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STUDYING HEAT TREATMENT IMPACT ON HEAT RESISTING PROPERTIES OF Cr-Ni – A. E. SYSTEM ALLOY

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Preliminary Note – Prethodno priopćenje

The article presents the results the impact of heat treatment on iron-nickel alloys with adding Mo, Nb, Ti and Al, at this the content of chrome was increased in comparison with the classical structure to 40 - 45 %.

Keywords: chromium- nickel alloy, chemical composition, heat resisting, heat treatment, microstructure.

INTRODUCTION

Carried out earlier studies of heat resisting properties of the Cr-Ni-a.e. system alloys showed the prospects of using these alloys as heat resisting [1-3]. Hardening the alloys is reached due to forming the intermetallic phases which are dropping out in the course of aging.

It is well-known that the increasing content of soluble elements enhances a creep resistance of solvent and that the injecting small doses of soluble elements gives better results than adding same amount of one element. The fallout of second phase from saturated solid solution leads to further remarkable improvement of creep resistance. The creep resistance also depends on conditions of solid solution treatment. So, altering treatment temperature significantly influenced on creep resistance value.

This phenomenon usually is related to change of grain size. A large grain, formed during treatment on elevated temperatures, reduces a rate of creep at constant testing.

But following heat treatment, which defines the feature of excess phase fallout, is important for understanding influence of structure on creep.

So the object of research is an alloy, which differs from traditional group of iron-nickel alloys, and the offered compound of Cr-Ni-a.e. system alloy was studied for influence of heat treatment on high-temperature properties.

There were chosen 2 types of heat treatment, followed by defining a creep resistance in 700 – 870 °C temperature range.

The next alloy compounds were used as samples for study. A distinctive feature of proposed alloy is a high concentration of chrome, titan and aluminum (usually, concentration of these elements does not exceed 25 %, 3 % and 1,7 % respectively).

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The composition of the studied alloys is presented in Table 1.

Table 1 **Chemical composition of the studied alloys / wt. %**

Alloy	2/2	2/3	1/2	1/3 series 1, No. 3
C	0,07	0,065	0,074	0,063
Cr	39,80	44,9	40	45
Ni	44, 96	35,94	45,92	40,94
Fe	10	10	10	10
Mo	0,92	0,95	1	1
Nb	1	1	1	1
Ti	4,25	4,145	1	1
Al	3	3	1	1

MATERIAL AND EXPERIMENTAL METHODS

The laboratory samples were melted in the UIP-25 induction furnace in the regular atmosphere, the average weight of pilot melting constituted 2,5 kg.

After complete cooling from the ingot there were made the samples for determining long-term strength according to GOST 10145-81.

Before testing for long-term strength the samples were exposed to heat treatment in different modes:

Mode 1. Holding within 2 hours at 1 200 ^{0}C and cooling in water; aging within 6 hours at 700 ^{0}C.

Mode 2. Holding within 2 hours at 1 100 ^{0}C and cooling in water; aging within 4 hours at 700 ^{0}C.

Heat treatment was carried out in the NabermL-HT 02/17 furnace. After heat treatment the samples were tested for long-term strength on the TRPME-50 machine within 100 hours at temperatures 700 ^{0}C, 750 ^{0}C. and 870 ^{0}C. The results of studying the impact of heat treatment on heat resisting properties of the Cr-Ni-l.e. system alloy are given below (see Table 2).

RESULT AND DISCUSSION

To confirm reliability of the obtained results experimental data were processed in the correlation-regres-

Table 2 **Data of long-term strength depending on the alloy composition and heat treatment type**

Testing temperature / ^{0}C	Ultimate long-term strength within 100 hours / MPa					
	2/2		2/3		1/2	1/3
	Mode h/t 1	Mode h/t 2	Mode h/t 1	Mode h/t 2	aging 470 ^{0}C 4 hours	aging 470 ^{0}C / 4 hours, tempering 1 220 ^{0}C, aging - 2 hours 470 ^{0}C
700	483	475	480	469	-	-
750	390	386	385	378	-	-
870	321	315	317	323	240	240

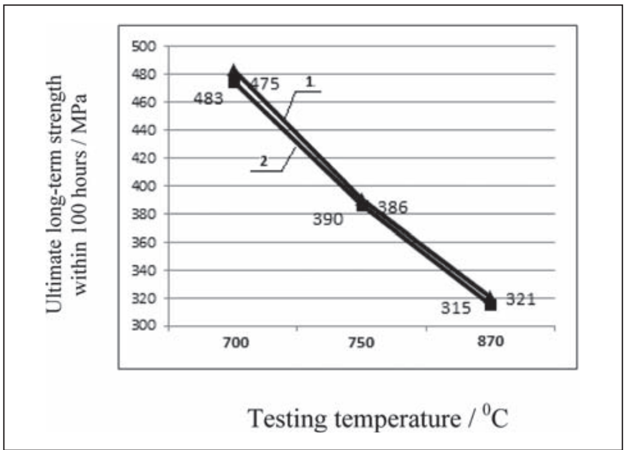

Figure 1 Dependence of the ultimate long-term strength on temperature for alloy 2/2

sive way. As a results there were obtained the equations of regression (Figures 1, 2), the coefficients of reliability of approximation for all the calculated lines of R^2 = 1 regression.

The calculated lines of regression were built by the equations y = 600 – 129 x + 12 x^2 (curve 1) and y = 582 – 116 x + 9 x^2 (curve 2). The coefficients of reliability of approximation are for both calculated lines of R^2 = 1 regression.

In Figure 1,2 there is shown the dependence of the ultimate long-term strength within 100 hours for alloy 3 in the identical modes of heat treatment.

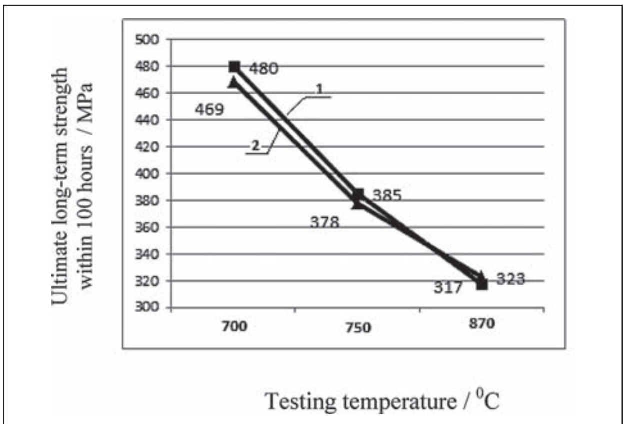

Figure 2 Dependence of the ultimate long-term strength on temperature for alloy 2/3

The calculated lines of regression were built by the equations y = 602 -135,5 x + 13,5 x^2 (curve 1) and y = 596 – 145 x + 9 x^2 (curve 2).

From the data of Table 2 it is obvious that increasing the content of Ti and Al in all the alloys irrespective of the heat treatment type leads to increasing long-term strength from 240 MPa to 321 MPa.

This fact is explained by the loss of the strengthening intermetallic phase of the Ti_3Al type which is present in all the Fe-Ni-based alloys.

It is obvious that with such a composition of the alloy hardening is reached not only owing to the loss of the intermetallic phase, but also the other interstitial phases.

For the purpose of studying the strengthening intermetallic phase there were carried out microstructure

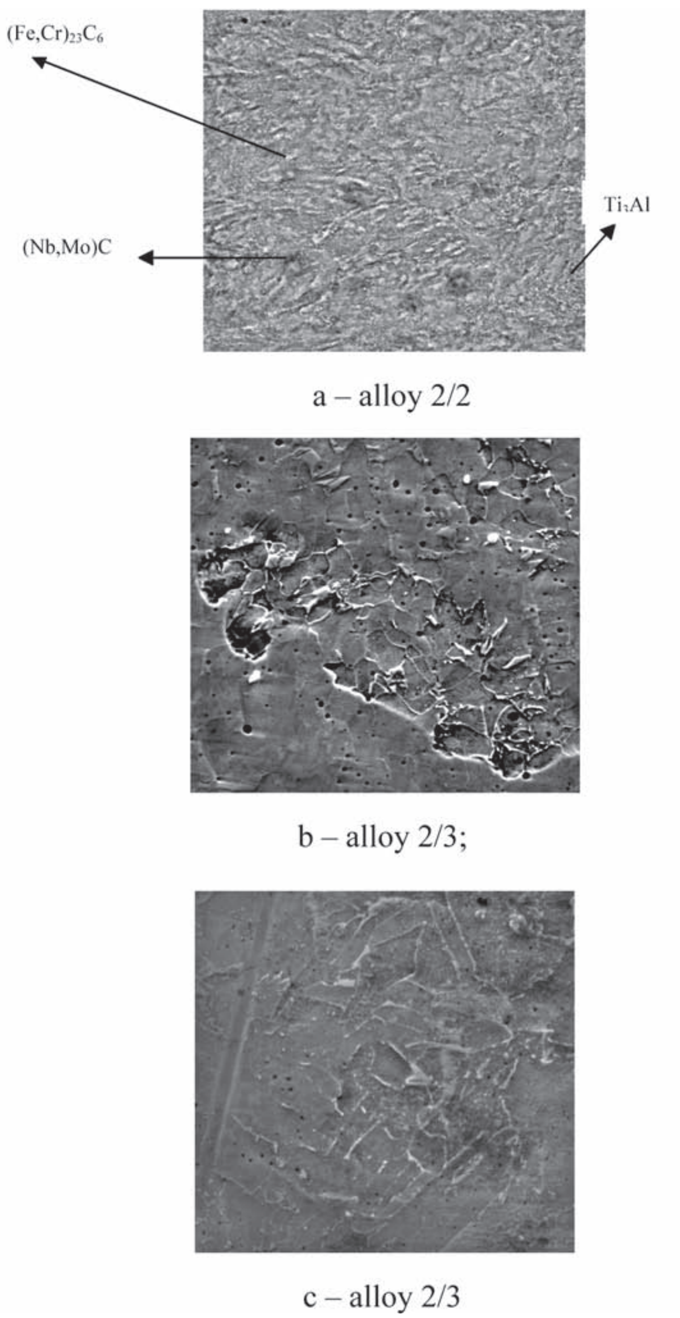

Figure 3 Strengthening interstitial phases in alloy 2/2 after heat treatment: mode 1 - $(Fe,Cr)_{23}C_6$, (Nb,Mo)C, Ti_3Al

studies with different multiplications. Metallographic studies were carried out on the METAMR-1 microscope.

For studying the microstructure there was also used a TESCAN raster electronic microscope of the Vega\\ LSU series with resolution 3.0 nanometers with the system of the microanalysis INCA Energy350.

The local chemical composition was defined by the method of the quantitative micro-X-ray spectral analysis by means of an electronic energy dispersive spectrometer INCA PentaFETx3.

CONCLUSIONS

Studying the nature of the strengthening phase in alloys 2/2 and 2/3 (Figure 3) showed the existence of the strengthening intermetallic Ti_3Al type phase and the presence the carbide phase of the $(Fe,Cr)_{23}C_6$, (Nb,Mo) C type.

Metalgraphic studies showed that allocation of interstitial phases takes place rather evenly, the inclusions have a rounded shape, the segregation along the grain boundaries does not occur.

Thus, it is possible to assume that hardening of alloys happens owing to realization of two mechanisms: intermetallic hardening and dispersive curing with the loss of the carbide phase proceeding at the aging stage.

The comparative analysis of the data of long-term strength depending on heat treatment showed that increasing the temperature of tempering and the time of aging in the studied ranges does not significantly impact long-term strength.

As it is seen from the data of Table 2, increasing the temperature of tempering from 1 100 ^{0}C to 1 200 ^{0}C and increasing exposure when aging from 4 to 6 hours leads to insignificant increasing of long-term strength.

In other words, increasing the temperature of tempering over 1 100 ^{0}C, i.e. changing the treatment mode to the oversaturated solid solution and increasing the time of aging over 4 hours has no significant effect on the formation and distribution of excess phases.

The recommended heat treatment can be considered mode 2 since from the point of view of technology it is more economic.

The strength properties of alloys 2/2 and 2/3 with the identical modes of heat treatment do not differ practically: 321 and 317 MPa at 870 ^{0}C, respectively.

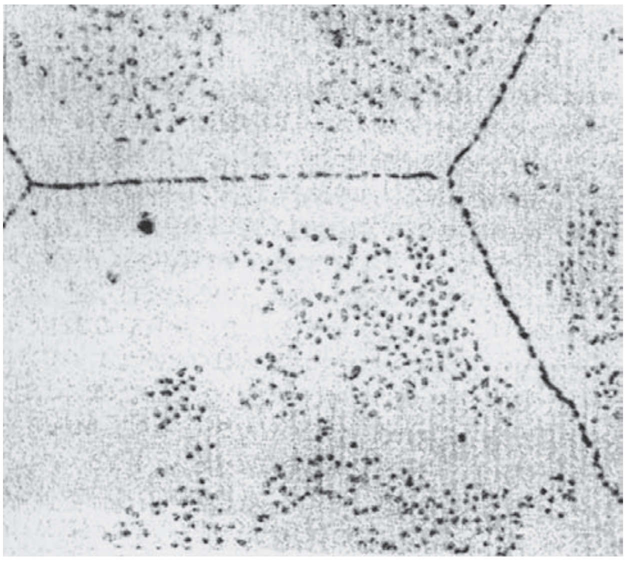

Figure 4 Strengthening interstitial phases in alloy 2, 2nd batch after heat treament (x500)

Summing up the results, there can be recommend alloy 2/3 with the increased content of Ti and Al as the alloy for working at the temperatures up to 800 ^{0}C – 850 ^{0}C. The recommended heat treatment mode is tempering at 1 100 ^{0}C with the subsequent aging within 4 hours at 700 ^{0}C.

The recommended alloy structure differs from classical Fe-Ni-based alloys in the increased content of chrome, titan and aluminum, showing thermal stability indicators that are comparable with indicators of alloys of the nimonic group. At this the proposed alloy contains a smaller amount of scarce nickel.

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Note: The responsible for England language is Nataliya Drag, Karaganda, Kazakhstan