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TRIBOLOGICAL PROPERTIES OF HIGH NITROGEN STEELS AFTER HYDROGENATION

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Summary. The articles has presents the results and original experimentals data of wear resistance of high nitrogen steels after hydrogenation. The results of tribological tests revealed that the size of the wear products after hydrogenation are much higher, than before the hydrogenation of samples (linear sizes has differed in 5 - 6 times).

Key words: hydrogen resistance, high nitrogen steels, wear products.

INTRODUCTION

The operational stability of the industrial equipment is determined by the intensity of deterioration of the interfaced surfaces, and up to 80 % of refusals of machines and mechanisms occur became of to fracture of materials in friction units [1, 2]. High nitrogen steels are the perspective materials as a hydrogen resistant materials, including in the friction conditions. The problem of hydrogen wear up to this time still is not complete investigated, but some data it is possible to find in the papers [1 –8]. Hydrogen embrittlement is the process by which various metals (including high-strength steel) become brittle up to fracture due to exposition in hydrogen. The mechanism of this phenomenon based on the diffusion of hydrogen atoms through the metal. At high temperatures, the elevated solubility of hydrogen allows hydrogen to diffuse into the metal (or the hydrogen can diffuse in at a low temperature, assisted by a concentration gradient). When these hydrogen atoms re-combine in minuscule voids of the metal matrix to form hydrogen molecules, they create pressure from inside. This pressure can increase to levels where the metal has reduced ductility and tensile strength up to the cracks initiation (*hydrogen induced cracking*, or HIC). High-strength and low-alloy steels, nickel and titanium alloys are also susceptible to hydrogen [3]. The purpose of the work is to analysed literary sources devoted hydrogen resistant steels and investigated the wear products after hydrogenation.

EXPERIMENTAL PROCEDURE

The wear resistance was measured on SMT-1(2070) friction machine according the roller-shoe scheme under the conditions of boundary and dry friction. As the counterbody, we used a roller made of steel 1.0503 (VSG) equivalent of 45 hardened steel with a hardness of 55…60 HRC and stainless steel (with Cr = 11...15 %).

Hydrogenation of alloys was carried out at a current from 50 to 100 A/m^2 in a solution of sulfuric acid (26% H_2SO_4).

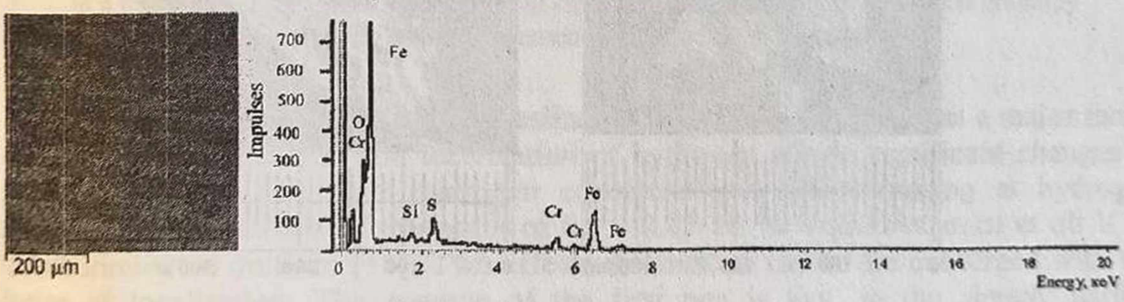
The wear products were studied with a Neophot-2 microscope by treating the images of a Canon EOS 30D digital camera on a personal computer, and friction surfaces were examined with an EVO-40XVP electron microscope with an INCA Energy 350 system of X-ray microanalysis. The wear products of high-nitrogen austenitic steels and steel 45 were separated with a permanent magnet.

Table 1. **Chemical Compositions of Steels and Alloys (wt. %)**

Num.	Grade	C	Cr	Mn	Si	Ni	V	Si	Mo	V	N
1.	Alloy No. 1 (DDT 68)	0.06	17.5	19.4	0.52	0.13	0.14	0.52	2.08	0.14	0.97

RESULTS AND DISCUSSIONS

The surface layers of manganese steel and stainless steel are destroyed as a result of microcracking (fig.1) and separation of fragments of the material.



a b

Fig. 1. Friction surfaces of stainless steel (counter-body (a roller)) under the normal friction conditions (a). EDX – spectra of fracture surfaces of stainless steel (b)

The appearance of wear products is quite diverse, which provides evidence of different characters of fracture of the investigated materials and, correspondingly, of their different wear rates. Subsequent experiments with these samples (with increasing of time after hydrogenation), the wear rate is reduced (probably due to the two factors: the changing the characteristics of samples and decreasig the amount of hydrogen in the surface layer of the alloy). It was established that if the loading increases, the sizes of the wear products has increased. For non hydrogenated samples there are 25…40 µm (load 400 N), 25…100 µm (load 500 N). For the hydrogenated samples size of particles are from 350 μm (with loadig 250 N) up to 600 microns (with loading 400 N). The morphology of the wear products has shown the significant difference in the intensity of appearance of wear particles of hydrogenated and not hydrogenated alloys.

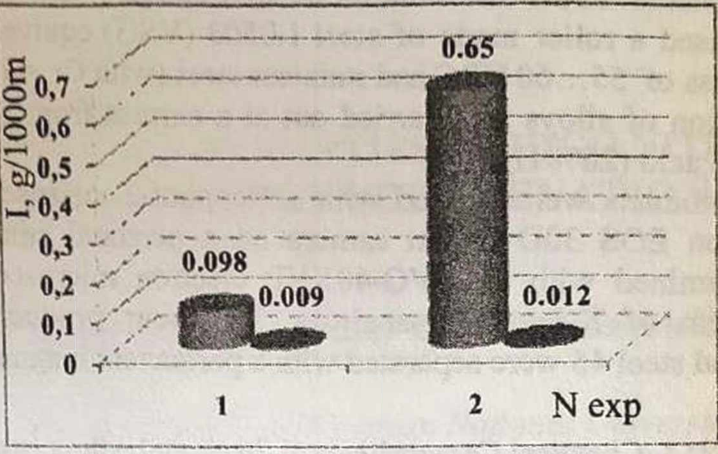


Fig. 2. Wear of alloys under conditions of dry friction under a load $P = 450$ N ((1) (alloy No. 1 is steel 1,0503); (2) (alloy No. 1 is stainless steel) (immediately after hydrogenation)

The results of tribological tests revealed that the sizes of the wear products after hydrogenation are much higher than before the hydrogenation of samples (linear sizes increased in 5 - 6 times) [2].

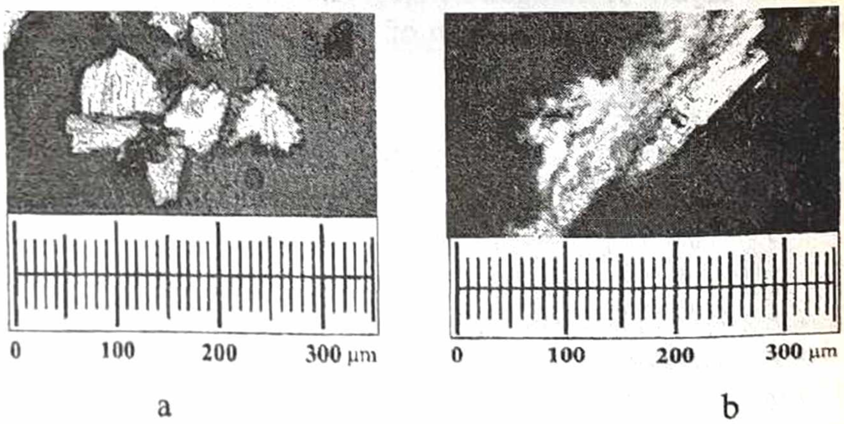
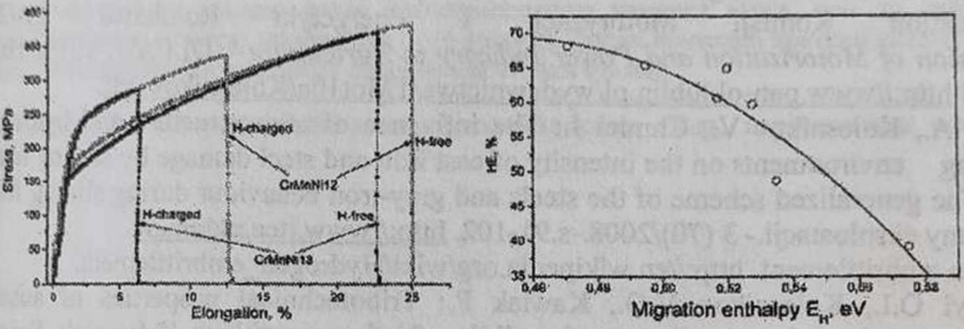


Fig. 3. Wear products: a) before hydrogenation; b) after hydrogenation

Taking into account the general laws of fracture of alloys (and taking into account the average statistical sizes of wear products), applying the methods of mathematical statistics, we established the general structural-energetic criteria describing the relation of fracture intensity with the parameters of structural-phase composition and the sizes of wear products with regard for the external friction parameters (slip velocity and load) [4 -6].

The problem of hydrogen resistance of steels is complicated, some data it is possible to find in the papers [1 -9]. In the [10] has proposed to develop the new engineering materials for long term service in hydrogenating environments. The approach is based on the electronic concept of hydrogen embrittlement (HE), studies of atomic interaction between hydrogen and alloying elements in steel and the effect of alloying elements on hydrogen migration, hydrogen-induced phase transformations and mechanical properties of hydrogenated steels. It is shown that a reason for HE is the hydrogen-caused increase in the concentration of free electrons leading to a striking decrease of the shear module, which results in a strongly modified mechanism of plastic deformation leading to pseudo-brittle fracture.

The developed concept is applicable for all non hydride-forming metals. The knowledge of optimal chemical compositions of hydrogen-resistant austenitic steels is obtained from the studies of Me-H bonding energies in the solid solution, mobility of dislocations, hydrogen migration enthalpy and hydrogen-induced phase transformations in relation to mechanical properties.



a *b*

Fig. 4. Stress-strain curve of hydrogen-free and hydrogen-charged steels. Effect of Ni in a model steel (*a*); effect of chemical composition on hydrogen migration enthalpy and hydrogen embrittlement of austenitic steels (*b*) [10]

The tendency of hydrogen to localization should be considered as a major factor of hydrogen degradation. The localization of hydrogen allows significant changes in materials even at very low hydrogen concentrations. Effects arising at hydrogen concentrations in metals of the order of 0.1 - 0.01 at. % would not exist at all if its distribution were uniform [11]. Two effects different in nature are concerned with the factor of localization. The essence of the first one is that, in the already perfect crystalline lattice of metal, the presence of clusters [12, 13] in the form of a nearly periodic lattice of the protonic subsystem (electrons of hydrogen and the metal are collective), which is "dipped" into the lattice of the metal and has a lattice constant of order nearly identical to that of the metal [13], is more favorable in terms of energy rather than the uniform distribution of the dissolved hydrogen. This means that the atomic concentration of hydrogen in these regions of the phase enriched in hydrogen approaches 100%. This effect depends on the electron density of the metal and on temperature, since clusters become unstable and resolve at temperatures of about 500 K, i.e., when the effects of hydrogen embrittlement of metals disappear.

The other effect of hydrogen localization is its segregation in defects of the crystalline structure [14, 15, 16]. The importance of this effect for the behavior of materials is attributable to the fact that, on the one hand, it is structural defects, their structure, and properties that determine the properties of materials [11].

CONCLUSIONS

In the absence of hydrogenation, the sizes of wear products has range from 25 to 40 μm under $P = 400$ N and from 40 to 100 μm under $P = 500$ N. For hydrogenated specimens, the sizes of wear products are above 350 μm under a load $P = 250$ N and range from 600 to 1000 μm under $P = 400$ N. The surface layers of manganese steel and stainless steel are destroyed as a result of microcracking and separation of fragments of the material.

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ИССЛЕДОВАНИЕ ТРИБОТЕХНИЧЕСКИХ СВОЙСТВ ВЫСОКОАЗОТИСТЫХ СТАЛЕЙ ПОСЛЕ НАВОДОРАЖИВАНИЯ

Валерий Колесников, Александр Балицкий, Яцек Елиаш

Аннотация. Статья посвящена экспериментальным данным триботехнических свойств высокоазотистых сталей после наводораживания. Результаты трибологических испытаний выявили, что размер продукции одежды после наводораживания намного выше, чем до наводораживания образцов (линейные размеры отличаются 5 - 6 разами). Также приведен краткий анализ литературных и интернет источников посвященных водородной стойки сталей.

Ключевые слова: водородстойкая сталь, высокоазотистая сталь, нержавеющая сталь, продукты износа.