RESEARCH NOTE

PREDICTION OF TRIBOCORROSION WEAR RATE

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Abstract Basic properties of the suggested phenomenological model of tribocorrosion wear are considered. Using a friction pair austenitic stainless steel-ceramic in acid electrolytes as an example, a good agreement between predicted data and experimental evidence was obtained.

Key Words Tribocorrosion, Wear Rate

چکیده دراین تحقیق خصوصیات اصلی مدل پیشنهادی عرضی برای سایش ناشی از خوردگی سطحی ارائه شده است. قراردادن زوج اصطکاک از جنس فولاد زنگ نزن آستنیتی-سرامیک در الکترولیتهای اسیدی برای نمونه توافق خوبی رابین اطلاعات پیش بینی شده و شواهد تجربی بدست داده است.

INTRODUCTION

The methods of formal kinetics were used in predictions of wear rate under dry friction and boundary lubrication [1].

Some theoretical and experimental aspects of the phenomena discussed in the reference are discussed and applied to the friction processes in acid aqueous electrolytes.

KINETIC MODEL

In Compliance with the concepts of formal chemical kinetics, out of the total number of atoms (N_0) per a surface unit the number of atoms capable of entering a reaction can be presented by the equation

$$N = \alpha N_0 \exp(-E^{\#} / RT) \qquad (1)$$

where α is the probability of finding an atom at a reactive center, which under friction can be assumed to be equal to the ratio between the actual (A_a) and the nominal (A_n) contact areas ($\alpha = KA_a/A_n$ and K is mutual cover coefficient). For a plastic contact we assume to the first approximation in accordance with [2]: $\alpha = 2K\beta P\rho/m\sigma$ where σ is yield stress of a softer material in the friction pair in acid electrolyte. Introducing a dimensionless factor **m**, we take into account sliding velocity and properties of the boundary lubricating layers of the medium taking up a part of the nominal pressure (P). Therefore, **m** is a complex factor other than constant, and β is a fraction of atoms of the component whose corrosion wear is being estimated, and $\rho = \sqrt{1 + 3f^2}$ [3], where **f** is friction coefficient. A fraction of particles having the energy sufficient to overcome a potencial barrier equal to an apparent activation energy ($E^{\#}$) of a feasible process amounts to $\exp(-E^{\#}/RT)$. Tribocorrosion wear under friction in electrolyte is one of the components of a total mechanocorrosive wear rate. When calculating a partial quantity of the tribocorrosion component, one must take into consideration interdependence between corrosion and mechanical factors. Mechanical energy dissipation shall obviously reduce the value of the apparent activation energy. This variation can be estimated using the concepts of kinetic theory of solid strength developed by S. N. Zhurcov [4].

The atom acquires, under the action of the force P, a complementary energy $E = \nu\gamma P$, where ν is activation volume, and γ is the fraction of stored energy.

In the case of activation by friction one can write for the stored energy of cold plastic deformation

$$E_f = \nu\gamma f P_a \tag{2}$$

where P_a is pressure on the acutal contact area. Taking relation $P_a = \sigma/\rho$ into account, the above expression can be formulated as:

$$E_f = \nu\gamma f \sigma/\rho \tag{3}$$

Investigation of electrochemical processes under friction has shown the quantity of steady-state potential under friction (φ_{sf}) to be as essential tribotechnical property as the friction coefficient and wear rate [5].

Surface atom energy is observed to increase under the electrochemical processes by the quantity

$$E_e = az\Delta\varphi F \tag{4}$$

where **a** is a transfer number (equal to 0.5), **z** is electron quantity, $\Delta\varphi$ is potential difference, **F** is faraday.

Taking into account the above mentioned points, as well as the fact that fraction of the surface atoms being potentially ready to participate in the process will amount to N/N_0 and, as applied to tribocorrosion processes, will be equal to the tribocorrosion wear rate, Equation 1 will take the form of:

$$J = N/N_0 = (2\beta K P\rho/m\sigma)\exp[-(E^{\#}_0 - \nu\gamma f\sigma/\rho - az\Delta\varphi)/RT] \tag{5}$$

where $E^{\#}_0$ is apparent activation energy of corrosion under static conditions. Analysis of Equation 5 has shown that it is necessary to define some of the parameters included. That is why at the first stage of investigation, values of σ, $E^{\#}_0$ and ν were determined. At the second stage the tribotechnical investigation was carried out.

EXPERIMENTAL METHODS

The effect of medium acidity on yield stress was determined on a mechanical testing device. A wire sample was put into a glass test tube whose bottom was plugged with acid-resistant rubber. One end of the wire was put through the plug and fixed in the lower clamp of the testing device. A model medium was poured into the test tube and then the top end of the wire was fixed. Wire samples of 18/10 steel 0.31mm in diameter were used. The rate of deformation was 5% per minute. To determine the apparent activation energy of $E^{\#}_0$, the dependence of the rate of dissolving due to the medium temperature was investigated. The steel-dissolving investigation was carried out by the ohmic method, with control of the change of the electric resistance of the wire sample, occurring in the process of corrosive dissolving. To calculate the apparent energy of activation of the corrosion process, the experimental data were presented in Arrhenius coordinates.

The quantities of ν can be estimated from the value of stored energy in the process of plastic deformation [6]. Tribotechnical investigation was carried out using a facility allowing the estimation of friction coefficient, self-diffusion currents electrode potential under friction and at rest. Total wear was determined by the weight method, and by spectral analysis of a lubricating medium using standard methods enabling one to execute control over dissolution of the components of an alloy. The measured values of tribocorrosion current allow estimation of the value of tribocorrosion component of total wear rate using the equation

$$J = iKM / \eta A_n vF \qquad (6)$$

where M is gramm-equivalent weight of alloy component metal, and η is alloy density.

Wear investigation was performed within the pressure range of 0.2-1.0 MPa and under velocity of 0.01-1 m/sec. The investigation object, was a friction pair: austenitic stainless steel 18/10 -5 mm diameter ceramic indenter with grain dimension of 50 mkm. Ring-shaped steel specimen was cut out of 0.1mm thickness foil and placed in a thermostatically held glass cell of the test facility. The steel specimen surfaces not engaged in friction were coated with an acid resistant lacquer. 0.1N H_2SO_4 was used as a lubricating medium.

RESULTS AND DISCUSSION

The experimental data obtained in the first stage of the investigation and presented below testify to a considerable effect of acidity on the parameters of Equation 5.

σ, MPa	$E^{\#}_0$, kJ/mol
300	71,4

Thus, the decrease of the yield stress in acid media in comparison with the value, determined in the open air at the same temperature, is 30%.

Calculated value of the activation volume for austenitic steel used in experiments amounted to $\nu = 3.3 \times 10^{-3}$ m^3/mol.

At the second stage the influence of loads velocities on the coefficient of friction, electrode potential, and tribocorrosion wear rate was investigated.

Dependence of the tribocorrosion wear rate on temperature is a most informative dependence, so it allows to trace the influence of wear conditions on pre-exponent and the exponental parts of Equation 5.

In order to define apparent activation energy of tribocorrosion, temperature influence on the tribocorrosion wear rate was investigated. The results given in Arrhenius coordinates, in Figure. 1, allow one to draw the following conclusions: the value of the pre-exponent depends linearly on pressure; pressure variation (by a factor of 5) brings about no pronounced change in the apparent activation energy; and decrease of friction coefficient is observed simultaneously with the tribocorrosion wear rate reduction.

The results obtained are in agreement with the kinetic model suggesteds in Equation 5. Variation of the friction coefficients and tribocorrosion wear rates for v= 0.01m/sec are given in Table 1.

Treatment of data made it possible to assume for the coefficient **m** the following expression relating its value with the coefficient of friction: **m** = 2.87/f over the velocity and load range considered. Analysis of

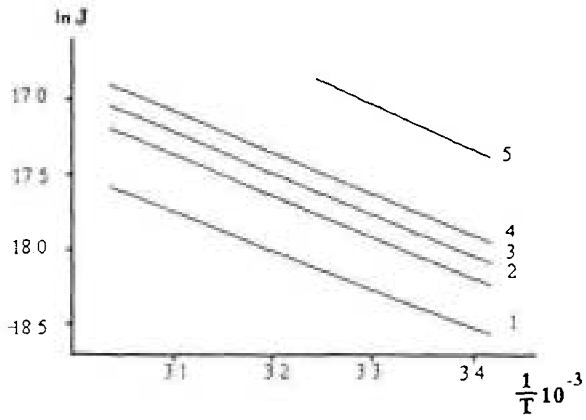

Figure 1. Arrehenius diagram of temperature dependence of tribocorrosion wear rate under different pressures (MPa): 1-0.2; 2-0.4; 3-0.6; 4-0.8; 5-1; v = 0.01 m/sec.

TABLE 1. Variation of the Friction Coefficients and Tribocorrosion Wear Rates for v= 0.01 m/sec.

P, MPa	0.2	0.4	0.6	0.8	1.0
f	0.34	0.32	0.29	0.26	0.24
J(experim)	6.0×10^{-9}	5.4×10^{-9}	5.1×10^{-9}	4.4×10^{-9}	4.0×10^{-9}
J(predict)	5.9×10^{-9}	5.5×10^{-9}	4.9×10^{-9}	4.5×10^{-9}	3.9×10^{-9}

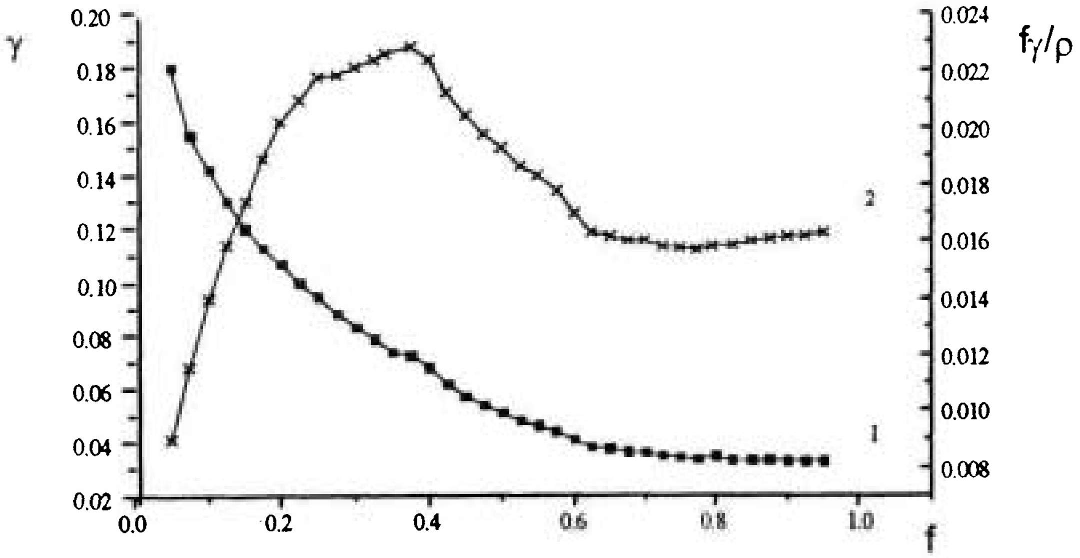

Figure 2. Dependence of the parameter of equation $E_f = v\sigma f\gamma/\rho$ on friction coefficient: 1-γ, 2-fγ/ρ.

the data obtained has shown that the amount of the stored energy of cold plastic deformation at friction (E_s) is the determining factor for exponential part of Equaiton 5. Calculations have shown that γ is a function of coefficient of friction (Figure 2). The dependence of γf/ρ on f (Figure 2, curve 2) has a noticeably expressed maximum for friction coefficient, undergoing changes within the interval of 0.35-0.4. With the decrease of friction coefficient from 0.34 to 0.24 the volume of the stored energy of friction decreases by 3kJ/mol and correspondingly the apparent activation energy increases by the same amount.

experimental results to be within the range of experimental error.

CONCLUSIONS

Good agreement between predicted and experimental results testifies to the conceptual validity of the approach suggested over the pressure and sliding velocity range studied. Allowance for the interdependence between tribotechnical characteristics, friction triad component properties, yield stress, stored energy and electrod potential inherent in the model allows us to improve the wear [illegible] and the directions of further investigations.

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