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THE INFLUENCE OF NANOMODIFICATION ON STRUCTURE AND PROPERTIES OF MULTICOMPONENT ALLOYS

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Urgency of the problem

The problem of hardening multicomponent alloys based on aluminum, titanium, nickel is particularly important for critical parts of mechanical engineering, aerospace engineering. Products should have a number of mechanical characteristics: high specific strength, reliability and performance properties. Aluminum alloys are used to form complex parts that require high specific strength, combined with satisfactory corrosion resistance and weldability. However the manufacturability of complexly doped aluminum alloys is reduced due to increased gas content and type of brittle phases $FeAl_3$, Mg_2Si, $MgZn_2$. Heat-resistant multi-component nickel alloys which are used in aviation and turbine construction must have the structural thermal stability, heat resistance and long-term strength. The effective way of grinding alloys' structural components at the macro and micro levels is handling multicomponent alloys by dispersed modifiers. In the past decade, the interest to this problem has increased considerably since it was found that the reduction of crystal size below some threshold can radically alter the properties of metals and alloys [1-3]. These effects are manifested when the average crystal grain size is not greater than 100 nm, and most clearly observed when the grain size is less than 10 nm. In this regard, one of the important scientific and technical fields is producing high-strength alloys modified by nanodispersed compositions.

Statement of the problem

The terms of blades for gas turbine aircraft engines of the new generation are becoming more and more strained due to the increase of the gas temperature at the turbine inlet and increasing airspeed and resource cycles of the engine. These extreme conditions require the use of advanced materials with fundamentally new structure and properties different from traditional materials [4].

The task of materials engineering is to create a modern superalloys with a stable structure capable of operating at high temperatures and tensions. The objective of this study is to improve the strength characteristics of aluminum alloys of Al-Mg-Sc and multicomponent nickel alloys of Ni-Cr-Al-Ti-Mo-W-Co processed by nanodispersed compositions which are prepared by plasma chemical synthesis.

Materials and methods of experimental research

The materials for research were cast superalloy nickel alloy, used for the manufacture of gas turbine engine blades [5] and wrought aluminum alloys 1424 and 1570 which are used for pipes (Table 1).

Table 1

The chemical composition of the alloys

Alloy grade	The content of chemical elements,% wt.							
	Ni	Al	Ti	Cr	Mo	W	Co	C
ХН59МВТКЮЛ	Major	4,17	3,2	12,5	3,92	4,21	9,53	0,11
Alloy grade	The content of chemical elements,% wt.							
	Al	Mg	Mn	Cu	Si	Fe	Zr	Sc
1424	Major	3,2	-	-	0,20	0,3	0,10	0,20
1570		5,8	0,35	0,15	0,40	0,2	0,15	0,35

The study of structural changes in the alloys before and after nanomodification was performed by metallographic analysis. The temperature of critical points was determined by derivatographic analysis. The distribution of alloying elements and modifying structural components of the alloys was determined by electron micro-probe analysis on the multipurpose scanning microscope JSM-6360LA.

Results and discussion

The structure of the original nickel alloy ХН59МВТКЮЛ - heterophase, representing fineparticles γ'-phase formed on the basis of the intermetallic compound Ni3Al. Intermetallic compounds are dispersed in a matrix which consists of γ- solid solution alloying elements in nickel. All refractory alloying elements (W, Mo, Cr) increase the area of existence of γ'- phase. Due to depletion of γ- phase refractory elements the efficiency of solid solution hardening of the matrix is reduced and, as a consequence, the resistance of alloy to slip dislocations, that ultimately leads to a decrease in heat resistance. Al and Ti in the alloy are γ'- generators and major reinforcers. Co, Mo and Cr form γ- solid solution . Thus complex alloy hardening of ХН59МВТКЮЛ occurs due to the hardening γ- solid solution, the presence of dispersed phase, the increasing of the content of γ'- phase, the reducing of the rate of consolidation γ'- phase at elevated temperatures.

Semi-finished products of aluminum alloys 1424 and 1570 have non-recrystallized structure that can further enhance the mechanical properties of alloys. Aluminum alloys are welded well and do not have tendency to form crystallization cracks [6]. The mofiying of melts is proposed in this study with the aim of strengthening the alloys [7]. Nanoparticulate compositions based on silicon carbide β-SiC with a particle size of 50...100 nm were used as modifiers for the aluminum alloys [8]. Nanosized powder (titanium carbonitride Ti(C,N)), obtained by the plasma chemical synthesis was chosen as modifier for nickel alloys [9]. The choice of modifiers was based on the principle of the size and crystallographic compliance with the matrix alloys [10].

The mechanism of action of the modifier in the nickel melt is the origin of many primary crystals of the matrix phase on the surfaces of nanoparticles. Nanomodificator which is based on Ti(C,N) disperses primary austenite dendrites.

The presence of modifying complex which is based on nanosized silicon carbide (fraction 50...80 nm) in aluminum alloys and micro-alloyed with scandium, has a decisive role in shaping the structure. Increasing the number of nucleation sites, which together with intermetallic compounds increases Al_3Sc leading role of α-Al-solid solution. Matrix structure and structural components refinement take place, thereby increasing the mechanical properties of complex alloys.

Nickel alloy blades macrostructure investigation before modifying showed extreme heterogeneity in the cross section. Initial samples had a coarse structure with a grain size of 5 ... 8 mm. Samples of modified blades characterized by uniform fine grain structure with a grain size up to 1 mm. Thus, by modifying the average grain size is decreased to 5 ... 8 times.

Unmodified samples contain large inclusions, which are located at grain boundaries. In the modified samples inclusions are significantly dispersed and located both along the grain boundaries and intragranular, thereby promoting hardening.

After the process of modifying the formation of the solid solution strengthened nickel and more advanced structure of the grain boundary led to improved mechanical properties of the complex of the modified alloy. Achieved a significant increase in the strength and plastic properties of the alloy ХН59МВТКЮЛ: σ_B increased by 8 ... 9%; $\sigma_{0,2}$ – 10 ... 13%; δ – 19 ... 21%.

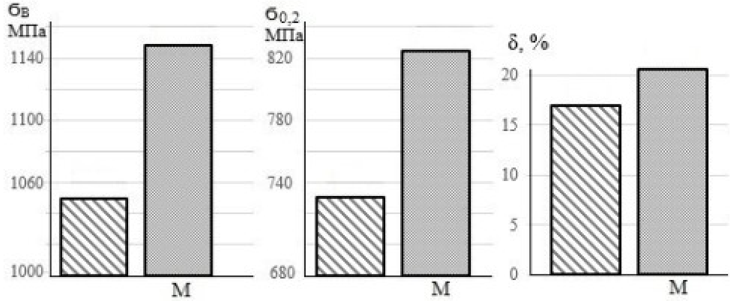


Fig. 1. The mechanical properties of heat-resistant nickel alloy ХН59МВТКЮЛ before and after modifying (M - modified alloy).

The modifying of aluminum based alloys led to lower gas content from 3 to 1 score porosity and a significant increase in strength and ductility characteristics of the alloy 1570: σ_B – 6 ... 7%; $\sigma_{0,2}$ – 4 ... 6%; δ – 14 ... 15 % (Fig. 2).

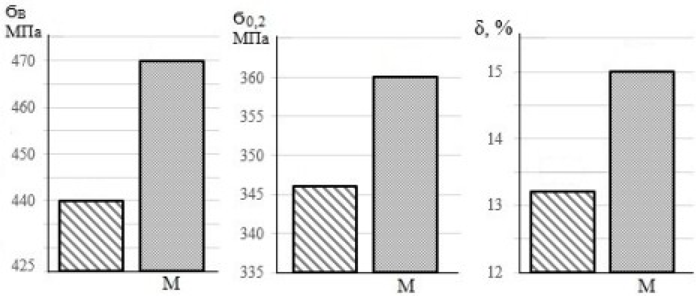
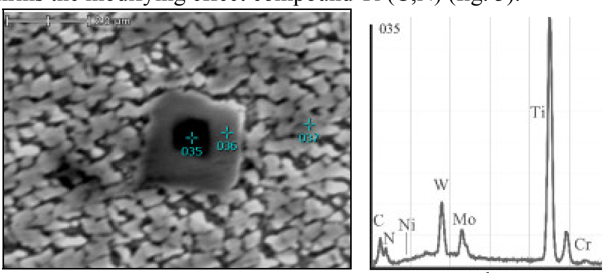


Fig. 2. Mechanical properties of 1570 aluminum alloy before and after modification (M - modified alloy).

To confirm the effectiveness of the Ti(C,N) as the electron microprobe analysis conducted nanomodifier alloy samples ХН59МВТКЮЛ. In unmodified samples the amount of Ti and C correspond to their contents in the alloy, the content of N has been detected. In the modified samples surge is detected intensities of Ti, C and N, which confirms the modifying effect compound Ti (C,N) (fig. 3).



a b

Fig. 3. The microstructure of the modified nickel alloy ХН59МВТКЮЛ, x 15000 (a), and the schedule of the intensity distribution of the characteristic radiation of elements (b).

Microprobe analysis proved digestibility of complex modifier based on titanium carbonitride heat-resistant nickel alloy ХН59МВТКЮЛ.

Conclusion

The choice of compositions of nanomodificators is proved: β-SiC for hardening aluminum-based alloys and Ti(C,N) – based on nickel. Granulometric composition of nanopowders was 50 ... 100 nm. It was conducted the research and industrial testing of modifying aluminum alloys 1424, 1570 and nickel alloy ХН59МВТКЮЛ.

As a result of the modifying aluminum alloys gas content became lower, mechanical properties of the alloys increased by an average of 4...7% plastic – 14...15%.

Also there was achieved dramatic grain refinement – 5 ... 8 times. As a result of the modifying it was got a homogeneous structure with intermetallic inclusions in phases along the boundaries and within the grains. The complex of mechanical properties was achieved: σ_B – more 8…9%; $\sigma_{0,2}$ – more 10…13%; δ – more 19…21%.

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