# INVESTIGATION OF THE WEAR PRODUCTS OF HIGH- NITROGEN STEEL AFTER HYDROGENATION

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**Summary.** Assumptions are made about the mechanisms of destruction of these alloys in terms of friction and degradation of the material under the action of hydrogen. The studies wear products of high nitrogen steels.

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

## INTRODUCTION

High nitrogen steels have high physical and mechanical properties ( $\sigma_{\rm B} = 1800$  ...

2000 MPa,  $K_{IC} \ge 500$  MPa  $\sqrt{m}$ ). Due to this they are widely used in railway transportation, construction, marine engineering, and medicine. However, their spheres of usage has not yet been exhausted. One of the most promising directions for their use is hydrogen power. It is possible that such materials will have to work in conditions of friction and hydrogen environments [1]. There is some data [2] that a high nitrogen steels have increased resistance to hydrogen compared with other materials.

It is [2] show in the work that among the materials studied most sluggish steel to hydrogen is of high-tensile strength steel with 900 MPa and ductility 60%, which it keeps in an environment of hydrogen up to T = 650 K. It is noted that for high hydrogen resistance it is necessary to avoid the appearance of nitrides.

Now, with the development of new technology, the requirements for materials of parts for the manufacture of friction is constantly being tightened It is possible that a significant number of them will work in conditions of hydrogen wear.

High nitrogen steels with high manganese content can be used as tribotechnical materials [1], and, hence, elucidation of the mechanism of their fracture under friction conditions is a timely problem [3, 4]. Researchers devote much attention to wear products since their parameters contain important information on the nature and intensity of this process.

## **RESEARCH OBJECT**

The wear resistance was measured in an 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 (Germany) equivalent of 45 hardened steel with a hardness of 55..60 HRC.

Hydrogenation of alloys was carried out at a current of 0.5 A per  $cm^2$  in a solution of sulfuric acid.

Metallographic studies were carried (wp wear products) on the microscope Neophot 2, connect to laptop and digital camera Canon EOS 30D.

The surface friction was studied on an electron microscope EVO-40XVP microanalysis system INCA Energy 350.

## **RESULTS OF EXPERIMENTAL RESEARCH**

Found that hydrogenated steel wear is in 5 times stronger than wear of not hydrogenated. The outward appearance of wear products is quite diverse, which provides evidence of different characters of fracture of the materials under study and, correspondingly, of their different wear rates. Subsequent experiments with these samples (with increasing time after hydrogenation), the wear rate is reduced (probably due to two factors: the running-in of samples and decrease the amount of hydrogen in the surface layer of the alloy). It is stated that the more loading increases, the more size of the wear products increases. For not hydrogenated samples it is  $25...40 \,\mu$ m (load 400 N),  $25...100 \,\mu$ m (load 500 N). For the hydrogenated samples size of particles is  $350 \,\mu$ m (with a load of  $250 \,$ N), 600 microns (load 400 N). The morphology of the wear products is analyzed and described. Noted a significant difference in the appearance of wear particles of hydrogenated and not hydrogenated alloys (Fig1).

The results of tribological tests revealed that the size of the wear products after hydrogenation is much higher than before the hydrogenation of samples (Linear sizes differ in 5 - 6 times) (Fig. 1).

From Fig. 1 shows that after hydrogenation the appearance of the wear products is significantly different from not hydrogenated wear products. Wear products are separated in terms of friction as a rolling and sliding, have significant pockets of seizure and failure rate, compared with the products of wear, which separated from not hydrogenated samples.

Fig. 1.a Arabic number 1 notes the surface which has a stepped microrelief, 2 - zone subjected to intense heat seizure, 3 - crack in the surface wear particle.

It is show on Fig. 1 b wear particles do not have such intense foci of damage. They are characterized by a stepped microrelief - corresponding to fragile fracture of a particle I, the arrow 1, and the flat surface of a particle III the arrow 4. Assumptions are made about the mechanisms of destruction of these alloys in terms of friction and degradation of the material under the action of hydrogen.



Fig. 1. Wear products: a) after hydrogenation; b) before hydrogenation

Atomic hydrogen has a very active and penetrating ability. It directs into the space between the metal crystal enters into chemical reactions with its atoms and forms a fragile compound hydrides. It means that, the crystalline grain of the metal on its borders "becomes fragile" and loses strength, which leads to accelerated wear. Simultaneously, atomic hydrogen is stored in the intergranular space of the metal and transformes into molecular hydrogen. The result is high pressure, which "tear" metal forming microcracks. It destruction (fracture) of oil atomic hydrogen is released, which it penetrates into the surface and subsurface layers of metal. And because the metal is already atomic hydrogen, is it's a glut. Atomic hydrogen reacts with metal what forms between the crystals of the metal fragile compounds (hydrides), what leads to a decrease in the strength of the crystal lattice of the metal. Accumulating in microcavities of metal (micropores, defects in casting, embryonic microcracks), hydrogen atoms combine into molecules, forming gas (H<sub>2</sub>), creating superfluous pressure inside the micro.

As a result, metal which lost it is strength under the influence of hydrogen pressure from inside and the forces of friction from outside is easily destroyed, this means that upper layer of metal gradually separates from its surface [3].

In the hydrogenated sample, the dislocation density is much higher with a trend towards the concentration of strain at the grain boundaries [5].

To study the distribution of deformation in micro-volumes of the metal used metallographic etching method is used, which reveals the exit of "fresh", the newly formed dislocations on the surface of the sample [6].

Solubility of hydrogen in austenite is in several times higher than in martensite. In addition, diffusion mobility in it is lower. Austenite is a kind of hydrogen battery [5].

The shape of wear products themselves corresponds to the mechanisms that are realized in the course of friction [7]. The particles have a plate-like shape in the case of normal wear and the shape of a microchip for abrasive wear, whereas rounded or even spherical particles correspond to the mechanisms of fatigue fracture [8]. However, this classification for heterogeneous alloys is quite conditional because the wear particles can be more diverse due to a complex structure and numerous factors affecting fracture under these conditions. Kragel'skii [9] emphasizes that one should carefully interpret

conclusions concerning the mechanism of fracture based on analyzing wear particles since the substance being destroyed is not equivalent to the substance becoming a wear particle.

Based on the results of electron microscopic investigations, the following types of main wear particles were indicated in [10]: The first type consists of particles in the form of diminutive spirals, loops, and bent wire, which are similar to small chips in the course of cutting. This type is characteristic of microcutting or abrasive wear. An increase in the concentration of such particles in an oil sample provides evidence of early damage of the ma- chine. The second type (plate-like particles of different thicknesses) is typical of normal service conditions. According to the wear theory, their formation is explained by exfoliation [11].

It is interesting to study the specific features of motion of the wear particles between the contacting bodies after their segregation from the surface [8]. The substance that is formed from wear particles and their fragments affects substantially the total wear [12]. Hence, it is necessary to investigate the quantitative laws of formation of this layer and to evaluate the time of retention of the particles in contact and the yield of the layer under conditions of dynamic equilibrium.

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Previously, we put forward a hypothesis that in conditions of sliding friction sulfides can initiate origin of cracks in the iron [4]. Now me, hypothesized that under conditions of sliding friction and rolling friction, the initiators of the origin and development of cracks in steel, in some cases may be: carbides, nitrides, intermetallic phases  $\sigma$  – type.

Taking into account the general laws of fracture of alloys [13 16] and applying the methods of mathematical statistics, one can establish the criteria describing the interrelation 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).

### CONCLUSION

The concentration of hydrogen increases on the Limits of the interface. Thus, it is possible to predict the saturation of the alloy with hydrogen, by the dispersion of the alloy and therefore, if to correlate the size and morphology of wear products from the structural - phase composition, it becomes possible to predict the intensity of the destruction, including in conditions of friction.

### REFERENCES

- Balytskyi O.I., Kolesnikov V.O., Kaviak P., 2005. Tribotechnical properties of austenitic manganese steels and cast-irons under sliding friction conditions. Materials Science. Vol.41, № 5, 624 – 630.
- 2. Tkachev V.I., Holodnyi V.I., Vitvitskiy V.I., 2004. Hydrogen fatigue of steels // International Scientific Journal for Alternative Energy and Ecjlogy ISJAEE. № 3 (11), 34 36.
- 3. The.physico-chemical picture of the process of friction on the example of a pair of metal-metal. http://www.reagent-2000.info/articles 7.html
- Balytskyi O.I., Kolesnikov V.O., 2004. Investigation of wear products of austenitic manganese cast-iron. Materials Science. Vol.40, № 1, 78 – 82.
- 5. Tkachev V.I., Holodnyi V.I., Levina I.N., 1999. The efficiency of steels and alloys in a hydrogen environment. Lviv: Vertikal, 256 p.
- Ivanova V.S., Rusavskaya V.D., Sabitova I.S., 1963. The experience in the identification of dislocations in deformed metals. Plant laboratory. № 2., 193–197.
- 7. Vlasov V. M., 1987. Serviceability of Hardened Rubbing Surfaces (in Russian), Mashinostroenie, Moscow, 304.
- 8. Kuz'menko A. G., Sytnik S. V. 1999. Methods of wear tests. Probl. Tribol., No. 2, 38-109.
- 9. Kragel'skii I. V., Dobychin M. N., Kombalov V. S. 1977, Foundations of Friction and Wear Analysis (in Russian), Mashinostroenie, Moscow, 526.
- 10. Marchenko E. A., 1979. On the Nature of Fracture of Metal Surface in Friction (in Russian), Nauka, Moscow 118.
- 11. Suh N. P., 1973. The delamination theory of wear. Wear, 25, No. 1, 43-51.
- Bobro Yu. G., Aleksandrov B. I., Ivanov V. T., 1983. An investigation into the wear resistance of cast irons at high temperatures and pressures. Enhancement of the Wear Resistance of Cast Materials (in Russian), IPL AN Ukr. SSR, Kiev, 20–22.
- Balitskii A., Chmiel J., Kawiak P., Ripey I., Kolesnikov W., 2007. Odpornośc na zużycie ścierne i niszczenie wodorowe austenitycznych stopów Fe-Mn-Cr. Problemy eksploatacji.-4 (67)/.7-16. <u>http://www.itee.radom.pl</u>.
- Balitskii A., Kolesnikov V., Chmiel J., 2007. The influence of microstructure and hydrogen

  containing environments on the intensity of cast iron and steel damage by sliding friction.
  Part 1. Construction of a generalized model of surface layer friction of graphitized steel and
  cast-iron objects. Problemy eksploatacji.-4 (67), 17-29. <a href="http://www.itee.radom.pl">http://www.itee.radom.pl</a>.
- Balitskii A., Kolesnikov V., Chmiel J., 2008. The influence of microstructure and hydrogen

  containing environments on the intensity of cast iron and steel damage by sliding friction.
  Part 2. The generalized scheme of the steels and grey-iron behaviour during sliding friction //
  Problemy eksploatacji.- 2 (69), 17-29. <a href="http://www.itee.radom.pl">http://www.itee.radom.pl</a>.
- Balicki A., W.Kolesnikow, J.Kubicki, 2003. Podwyższanie odporności na zużycie ścierne stopów Fe-Mn poprzez wprowadzenie wybranych dodatków stopowych / Inzynieria Materialowa, 244-246.

### ИССЛЕДОВАНИЕ ПРОДУКТОВ ИЗНОСА ВЫСОКОАЗОТИСТЫХ МАРГАНЦЕВЫХ СТАЛЕЙ ПОСЛЕ НАВОДОРАЖИВАНИЯ

### Колесников В.А.

Аннотация. Сделаны предположения о различных механизмах разрушения данных сплавов в условиях трения и деградации материала под действием водорода. Исследовались продукты износа.

Ключевые слова: высокоазотистые стали, водородная стойкость, продукты износа.