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STUDYING INTERMETALLIC PHASE OF Ni-Cr SUPERALLOY AFTER THERMAL PROCESSING

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The superalloys on basis of Ni-Cr is meant for manufacturing rotor blades, disks and fastening details, which are used under 850 °C. These alloys additionally doped with Mo, Mo, W, Al and etc. for giving them a high-temperature properties. The main strengthening phase in these alloys is intermetallic phase, its nature, distribution pattern and dispersity [1].

Keywords: Ni - Cr superalloy, thermal processing, melting, mechanical properties, metallographic analysis.

INTRODUCTION

This work studies an influence of thermal processing on intermetallic phase, which defines the parameters of high-temperature strength. Ni

The research samples were melted in induction furnace, the weight of cast was 5 kg. A chemical compound of experimental alloy is shown in Table 1.

Table 1 **Chemical composition of experimental alloy / wt. %**

C	Ni	Si	Mn	Cr	Co	B	Ce	Fe
0,1	58,9	0,6	0,3	10,5	5,5	0,02	0,02	3,5

The cast was poured into molds, which match form of samples for testing stress-rupture strength. After cooling the samples were exposed to thermal processing in Nabertherm LHT 02/17 furnace under different modes (Table 2).

After thermal processing the samples were subjected to a stress-rupture test and long-term strength test.

The tests were performed at INSTRON – 5972 and TRMP-50. The test results are shown on Table 2.

The data from Table 2 show that 1st quenching from 1 000 °C leads to significant drop of strength as at room temperature, so at high temperatures, i.e. the long-term strength than standard.

It is well-known that the hardening of alloys based on Ni - Cr, a.e. is obtained by formation of intermetallic phase. It is reasonable to assume that such drop of strength and long-term strength (about 20 %) is due to change of alloy's microstructure. To check this assumption a fine texture of alloy was studied after different types of thermal processing. The samples № 4 - 6 (Table 2) were objects of the study.

Table 2 **The value of strength and long-term strength depending on thermal processing mode**

Sample number	Thermal processing mode	Tensile strength R_m / MPa	Long-term strength σ_{50}^{600} / MPa
1 (standard)	Quenching from 1 220 °C, aging 960 °C 8 hours, air	950	530
4	Quenching 1 000 °C, aging 960 °C 8 hours, air	840	415
5	Quenching 1 150 °C, aging 960 °C 8 hours, air	920	490
6	Quenching from 1 100 °C, aging 700 °C, 4 hours+aging 1 050 °C, 2 hours, air	940	530

EXPERIMENTAL STUDIES
Equipment and tools

The task of this research was to study quantity, structure, dispersity and distribution of intermetallic phases in experimental alloy after thermal processing and interaction of these phases with long-term strength index.

The compound of phases were studied by using TescanVega// LSU electron microscope (KSTU) with 0,5 nm resolution, INCA Energy350 micro analysis system and INCA PentaFETx3 nitrogen energy-dispersive spectrometer.

Struers, a modern materials science set for sample preparations, was used for making specimen; the samples were etched in A3 electrolyte during 25 seconds. A dispersity and phase distribution analysis were performed at least 10 fields of vision.

At first stage there was studied general quantity of interstitial phases in each sample. Thixomet software was used for execution of quantitative metallographic analysis.

The grain counting was done according to GOST, total quantity of grains (N_{100})

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$N_{100} = N_1 + N_2/2$, where N_1 is quantity of grains got inside; N_2 is quantity of grains crossed by its boundaries.

Average section area of grain (a) in mm^2 is defined by:

$A = 1/M$

Average diameter of grain (d) is defined by:

$D = 1/\sqrt{M}$

Table 3 shows data of quantitative metallography. The counting was made at 10 fields of vision, and the mean value was considered as a result.

Table 3 **Data on quantitative metallography**

Sample number	Quantity of grains in circle N_1	Quantiy of grains in crossed by circle N_2	Total quantity of grains on 0,05 mm^2 area N_{100}	Average area of grain A / mm^2	Average diameter D, mm	Total quantity of interstitial phases/ unit/ mm^2
4	122	32	276	0,005	0,06	14
5	126	32	285,5	0,048	0,059	9
6	118	32	268,5	0,052	0,061	12

Analyzing relation between the quantity of interstitial phases and value of strength and long-term strength (Table 4) showed that the interstitial phase quantity and these parameters have the definite relation: the more interstitial phases are, the higher strength parameters will be. Decrease of interstitial phases at lowering quenching temperature to 1 000 ^{0}C can be explained by insufficiently developed dissolution process of doping element in solid solution. It leads to decrease of interstitial phase formation at aging. Hence, reducing the quenching temperature lower than 1 100 ^{0}C is unacceptable, because it doesn't provide solution process of alloying elements.

Table 4 **Dependence of mechanical properties on quantity of interstitial phases**

Sample number	Quantity of interstitial phases / unit/mm^2	Strength R_m / MPa	Long-term strength σ_{50}^{600}/ MPa
4	14	950	530
5	9	840	415
6	12	940	530

The main strengthening phase of alloy after thermal processing is a-phase type. A similar phase was noted in work [2].

The compound of phases was identified by INCA PentaFETx3 spectrometer. The average compound of intermetallic phase (more than 50 %) can be identified as Fe_3NiMo_2Al. X-ray diffraction analysis showed that a-phase allegedly has tetragonal structure with next parameters: a = 0,863 nm; c = 0,433 nm.

Besides a-phase, there were phases, which were identified as Laves phase, carbide phase of $Me_{23}C$ type and interstitial phases, which have a boron in their compound.

It is known that nature of intermetallic phase, as its distribution and dispersity, define strength properties of superalloys. To this end, there was studied a quantitative relation of intermetallic phase in alloy.

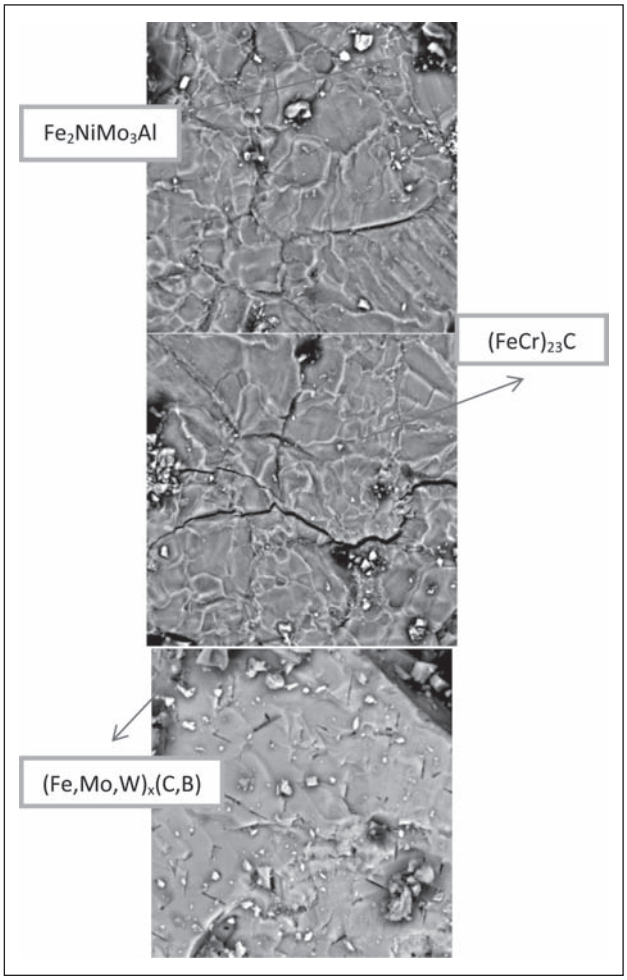

Figure 1 Microstructure of alloy in different field of vision (x 30 000)

The chart shows quantitative (average) relation of interstitial phases in 4 - 6 samples.

RESULTS AND DISCUSSION

As it can be seen on diagram, quantitative relation of interstitial phases in all samples is almost equal. Main part of intermetallic phases is represented by a–phase (Fe_3NiMo_2Al). However, sample 5 has minimum number of a–phase (58 %), but the number Laves phase is increased. It is well-known that Laves phases cause embrittlement of alloy, especially at room temperatures [3]. This fact and the decrease of total quantity of interstitial phases, apparently, lead to loss in strength properties.

A quantitative statistical analysis showed some patterns of intermetallic phase allocation (Figure 3). Regardless of thermal processing mode, the distribution of intermetallic phases by sizes has approximately same nature in all samples.

The dispersity of phase varies from 0,002 micron to 0,04 micron, moreover the most part of intermetallic phase have size less than 0,02 micron. The interstitial phases distinguished with even frequency, as in amount of grain bond, so at boundaries.

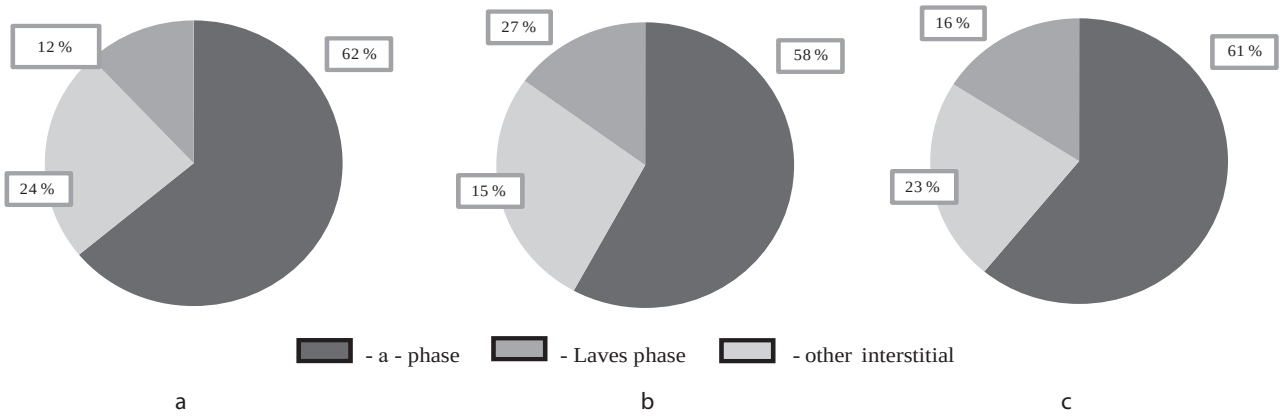

Figure 2 Quantitative relation of intermetallic phases: a- sample 4; b-sample 5; c-sample 6

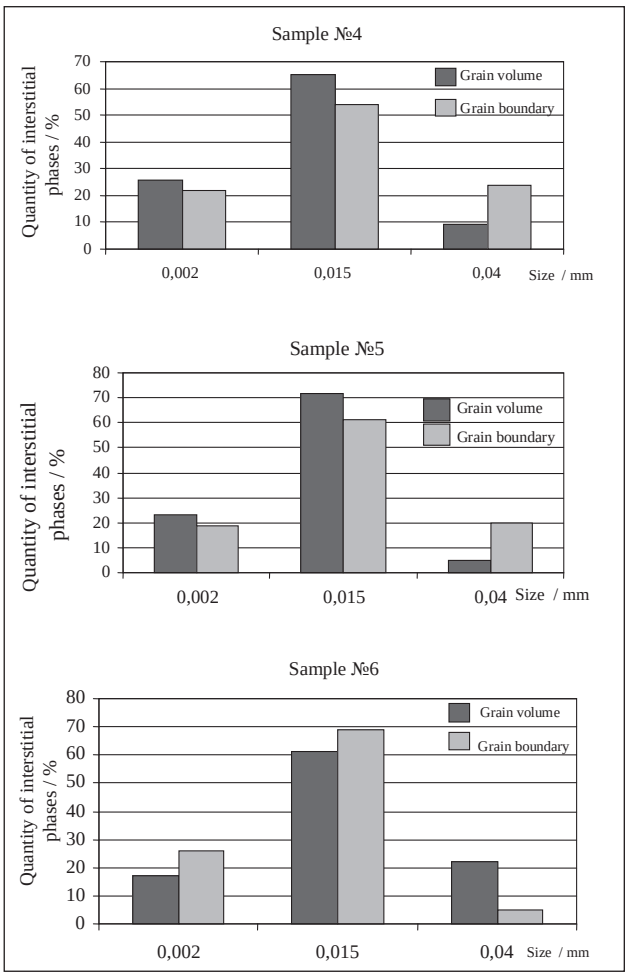

Figure 3 Distribution of interstitial phases depending on size

CONCLUSION

As a result of studies it is found that the main strengthening phase, regardless of thermal processing mode, in experimental alloy is a-phase Fe_3NiMo_2Al. Also its structure has Laves phase and carbide phases of $Me_{23}C$ type. Increase of Levas phase in structure leads to decrease of strength properties of alloy. The dispersity of phase varies between 0,002 micron and 0,04 micron; moreover the most of part of intermetallic phase have size less than 0,02 micron. The interstitial phases distinguished with even frequency, as in amount of grain bond, so at boundaries.

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