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# Kinetics of heterogeneous chemical reactions, initiated by metal deformation

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**Abstract**

Topochemical processes in the air environment initiated by plastic deformation of the metal of various intensities and types were investigated : cyclic bending of the sample, rolling friction, sliding friction, cutting. It was established that during the cyclic loading of the metal, the concentration and composition of the air components in the test chamber change: a decrease in the content of the reagent - molecular oxygen and the appearance of the interaction product - hydrogen. The influence of the type of plastic deformation of the metal and the processes that occur during this on the kinetic dependences of the topochemical processes was revealed: damped, rectilinear and exponential. The dependence of the speed of topochemical processes on the intensity of plastic deformation was established. An indicator for assessing the competing effect of metal oxidation on the active centers of the surface subjected to plastic deformation was proposed. The results obtained reveal the nature of the friction and wear process and ways to increase the durability of friction units.

**Keywords :** topochemical reactions, kinetics, rate, plastic deformation, intensity, oxygen, hydrogen

## Introduction

The widespread use of low-, medium-, and high-strength metals requires new nonlinear approaches to ensure their long-term strength, which take into account elastic-plastic deformation and physicochemical factors of the interaction of the environment with the stressed metal [1].

Deformation of a metal is its reaction to the influence of external mechanical forces. The external change in the shape and dimensions of a part made of metal is the result of a change in the arrangement of atoms, that is, the structure of a solid body during the development of deformation. Internal changes in the metal depend on the characteristics of its structure and the conditions of external mechanical loading. They can cause an increase or decrease in interatomic distances, and therefore a change in the shape and type of the crystal lattice , the nucleation, movement and propagation of structural defects: point, linear, coplanar [2,3,4]. Changes in the structure of the metal cannot but affect its structurally sensitive property - reactivity. First of all, this concerns reactions between the metal and components of the environment, which are heterogeneous, that is, those that occur at the interface of the phases: metal - gas medium (air), metal - liquid.

The initial components – metal and components of the environment that take part in the chemical interaction, the intensity of the reactions and the products that are formed in this process affect the formation of the long-term strength of metals [5,6]. The study of heterogeneous chemical reactions in the process of plastic deformation of metals and their influence on the long-term strength of metals is given considerable attention [1,7,8]: in the process of friction and wear, - in connection with the formation on the contacting conjugate surfaces of products of the interaction of the metal with oxygen in the surrounding air [9,10], and the development of hydrogen wear [11,12,13], under static and cyclic loads, - the influence of metal hydrogenation on its strength [14,15]. In most cases, the studies concern the qualitative analysis of products of heterogeneous chemical transformations: oxide films, metal hydrides by X-ray structural analysis, OGE spectroscopy, etc. , the presence of the release of gaseous components (primarily hydrogen ions) by mass spectrometric analysis. However, not enough attention is paid in scientific research to the measured, quantitative analysis of the presence and intensity of heterogeneous reactions that occur under the influence of deformation of metals with components of the environment. In view of this, the aim of this work is to study the kinetics of topochemical reactions under the influence of various mechanical loads, which will allow to expand the understanding of the nature of chemical processes that are the response of a solid to its plastic deformation and the key to a controlled effect on the long-term strength of metals from the point of view of relaxation processes.

**Equipment and Materials**

During plastic deformation of a metal, conditions arise for the realization of its chemical interaction with the components of the surrounding environment. As a result of the course of heterogeneous chemical reactions, the composition of the environment will change - reactants will disappear and products will appear. By quantitative dependencies, one can judge the nature of the reactions, that is, study the mechanism of interaction of the environment with the metal during plastic deformation.

To ensure not only qualitative, but also quantitative control over the change in the content of environmental components due to their participation in chemical interaction with the activated solid, the unit in which the metal undergoes plastic deformation must be placed in an isolated, hermetic chamber .

To study the chemical processes that occur during plastic deformation of metal by bending, a device was manufactured (Fig. 1), consisting of a sealed chamber made of a vacuum rubber hose, which is closed at both ends by sample holders.

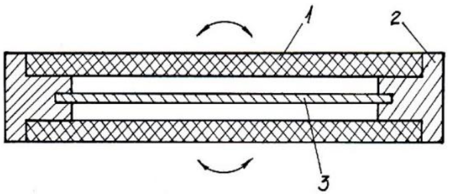


**Fig. 1. Device for studying the kinetics of heterogeneous chemical reactions during cyclic bending of metal: 1 – chamber; 2 – sample holder; 3 – sample**

The study of the change in the composition of the gas medium due to the course of chemical processes was carried out after a certain number of cycles of bending the sample. For this, an air sample was taken from the chamber using a medical syringe, which was used to pierce the wall of the vacuum hose. The selected sample of the gas medium was subjected to chromatographic analysis.

A common drawback of most friction machines is the lack of sealed chambers for housing the friction unit, which makes it impossible to study the physicochemical processes occurring between the surrounding environment and the contacting surfaces, to investigate the influence of gaseous media and gases dissolved in liquids on their tribotechnical properties.

To conduct studies of heterogeneous chemical reactions during friction, installations were used that allow testing under rolling and sliding friction conditions in a closed, hermetic volume (Fig. 2, 3) [1].

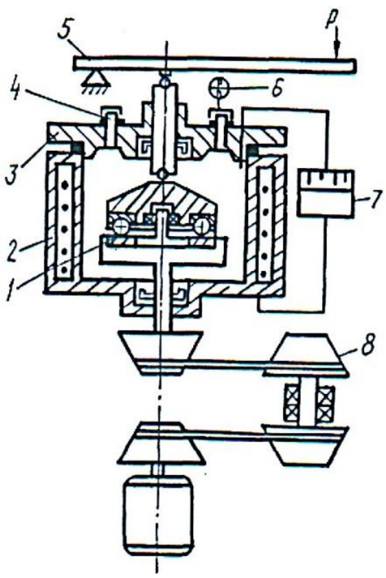


**Fig. 2. Friction installation rolling : 1 – friction unit; 2 – chamber; 3 – cover; 4 – sampler; 5 – loading device; 6 – pressure gauge; 7 – temperature block; 8 – drive**

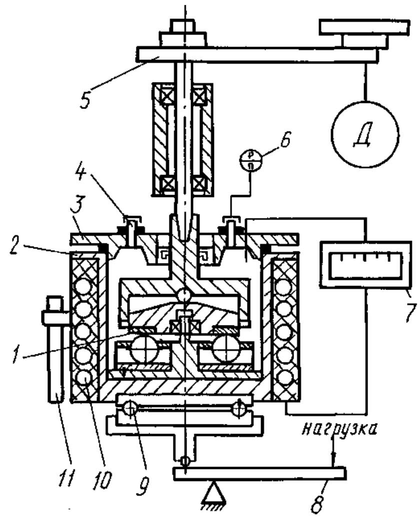


**Fig. 3. Sliding friction setting (3 balls – plane) : 1 – friction unit; 2 – chamber; 3 – cover; 4 – sampler; 5 – drive; 6 – pressure gauge; 7 – temperature block; 8 – loading device; 9 – thrust bearing; 10 – heating element; 11 – tensile beam**

The devices were equipped with lids with samplers, through which, using a medical syringe, samples of the medium surrounding the friction unit were taken from the chamber for chromatographic analysis of the changes that occur in it during friction. To ensure control of changes in the composition of the gas environment during cutting, the cutting unit was also placed in a sealed chamber. In all test chambers, an excess pressure was created to ensure the possibility of sampling the medium for subsequent chromatographic analysis. To determine the component composition and concentration of gases, gas chromatographs " Chromatec -Crystal 5000" and " Gazochrom 3101" were used, which have a sensitivity threshold for hydrogen, respectively, $4\times10^{-10}$ g/ml and $1\times10^{-4}$ % by volume. Cyclic bending was tested on samples made of St3 steel, made in the form of a plate with dimensions: $l \times b \times h = 80 \times 6.0 \times 0.3$ (mm). Rolling friction experiments were carried out at contact stresses of 2300 MN/m $^2$ , the speed was 850 min $^{-1}$ . The conditions for testing sliding friction on the installation had the following parameters: sliding speed 1.18 m/s, speed 450 s $^{-1}$ , axial load 150 N, to ensure the registration of changes in the air environment, the test time was 30 min. The test specimens were made of ShKh15 steel.

Cutting of metal – steel 45 by drilling was carried out with a drill with a diameter of 5.8 mm made of steel P6M5 at an axial load of 500 N, a cutting speed of 0.45 m/s, and a productivity of $5\times10^{-5}$ m/s for 5 min.

**Results and Discussion**

Cyclic deformation of a sample of St3 steel in an air environment leads to the initiation of heterogeneous chemical processes (Fig. 4) and with an increase in the number of cycles, the amount of released hydrogen increases, the oxygen content decreases, and the nitrogen content remains unchanged. The loading frequency was 1 bend per second.

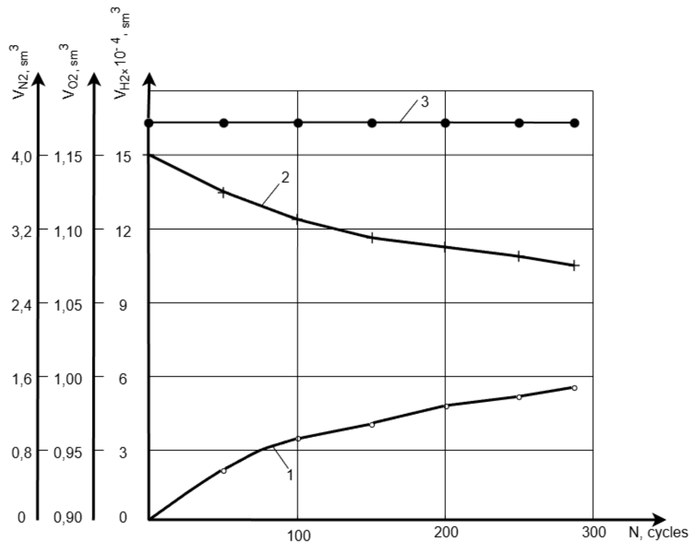


**Fig. 4. Kinetics of heterogeneous reactions during cyclic bending of the sample (St3): 1 – hydrogen ( $H_2$ ); 2 – oxygen ( $O_2$ ); 3 – nitrogen ( $N_2$ )**

In the conducted studies, the release of hydrogen is the result of the interaction of water vapor present in the air surrounding the zone of influence of mechanical loads on the metal, with activated plastic deformation of the steel. The chemical nature of the processes can be depicted by the following schemes:

$$Fe + H_2O \rightarrow FeO(FeOH) + H_2 \uparrow; \quad (1)$$

$$Fe + 2H^{\bullet} \rightarrow Fe^{2+} + H_2 \uparrow.$$

The absorption of molecular oxygen and the corresponding reduction in its volume in the test chamber is due to the topochemical reaction of the interaction of $O_2$ with the activated metal, in our case steel, which mainly consists of iron, its oxidation with the formation of oxides on the surface:

$$3\,Fe + 2\,O_2 \downarrow = Fe_3O_4 \quad (2)$$

Mechanochemical transformations have the character of a complex multi-stage process, which includes stages of metal deformation under the influence of mechanical loads with the supply , accumulation and dissipation of mechanical energy, direct chemical interaction of the metal with the components of the environment and solid-phase transformations, the implementation of various secondary processes associated with electron emission, quantum radiation and others. In the kinetics of topochemical processes under the influence of mechanical load, two extreme cases can be distinguished [16]: the first corresponds to the conditions under which the speed of the entire process is determined by the speed of the primary mechanochemical stage, and the second - when the limiting stage is the supply or absorption of mechanical energy. Thus, the criterion for dividing heterogeneous chemical reactions caused by mechanical loading of a solid body by kinetic features is the ratio between the rates of absorption of elastic energy and directly mechanochemical reactions. The first case concerns conditions when a solid is in a constant field of mechanical stresses. The conditions of our research relate to the second case, when heterogeneous reactions occur under variable metal loading and the rate of elastic energy input is much lower than the rate of the chemical reaction initiated by the absorption of this energy by the solid.

With a steady-state cyclicity of mechanical energy supply under steady-state conditions, the average mechanical power supplied to a solid body over time remains constant. For each unit load cycle, a part of the mechanical energy is absorbed by the metal and over a certain number of cycles, the average steady-state degree of material deformation and the corresponding average energy level $\Delta E_{def}$ that was absorbed are established. The rate of energy absorption is directlyproportional to the supplied power $W$ *, and the rate of dissipation is proportional to the average level* $\Delta E_{def}$. In steady-state mode:

$$\alpha W = \frac{1}{\tau_p} \Delta E_{деф} \qquad \text{or} \qquad \Delta E_{деф} = \alpha \tau_p W, \quad (3)$$

where $\alpha$ is a coefficient that is close in magnitude to the efficiency of the metal deformation process, and therefore lies within the efficiency range $< \alpha < 1$, $\tau_p$ – stress relaxation time.

The nature of the distribution of deformation energy in a metal depends on many factors [1]: the heterogeneity of the structure, the presence of impurities and alloying elements, the damping properties of the system, the speed of load application and is unknown, but it can be suggested that it is quite steep and can be described by an exponential law, that is, the part of the bonds that acquire deformation energy is proportional to the value exp. $\left(-\frac{E_{деф}}{\Delta E_{деф}}\right)$. Also, it should be taken into account that the external load on the metal is applied periodically and in the system there is a constant redistribution of deformation energy between the bonds with a speed A ($s^{-1}$) or, accordingly, with a characteristic time 1/A (s), which depends on both the intensity of the force load and the inherent relaxation time of the material. In the case when the kinetics of a chemical process initiated by the application of mechanical energy is limited by its redistribution in the metal, the rate constant should be proportional to the rate of redistribution of the strain energy between the bonds A ($s^{-1}$) and the probability of accumulation on a certain bond of the critical strain energy $E^{i}_{деф}$sufficient to initiate a topochemical reaction under the influence of mechanical loading and the deformation caused by it. Therefore, in this case, the dependence of the rate constant of the heterogeneous reaction on the intensity of the application of mechanical energy in variable load fields will have, taking into account equation (3), the following form:

$$k_{mech} \sim A\,exp\left(-\frac{E^{i}_{деф}}{\Delta E_{деф}}\right) = A\,exp\left(-\frac{E^{i}_{деф}}{\alpha \tau_p W}\right) \quad (4)$$

From the above equation it is clear that under loads the rate of heterogeneous chemical processes should be directly proportional to the intensity of the mechanical energy supply and the metal deformation caused by it, the processes of accumulation and dissipation of elastic energy.

Plastic deformation of the metal, and therefore the disordering of the structure with the formation, propagation and migration of structural defects as centers of catalysis , initiates the course of topochemical reactions, the result of which is a change in the composition of the surrounding gaseous medium - the release of hydrogen in the volume of $5.1\times10^{-4}$ cm $^3$ , and the absorption of oxygen in the volume of $6.4\times10^{-2}$ cm $^3$ . If the metal is thermodynamically unstable, in the air environment a film of solid products of interaction with components is formed on the surface, most often oxide [17], which inhibits the further course of chemical processes. However, cyclic bending of the sample leads to cracking and destruction of this film, and therefore contributes to the exposure of the metal. At the initial stage of deformation, processes of intensive propagation and movement of dislocations occur in the metal, their emergence to the surface, and this contributes to a significant activation of the course of topochemical reactions with the participation of active components in the air. At the same time, there is intensive dissipation of the supplied mechanical energy into heat due to internal friction processes, as evidenced by the heating of the sample.

Further deformation of the sample leads to an increase in the density of dislocations, complication of their movement, interaction between themselves and with impurity atoms , i.e. contributes to the exhaustion of both physical and chemical processes of dissipation of the supplied energy. This is manifested in the slowing down of the course of topochemical reactions and, ultimately, the development of damaging phenomena, the appearance of microcracks in the places of accumulation of dislocations , which grow, merge and cause the destruction of the sample under conditions of low-cycle fatigue ( $N_p = 280$ cycles).

The kinetics of heterogeneous chemical reactions of the interaction of components of the surrounding gas environment with activated plastic deformation metal at different intensities of contact load were studied: during rolling friction, sliding friction and during metal cutting. As can be seen from the obtained experimental data (Fig. 5,6,7,8), in the process of friction, as well as during metal cutting, regardless of the materials studied, hydrogen is also released and oxygen is absorbed. The nitrogen content remained unchanged. However, the nature of topochemical processes, depending on the conditions of mechanical impact on the metal, is significantly different. This is due to the intensity of plastic information, which is also the initiator of the increase in the reactivity of the metal and the conditions of the presence on the metal surface of solid products of its interaction with active components of the environment.

The load intensity during rolling friction (Fig. 5), which is formed by the angular velocity of the sample ( $\omega = 14.2$ s $^{-1}$ ) and six balls in the separator, increases to 85.4 s $^{-1}$ of deformations per unit surface per second. This causes acceleration of heterogeneous reactions between the activated metal and air components and, as a result, a change in the component and quantitative composition of the environment - the amount of released hydrogen is $132.4\times10^{-4}$ cm $^3$ , i.e. it increases 25.9 times compared to the cyclic bending of the sample, and the absorbed oxygen is $29.4\times10^{-2}$ cm $^3$ , which is 4.6 times higher than the previous test (Fig. 4).

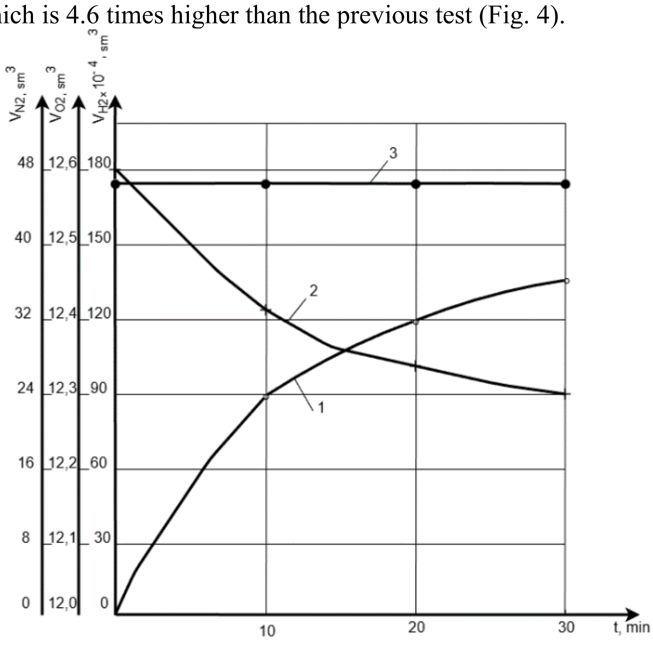


**Fig. 5. Kinetics of heterogeneous reactions during rolling friction (ShKh15 – ShKh15): 1 – hydrogen ($H_2$); 2 – oxygen ($O_2$); 3 – nitrogen ( $N_2$ )**

During sliding friction on the friction pair "3 balls - plane" the angular velocity of the moving sample was 7.5 s $^{-1}$ , and taking into account 3 balls, the number of re-deformations per unit surface was 22.5 s $^{-1}$ , i.e. it was significantly less than the value during rolling friction, but the intensity of topochemical reactions significantly increased (Fig. 6): $2570.0\times10^{-4}$ cm $^3$ of hydrogen was released and $470.0\times10^{-2}$ cm $^{3}$ of oxygen was consumed , which, respectively, is 19.4 and 16 times higher than the result during rolling friction. This is due to the peculiarities of the sliding friction process.

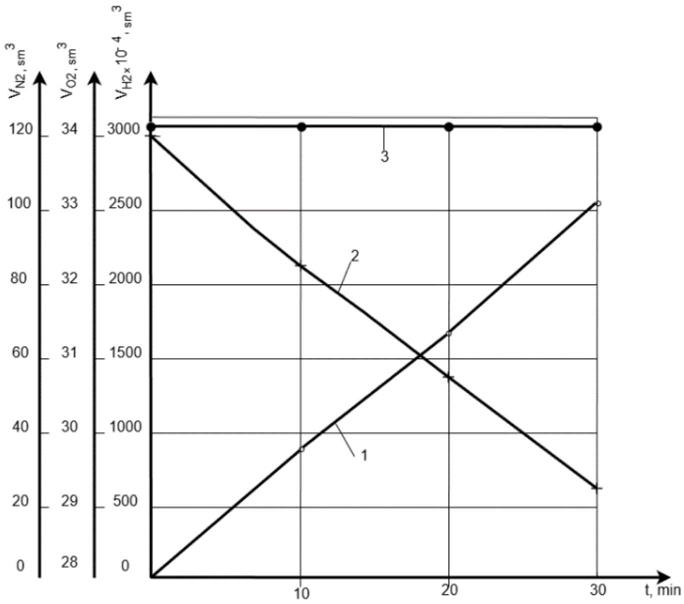


**Fig. 6. Kinetics of heterogeneous reactions under sliding friction (3 balls – plane, ShKh15 – ShKh15): 1 – hydrogen ( $H_2$ ); 2 – oxygen ($O_2$ ); 3 – nitrogen ( $N_2$ )**

During bending tests and friction rolling, plastic fatigue deformation of the metal surface occurs, but the solid products of the interaction of active air components with the activated metal - oxides (hydroxides) - crack, in small quantities collapse, but remain on the surface and thus shield it from the access of reagents. At the same time, during friction sliding, solid products of the interaction are removed from the friction surface, and therefore its constant renewal, the formation of a juvenile surface, which has an exceptionally high reactivity, which leads to the intensification of hydrogen release and oxygen absorption as components of heterogeneous chemical processes and their kinetics is characterized by linearity.

The friction pair "3 balls – plane" is open for access of active components of the environment to the plastically deformed metal. To study the influence of the closedness of the friction pair on the course of topochemical reactions, experiments were conducted on the plane-plane friction pair (Fig. 7). As a result, it was found that the closedness of the activated surface of the friction pair by the counterbody for access of water vapor and oxygen does not affect the nature of the chemical interaction and the linearity of the kinetic dependence. During the friction process, $1170.0\times10^{-4}$ cm$^{3}$ of hydrogen was released and $185.0\times10^{-2}$ cm$^{3}$ of oxygen was consumed , which is comparable in order, but somewhat lower than the results obtained with sliding friction on the pair "3 balls – plane", but significantly exceeds the results with cyclic bending and rolling friction.

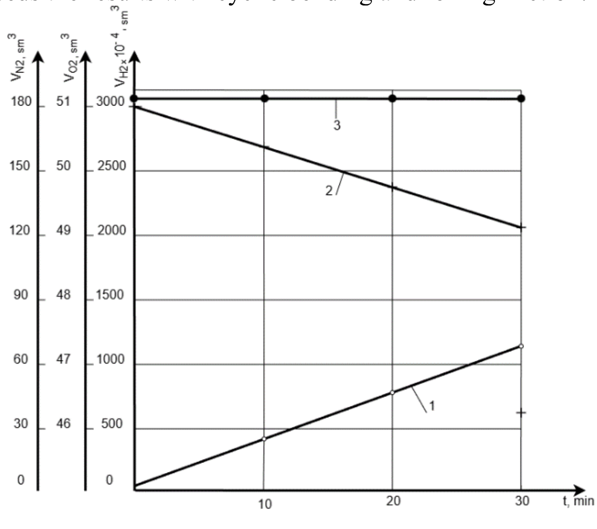


**Fig. 7. Kinetics of heterogeneous reactions under sliding friction (plane – plane, ShKh15 – ShKh15): 1 – hydrogen ( $H_2$ ); 2 – oxygen ($O_2$ ); 3 – nitrogen ( $N_2$ )**

If sliding friction mechanically removes solid compounds from the friction track topochemical interaction, which are relatively weakly connected to the surface, then during cutting the cutting edge of the tool cuts off the base metal layer with the products present on it, which leads to intensive plastic deformation of the juvenile surface and acceleration of tribochemical processes. At an angular velocity cutting $\omega$ = 28 s $^{-1}$ In 5 minutes of the experiment, 1200.0×10 -4 cm 3 of hydrogen was released and 114.0×10 -2 cm 3 of oxygen was consumed (Fig. 8). The kinetic dependence of topochemical reactions has an exponential form, which is due to the nature of the drilling process, namely, the increase in the contact area of the cutting tool with the sample, and therefore the increase in the intensity of plastic deformation of the metal as the drill is deepened.

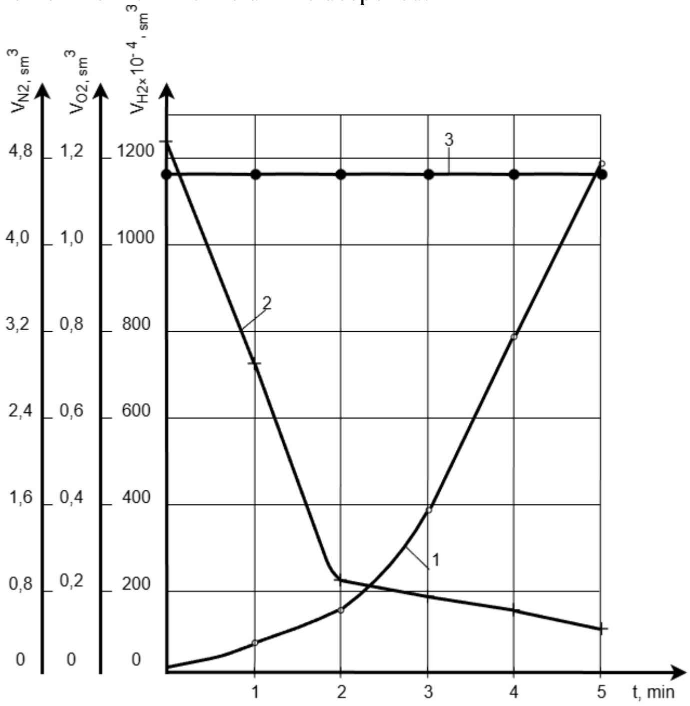


**Fig. 8. Kinetics of heterogeneous reactions during cutting (steel 45 – steel P6M5): 1 – hydrogen ( $H_2$ ); 2 – oxygen ($O_2$ ); 3 – nitrogen ( $N_2$ )**

More complete information about the features of topochemical reactions is provided by the analysis of the speed (cm 3 /s) of the processes of hydrogen evolution $(\upsilon_{H_2})$and oxygen absorption $(\upsilon_{O_2})$(Table 1). The intensity of chemical oxidation reactions initiated by mechanical loading of the metal increases in the following order: cyclic bending of the metal → rolling friction → sliding friction (plane-plane pair) → sliding friction (pair "3 balls-plane") → cutting. At the same time, the speed of the surface oxidation reaction by water vapor, which causes the release of hydrogen, increases by 222 times: from $\upsilon_{H_2} = 1{,}8 \times 10^{-6}$cm 3 /s during cyclic bending to $\upsilon_{H_2} = 400{,}0 \times 10^{-6}$cm 3 /s during cutting, and by oxygen by 16 times, respectively, from $\upsilon_{O_2} = 2{,}3 \times 10^{-4}$ cm 3 /s to $\upsilon_{O_2} = 38{,}0 \times 10^{-4}$cm 3 /s.

Table 1

**Influence of the type of metal deformation on the rate of hydrogen evolution $(\upsilon_{H_2})$, oxygen absorption $(\upsilon_{O_2})$and their ratio$(\upsilon_{H_2}/\upsilon_{O_2})$**

| Type of deformation | Speed, cm 3 /s | | The ratio of the rates of hydrogen evolution and oxygen absorption, $(\upsilon_{H_2}/\upsilon_{O_2})$ |
|---|---|---|---|
| | Selection hydrogen, $\upsilon_{H_2} \times 10^{-6}$ | Oxygen absorption, $\upsilon_{O_2} \times 10^{-4}$ | |
| Cyclic distillation | 1.8 | 2.3 | 0.0078 |
| Rolling friction | 7.3 | 1.6 | 0.0456 |
| Sliding friction pair: plane – plane | 65.0 | 10.3 | 0.0631 |
| Sliding friction pair: 3 balls – plane | 142.7 | 26.1 | 0.0547 |
| Cutting | 400.0 | 38.0 | 0.1053 |

The simultaneous presence of oxygen and water molecules in the air environment causes the emergence of a competing effect of metal oxidation on the active centers of the surface, which is subject to plastic deformation. An idea of the possible prevailing course of chemical reactions is indirectly given by the value of their activation energy [17]. Studies [18] have established that for the reaction of iron with water vapor, the calculated activation energy is 28±3 kJ /mol. This value is close to the activation energy of iron oxidation by oxygen (32±6 kJ /mol), which indicates a similar limiting step of the process, which consists in the exchange of metal atoms and adsorbed oxygen or water. With increasing temperature and thickness of the oxide film, the mechanism can change to diffusion or electric field-controlled. The energies of chemical bond breaking in the oxygen ($O_2$) and water ($H_2O$) molecules are similarly close , that is, splitting of the substance into free atoms , as a prerequisite for their activation to enter into chemical interaction with the metal, which is, respectively, 498 kJ / mol (O = O) and 463 kJ / mol (H - O) [19]. The proximity of both activation and dissociation energies indicates a comparable possibility and speed of the processes of metal oxidation by oxygen and water vapor and the expected preservation of the constancy of the ratio of their rates under stationary conditions.

An idea of the activation of characteristic oxidation reactions is given by the ratio of the rates of hydrogen release and oxygen absorption: $\upsilon_{H_2}/\upsilon_{O_2}$. The faster hydrogen is released, the more the metal is oxidized by water vapor, and, accordingly, the faster the oxygen present in the atmosphere is absorbed, the more intensively it oxidizes the metal. Analysis of the results obtained (Table 1) The ratio $\upsilon_{H_2}/\upsilon_{O_2}$of the rates of hydrogen release ($\upsilon_{H_2}$)and oxygen absorption ($\upsilon_{O_2}$)during dynamic plastic deformation of the metal indicates a significant differentiated influence of the supplied mechanical energy on the activation of chemical reactions of metal oxidation by water vapor and oxygen. The lowest value of the ratio $\upsilon_{H_2}/\upsilon_{O_2}$is observed at the least intense cyclic loading of the sample - cyclic bending and is 0.0078. With an increase in the intensity of the supplied mechanical energy and, accordingly, the plastic deformation of the metal, the ratio increases $\upsilon_{H_2}/\upsilon_{O_2}$: with rolling friction it is 0.0456, with sliding friction: for the pair "3 balls - plane" - 0.0547, for the pair plane - plane - 0.0631, with cutting - 0.1053. Thus, an increase in the ratio is observed $\upsilon_{H_2}/\upsilon_{O_2}$ by 13.5 times, which indicates the prevailing influence of the intensity of plastic deformation on the activation of the reaction of metal oxidation by water vapor, which is accompanied by the release of hydrogen.

In all cases of dynamic loading of steel, as shown by the research results (Fig. 4,5,6,7,8), the nitrogen content in the test chamber remains unchanged, which indicates its inertness in relation to the activated metal.

**Conclusions**

Installations and methods for studying heterogeneous chemical reactions in the process of plastic deformation of metals have been developed. The kinetics of the topochemical interaction of active air components initiated by plastic deformation of the metal have been established: during bending and rolling friction, there is a damped dependence, for sliding friction, both for an open pair (3 balls – plane) and a closed pair (plane – plane) – it is rectilinear, and during cutting – exponential. Regardless of the type of plastic deformation, the openness of the friction pair, the same type of topochemical reactions occur with the absorption of the reacting component – oxygen and the release of the interaction product – hydrogen, nitrogen is inert and does not participate in chemical processes. It was found that the intensity of topochemical reactions depends on the type of plastic deformation and increases in the order: cyclic bending of the metal → rolling friction → sliding friction (plane-plane pair) → sliding friction (pair "3 balls-plane") → cutting. At the same time, the rate of the surface oxidation reaction by water vapor, which causes the release of hydrogen, increases by 222 times, and by oxygen by 16 times. An indicator of the activation of characteristic oxidation reactions in the air environment depending on the type of plastic deformation is proposed: the ratio of the rates of hydrogen release and oxygen absorption - $\upsilon_{H_2}/\upsilon_{O_2}$. An increase in the ratio $\upsilon_{H_2}/\upsilon_{O_2}$in the revealed order of increasing the intensity of mechanochemical reactions from the type of plastic deformation by more than 13 times was established, which indicates the prevailing influence of the intensity of plastic deformation and substructural processes that occur in this case on the activation of the metal oxidation reaction by water vapor, which is accompanied by the release of hydrogen. The results revealed reveal the essence of the influence of metal deformation on the kinetics and nature of mechanochemical processes and the principles of regulating their intensity in order to ensure the increase in long-term strength and durability of machine parts.

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**Шевеля В.В., Олександренко В.П., Стечишин М.С., Соколан К.С., Федорів В.М., Нелюбін Ю.М.** Кінетика гетерогенних хімічних реакцій, ініційованих деформацією металів

Досліджено топохімічні процеси в середовищі повітря, які ініціюються пластичною деформацією металу різної інтенсивності та виду: циклічний перегин зразка, тертя кочення, тертя ковзання, різання. Встановлено, що в процесі циклічного навантаження металу відбувається зміна концентрації і складу компонентів повітря, яке знаходиться у випробувальній камері: зниження вмісту реагенту – молекулярного кисню та поява продукту взаємодії – водню. Виявлено вплив виду пластичної деформації металу та процесів, що при цьому відбуваються на кінетичні залежності топохімічних процесів: затухаючі, прямолінійні та експоненціальні. Встановлено залежність швидкості топохімічних процесів від інтенсивності пластичної деформації. Запропоновано показник оцінки конкуруючого ефекту окиснення металу на активних центрах поверхні, що піддається пластичній деформації. Отримані результати розкривають природу процесу тертя та зношування та шляхи підвищення довговічності вузлів тертя.

**Ключові слова**: топохімічні реакції, кінетика, швидкість, пластична деформація, інтенсивність, кисень, водень