UDC 621.793.1:539.234

STRUCTURE AND PROPERTIES OF STEEL COATINGS DOPED WITH ALUMINUM

Eremin E.N.[1], Yurov V.M.[2], Guchenko S.A.[2], Syzdykova A.Sh.[3]

[1]Omsk State Technical University, Omsk, Russia, weld_techn@mail.ru
[2]Karaganda State University named after E.A. Buketov, Karaganda, Kazakhstan, exciton@list.ru
[3]Polytechnic College Corporation "Kazakhmys", Balkhash, Kazakhstan, aigul.syzdikova@gmail.com

The paper presents the results of an experimental study of the structure and properties of coatings 12X18H10T + Al. Coatings were deposited in vacuum on a substrate 45 made of steel while the steel and the aluminum sputtering cathodes. The structure and properties of the coatings were investigated in an argon atmosphere, and nitrogen. An increase in the microhardness and the simultaneous reduction of friction coatings. This result has important practical significance to improve the performance of parts made of steel 45.

Keywords: structure of the coating, steel, aluminum, microhardness, friction

Introduction

Plain carbon steel does not always meet the requirements of art. In industry, widely applied steel alloys that have high mechanical or special physical and chemical properties obtained after appropriate heat treatment.

Modern stainless steels as alloying elements are mainly used: chromium, nickel, manganese, silicon, molybdenum, tungsten, vanadium, titanium, rare - cobalt, aluminum, copper, zirconium, boron, nitrogen. These alloying elements dissolve in solid solution carbides form at certain concentrations special phase.

Alloying elements when introduced into the steel in an amount of less than 5% soluble in the crystal lattice of iron and cementite forming doped ferrite, austenite, cementite. Steel with such a structure is called pearlite class steels as preserve the structure of carbon steel. When more alloying elements exceeds the solubility limit of solid solutions, which leads to the formation of specific phases in the form of excess carbides, or intermetallic compounds.

Structure and properties of alloy steels devoted a huge amount of work, some of which are reflected in the monographs [1-7].

However, the end of the XX century and the beginning of the XXI century are characterized by a decrease in world production of alloyed (especially special) were both due to the difficulty of obtaining and because of their high cost. In their place come new structural materials (metal, metal-ceramic) and coatings. This coating can be applied to low-grade steels, giving them the properties of alloy steels. Considering that the thickness of the coating is (5-7) micron, come to a conclusion about the economic efficiency of the vacuum coating.

In this paper we present results of the study of structure and properties of steel coatings doped with aluminum.

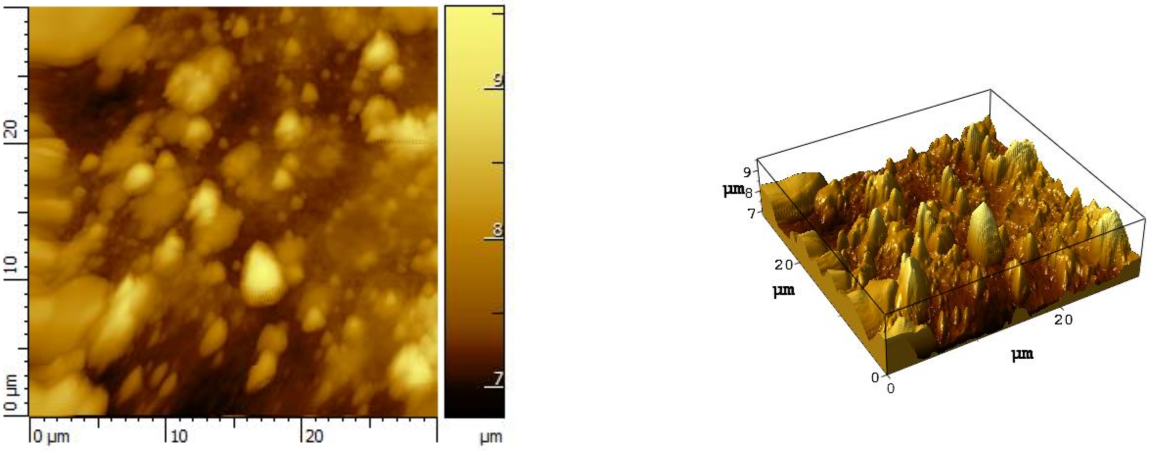
Objects and methods of the experiment

The coating used aluminum anodes and cathodes made of steel 12X18H10T. With these applied coatings to cathodes installation HHB - 6.6.I1 a substrate of steel 45 in a gas atmosphere of argon and nitrogen for 40 minutes at a current of I = 80 A, the reference voltage U = 200 V and a gas pressure in the chamber $p = 5\times10^{-3}$ Pa.

Electron microscopic study was conducted on a scanning electron microscope MIRA 3 firms TESCAN. The studies were conducted at an accelerating voltage of 20 kV and a working distance of about 15 mm. Each sample was done by 4 shots at 4 points on the surface at different magnifications: 245-fold, 1060-fold, 4500-fold and 14600-fold. Also, energy dispersive analysis conducted at four points on the surface of each sample. The optical microstructure was investigated on metallographic microscope Epikvant and nanoscale atomic force microscope NT-206. To measure the microhardness used Micro Durometer HVS-1000A, and for tribological investigations - was established in the University laboratory setting to determine wear and sliding friction. [8].

Experimental results

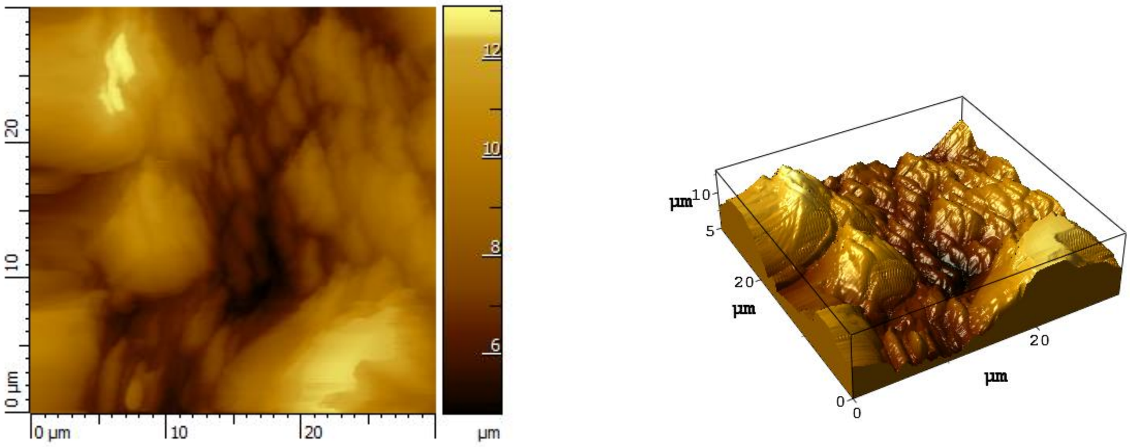
Fig. 1 and 2 show the AFM, and Fig.3 - electron-microscopic images of the coatings obtained in argon and nitrogen. Fig. 4 and 5 show XPS coatings obtained in argon and nitrogen. By processing the energy-dispersive spectra for a special application PHI-RHO-Z were determined element concentrations (Table.1 and 2).



a)

b)

Fig. 1. AFM image of the coating 12X18H10T + Al in 1D (a) and 3D (b) the projections in argon



a)

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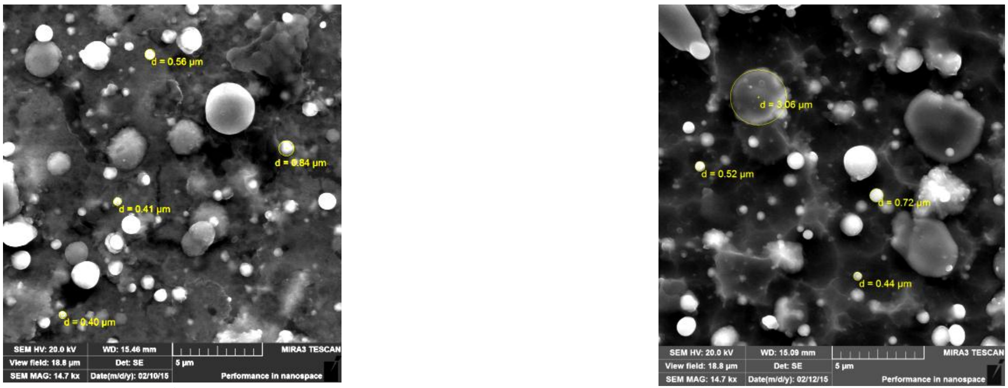
Fig. 2. AFM image of the coating 12X18H10T + Al in 1D (a) and 3D (b) under nitrogen projections



a) b)

Fig. 3. REM- coating image 12X18H10T + Al in an argon atmosphere (a) and nitrogen (b)

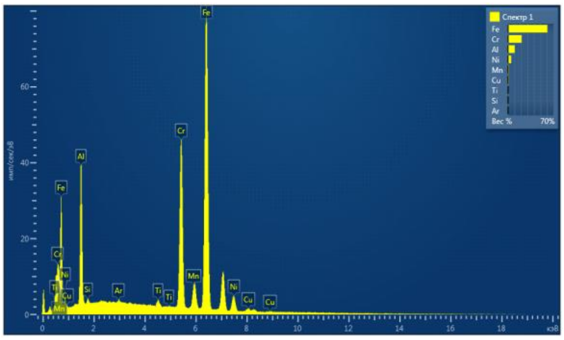


Fig. 4 - XPS coating 12X18H10T + Al argon

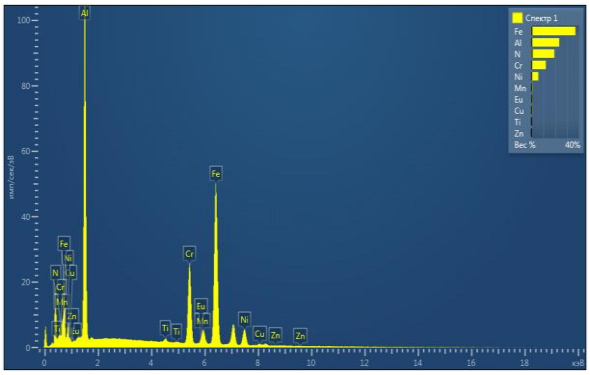


Fig.5. XPS 12X18H10T + Al coating in a nitrogen atmosphere

Table 1. The elemental composition of the coating 12X18H10T+Al argon

Element	line Type	Conventional concentration	Ratio k	Weight %	Sigma Weight. %
Al	K series	17.23	0.12374	10.24	0.13
Si	K series	0.61	0.00481	0.32	0.06
Ti	K series	1.89	0.01895	0.60	0.06
Cr	K series	69.27	0.69270	20.84	0.17
Mn	K series	3.94	0.03937	1.33	0.12
Fe	K series	175.92	1.75921	60.46	0.25
Ni	K series	13.32	0.13315	4.88	0.16
Cu	K series	3.06	0.03058	1.15	0.14

Table 2. The elemental composition of the coating 12X18H10T+Al in nitrogen

Element	line Type	Conventional concentration	Ratio k	Weight %	Sigma Weight. %
N	K series	99.37	0.17693	19.19	0.53
Al	K series	48.42	0.34774	23.32	0.22
Ti	K series	1.07	0.01069	0.35	0.05
Cr	K series	38.02	0.38017	12.01	0.15
Mn	K series	2.60	0.02597	0.90	0.11
Fe	K series	106.72	1.06716	36.95	0.32
Ni	K series	15.91	0.15908	5.75	0.15
Cu	K series	1.80	0.01796	0.67	0.12
Zn	K series	0.00	0.00000	0.00	0.00

Table 3 shows the values of the Vickers microhardness μ f and coefficient of friction for coatings produced at different times t spraying.

Table 3. Microhardness and friction coefficients covering 12X18H10T+Al

Coating	t, min.	μ, MPa	f (in copper)	f (in aluminum)
12X18H10T+Al (argon)	10	292,5	0,193	0,264
12X18H10T+Al (argon)	20	356,7	0.198	0,323
12X18H10T+Al (argon)	30	393,5	0,203	0,367
12X18H10T+Al (argon)	40	416,2	0,206	0,426
12X18H10T+Al (nitrogen)	10	391,7	0,230	0,325
12X18H10T+Al (nitrogen)	20	404,7	0,263	0,366
12X18H10T+Al (nitrogen)	30	436,9	0,283	0,374
12X18H10T+Al (nitrogen)	40	474,4	0,294	0,337

Discussion of the results of the experiment

In alloying the aluminum in the coating 12X18H10T nitrogen atmosphere its columnar structure (Fig. 2) is less pronounced than in argon (Fig. 1). This is due to an increase in austenite grain (Figs. 2 and 3). Elemental coating composition undergoes a significant change in the deposition of coatings under argon and nitrogen. The coatings obtained in a nitrogen atmosphere, contain aluminum in 2 times more iron and less than 2 times. And reduced chromium content.

Such behavior of the concentration of alloying elements in the coating is due, in our view, to the processes of ion scattering of alloying elements in the atoms and molecules of argon and nitrogen. The change in concentration of alloying elements in the coating affects their mechanical properties (Table. 3). The microhardness of the coating, and friction coefficient obtained in a gas atmosphere of nitrogen, more - than argon. This is due, first of all, the formation of chromium nitride, since the formation of nitrides of iron and aluminum at these thermodynamic conditions is insignificant. However, the coefficients of friction of the coating is significantly lower than those of most friction pairs. For comparison, the Table. 4 shows the values of the coefficients of dry friction pairs of the most common metals.

Microhardness steel 45 is about 200 MPa Vickers. This means that the obtained coating in a nitrogen environment to increase the hardness of almost 2 times. Increasing microhardness and simultaneous decrease friction coefficients may significantly improve the wear resistance of coated parts 12X18H10T + Al, obtained in an environment of nitrogen or argon.

Table 4. Coefficients of dry friction for pairs of the most common metals [9]

Combinations of materials		The coefficient of dry friction
Aluminum	Aluminum	1.05 - 1.35
Chromium	Chromium	0.41
Copper	Copper	1.0
Iron	Iron	1.0
Steel	Steel	0.8
Aluminum	Steel	0.61
Copper	Steel	0.53

Conclusion

One of the major problems of tribology is a problem of increasing the wear resistance of structural materials, components and assemblies tribomating friction, for this reason, along with the improvement of anti-friction characteristics, wear reduction is a priority engineering problems. In this paper we show that the improved performance of friction units, it is possible by the application of multi-coating while spraying various cathodes.

REFERENCES

1. Brown M.P. *The influence of alloying elements on properties of steel*. Kiev, Gostekhizdat the USSR, 1962, 192 p.
2. Vinokur B.B., Pilyushenko V.L., Kasatkin O.G. *The structure of the alloy structural steel*. Moscow, Metallurgy, 1983, 216 p.
3. Hubenko S.I., Parusov V.V., Derevyanchenko I.V. *Non-metallic inclusions in the steel.* Dnepropetrovsk, ART Press, 2005, 536 p.
4. Bolshakov V.I., Suhomlin D.V., Laukhin D.V. *Atlas structures of metals and alloys*. Dnepropetrovsk, PGASA, 2010, 174 p.
5. Ferry M. *Direct Stripcasting of Metals and Alloys: Processing, Microstructure and Properties*. Woodhead Publishing and Maney Publishing, 2006, 275 p.
6. Verhoeven J.D. *Steel Metallurgy for the Non-Metallurgist*. *ASM International*, 2007, 212 p.
7. Sha W. *Steels: From Materials Science to Structural Engineering.* Springer-Verlag, 2013, 268 p.
8. Kolesnikov V.A., Baysagov Ya.Zh., Yurov V.M. Information-measuring device to determine the coefficient of sliding friction. *Basic Research*, 2011, No. 12, pp. 121-124.
9. KragelskyI.V., Vinogradova I.E. *The coefficients of friction*. Moscow, Mashgiz, 1962, 220 p.

Article accepted for publication 23.11.2015