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Behaviour of nitriding layers for condition of small amplitude fretting

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Properties

ABSTRACT

Purpose: It was explored fretting resistance titanic alloy VT3-1 (Ti-Al6-Cr2-Mo2,5) after low temperature ionic nitriding in unhydrogen environment.

Design/methodology/approach: Small amplitude fretting was initiated by the dynamic contact of ball and flat in the regime of the partial slip on edge of spot of contact. A method differs by simplicity and express determination of fretting resistance, namely areas of destruction by action of fretting for part nominally fixed contact - how the functions of cycles of loading.

Findings: As a result of fretting the central region of sticking decreasing, and the edge of areas of fretting are increasing.

Practical implications: The method of initiation of small amplitude fretting within bounds of preliminary displacement is offered. On the offered method the destruction of titanic alloys is explored at fretting and influencing of ionic nitriding on fretting. By a computation method the work of forces of friction in the area of wear, which in 5..6 times is less for nitriding titanic alloys, is appraised.

Originality/value: A method allows defining reactionary power of nitriding layers for small amplitude fretting.

Keywords: Mechanical properties; Titanic alloy; Jonic nitriding; Fretting, Stick-slip.

1. Introduction

From all kinds Chemical Thermal Processing for titan and his alloys nitriding is regime perspective. At nitriding on the surface of tribopart thin nitriding layers appear thickness 5.20 mkm, with middle microhardness 1500 MPa and enriched by nitrogen hard solution on the basis of α-phase. The thickness of enriched by nitrogen layer achieves 0,1….0,15 mm, his microhardness arrives at 700.900 MPa [6]. The temperature of nitriding must not exceed 980^{0}C, as at more high temperatures the fragility of superficial layer increases rarely. And here the temperature of nitriding must not be below 550^{0}C, as speed of diffusion of nitrogen in titan strongly diminishes here. The increase of hardness of nitriding layer is related to the increase of closeness of distributions. The rise of dispersion of nitriding in an nitriding layer is the result of increase of quantity of centres of formation of nitriding excretions at nitriding which is instrumental in the rise of imperfectness of structure of material [5]. A layer adjoining to the basis has a characteristic the columnar structure, and an outward wearproof layer is continuous. Such structure allows in the process of fretting redistributing stretching tensions and hinders to grasping of the attended surfaces at considerable contact tensions.

2. Experimental

For researches by us the standards from an α+β alloy Ti-Al6-Cr2-Mo2,5 were used. Ionic nitriding was conducted after different regimes [1], the technological parameters of process were varied in such scopes: temperature (T^0 C) within the limits of 540 – 700^0 C, pressure (P, Pa) - 80- 400 Pa, time (min) - 20-240 min, maintenance of argon (Ar %) - 0-96 %. Researches of frettingresistance titanic alloy Ti-Al6-Cr2-Mo2,5 were conducted on the special options which are described in work [1].

Regimes of researches for fretting: a) number of cycles of loading-$15\cdot10^3 \ldots 2\cdot10^6$; b) initial pressure in the area of contact is 10 MPa; c) frequency of vibrations 100 Hz.

The X-ray diffraction measurement on Ti-Al6-Cr2-Mo2,5 was conducted on DRON-3M-3M in the CoK$_\alpha$ radiation, on the chart of θ-2θ in the interval of corners of 30°-100° with the step of 0,05° and display 2 sec. On to the results of X-ray method also was definitely thickness of coverage. A method consists in measuring of intensity of x-ray diffraction beaten back from a standard with coverage and without coverage. Computation of thickness of coverage was conducted after a formula [4]:

$$h = \left(\frac{\sin\theta}{2\mu}\right)\cdot\left(\ln\frac{I_{non\ coating}}{I_{coating}}\right) \qquad (1)$$

where μ - linear coefficient of weakening of x-rays; $I_{noncoating}$ – intensity of the regent rays beaten back from the surface of standard without coverage; I_{coting} - intensity of regent rays, that passed through the layer of coverage; q - corner of diffraction on a diffraction picture from a standard without coverage.

Table 1.
Regime of ionic nitriding

№	T^{0}C	P, Pa	τ,min	%,Ar
1	660	320	185	72
2	580	320	185	72

The two-dimensional direction illustrated in Fig.1 for elastic bodies: ball with diameter 12 mm and flat. The scheme of plant for a research of frictional contact in conditions of fretting represented in a Fig. 2. On an elastic beam with a sufficient rigidity in a tangential direction ($2\cdot10^6$ H/m) the flat specimen 3 is placed. The ball 2 is fixed on vibrator 1 electromagnetic type.. The displacement of each element of contact pair is check by through indicators (6, 7) inductive type, which probes are rigidly fixed. It excludes inertia micro impacts between a probe of the gauge and checking body. The normal load in contact formed by an elastic element 4 with the help of rotations of the screw 5. Visual monitoring for oscillations and the digital information processing was made because of software product, developed by us, Dual ADC [2].

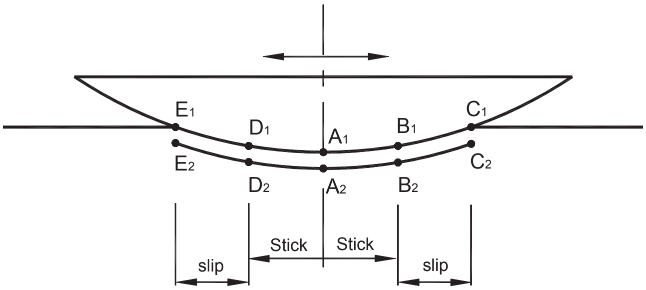

Fig. 1. Schematic of two - dimensional stick-slip contact between ball and flat subject to an oscillating tangentional motion

Optic research carry out on microscope MIM-10 and measurements of geometric parameters of contact on tool microscope IMC-10. Contrspeciment is ball-beating steel by a diameter 12 mm.

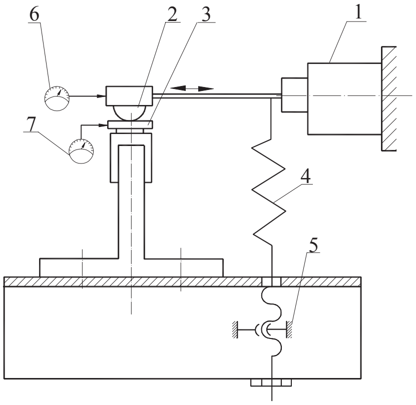

Fig. 2. The scheme of plant for a research of frictional contact in conditions fretting

3. Results and discussion

X- ray researches showed that as a result of low temperature ionic nitriding in a non-water environment, TiN (δ -phase) and mono nitride appears on the surface of titanic alloy Ti-Al6-Cr2-Mo2,5 - phase Ti$_2$N. On the basis of data about the change of intensity of x-ray photography data depending on the mode of ionic nitriding with the use of formula (1) was counted up thickness of coverage. Dependence of influencing of technological parameters of ionic nitriding on the thickness of coverage of titanic alloy Ti-Al6-Cr2-Mo2,5 is presented on Fig. 3.

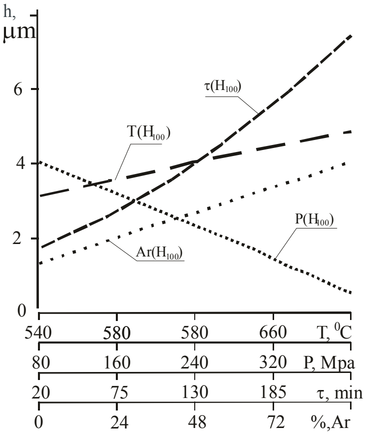

Fig. 3. Influence of technological parameters of ionic nitriding on the thickness of coverage of titanic alloy Ti-Al6-Cr2-Mo2,5

During ionic nitriding of titanic alloy on a surface a nitriding layer appears instantly, that results in complication of formation of greater depth of the modified layer. Titan is strong nitrideforming, therefore and such speed of formation of nitriding layer which is characteristics blocking effect is explained. Only, application of mixture with low maintenance of nitrogen, it is possible to get considerable thickness of the modified layers. What the graph on rice testifies about Fig. 3, where it is visible, that only from the increase of argon in the gas mixture of nitrogen with an argon the thickness of nitriding coverage grows.

Definite part in hardening of titanic alloys is acted by education on the surface of connections of type of hard solution of oxygen in titan. The process of destruction of spot of contact has a fatigue character in the central area of contact and relative on edges (Fig 4,5). At the identical terms of the dynamic loading the geometrical parameters of destruction of contact will rely on the modes of nitriding.

On the fig. 5 kinetics of change of geometrical parameters of spot of contact is shown, namely attitudes of stick area to grounds of contact. The mode 1 shows itself to most resistance to the fretting on the edges of ground of contact.

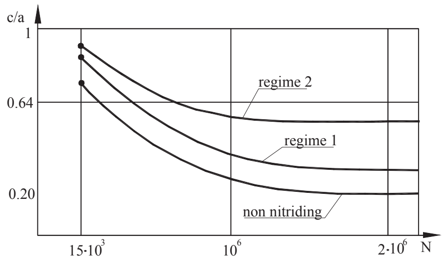

Fig. 5 Changes of rate of stick area to the spot of contact depending on the number cycles of fretting

4. Calculation of energy friction for slip area

The relation of difference of points of contact in directions of axeses *x* and *y* a little also is possible to neglect displacements in a vertical direction [4]:

$$\nu/(4-2\nu)\approx 0{,}09 \qquad (2)$$

where ν - Poisson's constant.

Magnitude slip in a ring $c \le r \le a$ we determined from the equation:

$$s=\frac{3\mu P}{16Ga}(2-\nu)\times$$
$$\times\left[\left(1-\frac{2}{\pi}\arcsin\frac{c}{r}\right)\left(1-2\frac{c}{r}\right)+\frac{2c}{\pi r}\left(1-\frac{c^2}{r^2}\right)^{1/2}\right] \qquad (3)$$

where μ -coefficient of friction,

P – normal force,
G – shear module,
c – radius of stick zone,
a – radius of contact area

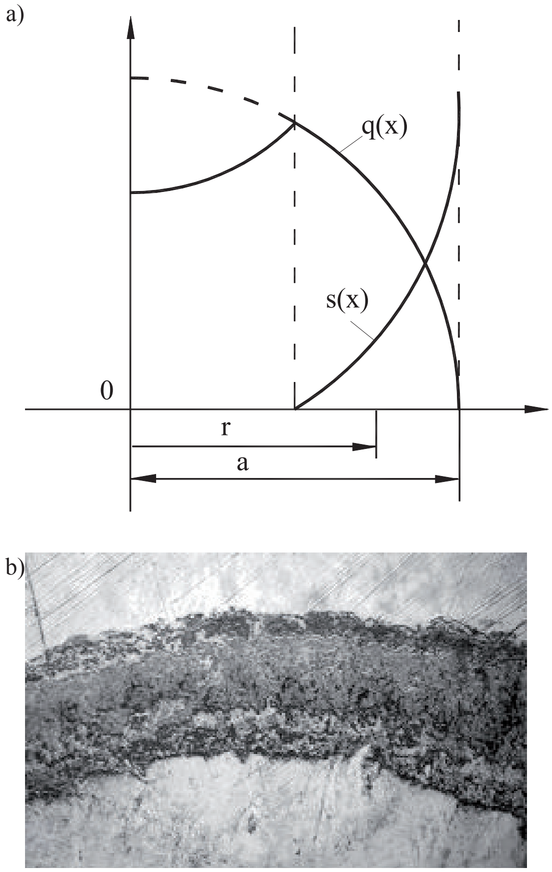

Fig. 4. A configuration of tangential stress and relative displacements in a zone slip (a). Structures of a zone slip in a result of small amplitude fretting (b)

where μ -coefficient of friction,

P – normal force,
G – shear module,
c – radius of stick zone,
a – radius of contact area

Relative tangential displacement [4]:

$$\delta_x=\frac{3\mu P}{16a}\left(\frac{2-\nu_1}{G_1}+\frac{2-\nu_2}{G_2}\right)\left[1-\left(1-\frac{Q_x}{\mu P}\right)^{2/3}\right] \qquad (4)$$

where , Q_x – tangential force

Dissipation of energy for a cycle of oscillations:

$$\Delta W=\frac{9\mu^2P_0^2}{16a}\left(\frac{2-\nu_1}{G_1}+\frac{2-\nu_2}{G_2}\right)\times$$
$$\times\left\{1-\left(\frac{Q}{\mu P}\right)^{5/3}-\frac{5Q}{\mu P_0}\left[1-\left(1-\frac{Q}{\mu P_0}\right)^{2/3}\right]\right\} \qquad (5)$$

where, Q – maximum tangentional force

G_1,G_2 - shear module

Settlement dependence of magnitude of slip˙ of area $c \le r \le a$ depending on coefficient of friction is shown in a Fig. 4. Significance of a breadth of a ring zone and normal gain are taken from experiment. It is visible, that maximum slip takes place on the boundary of area of contact and their magnitude small enough.

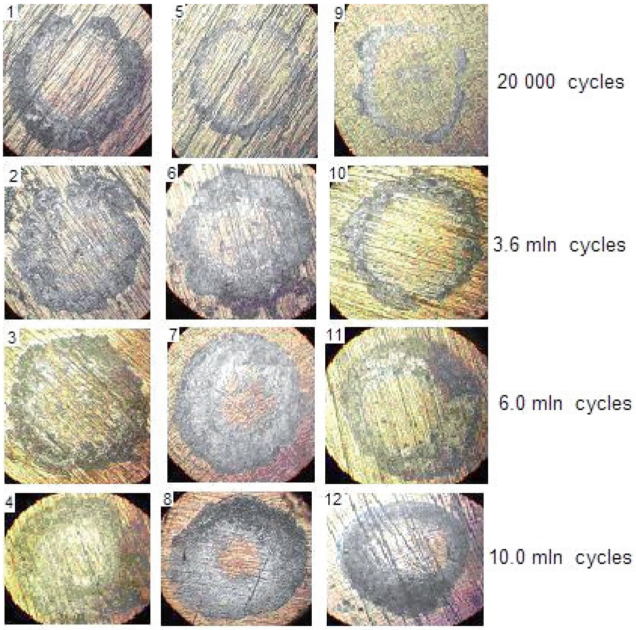

Fig. 5. Evolution of contact ball-plane in the conditions of smallamplitude fretting. (1-4, non nitriding alloy, 5-8, nitriding on the mode №1, 9-12, nitriding on the mode №2)

Distribution of tangential stress, at condition of absence slip for only in two points of a ring zone in the (beginning and the end contact) extremity is determined from a ratio:

$$q = \mu P_0 \left(1 - \frac{r^2}{a^2}\right)^{1/2} = \mu \frac{2P}{\pi a}\left(1 - \frac{r^2}{a^2}\right)^{1/2} \tag{6}$$

Significance P and radius of contact taken from experiment. By such, the work of forces of friction in slip area is described by a configuration of two associations q(x) and s(x) (Fig. 6).

On the Fig. 6 specific work of forces of friction is shown in area of slip which is calculated on a formula:

$$\int_c^a q(x)s(x)dx \tag{7}$$

where $q(x)$ - distributing of tangential efforts in area of sliding

$s(x)$ - relative sliding on the region of sliding.

The change of physicist-mechanical properties of not nitriding surface was following: module of the G change = $0{,}44{\cdot}10^{10}$ Pa, coefficient of friction 0,6, the scopes of integration are taken from the experiment at 107 cycles of loading. For the mode of a 1 increase G it is accepted 20 %, reduction of coefficient of friction to 0,4. For the mode 2 10 % and 0,5.

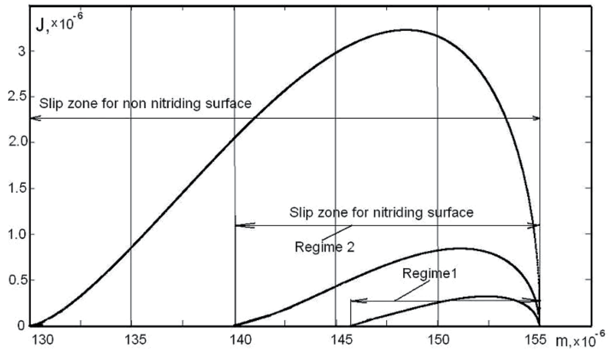

Fig. 6. Computation work of friction in area of slip of titanic alloys to the ambassador of 10^7 cycles of loading

4. Conclusions

1. The method of initiation of smallamplitude fretting within bounds of preliminary displacement is offered.
2. On the offered method the destruction of titanic alloys is explored at fretting and influencing of ionic nitriding on fretting.
3. By a computation method the work of forces of friction in the area of wear, which in 5..6 times is less for nitriding titanic alloys, is appraised.

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