UDC 669.14.018

G.N. Tregubenko. professor, d.t.s.

RESEARCH FOR INFLUENCE OF TITAN AND NITROGEN ADDITIONS ON STRUCTURE AND HOT-RESISTANCE OF CHROMIC FERRITIC STEELS

National metallurgical academy of Ukraine, Dnipropetrovsk. Ukraine

Research of influence of additions for titan and nitrogen on a structure and hot - resistance of chromic ferrites steels has been carried out. It is certain that for increase of hot - resistance most essential is a receipt of ultrafine dispersible nitrides of titan, evenly up - diffused on all of volume of metal.

Keywords: hot-resistance, structure, steel, titan, nitrogen, nitride of titan, mechanical properties

Introduction. One of problems for development of high temperature nuclear power generating system is a necessity of increase of hot-resistance of constructive materials for active area of reactor. It has been caused that thermal creep in combination with radiative effects in materials of shells for heat-generating elements result to irreversible deformations and forming, diminishing the resource of exploitation of active area and techno-economic factors of nuclear generative system [1].

Basic constructive materials of shells of for heat-generating elements of reactors with gaseous and liquid-metal heat transfer agent are hard chromo-nickel steels of austenitic class. These steels, possessing the acceptable level of radiation properties at working temperatures 500-550 °C, have insufficient creep-resistance. Application of considerable less expensive and far more radiative-steadly chromic without nickel ferritic steels presently is not possible from their subzero hot-resistance.

Analysis of researches and publications. One of methods for increase of creep-resistance steels of austenitic class is putting the second high disperse phase. Thus, the particles of the second phase must be steady against coagulation. Basic high disperse phases, applied for work-hardening of austenitic steels, the oxides of rare-earth elements, nitrides of titan and carbonitrides of niobium are serve. However dispersible work-hardening of steels, for example, by oxides, by metallurgical methods difficultly, as it is impossible to create necessary volume distribution of consolidating phase, that force to apply the methods of powder metallurgy, substantially complicative technology of made for shells of heat-generated elements.

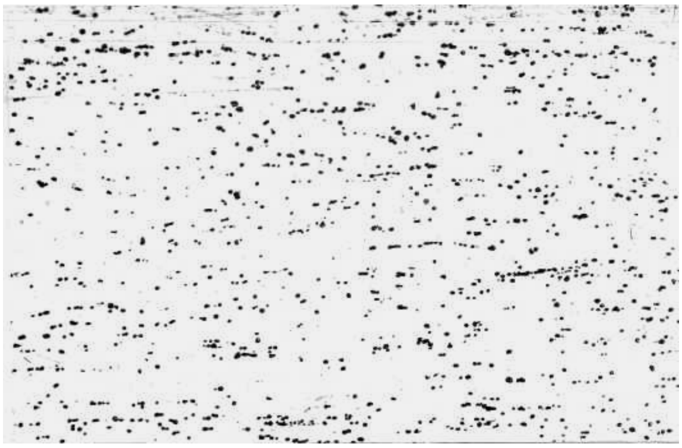
There are known that austenitic steel (for example, X20H25), is steady-state by nitrides of titan or caronitrides of niobium [2]. High durability of these steels is arrived by thermomechanical treatment at which the optimal selection of nitrides of titan or caronitrides of niobium is provided in the metal volume. As nitride of titan has large energy of formation and steady, than other dispersible excretions are in austenitic steels, complex alloying by titan and nitrogen more preferably from the view point for increase of hot-resistance, what the use of niobium carbonitrides.

Problem formulation. In the real work influence of the joint alloying by titan and nitrogen there are investigated on a microstructure and mechanical properties of chromic without nickel ferritic steels with the purpose of increase for their hot-resistance.

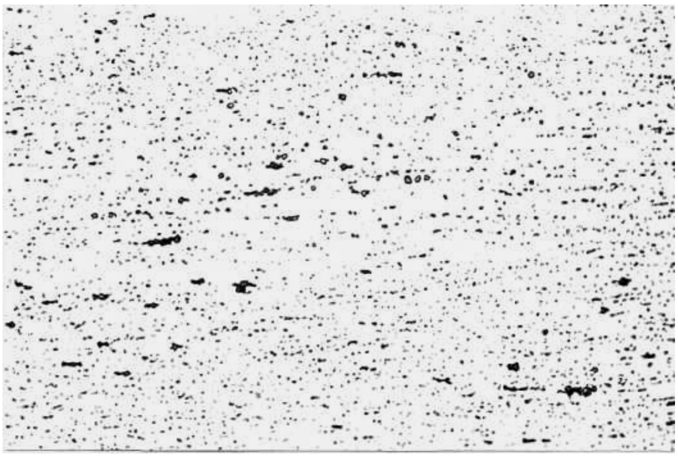
Exposition of research results. In work used ferritic steel 13Х12М2ТБФР with content of titan from 0.03 to 1.75 %. Chemical composition of the investigated metal is offered in the table. 1.

Table 1 is Chemical composition of steel 13Х12М2ТБФР

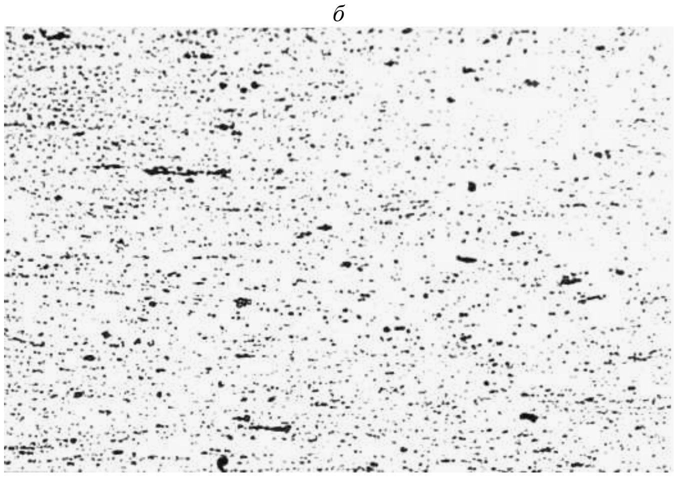
Chemical element	*C*	*N*	*Cr*	*Mo*	*Ti*	*Mn*	*Al*	*V*	*Nb*	*Si*	*S*	*B*
C contents, %	0.15	0.028	11.2	1.55	0.03-1.75	0.35	0.13	0.21	0.45	0.18	0.004	0.005



a



б



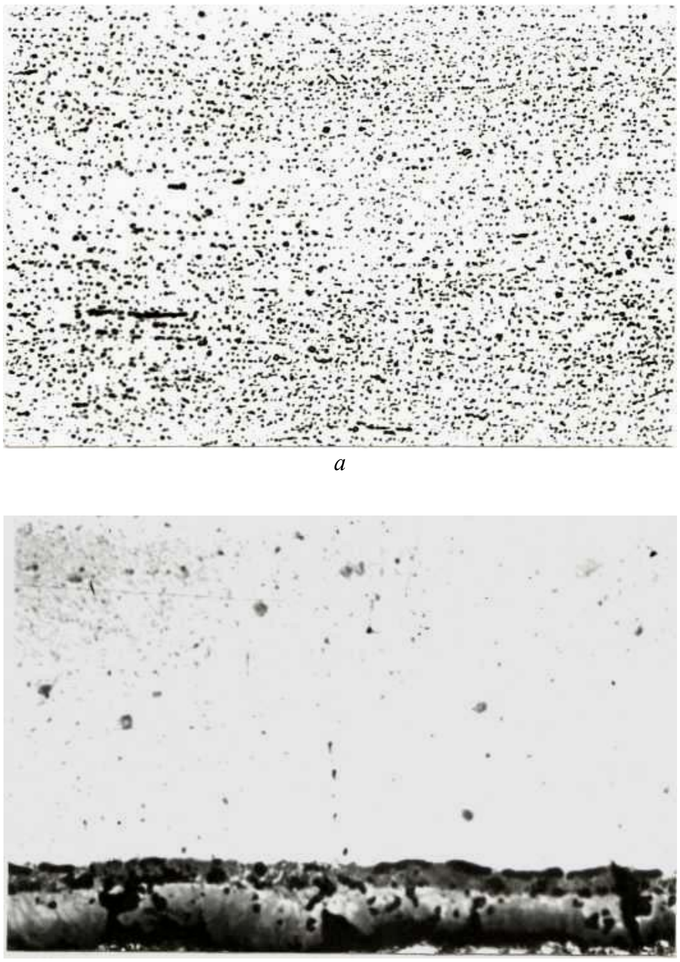
c

a – 1.20 % Ti and 0.028 % N; б – 1.20 % Ti and 0.287 % N; c – 0.35 % Ti and 0.182 % N
Figure 1 is microstructure of the experimental thin-walled rolling from steel 13Х12М2ТБФР with different content of titan and nitrogen (x 125)

Laboratory experiments on a satiation nitrogen titan containing chromic ferritic steels executed by the method of the hardphaseby decarbonating and alloying nitrogen (TOLA) [3] in a vacuum furnace of resistance at the conditions of problem laboratory of new metallurgical processes of NMAY. Samples placed in working space to the furnace and heated in a vacuum to the temperature 1200-1300 °C. After achievement of the given temperature in working space of furnace extra clean nitrogen ($N_2 \geq$ 99.996 %) filled and isothermal self-control executed.

It was certain in preliminary experiments that phase composition of metal after its satiation by nitrogen, at other things equal, depends on speed of cooling in a furnace. So, at the decline of mean speed of cooling in the interval of temperatures 1300-650 °C from 51 to 29 °C/min., except for a ferrite and dispersible nitrides, in a microstructure 13X12M2TБФР steel there is a martensite. Therefore during realization of basic experiments middle speed of cooling back up permanent at the level 51 °C/min.

It is set that quantity, sizes and character of distribution of the nitrides scions in the matrix of samples from steel 13X12M2TБФР is determined the by both content in its titan and nitrogen and mode of annealing (fig. 1 and fig. 2).



a

b

a - x125; b - x800.

Figure 2 is microstructure of the experimental thin-walled rolling from steel 13X12M2TБФР with content 1.75 % Ti and 0.410 % N

In a metal without titan after isothermal self-control at the temperature 1200-1250 °C there is an ultrafine needle-shaped phase, equipartition on the section of samples. Although composition of phase from its dispersion to set was not possible, it is may to suppose that it is complex carbonitrides, the metallic constituent of which includes niobium, vanadium, chrome and molybdenum, and also, presumably, the presence of aluminum nitrides is possible. With the increase of temperature of isothermal self-control to 1300 °C and, accordingly, by the decline of concentration of nitrogen in a metal a quantity and sizes of needle-shaped excretions diminish notedly.

In steels, containing 0.3-1.35 % *Ti*, after their satiation by nitrogen there is even enough distribution of nitrides of titan with insignificant picking (fig. 1.b and fig. 1.c). With the height of content of titan in the indicated limits there is a tendency to the increase of both size of separate nitrides and their quantity. With diminishing of temperature of process to 1200 °C on the surface of samples steel with 1.20-1.35 % *Ti* here are areas of small extent with a thin continuous nitrides skim layer. The same character of surface takes place and in steel, containing 1.75 % *Ti*, but after nitriding at the temperatures 1250-1300 °C. Decline of temperature to 1200 °C results to formation on a surface practically continuous nitride layer (fig. 2,b), being by reason uneven distribution of nitrides on the section of samples. In this case volume of nitrides substantially and asymmetrically diminishes to the center of sample.

By the balance analyses of samples with continuous skin and after its moving away by mechanical way or etching it is shown that, in spite of relatively small depth of this layer, making both-side in a sum about 1.5 % from the thickness of sample, in its contained more than 40 % oxygen and 10 % nitrogen. Id est. it is more correct to interpret this phase as oxynitrides. At default of continuous layer (1250.1300 °C) steel, containing 1.75 % *Ti*, has a most closeness of nitrides on a section (fig. 2 and table 2).

Table 2 is the mass and by volume stake titan nitrides in the experimental thin-walled rolling from steel 13X12M2TБФP with different content of titan and nitrogen

[Ti], mass stake, %	[N], mass stake, %	*TiN*	
		mass stake, %	vol. stake, %
0.03	0.028	-	-
0.35	0.182	0.45	1.07
1.00	0.276	1.28	1.82
1.20	0.287	1.49	2.11
1.35	0.368	1.74	2.45
1.75	0.410	2.16	3.08

For research of influence of titan and nitrogen additions on mechanical properties of the thin-walled rolling (~ 0.5 mm) from ferritic steel 13X12M2TБФP part of samples was 850 °C, self-control during one minute and cooling on air. Other part of samples was exposed to the hard phase alloying by nitrogen (by the method TOLA), rolled in a few passage-ways on a laboratory figure (ε = 50 %) and recrystalized on the indicated higher mode. All samples tested on tension (ГОСТ 11701-84) at a temperature 20 and 650 °C on the break machine FP 10/1. The results of tests are offered in the table 3 and table 4.

As be obvious from data, offered to the table 3, high enough level of strength properties at brief tests (t = 20 °C) it was succeeded to attain only in samples from steel 13Х12М2ТБФР with the maximal (from tested) volume stake of titan nitrides 2.45 % (1.35 % *Ti* and 0.368 % *N*). In other sampled strength descriptions in all states of metal are relatively near.

The samples of the experienced metal before and after alloying by nitrogen tested also and on the protracted durability at the temperature 700 °C (table 5). As see, joint additions of titan (0.35-1.35 %) and nitrogen (0.182-0.368 %) considerably increase time to destruction (in 9.5-34 time) in the interval of tensions 32-101 MPa. Thus, as well as at brief tests at a high temperature (650 °C), most high characteristics is a steel, containing 0.35 % *Ti* and 0.182 % *N*, that it can be explained by a presence in its ultrafine high dispersive nitrides of titan as compared to a metal with their higher volume stake, but by largenesses.

Table 3 are results of tests of mechanical properties at temperature 20 °C of the experimental thin-walled rolling from steel 13Х12М2ТБФР with different content of titan and nitrogen

State metal	Contents, mass. stake, %		Mechanical properties*		
	[Ti]	[N]	Limit of fluidity, MPa	Limit to durability, МПа	Relative lengthening,%
After the cold rolling and thermal treatment**	1.00	0.028	420	600	20,0
After TOLA, cold rolling and thermal treatment**	0.35	0.182	420	640	15.0
	1.00	0.276	415	615	17.5
	1.20	0.287	395	540	21.5
	1.35	0.368	555	740	15.5

Note: * - mean values over of mechanical properties are brought on a few tests; ** it is thermal treatment at 850 °C, 1 minute of self-control and cooling on air.

Table 4 are Results of tests of mechanical properties at 650 °C of the experimental thin-walled rolling from steel 13Х12М2ТБФР with different content of titan and nitrogen

State metal	Contents, mass stake, %		Mechanical properties		
	[Ti]	[N]	Limit fluidities, MPa	Limit to durability, MPa	Relative lengthening, %
After the cold rolling and thermal treatment	1.20	0.028	160	215	50.0
After TOLA, cold rolling and thermal treatment	0.35	0.182	210	235	25.0
	1.20	0.287	180	215	45.0

At tests on the protracted durability time to destruction (τ) and tension (σ) is bound by dependence [4]:

$$\tau = A \cdot \sigma^{-n} , \qquad (1)$$

where A and n are empiric coefficients in double logarithmic co-ordinates.

Therefore on the basis of standard treatment of data for tables 5 as equation (1) it is certain, that optimal joint alloying by titan and nitrogen of chromic ferritic steels provides the increase of their protracted hot-resistance (τ = 105 hours) in 1.4 time.

Table 5 are Results of tests on the protracted durability at 700 ^{o}C of the experimental thin-walled rent from steel of 13Х12М2ТБФР with different maintenance of titan and nitrogen

State metal	Table of contents, mass. stake, %		Mechanical properties		
	[Ti]	[N]	Tension, МПа	Time to destruction, hour	Relative lengthening, %
After the cold rolling and heat treatment	0,03	0,028	37,4	35,5	33,0
			64,0	1,0	64,0
	0,35	0,028	32,0	170,0	187,7
			42,6	17,5	83,5
			53,5	3,5	50,8
			64,0	2,1	42,0
			96,0	0,1	52,5
After TOLITE, cold rolling and heat treatment	0,35	0,182	42,6	304,0	20,8
			64,0	34	16,2
			85,0	6,2	17,5
	1,35	0,368	42,6	104,0	31,7
			53,4	32,5	33,0
			64,0	9,5	32,3
	1,75	0,410	64,0	0,5	21,6

Conclusions. The results of the carried out researches allowed experimentally to define the optimal concentrations for titan and nitrogen, providing the considerable increase of the protracted hot-resistance of chromic ferritic steels. It is set that for a receipt high level of strength properties at brief tests at the temperature 20 °C the large volume stake of titan nitrides (2.45 vol. stake, %) is needed. However for the receipt of increase of durability at high temperatures (650-700 °C) most essential is a size of titan nitrides, but not their quantity.

REFERENCES

1. **Ма, Б. М.** Материалы ядерных энергетических установок. [Текст] : пер. с англ. под ред. Ю. Ф. Чернилина / Б. М. Ма. – М. : Энергоатоиздат, 1987. – 408 с. - Библиогр.: с. 381-404. – 1840 экз.
2. **Робертс, А. С.** Влияние добавок титана и кремния на ползучесть дисперсноупрочненных TiN коррозионностойких сталей 20Cr [Текст] / А. С. Робертс, Х. Е. Эванс // Труды конференции «Высокотемпературные механические свойства коррозионностойкой стали для атомной техники»: пер. с англ. Г. Н. Мехеда, под ред. С. Б. Масленкова. – М.: Металлургия, 1987. – С. 104-116. – Библиогр.: с. 116.
3. **Трегубенко, Г. Н.** Возможности производства тонкостенного проката из высокоазотистых коррозионно-стойких сталей. [Текст] / Г. Н. Трегубенко, Ю. Б. Заславский, М. И. Тарасьев, А. В. Рабинович // Сталь. – 1999. – № 8. – С. 61-63. – Библиогр.: с. 63.

4. **Масленков, С. Б.** Жаропрочные стали и сплавы. Справочник [Текст] / С. Б. Масленков. – М. : Металлургия, 1983. – 192 с. – Библиогр.: с. 191. – 15000 экз.