drilling.

Drilling lines do not unwind, as they are made of pre-deformed wires and strands. As a result of preliminary deformation, the wires and strands have geometric shapes that correspond to their position in the finished line. The endurance of such a line, all other things being equal, is 25-30% higher than that of a conventional untwisted line. Line types: LK-DS-6×25+1-MO; LK-DS-6×19+1-SC and LK-DS-6×37-OC, where 6 – number of strands; 25, 19, 37 – number of wires in the strand; SC – steel core; OC – organic core. When drilling wells, LK-DS drilling lines with diameters of 25, 28, 32, 35, 38 mm are mainly used. The tribological and fatigue characteristics of the interaction of a curved steel rope and the groove of the drum of an offshore drilling rig winch were studied by S. O'Halloran *et al.* (2018) and Z. Wang *et al.* (2025). Z. Ren *et al.* (2018) and C. Lu *et al.* (2022) experimentally tested the effect of groove coverage angles, fatigue loads, and fatigue cycles on the tribological properties of the line (coefficient of friction, wear mechanism, volume loss, wear rate, etc.). Research findings by H. Liu *et al*. (2018), C. Wokem *et al*. (2018) showed that an increase in variable load and fatigue cycles leads to more serious damage to lines that are subject to bending fatigue, while an increase in the wrapping angle somewhat mitigates the severity of this grip damage.

The studies by Y. Shen *et al.* (2023), A. Lomakin (2024) and T. Ta *et al.* (2024) are devoted to theoretical and experimental approaches to the investigation of additional stresses that occur in steel rope elements when hitting blocks and drums. The researchers conducted a critical analysis and generalisation to determine additional stresses in the elements of steel ropes. It was noted that the current practice of determining additional stresses that occur in the line when it runs on a pulley or drum is far from the results obtained experimentally. The analysis of experimental approaches indicates the existence of various approaches that require generalisation and further development and implementation in the form of a comprehensive experimental study. D. Zhang *et al.* (2021), B. Kubiś *et al.* (2023) and Y. Peng *et al.* (2024) conducted unique fatigue tests of steel lines. The obtained findings and their interpretation revealed several important aspects of assessing the stress-strain state and wear of lines. As a result of the research, the characteristics of line elongation were established, showing three different periods (phases): a short initial period with a sharp increase in elongation associated with the winding of a new line, a long period with stable elongation, and a final phase characterised by accelerated elongation associated with rapidly progressive fatigue wear with the occurrence of a large number of wire breaks.

Features of wear and damage of drilling lines

During operation, drilling lines are subjected to stretching and repeated kinks on the pulleys of the crown block, hoist block, and drum winches, resulting in their fatigue destruction (Kryzhanivskyi *et al.*, 2003; Kryzhanivskyi *et al.*, 2007). The outer wires of the line are subject to wear on the pulleys and drum of the winch, so the process of their fatigue destruction is accelerated. Due to insufficient durability, the consumption of drilling lines and the waiting time for the drilling rig to replace worn lines increases, which negatively affects the technical and economic performance of drilling. The main reason for rejection or failure of drilling lines is wear, which is caused by contact and friction interaction, accompanied by corrosion processes (Fig. 2-3) (Transport Department of PJSC "Ukrnafta", 2023). During operation, drilling lines are subjected to two main types of wear.

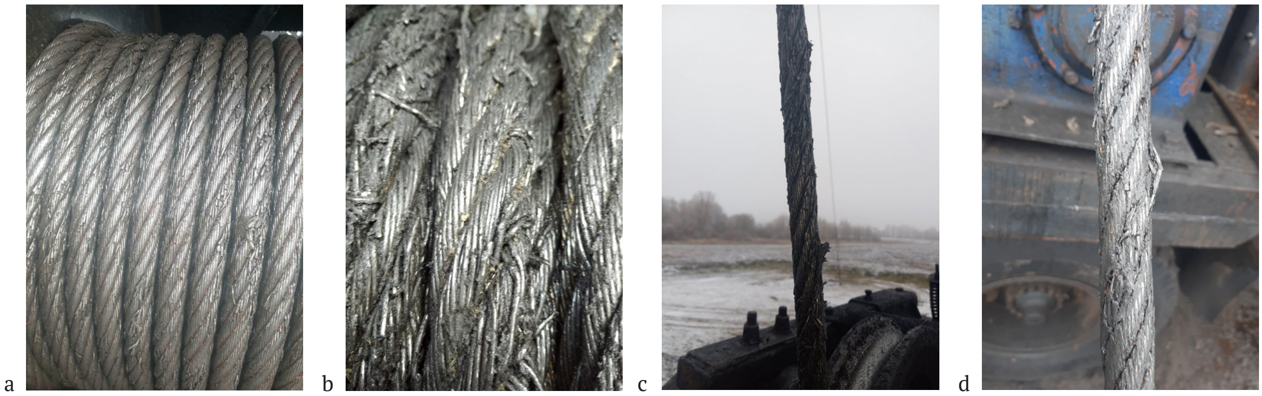

Figure 2. Appearance of the drilling line with signs of fretting damage and destruction of the wires of the drilling line of the UPA-60X unit

Note: a, b – local wear due to abrasion on the supporting structure; c, d – typical wire breaks as a result of bending fatigue

Source: Transport Department of PJSC "Ukrnafta" (2023)

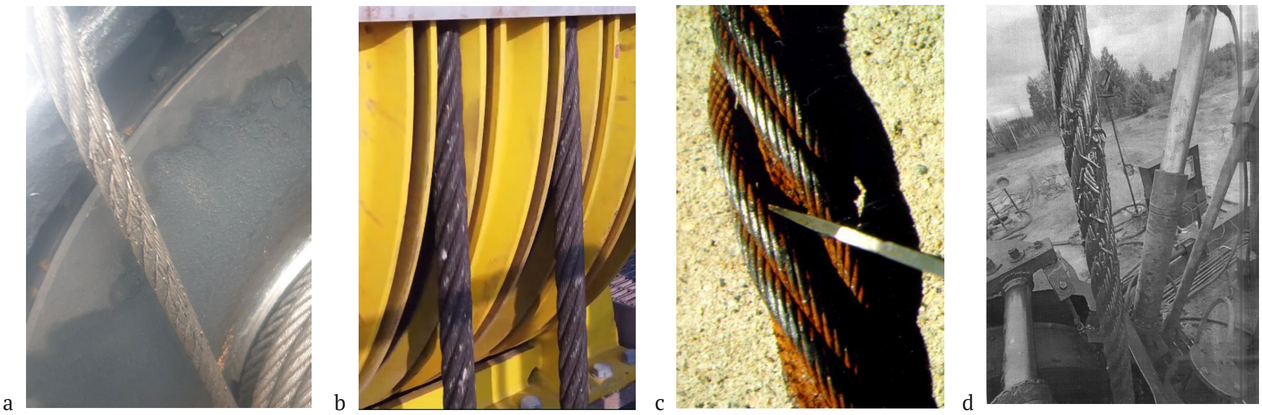

Figure 3. Appearance of the drilling line with signs of fretting and corrosion damage and destruction of the wires of the drilling line of the UPA-60X unit

Note: a – local corrosion; b – continuous surface corrosion; c – corrosion along the contact lines of strands; d – corrosion cracking with wire breakage

Source: Transport Department of PJSC "Ukrnafta" (2023)

External wear is a type of wear in which the drilling line comes into contact with external surfaces, such as drums, pulleys, guide elements, or any other parts of equipment with which it interacts. For drilling lines of drilling rigs, external wear is determined by the operating conditions of lifting equipment and the specifics of lifting operations. When the drill tool is lowered into the well (lowering the loaded hoisting block), the drilling line is unwound from the drum under load, and wound on the drum without load (lifting the unloaded drilling line). In this case, the non-stressed state in the line turns on the drum changes to the stressed state in the leading branch. In the process of lifting the drill tool from the well (lifting the loaded drilling block), the drilling line is wound on the drum under load, and unwound without load (lowering the unloaded drilling block).

Internal wear is a type of wear in which wires and strands come into contact with each other during operation. Actually, during the accelerated lifting of drilling or operational equipment in the line, the strands located on the outside of the line are most stretched. This is conditioned by the fact that the outer strands are subjected to a greater load than the inner ones, which are under less stress. When a line is bent, for example, around a pulley, those strands that are on the outside of the curve travel a longer path and experience more tension than the strands located inside. The amount of internal wear mainly depends on the amount of contact stresses in the wires in contact with each other, the method of twisting the wires and strands of the line, the amount of load, and the method of lubrication. In turn, the contact stresses in the wires that are in contact with each other depend on the shape of the cross-section of the drilling line. The drilling line loses its shape due to: non-compliance of the rope diameter with the profile of the pulley gutters and grooves on the drum; winding the line turns under the load of the first layer on the drum with a smooth surface; and multi-layer laying procedures. The latter causes compressive stresses and contact stresses: in the wires and turns of the lower layers in the zones of parallel laying of twists; in the zones of transition of the twist to twist and transition from one strand to another (Ivashko *et al.*, 2017; Chunming *et al.*, 2022).

Thus, both external and internal wear occurs mainly under the influence of variable tensile and bending loads. Such loads occur, as a rule, when the system is loaded: during drilling, during the period of increasing load in the drilling system, during acceleration when lifting the loaded hook, and during braking of the system when the drilling line is lowered. The oscillatory process is most pronounced during drilling, and during certain periods of lifting operations. In addition, the vibrational nature of the load occurs during the descent and ascent of the drilling block due to the uneven winding of the line on the drum, due to the specifics of the kinematics of multi-layer winding. As a rule, dynamic loads have a relatively high frequency compared to a change in the frequency of the main load (1-8 Hz) and a change in the amplitude of vibrations (stresses) within a wide range. The nature of dynamic loads in the elements of the drilling system during lifting operations is in principle different from the nature of vibrations that occur during drilling. In the first case, the source of forced vibrations is the uneven winding of the line on the drum, that is, the uneven movement of the leading branch. In this case, the maximum range of dynamic forces occurs in the leading and stationary branches, and the forces themselves in these branches are in antiphase. In the middle branches, the dynamic component of forces is minimal. In the second case, the source of forced vibrations of the system is a drill bit with a drill string, and these vibrations manifest themselves to a greater extent in rotary and combined drilling methods. Dynamic loads during this period in all branches of the drilling system are approximately the same and are in the same phase.

Therefore, the accumulation of both external and internal wear of drilling lines and the accompanying damage can be identified as fretting processes. Fretting (fretting fatigue) is the process of accumulation of damage and wear of materials of surfaces that come into contact and carry out vibrational relative movements with a small amplitude under the action of cyclic loading, which causes variable deformations of surface layers, setting and separation of particles, the appearance of oxides, accelerated crack appearance, their development, and destruction of the unit. Fretting wear and corrosion damage occurs in many detachable and all-in-one joints of mechanisms, machines, and structures (Ventsel *et al.*, 2007; Zakalov & Zakalov, 2011). The latter include rivet, thread, spline, key and pin connections, tight fit parts, steel ropes, hinges, couplings, leaf springs, valves, electrical contact regulators, cam mechanisms, gears, rolling bearings, gas turbine engine parts, etc.

Special attention is paid to fretting processes in drilling lines – flexible links of lifting mechanisms of drilling rigs, which are subjected to stretching and alternating bending during descent and lifting operations (Kryzhanivskyi *et al.*, 2003; Borysevych *et al.*, 2004; Kryzhanivskyi *et al.*, 2007). The branches of the drilling line go around the pulleys of the crown block and drilling block, which are components of the hoist system – the heavy-bearing part of the drilling rig. Consideration of the features of fretting corrosion damage is important both for assessing the tension forces in drilling lines and for predicting their durability. Surface damage due to wear during fretting serves as stress concentrators and reduces the endurance limit of the line material. V. Ivashchenko *et al*. (2017) characterised the wear process of wire line material: inside the line and out. A quantitative assessment of the influence of dynamic loads on the accumulation of fatigue factors is given, based on the line fatigue curve. Analytical dependences of the influence of design and operating parameters of drilling systems and their characteristics that affect the failure of the drilling line are presented.

Based on the results of experimental studies, it was found that for such a process, it is sufficient to move surfaces with an amplitude of 0.025 mm (1-2). As a result of the destruction of wire surfaces, miniature scratches, small point workings, and small grooves appear. Fretting corrosion is a local corrosion destruction that occurs during the cyclic mutual movement of two contacting surfaces and the action of a corrosive medium. It occurs due to the continuous destruction of the protective oxide film at the points of mobile contact of wire and rope strands. The result of physico-chemical interaction of drilling lines with the environment are: continuous (flowing over the entire surface of the metal) and local (localised on certain areas of the surface) corrosion; filamentous corrosion (flowing along the contact line of neighbouring wires); and corrosion cracking (occurring under the simultaneous influence of a corrosive medium and tensile residual or applied mechanical stresses). Fretting corrosion is caused not only by carbon steels, but also by corrosion-resistant steels.

Studies by L. Oleksiieva *et al.* (2022) showed that increased contact load leads to smoother wear of the line surface, while fatigue corrosion wear itself is mainly abrasive and adhesive in nature. In addition, surface wear leads to a decrease in the resistance of the lines to bending fatigue, and the deterioration of bending fatigue is more serious under a larger sliding contact load. I. Dmytrakh *et al.* (2003), H. Mouradi *et al.* (2018) and Xu. Chunming *et al.* (2022) investigated the fretting wear of steel ropes under the action of tensile and torsional forces. The research findings showed that the law of change in the coefficient of friction between steel wires of a line is proportional to the angle of intersection by the axis of the line of the axis of symmetry of the pulley. By investigating the hysteresis loop, it was found that the main mechanisms of wear of steel wires are fatigue and adhesive wear, and the worn surface of steel wires shows more obvious abrasive wear with a decrease in the angle of intersection of the line axis of the pulley symmetry axis.

Influence of operational factors on the intensity of fretting corrosion

The wear rate increases when drilling lines operate in aggressive environments, in particular, in aqueous solutions of mineral acids, alkaline solutions, and hydroxides. In this case, accelerated wear of the contacting surfaces of wires or line strands occurs due to fretting corrosion. On the surfaces of the contacting parts, protective oxide films are destroyed, and pure metal is exposed. Metal particles are separated (as in fretting), which are then oxidised (Fig. 4). Therefore, the products of wear during fretting corrosion are usually oxides. In the absence of lubrication with fretting corrosion products, the following oxides are mainly used: Fe_2O_3, FeO, Fe_3O_4. Oxides cause an abrasive effect that depends on the hardness of the oxides and the size of their particles in the wear products. According to the results of surveys (12), such indicated injuries are both local and large-scale in nature.

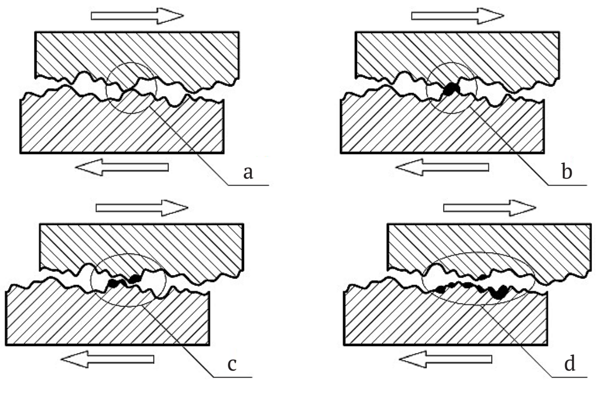

Figure 4. Mechanism of fretting wear of wire surfaces and simultaneous abrasive action of the results of their corrosion

Note: a – local contact of surfaces without corrosion; b – contact with spot corrosion; c – abrasive friction with corrosion elements; d – propagation of corrosion elements

Source: created by the authors based on O. Zakalov & O. Zakalov (2011)

According to Ye. Ventsel *et al.* (2007) and O. Zakalov & O. Zakalov (2011), the relative sliding rate of contacting surfaces during fretting corrosion is low. For harmonic vibrations with a frequency of 50 Hz and an amplitude of 0.025 mm, the average speed is 2.5 mm/s, and the maximum speed is 7.5 mm/s. If the oscillation amplitude is large (about 2.5 mm), the surface of damage caused by fretting corrosion will also be larger, and the rubbing surfaces will have both linear and volumetric defects (Fig. 5). Thus, the main criterion for the development of fretting corrosion damage should be considered the specified amplitude and speed of relative sliding motion of the contacting surfaces. Electrochemical processes of interaction of the contacting surfaces of lines with the environment, and the mechanical component (deformation process) are influential indicators of the intensity of development of fretting corrosion damage.

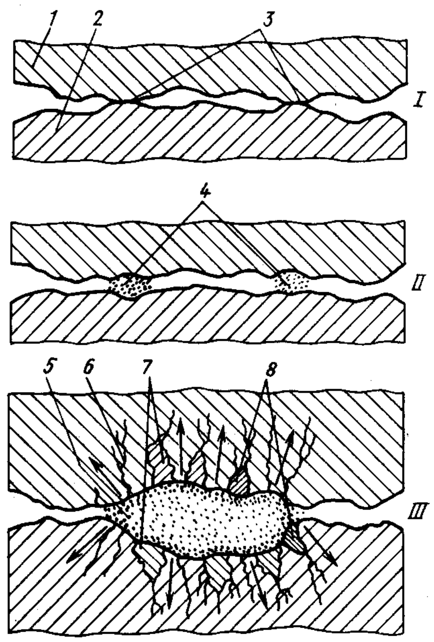

Figure 5. Diagram of wear and destruction of contacting surfaces during fretting corrosion

Note: 1, 2 – contacting surfaces; 3 – points of contact of surfaces; 4 – small caverns; 5 – general large cavern; 6 – cracks; 7 – volumes of broken metal; 8 – particles with a solid structure that have broken off

Source: O. Zakalov & O. Zakalov (2011)

With an increase in the speed of relative slipping of surfaces, the amplitude and frequency of their vibrations, and the level of load, the intensity of fretting corrosion destruction of these surfaces increases. With an increase in the relative sliding rates, metal oxides prevent the setting of rubbing surfaces, and the surfaces themselves have a low roughness. During the fretting corrosion destruction of surfaces, the following occurs. The crystal lattices of the surface layers of metal gradually loosen and collapse due to the action of friction forces during cyclic tangential shifts. There is a separation of metal particles, their mechanical grinding together with oxides into small particles without removing wear products. Detached metal particles, and places and areas of short-term setting of rubbing surfaces, undergo rapid oxidation. The chains of atoms captured during sliding are distorted and then broken, which causes individual atoms to separate from the crystal lattices and can further provoke the development of fatigue cracks. The rate of accumulation of wear products between steel surfaces and the development of new oxide films will depend on the physical and chemical properties of the materials and the newly formed chemical compounds. The accumulation of wear products and metal oxides in closed volumes leads to a local increase in pressure and point destruction of the metal in the form of pits – the so-called pitting. As practice shows, the hardness of metal oxides is greater than the hardness of pure rope metal, which explains their abrasive effect on the contacting surfaces of the wires themselves. The amount of abrasive action of oxides on the contacting surfaces depends on the hardness of oxides, the size of their particles in the wear products, and the adhesion forces of oxide films to the base metal.

From the very beginning, the contact of the rope wires occurs at separate points of the contacting surfaces (I) (Fig. 5). In the presence of vibration in the actual contact zone, the oxide films are destroyed, in place of which small cavities are formed, filled with oxide films (II). The latter, further increasing in size, merge into one large cavern (III), in which, due to an increase in the volume of oxides, pressure increases and small cracks form. In the future, small cracks can merge into larger ones, which causes chipping and large volumes of metal. In the chipped parts of the metal, due to the action of increased pressure, friction forces and increased temperature, new solid structures are formed. According to research by the Transport Department of PJSC "Ukrnafta" (2023), the intensity of fretting wear on surfaces in dry air is significantly higher than in wet air. In fretting corrosion, the wear rate in the presence of a liquid medium is much lower. Thus, in a liquid solution of sodium hydroxide, the weight of material lost due to friction is several times less than in air under normal atmospheric conditions. It is impossible to fully prevent and eliminate the manifestations of fretting corrosion. Assuming that it is impossible to get rid of the mutual micro-placement of wire surfaces in the rope, then it is possible to reduce the impact of fretting corrosion on the material by: reducing the friction force; reducing micro-placements; concentrating sliding in an intermediate medium.

Reducing the impact of fretting corrosion and design solutions to increase the durability of lines

The most effective method of combating this type of line destruction is the transfer of micro slip to the intermediate medium (Chunming *et al.*, 2022; Lomakin, 2024). Such a medium can be lubricants, special wire coatings, or polymer isotropic inserts. In fretting conditions, when the lubricant film does not renew during operation and quickly collapses, conventional viscous lubricants do not affect the coefficient of friction. The use of solid lubricants also does not give the desired results, although the friction force will decrease, the main purpose of coatings is to transfer the displacement process inside the coating, but the process of fretting destruction that has begun quickly turns into the base metal. The effectiveness of all coatings is determined by the service life, since sooner or later they are triggered.

Given that fretting is a process that determines the rate at which a line deteriorates, it is advisable to use lines with special rubber inserts that prevent the wires from rubbing against one another. In this case, a rational and effective measure is the use of lines, the core of which is coated with polymer (Wang *et al.*, 2018; Stalkanat, 2024). Steel ropes with a polymer-coated steel core consist of a layer of steels twisted around the metal core, on which a shell of polymer material is applied by extrusion. Plastic aggregate significantly reduces possible sliding between different elements and prevents changes in the geometric dimensions of lines (Fig. 6).

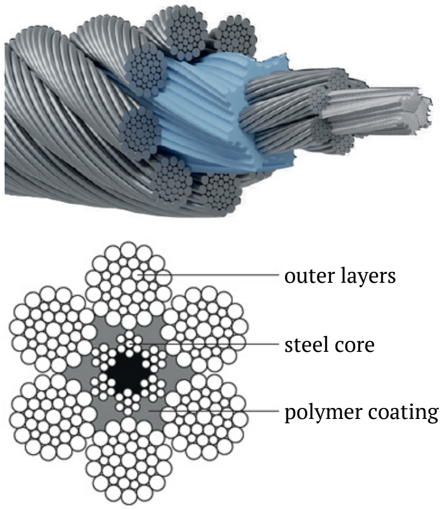

Figure 6. Steel rope with polymer coated steel core
Source: Stalkanat (2024)

The application of a polymer shell allows creating a mechanical connection that fixes the position of the corresponding elements of the steel wire rope, while simultaneously ensuring their necessary displacement; reducing internal corrosion caused by pollutants, which is achieved due to the increased tightness of the rope; and filling the free space between the outer rods and the core to prevent wear. The stabilising effect of the plastic-polymer coating is particularly evident when the rope is exposed to transverse pressure, torsion caused by a wide lateral deflection angle on pulleys or winches, and/or shock loads. The advantages of using polymer core coated ropes are as follows: preventing internal breaks; sealing grease in the rope; preventing water, dust, etc., from entering; reducing internal stresses; improving the stability of the line shape; absorbing dynamic load and partial damping. Adapted steel ropes can also be used based on the use of polymer shells.

The essence of this solution is to design and manufacture a lifting line in advance with geometric parameters as close as possible to those parameters that the line acquires in vertical hanging due to gravitational torsion (Patent No. 85078, 2008). Gravitational torsion of a rope is understood as the phenomenon of rotation, or tendency to rotation, which occurs in steel ropes under the action of a load (its own weight or suspended load), especially in those that have a one-way twist. This technique, developed under the supervision of Professor V.A. Malinovsky, is used in the manufacture of steel ropes that have already been tested in aggressive mine workings. The proposed design reduces the gravitational torsion of the line in the barrel and leads to a more uniform distribution of stresses between the wires in the line rods, which helps to increase fatigue strength, reduce the impact of fretting damage and service life.

Conclusions

As a result of the inspection and analysis, certain features of fretting wear and fretting corrosion of wires and strands of hoisting ropes of lifting mechanisms of drilling rigs, and their influence on the occurrence and development of damage and destruction, were revealed. In particular: a critical analysis of the phases of fretting corrosion processes that occur during the operation of hoisting ropes, and mechanisms of wear and damage of hoisting ropes in operational conditions was carried out; the search for opportunities to reduce the impact of fretting corrosion damage in hoisting ropes was carried out. It was established that the key factors of fretting corrosion wear of hoisting ropes were corrosion of the surface layers of wire and abrasive movement of corrosion products between the surfaces of wire and steel, and the main criterion for the development of fretting corrosion damage should be considered the amplitude and speed of relative sliding motion of the contacting surfaces.

Repeated kinks of the rope on the pulleys of the drilling block, crown block, and winch drum during descent and lifting operations create cycles of alternating stresses that lead to metal fatigue and, as a result, to wear and possible wire breakage. Dynamic loads, acceleration and braking, and changes in the weight of the drill string (during descent, ascent, drilling) create significant stresses that directly affect the intensity of wear. An incorrect angle of convergence of the rope between the winch drum and the crown block or deflecting pulley increases the lateral pressure and friction of the line against the edge of the groove, which causes intense abrasion. Multi-layer line winding on the winch drum (typical for mobile installations) leads to additional friction between the rope turns (line-to-line friction), which significantly increases wear.

Lack or insufficient lubrication is one of the main causes of premature wear. The lubricant reduces internal friction between wires and strands, and external friction on pulleys and drums, and protects against corrosion. Exposure to moisture, aggressive chemicals, namely aqueous solutions of mineral acids, alkaline solutions, hydroxides, and dustiness of the working environment leads to corrosion wear, which significantly reduces the strength of the line and accelerates its destruction. The increased speed of lifting operations increases dynamic loads and friction intensity, which accelerates wear. Considering the features and potential hazards of damage and destruction of elements of hoisting ropes due to fretting corrosion phenomena, it is proposed to use ropes with a polymer core coating for further operation. The use of these lines will help to: prevent the ingress of water and dust; reduce internal stresses; improve the stability of the line shape; absorb fluctuations in dynamic loads. Theoretical and experimental studies of the magnitude and speed of fretting corrosion wear, and the durability and residual life of drilling lines, depending on the amplitude frequency and phase frequency characteristics of vibrations and the dynamism coefficient of the drilling system are considered promising in this area.

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Conflict of Interest

None.

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Особливості фретинг-корозійних пошкоджень талевих канатів вантажопідйомних механізмів мобільних бурових установок

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Анотація. Глибинне бурове, експлуатаційне та ремонтне обладнання спускається, підіймається та утримується у свердловині за допомогою талевої системи, основним виконавчим елементом якої є талевий канат. В процесі тривалої експлуатації талеві канати зазнають фретинг-корозійних пошкоджень, механізми впливу та розвитку яких вимагають додаткових досліджень. Метою даної статті було проаналізувати процеси деградації шляхом оцінки особливостей фретинг-зношування та фретинг-корозії дротин, сталок та осердь талевих канатів вантажопідйомних механізмів бурових установок та їх вплив на виникнення та розвиток пошкоджень. Проведено аналіз публікацій за обраною тематикою в циклі досліджень, постановку проблеми, збір первинних даних візуального та неруйнівного контролю канатів із літературних джерел і даних експертизи для оцінки їх технічного стану та вивчення впливу фретинг-корозійних пошкоджень. Методологія досліджень талевих канатів охоплює комплекс теоретичних та практичних підходів, спрямованих на вивчення їхніх характеристик, оцінку технічного стану, прогнозування довговічності та забезпечення безпеки експлуатації. Вона сформована з врахуванням актуальності та практичної необхідності на основі даних літературних джерел, що характеризуються високою цитованістю, вимогам міжнародних стандартів щодо дослідження пошкоджуваності канатів в умовах корозійного та зношувального впливу. Виявлено окремі особливості абразивного впливу оксидів на стан дротин, сталок та осердь талевих канатів. Проаналізовано залишковий напружено-деформований стан спряжених поверхонь у канатах, обумовлений особливостями кінематики багатошарового намотування канатів на барабан. Проведено аналіз зовнішнього та внутрішнього фретинг-зношування та фретинг-корозії пошкоджень для талевих канатів вантажопідйомних механізмів мобільної бурової установки УПА-60Х. Встановлено передумови виникнення критичного стану поверхонь елементів талевих канатів внаслідок фретинг-корозійних пошкоджень. З урахуванням особливостей та потенційних небезпек пошкодження та руйнування елементів талевих канатів внаслідок фретинг-корозійних явищ для подальшої експлуатації надано практичні рекомендації щодо застосовування канатів з осердями покритими полімером. Застосування зазначених канатів у нафтогазовій галузі дасть можливість: запобігти попаданню води, пилу на осердя, зменшити сили тертя сталок до осердя та внутрішні напруження, покращити стабільність форми каната; поглинати коливання динамічних навантажень

Ключові слова: фретинг-зношування; фретинг-корозія; втомне пошкодження; талева система; спуско-підйомні операції; тертя