Hydrogen Wear of Friction Pairs of Band-Shoe Brake

A.Kh. Janahmadov[1], D.O. Volchenko[2], M.Ya. Javadov[3], D.Yu. Zhuravlev[2], Ye.Yu. Andrejchikov[2], V.V. Nischuk[2], N.A. Volchenko[4], A.S. Yevchenko[4]

[1]*Azerbaijan National Academy of Aviation (Mardakan ave, 30, Baku, AZ1045, Azerbaijan)*
[2]*Ivano-Frankivsk National Technical University of Oil and Gas (Ivano-Frankivsk, Ukraine)*
[3]*Azerbaijan Engineering Academy (Mardakan ave. 30, Baku, AZ1045, Azerbaijan)*
[4]*Kuban State Technological University (International Activities Support Department, Room A-523, Moskovskaya st., 2, Bld. A, Krasnodar, 350072, Russia)*

For correspondence:
Zhuravlev Dmitriy / e-mail: dmytro.2103@ukr.net

Abstract

The article analyzes the features of hydrogen wear of friction pairs of a drawworks band-shoe brake. The research is based on the components of structural steel 35KhNL (35ХНЛ), from which the brake pulley is made, and their interaction with atomic hydrogen. The general regularities of hydrogen wear as a specific type of surface destruction are considered. At the same time, the following was established: the crystal lattice of the metal is the main calmer and exciter in the metal due to the uneven distribution of the components of the structure of the mismatch parameters, oxidation of the metal at the grain boundary, distortion of the crystal lattice and other factors; an increase in the surface temperature at the metal-polymer contact causes thermal degradation of polymers with the formation of various kinds of hydrocarbons and other intermediate compounds, the dehydrogenation of which releases hydrogen; the "oxygen-hydrogen" bond in the H2O molecule, according to Pauding, is 39% ionic in nature, which allows, with an increase in water concentration, to shift the equilibrium towards the formation of hydrogen ions; making through holes of different diameters in the pulley rim and in the friction linings makes it possible to remove hydrogen from the friction zone of the brake friction units.

Keywords: hydrogen wear, friction pairs, band-shoe brake, hydrogenation, wear of a metal friction element.

DOI 10.52171/2076-0515_2023_15_01_43_54

Received *11.06.2022*
Revised *15.03.2023*
Accepted *27.03.2023*

For citation:
Janahmadov A.Kh., Volchenko D.O., Javadov M.Ya., Zhuravlev D.Yu., Andrejchikov Ye.Yu., Nischuk V.V., Volchenko N.A., Yevchenko A.S.
[Hydrogen wear of friction pairs of band-shoe brake]
Herald of the Azerbaijan Engineering Academy, 2023, vol. 15, no. 1, pp. 43-54 *(in English)*

Lentli-kündəli əyləcin sürtünmə cütünün hidrogen yeyilməsi

Ə.X. Canəhmədov[1], D.A. Volçenko[2], M.Y. Cavadov[3], D.Y. Juravlev[2], E.Y. Andreyçikov[2], V.V. Nişuk[2], N.A. Volçenko[4], A.S. Yevçenko[4]

[1] *Azərbaycan Milli Aviasiya Akademiyası (Mərdəkan pr. 30, Bakı, AZ1045, Azərbaycan)*
[2] *İvano-Frankivsk Milli Texniki Neft və Qaz Universiteti (Karpatska küç.15, İvano-Frankivsk, 76019, Ukrayna)*
[3] *Azərbaycan Mühəndislik Akademiyası (Mərdəkan pr. 30, Bakı, AZ1045, Azərbaycan)*
[4] *Kuban Dövlət Texnologiya Universiteti (Moskovskaya küç. 2, Krasnodar, 350072, Rusiya)*

Yazışma üçün: Juravlev Dmitri / e-mail: dmytro.2103@ukr.net

Xülasə

Məqalədə qazıma bucurqadının lentli-kündəli əyləcinin sürtünmə cütünün hidrogen yeyilməsinin xüsusiyyətləri təhlil olunub. Tədqiqatların əsasını əyləc qasnağının hazırlandığı 35ХНЛ polad strukturunun komponentləri və onların hidrogen atomları ilə qarşılıqlı təsiri tutur. Səthi dağılmanın spesifik növü kimi hidrogen yeyilməsinin ümumi qanunauyğunluqları nəzərdən keçirilib. Aşağıdakılar müəyyən edilmişdir: metalın kristal qəfəsi uyğunsuzluq parametrlərinin struktur komponentlərinin qeyri-bərabər paylanması, dənələrin sərhəddində metalın oksidləşməsi, kristal qəfəsin təhrif edilməsi və digər amillər səbəbindən metalda əsas sakitləşdirici və qıcıqlandırıcı hesab olunur; metal-polimer təmasda səth temperaturunun artması, termodestruksiya nəticəsində hidrogenin ayrılması ilə müxtəlif növ karbohidrogenlərin və digər ara birləşmələrin əmələ gəlməsi ilə polimerlərin istilik deqradasiyasına səbəb olur; H2O molekulundakı "oksigen-hidrogen" rabitəsi, Paudinqin qiymətləndirməsinə görə, 39% ion xarakterlidir ki, bu da suyun konsentrasiyasının artması ilə tarazlığı hidrogen ionlarının əmələ gəlməsi istiqamətində dəyişməyə imkan verir; qasnağın dəndənəsində və friksion kündələrdə müxtəlif diametrli deşiklərin açılması hidrogeni əyləcin friksion düyünlərinin sürtünmə zonasından çıxmasına şərait yaradır.

Açar sözlər: hidrogen yeyilməsi, sürtünmə cütü, lentli-kündəli əyləc, hidrogenləşmə, metal friksion elementin yeyilməsi.

DOI 10.52171/2076-0515_2023_15_01_43_54

УДК 625.08

Водородное изнашивание пар трения ленточно-колодочного тормоза

А.Х. Джанахмедов[1], Д.А. Вольченко[2], М.Я. Джавадов[3], Д.Ю. Журавлев[2], Е.Ю. Андрейчиков[2], В.В. Нищук[2], Н.А. Вольченко[4], А.С. Евченко[4]

[1] *Азербайджанская Национальная академия авиации (Мардакянский пр. 30, Баку, AZ1010, Азербайджан)*
[2] *Ивано-Франковский национальный технический университет нефти и газа (г. Ивано-Франковск, Украина)*
[3] *Азербайджанская Инженерная академия (Мардакянский пр. 30, Баку, AZ1045, Азербайджан)*
[4] *Кубанский государственный технологический университет (ул. Московская, 2, Краснодар, 350072, Россия)*

Для переписки: Журавлев Дмитрий / e-mail: dmytro.2103@ukr.net

Аннотация

В статье анализируются особенности водородного изнашивания пар трения ленточно-колодочного тормоза буровой лебедки. В основу исследований взяты компоненты структурной стали 35ХНЛ, из которой изготовлен тормозной шкив, и их взаимодействие с атомарным водородом. Рассмотрены общие закономерности водородного изнашивания как специфического вида поверхностного разрушения. Установлено следующее: кристаллическая решетка металла является основным успокоителем и возбудителем в металле из-за неравномерности распределения компонентов структуры параметров несоответствия, окисление металла на границе зерен, искажение кристаллической решетки и других факторов; повышение поверхностной температуры на металлополимерном контакте вызывает термодеструкцию полимеров с образованием различного рода углеводородов и других промежуточных соединений, в результате дегидрирования которых выделяется водород; связь «кислород - водород» в молекуле H_2O, по оценке Паудинга, имеет на 39% ионный характер, что позволяет с увеличением концентрации воды смещать равновесие в сторону образования ионов водорода; выполнение сквозных отверстий различных диаметров в ободе шкива и во фрикционных накладках позволяет удалять водород из зоны трения фрикционных узлов тормоза.

Ключевые слова: водородное изнашивание, пары трения, ленточно-колодочный тормоз, наводороживание, износ металлического фрикционного элемента.

Introduction

One of the intense types of hydrogen wear of the rubbing surfaces of parts is accompanied by the destruction of a harder surface layer of a steel or cast iron part and the transfer of wear products to a softer mating surface.

Most friction pairs of brake devices operate in a water-containing medium, which, when it gets on their heated surfaces, contributes to the generation of hydrogen. The interaction of the emitting hydrogen with the surface layer of brake discs, drums and pulleys causes their embrittlement materials and as a result, intensive wear.

The study of hydrogen wear of metal friction elements of brake devices is still at an early stage, therefore, it is of scientific and practical interest to determine the general patterns of hydrogen wear, as well as the development of scientific foundations for combating it.

Analysis of literary sources and the state of the problem

The main types and mechanisms of wear are considered [1]. From the standpoint of modern ideas, the physicochemical properties of the friction surfaces of parts, the conditions for their contact interaction are described. The types of friction, the main types of damage to the working surfaces and the wear mechanisms caused by them are analyzed. The requirements for wear-resistant materials are substantiated, and the main classes of wear resistance of materials are described. However, due attention was not paid to hydrogen wear.

The works [2, 3] consider the interaction of hydrogen with metals and nonmetallic elements. The effect of hydrogen on various types of metals and alloys and on the occurrence of specific defects in them is illustrated. Information about hydrogen embrittlement and the effect of hydrogen on the mechanical characteristics in the "hydrogen - metal" pair in the groups of D. Mendeleev's periodic system has been expanded.

The work [4] is devoted to the wear of subroughness of friction surfaces in a hydrogen-containing medium. In the latter, hydrogen is pumped into the subsurface layer of a metal body and interacts with its crystal lattice. It is noted that the driving force in the processes of hydrogen wear are temperature, pressure, deformation, structure and defects of the crystal lattice.

In works [5-8], physical and mechanical processes on the friction surface of hydrogen wear of machine parts and equipment were studied. The causes of hydrogen release, hydrogenation of rubbing surfaces and their destruction are established. A complex picture of the behavior of hydrogen in surface layers during friction under the influence of various factors is shown, and the influence of “biographical” hydrogen on the wear of parts is determined. The reasons for the transfer during friction of a harder material to a softer material are stated: steel to bronze, cast iron to plastic. Practical recommendations are given to suppress hydrogen wear and increase the durability and failure-free operation of friction units of machines and equipment. At the same time, the following was not considered: the effect of external hydrogen on the surface layer of a metal friction element and its entry into the subsurface layer by injection; the phenomenon of adhesion and the types of contacts of friction pairs during their frictional interaction, as well as the combination of adsorption-diffusion phenomena observed in the surface and subsurface layers of friction pairs, were not taken into account. And the most important thing is that external and internal hydrogen and their role in tribological reactions have not been isolated.

It was found in [2, 9] that under severe friction conditions, the maximum surface-volume temperature is formed at a certain depth from the friction surface. This creates conditions under which hydrogen, if it is adsorbed on the surface of the part, diffuses deep into the surface under the action of a temperature gradient, concentrates there, causes embrittlement of the surface layers and increases wear. However, it was not indicated what happens in the subsurface layer of a metallic element with the structures of its crystal lattices.

Considering the foregoing, we have come to the conclusion that no work has studied the interaction of hydrogen with the structural components of steel.

The statement of the problem is reduced to the consideration of the following issues: design and operation of the drawworks band-shoe brake; hydrogen wear in brake friction pairs; the discussion of the results.

The purpose of the work is to establish the regularities of the influence of the components of the brake pulley structure on the hydrogen wear of its working surface.

The design and operation of the band-shoe brake of a drawworks

The main requirement for friction units of drawworks band-shoe brakes is its reliability, which ensures safety and trouble-free operation. The practice of drilling wells in the zones - the core system of drawworks of the close-range units (HR-500, HR-5000; Uralmash: 2500/1600 ESK-BM4; 3000 EUK; 3900/225 EK-6M; 5000/320 EKM-BM4 with parallel echelons and etc.) and distant (types of winches of the company "National", "Oilwell", "Continental-Emcoo","Mid-Continent", Garden-Denver) with a diameter of the working surface of the pulley rim D_p = 1070.0-1680.0 mm and with a rim width b_p = 213.0-318.0 mm, made, for example, from steels 35L, 35KhNL, 35KhML, etc., have fine-shoe brakes.

So, for example, studies have shown that the intensity of destruction of pulleys made of steel 35L increases sharply at a temperature of -20°C and below, and that of steel 35KhNL at -30°C and below. The manufacturer of the considered brake pulleys guarantees their reliable operation at a temperature of -40°C. However, Western Siberia (Russia) belongs to a cold climate zone, where the equipment must remain operational at a temperature of -60°C.

Phenomena that occur during the destruction of the working surface of the pulley rim under the action of generated electric and thermal currents of a pulsed and long-term nature, thermal energy accumulated in the layers of the pulley rim, which contributes to the occurrence of high temperatures, and as a result, temperature gradients, both surface and deep, as well as permanent stresses on the pulley rim with closed and open friction pairs of a band-shoe brake. Therefore, the problem of taking into account thermal stresses is not just a problem of thermal strength. In this case, it is necessary to replace that the greatest influence on the destruction of the working surface of the pulley rim is exerted by electric and thermal currents during electrothermomechanical friction of the metal-polymer friction pairs of the brake. This circumstance should be taken into account when choosing materials for a real friction unit.

The main part of the emerging stresses is concentrated in the surface and subsurface layers of the working surface of the brake pulley rim, which affect its destruction [10,11].

According to the kinematic scheme (see Fig. 1 *a*, *b*), the friction linings 3 are installed on the brake bands 2, which at one end [from the side of its running branch (II)]-to the crank journals 6 and 9 of the crankshaft 10.

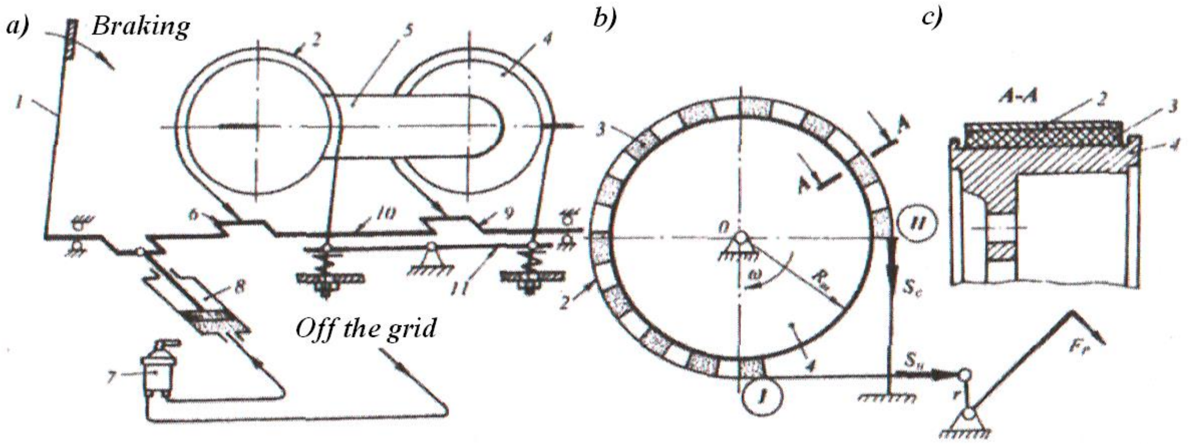

Figure 1 a, b, c - Schemes: kinematic drawworks (a); band-shoe brake (b) and its friction units (c)

Serial band-shoe brake drawworks work as follows. By moving the handle 1, the crankshaft 10 is rotated, as a result of which the driller tightens the brake bands 2 with friction linings 3, and they sit on the brake pulleys 4. The process of braking with a band-shoe brake is characterized by the following stages: initial (first), intermediate (second) and final (third). Let's take a look at each stage separately.

<u>At the initial stage</u> of braking, the friction linings 3, located in the middle part of the brake band 2, interact with the working surface of the brake pulley 4. The front of interaction expands towards the friction linings 3 of the incoming branch (I) of the brake band 2.

<u>The intermediate stage</u> of braking is characterized by the further propagation of the interaction front towards the friction linings 3 of the running branch (II) of the brake band 2.

<u>The final stage</u> of braking is characterized by the fact that almost all fixed linings 3 of the brake band 2 interact with the working surface of the rotating pulley 4. During braking, the sequence of surfaces coming into contact is repeated. The full braking cycle is completed by stopping the brake pulleys 4 with the drum 5. The drawworks brake is also controlled by supplying compressed air through the driller's valve 7 to the pneumatic cylinder 8, the rod of which is connected to one of the crankshaft journals of the crankshaft 10 of the brake. The pressure of compressed air in the pneumatic cylinder 8 is regulated by turning the tap 7 of the driller.

With uneven wear of the friction linings 3 mounted on the belts 2, the balancer 11 at the moment of braking deviates somewhat from the horizontal position and equalizes the load on the running branch (II) of the brake belts 2, while ensuring uniform and simultaneous circumference of the brake pulleys 4. Thanks to ball joints the implementation of loads from the brake bands 2 to the balancer 11 does not change.

The weakest link in the brake assembly is the friction linings. They are made in the form of separate parts that can be fastened in various ways (for example, using antennae) to a relatively flexible steel tape. Friction linings with constant and variable pitch are installed along the arc of the brake band around the pulley. When installing overlays with a constant pitch on the tape, their number is always even (12; 16; 18; 20; 22; 26). With a variable step, this number can be odd.

The total number of friction linings on the brake band depends on their geometric parameters, as well as on the angle of wrapping of the working surface of the brake pulley by the brake band in a given drawworks band-shoe brake.

When choosing a design option for new friction units of a band-shoe brake, it is necessary to proceed from the given conditions and the mode of its operation. In this case, the braking process should be smooth, without disruptions and jumps during the interaction of friction pairs of friction units, and the contact of mating surfaces should be elastic.

Hydrogen wear in brake friction pairs. Electrothermomechanical friction, increasing the energy of the crystal lattice of the metal, leads to a decrease in the work function of electrons and causes the occurrence of electron emission. Electrons emitted from the metal lattice during friction with excess energy are hydrated upon collision with molecules, which leads to dissipative ionization of water molecules (Fig. 2).

In this case, the oxygen-hydrogen bond in the H_2O molecule, according to Pauding, has 39% ionic character. In addition, it follows from the water dissociation equation that with an increase in water concentration, the equilibrium shifts towards the formation of hydrogen ions. In this regard, air humidity has a strong effect on the intensity of hydrogen wear of metals.

This is of great importance for band-shoe brakes operated outdoors and in conditions of high humidity [12].

During friction of surfaces of metals of different nature (Table 1), electrochemical processes also occur at the contact points due to the appearance of a potential difference sufficient for electrolysis to proceed in an aqueous solution of an electrolyte containing impurities or dissolved gases (CO_2, SO_2, SO_3, etc.). When metal surfaces come into contact with atmospheric moisture, ordinary electrochemical corrosion occurs [13]:

(cathode) $2H_2O + 2e \rightarrow H_2 + 2OH^-$.

(anode) $2H_2O - 4e \rightarrow O_2 + 4H^+$.

In friction pairs of brakes, various polymer composite materials are used, for which it increases in modern mechanical engineering [14]. An increase in temperature on the metal-polymer tribocontact initiates the thermal degradation of polymers with the formation of low molecular weight saturated and unsaturated hydrocarbons and other intermediate compounds, the dehydrogenation of which releases hydrogen.

In the surface layer of a solid body, during friction, as a result of mechanical action, the chemical bonds of the crystal lattice break, microdestructions occur, and the continuity of the material is disturbed. Forming fresh fracture surfaces of a solid material, they have free, uncompensated chemical bonds with active centers, are nonequilibrium, and differ greatly in their properties from a conventional surfa.

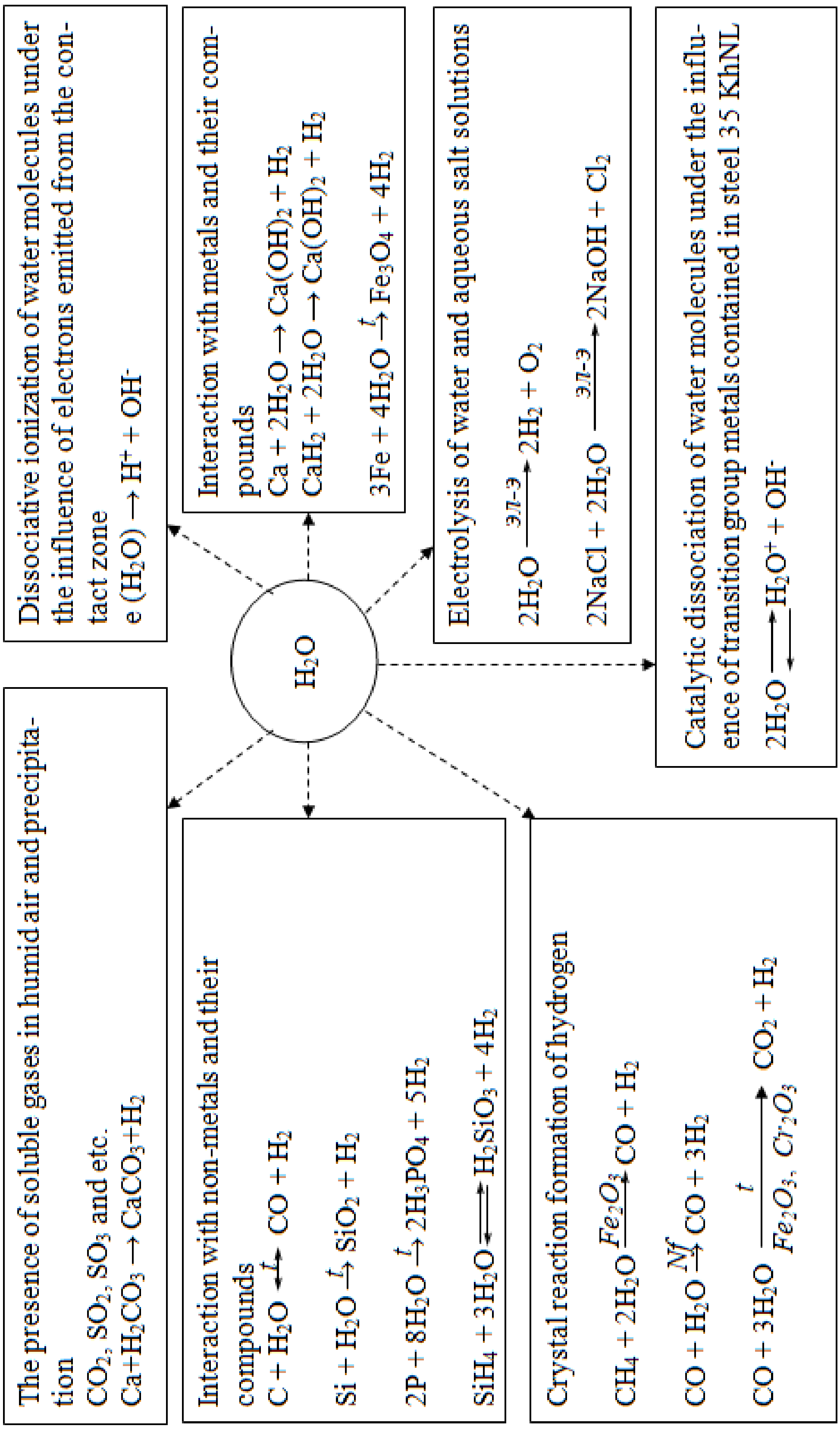

Figure 2 - Physical and chemical formation of hydrogen from water during tribocontacting of surfaces of friction pairs

The metals of transition groups (Cr, Ni, Mn, etc.) contained in structural steel are capable of catalyzing the processes of dissociation of water molecules.

Thus, on the friction surface in the contact zone of friction pairs, various physico-chemical processes can occur, leading to the formation of hydrogen.

The mechanism of hydrogen wear of friction pairs is characterized by a number of successive processes occurring in the friction zone of the contacting surfaces (Fig. 3).

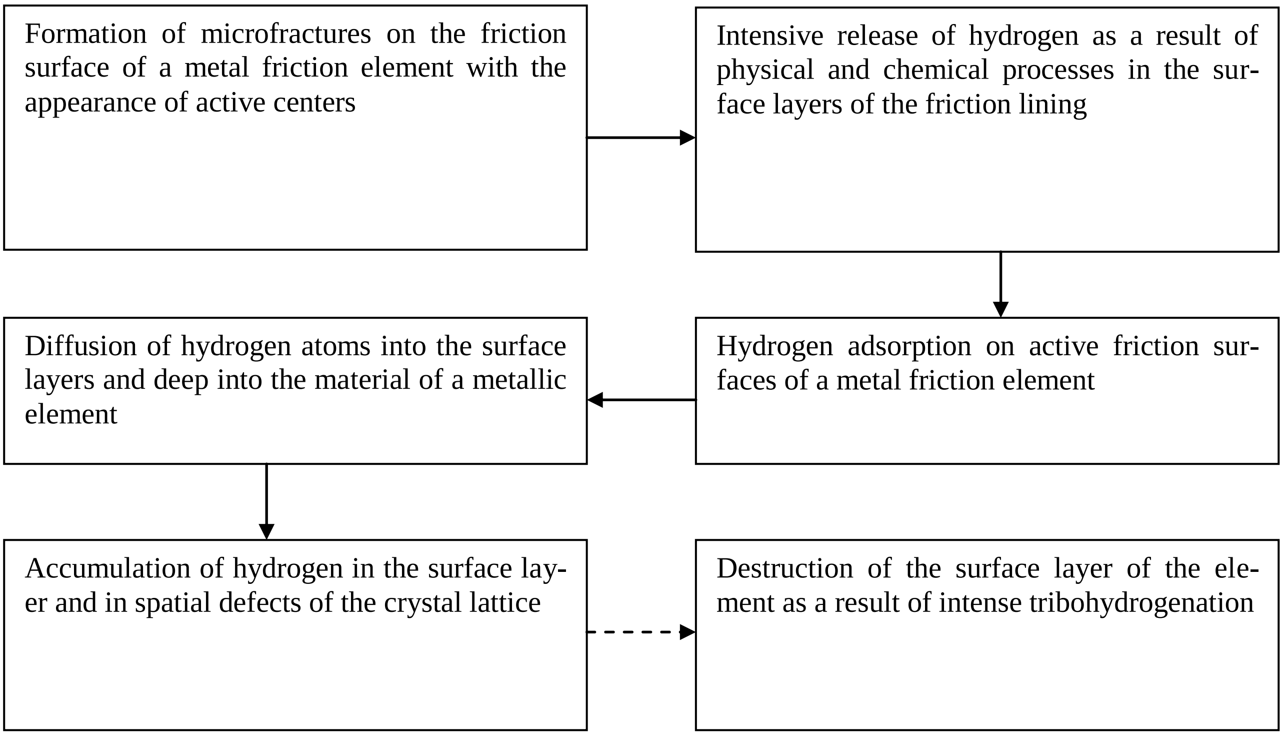

Figure 3 – The main stages of hydrogen wear of the drawworks pulley rim

The liberated hydrogen is adsorbed on the friction surfaces, for example, as a result of desorption of the lubricant due to an increase in temperature in the friction zone. In the process of friction, hydrogen atoms gradually occupy the places freed from lubricant molecules on the surface, since the hydrogen desorption temperature is much higher than the lubricant desorption temperature. Hydrogen atoms, due to their small size, have high mobility and high penetrating power. The non-equilibrium processes, temperature and stress gradients that arise during deformation of the surface layer of the material contribute to the diffusion of hydrogen into the surface layers and into the volume of the material of the elements of the friction pair.

The lightest element of this group - carbon - does not have the properties of a metal, so a detailed consideration of its interaction with hydrogen is beyond the scope of this article. However, it is advisable to provide some basic data on the C-H system for comparison with the Si-H, Cr-Ni, Ni-H, Cu-H systems. In addition, consideration of the C - H system should also be stopped because carbon and hydrogen are usually present together in iron-based alloys. It is possible that the behavior of carbon and hydrogen in iron alloys are mutually determined processes.

At elevated temperatures, hydrogen combines directly with carbon and forms chemical compounds - hydrocarbons. At 500 - 1000 °C, the primary product of the reaction is, apparently, methane, which is a volatile, gaseous hydride under normal conditions. The methane molecule consists of a central carbon atom and four hydrogen atoms located at the vertices of a regular tetrahedron.

Table 1 – The chemical composition of the components of the structure of steel 35 KhNL and their interaction with hydrogen

Chemical element and its percentage	**Interaction with hydrogen**
Iron (Fe) (96,6 – 97,8)*	Hydrogen - iron systems, in which the last element can have three (α-Fe, γ-Fe, δ-Fe) modifications of the structure with different types of lattice. Iron adsorbs hydrogen, and in any state the process of hydrogen occlusion by iron has an atomic character. Hydrogen diffuses through the crystal lattice of iron as a proton.
Silicon (Si) (0,20 – 0,42)	There are no data on the adsorption and occlusion ability of metallic silicon in relation to hydrogen and other gaseous elements.
Copper (Cu) no more (0,30)	When copper enters the microprotrusions of the rim at a flash point of 1084 °C, copper passes into a liquid state, which leads to a sharp drop in its thermal conductivity. It has been established that the thermal conductivity of liquid copper is two times lower than that of solid metal. There is an intense occlusion between liquid copper and hydrogen.
Manganese (Mn) (0,40 – 0,90)	At temperatures from 20 °C to 500 °C, the solubility of hydrogen in manganese decreases; above 500 °C, occlusion becomes endothermic and increases with increasing temperature.
Nickel (Ni) (0,70-0,90)	The adsorption and diffusion of hydrogen in nickel has been studied in detail. It seems likely that the hydrogen containing nickel with a high H/Ni ratio is a metallic bond type composition.
Phosphorus (P), no more (0,047)	Phosphorus gives chemical compounds with hydrogen corresponding to the formulas PH_3 (phosphine) and P_2H_4 (diphosphine). The existence of higher phosphorus hydrides has not been revealed.
Chromium (Cr) (0,50 – 0,80)	Prone to adsorption and desorption at various temperatures. Two new phases are observed in the chromium-hydrogen system. The maximum hydrogen concentration is determined by the H/Cr ratio.
Sulfur (S) no more (0,04)	At 310°C, the reaction of direct interaction of sulfur and hydrogen proceeds towards the formation of H_2S. At 400 °C, hydrogen sulfide is already decomposing: its formation at this temperature is possible only when sulfur and hydrogen vapor interact. At 600 - 650 °C, the content of hydrogen sulfide in the gas mixture is only 7% (vol.)

*** Note:** With increasing pressure and temperature, the diffusion rate of hydrogen in iron increases. The interaction of carbon and hydrogen is discussed below.

Data on the change in the concentration of methane in the gas mixture depending on the temperature below (table 2).

Table 2 – The change in the concentration of methane in the gas mixture depending on the temperature

Temperature, °C	475	500	550	600	625
The content of CH_4 in the gas mixture, %	69,86	62,53	46,89	31,68	24,75

Starting from 475°C, the amount of methane in equilibrium with carbon decreases with increasing temperature, i.e., the rate of the reverse process, methane dissociation, exceeds the rate of the direct reaction of elemental interaction.

At high temperatures, for example, at the temperature of an electric arc, the primary product of the interaction of hydrogen and carbon is acetylene. Methane and lower hydrocarbons are much more thermally stable than similar hydrides of the following elements of this group - silicon and germanium.

The uneven distribution of hydrogen in the metal largely depends on the imperfection of the crystal structure, for example, in the cracks that have arisen, hydrogen atoms upon collision form molecular hydrogen, the diameter of which is much larger than the size of atomic hydrogen. The reaction of formation of atomic hydrogen is accompanied by the release of a significant amount of heat, which also stimulates other chemical cracks (for example, hydrogen enters into chemical reactions with metal impurities, forming hydrides). As a result of these processes, significant tensile stresses arise, increased internal pressure in defects destroys the metal along all developed and connected cracks. Numerous cracks, merging, can instantly turn the surface layer of metal into powder.

The degree of hydrogenation of surfaces during friction changes under the influence of environmental factors. The influence of hydrogen, as an accelerator of wear and destruction of metal friction elements of brakes, is observed during the operation of various types of friction units during thermal construction of the working surface of the polymer lining, in contact with water, as well as in hydrocarbon media, with changes in humidity and temperature of the environment.

The process of hydrogen wear is intensified in humid and cold climates. One of the reasons for the rapid wear of metal friction elements of road construction equipment, handling equipment, as well as vehicles operated for a long time in a cold climate. Due to a significant temperature difference, hydrogen at low temperatures does not dissolve in the surface layers of the metal friction element, it concentrates between the friction zone and the surface of the polymer lining. It has been established that the wear rate under low temperatures exceeds by several times the values recorded with positive thermocouples.

The study of the mechanism of hydrogen wear of metal friction elements of drawworks band-shoe brakes made it possible to dwell on the main methods of protection against tribonation of hydrogen. The process of hydrogen generation can be slowed down by coating the active areas of the surface with a layer of neutral molecules. An effective way to protect against hydrogen wear is to introduce copper oxide into the composition of composite materials [15], which, as a result of its interaction with hydrogen, leads to the formation of a copper film, which is a barrier to the penetration of hydrogen. Hydrogen removal accelerators from friction zones are the implementation of through holes of various diameters in the pulley rim and in friction linings. In addition, they intensify the number of longitudinal and transverse changes of air surrounding friction pairs. This leads to a decrease in the surface-volume temperature in the zone of contact of the friction surfaces, and as a result, to a decrease in their hydrogen wear.

The discussion of the results

Based on the study of the components of the Drawworks band-shore brake, and their interaction with atomic hydrogen, it was possible to establish the following:

- the main supplier and recipient of atomic hydrogen is the surface and near-surface layer of the metal friction element;

- the crystal lattice of the metal is the main damper and exciter in the metal due to the uneven distribution of the components of the structure of the mismatch parameters, the oxidation of the metal at the grain boundary, the distortion of the crystal lattice and other factors;

- an increase in the surface temperature on the metal-polymer tribocontact causes thermal degradation of polymers with the formation of various kinds of carbons and other intermediate compounds, as a result of which hydrogen is released as a result of dehydrogenation;

- the oxygen-hydrogen bond in the H2O molecule, according to Pauding, is 39% ionic in nature, which makes it possible to shift the equilibrium towards the formation of hydrogen ions with an increase in water concentration;

- making through holes of different diameters in the pulley rim and friction linings allows you to remove hydrogen from the friction zone of the brake friction units.

Conclusion

In connection with the increasing mechanical and thermal load in friction units of braking devices in mechanical engineering, protection against hydrogen wear of their elements is of particular importance in solving a complex problem - increasing the durability and efficiency of machines.

Conflict of Interests

The authors declare there is no conflict of interests related to the publication of this article.

REFERENCES

1. Wear and wear-resistant materials: textbook. allowance / M. A. Filippov, A. V. Makarov, O. Yu. Sheshukov, O. I. Shevchenko, A. A. Metelkin; Ministry of Science and Higher. Education of the Russian Federation; FGAOU VO "UrFU im. First President of Russia B. N. Yeltsin, Nizhny Tagil. technologist. in-t (fil.). - Nizhny Tagil: NTI (branch) UrFU, 2019. - 372 p. *(in English)*
2. **Garkunov D.N.** Tribotechnics. Hydrogen wear of machine parts / D.N. Garkunov, G.I. Suranov, Yu.A. Khrustalev // Proceedings of USTU, Ukhta, 2007. - 260 p. *(in English)*

3. **Janahmadov A.Kh., Skrypnyk V.S., Volchenko N.A., Yahyayeva A.N., Juravlev D.Y., Yevchenko A.S.** Investigation of Hydrogen Wear in Heavy Loaded Metal Friction Elements of Brakes.. *Herald of the Azerbaijan Engineering Academy,* vol. 13, No. 4, 2021. - Pp. 34-46. *(in English)*

4. **Shalygin M.G.** Wear of the Subroughness of Friction Surfaces in a Hydrogen-Containing Medium, Diss. ... for the competition. scientific doctorate degrees. tech. Sciences: 05.02.04 - friction and wear in machines, Bryansk, 2017. - 254 p. *(in English)*

5. **Yudin V.M.** Tribochemistry of hydrogen wear / V. M. Yudin, E. A. Lukashev, M. E. Stavrovsky. - M.: MGUPS, 2004. - 282 p. *(in English)*

6. **Liu D., Bai B., Fang H., Zhang W., Gu J., Chang K.** Effect of temperature and carbide free bainite on the mechanical characteristics of a high stre-low alloy steel // Materials Science and Engineering. A. 2004. V. 371. Pp. 40-44 *(in English)*

7. **Astakhov V.** Tribology of Metal Cutting: Tribology Series. Else vier Science Ltd, Vol. 52, 2006. - 392 p. *(in English)*

8. **Biresaw G., Mital K.** Surfactants in Tribology. Volyme 3 PDF Taylor and Francis Group, LLC, CRC Press, 2013, XVII *(in English)*

9. **Kindrachuk M.V., Volchenko D.A., Volchenko N.A. [et al.]** Influence of a water conduit on the wear resistance of materials in friction pairs of brake devices // Phiz.-Khim. mechanics of materials. - 2017. - 53. No. 2. - Pp. 135 – 141 *(in English)*

10. Tribology: friction, wear and lubrication / A.Kh. Janahmadov, D.A. Volchenko, N.A. Volchenko [et al.] // Baku: "Apostrophe-A", 2019. - 640 p. *(in English)*

11. **Mukhametishina R.M.** Hydrogen wear of parts of road-building machines / R. M. Mukhametishina // Izvestiya KGSAU. - 2015. No. 4 (34). - Pp. 334 – 338 *(in English)*

12. **Mukhametishina R.M.** Influence of climatic factors on the properties of materials and the reliability of machines // Izvestia KSAU, 2014, No. 4 (30). – Pp. 490-495 *(in English)*

13. **Mukhametishina R.M.** Failures of road construction machines according to corrosion parameters // Izvestiya KSAU, 2013, No. 4(26). - Pp. 403-408. *(in English)*

14. **Baurova N.I.** Diagnostics and repair of machines using polymeric materials: monograph. – M.: TechProgramCentre, 2008. – 280 p. *(in English)*

15. **Galaktionova N.A.** Hydrogen in metals // M.: Iz-vo Metallurgiya. - 1967. - 303 p. *(in English)*