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Materials Science

Study of the High-Temperature Interaction Processes of the Alloy CM88Y with the System Co-Mo-Cr-Si-B

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The aim of the work was the research of the high-temperature interaction processes of the Co-Mo-Cr-Si-B system with the heat-resistant nickel alloy CM88Y concerning the development of the technology of the strengthening of the contact surfaces of the ship gas turbine engine blades. The methods of the microroentgen spectral analysis and electronic microscopy were used. The adhesive activity of the alloys was studied using the method of a lying drop. It was shown that the experiment materials have the high adhesive activity compared to the high-resistant nickel alloys at temperatures of 1190-1250ºC, creating favorable conditions for their application in the ship gas turbine building.

heat-resistant nickel alloys, wear-resistant materials, microstructure, adhesive activity

The development of the ship gas turbine building is connected with the efficiency, reliability and resource increase of the gas turbine engines operation. First, these parameters are defined by the wear intensity of the blades contact surfaces, which are in the most hard operation conditions. Therefore, the materials and the technologies of the strengthening contact surfaces require the improvement.

There is a wide range of the wear-resistant materials, which cover the contact surfaces with the melting or without melting of the basic material [1]. In this case, the conclusive criteria which meet the technological process, are the melting temperature and the possible for the use methods of the covering, which can give the mutually exclusive influence. It does not give the possibility to use the optimal combination of materials and technology [2].

Heat-resistant nickel alloys of the CM88, CM104 type and others are used in the ship gas turbine building for the producing of the blades. These alloys at the phase which it increases have the dispersed discharge of the γ'-phase $Ni_3(Al, Ti)$, which can lead to the coagulation due to the high temperatures. It gives the favorable conditions of the wear increase, including the intensification of the surface layer oxidation processes, which are depleted by the alloying elements have the ability to the damage, especially in the conditions of the operation at the high-temperature salt corrosion [3].

These alloys have not been practically melted. In this case, the material, which increases the contact surface, must have the melting temperature not more than 1210 ÷ 1220ºC. This requirement allows to classify the wear-resistant materials for the ship gas turbines into two groups in accordance with the melting temperature: more or less than 1210 ÷ 1220ºC [2].

For example, in the first group, there is the composition КБНХЛ-2, which has melting temperature in the range of 1070-1090ºC. However, this does not provide the possibility of the short-term heat up of 1150ºC [4]. All other known alloys are in the second group, such as: ВЖЛ-2, ВКНА-2М [5], В3К-р [6], Stellite 12 [7], Х30Н50Ю5Т2 [8], Х25Н10В8 [5], ХТН-61 [9], ХТН-62 [10], Tribaloy T-800, T 400, T 401 [11] etc. All these alloys have the melting temperature above 1220ºC. It makes worse the covering them on the contact surfaces of the ship gas engine blades by fusing.

Concerning this, the perspective wear – resistant materials are КМХ and КМХС, which have the necessary level of the wear-resistance at the temperatures up to 900ºC and the melting temperature less than 1220ºC [12]. Table 1 illustrates the chemical composition and melting temperature of the alloys.

The aim of the work was the research of the processes of the high-temperature interaction of the wear-resistant materials КМХ and КМХС with the heat-resistant nickel alloy СМ88Y for the definition of the basic regularities and the optimal conditions of the formation of the composition. The alloy СМ88Y has the classical level of the alloying, which allows to definite the general regularities of the influence of the base alloying level into the adhesive processes and the change of the chemical composition in accordance with the fusing temperature. The chemical composition of the alloy СМ88Y is given in Table 2.

The activity of the alloys КМХ and КМХС has been researched by "drop method", which is in the state of the still, at the melting in the vacuum of the level 10^{-2} Pa of the alloy СМ88Y. Curing time at the temperatures: from 1175 up to 1250ºC was 1 minute. The separation of the chemical elements at the area of the interaction of the alloys КМХ and КМХС with the heat-resistant alloy СМ88Y at the range of 1175-1190ºC has been shown in Figs. 1, 2. The concentration of B and carbon in the researched samples did not definite due to the absence of the technical possibility.

The analysis of the interaction of the alloy КМХ with the alloy СМ88Y at temperature 1175ºC has shown (see Fig.1, a-c) that during the crossing of the melting line up to the metal of fusing, the concentration of Ni is decreasing up to 6% mas. and fluctuating at the range of 6-9% mas. at length of 400 micrometers, with the ordinary slumps up to

Table 1. Properties of the alloys КМХ and КМХС

Grade of the alloy	Chemical composition , % mas.							Melting temperature, ºC*
	Co	Cr	Mo	Si	B	Ni	Cr_3C_2	
КМХ	base	17-18	27-28	2.8-3.2	0.8-1.2	–	–	1185^{+5}
КМХС	base	17-18	27-28	2.8-3.2	0.8-1.2	2.8-3.2	1.9-2.1	1165^{+5}

* The melting temperature was defined by method of the high-temperature differential thermal analysis.

Table 2. Chemical composition of the alloy СМ88Y

Grade of the alloy	Chemical composition, % mas									
	Ni	Cr	Co	Mo	W	Al	Ti	Nb	Hf	B
СМ88Y	base	15.8	11.7	1.96	5.30	3.00	4.60	0.15	0.30	0.09

3% mas. at the «light» phase. Cr from 15% mas., in the base metal, is increasing up to 20-21% mas. in the fusing, at the increasing up to 12% mas. in the «light» phase. Co is dispersed by the following way: in the base metal – 7% mas. at the distance of 200 micrometers from the line of fusing, 9% mas. at the distance of 70 mcm, 30% mas. at the passage in the joint, with the increasing at the fusing up to 38-43% mas. (at the «light» phase up to 31% mas.). Mo is increasing sharply in the deposited metal up to 21-26% mas. (at the «light» phase 33-43% mas.). W is in the base metal in the quantity of 5% mas, % mas. in the area of the composition and 2.5% mas. in the deposited metal at the distance of 340-350 micrometers from the line of fusing. Al is at the fusing up to 2.5% mas. at the distance of 340-350 micrometers from the line of fusing. Ti is at the same distance up to 0.5-0.8% mas. Si is at the fusing in the quantity of the output quantity (see Table 1).

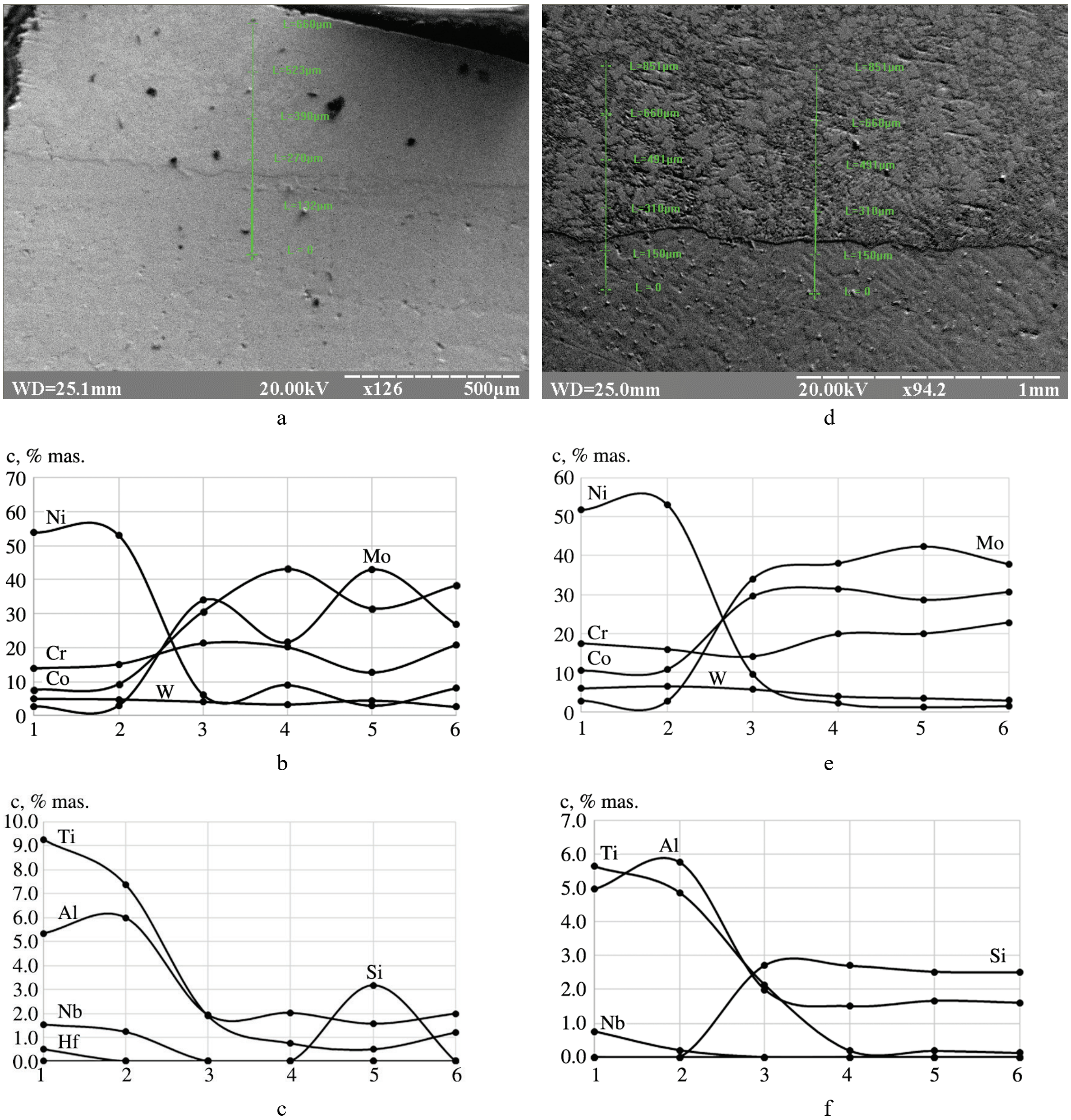

Fig. 1. Microstructure and the separation of the chemical elements at the area of the interaction of the alloys KMX (*a, b, c*) and KMXC (*d, e, f*) with the heat-resistant alloy CM88Y at temperature 1175°C.

The interaction of the alloy KMXC with the alloy CM88Y at 1175ºC is like the same process (see Fig. 1, d-f). Ni infiltrates freely in the fusing up to 6.5% mas. at the distance of 130 micrometers from the joint. The concentration of Cr is increasing smoothly at the passage across the line of fusing from the base metal (15% mas.) up to deposited metal (up to 20-26% mas.).

Co in the base metal is in the nominal quantity. It is increasing sharply and its volume in the fusing up to 30-33% mas., but it does not achieve its nominal value in the whole volume. Mo is increasing sharply its volume at the passage across the line of the melting. It increases its concentration sharply at the fusing (up to 40% mas. at the «light» phase). The mass part of W is 5-6% in the base metal, at the passage across the line of fusing at the distance of 130 micrometers. It keeps the maximum concentration which is 5-6%, at the distance of 330 micrometers from the joint and it is decreasing up to 3.5-4% at the joint and at the distance of 700 micrometers and it is 2.5-3%. The concentra-

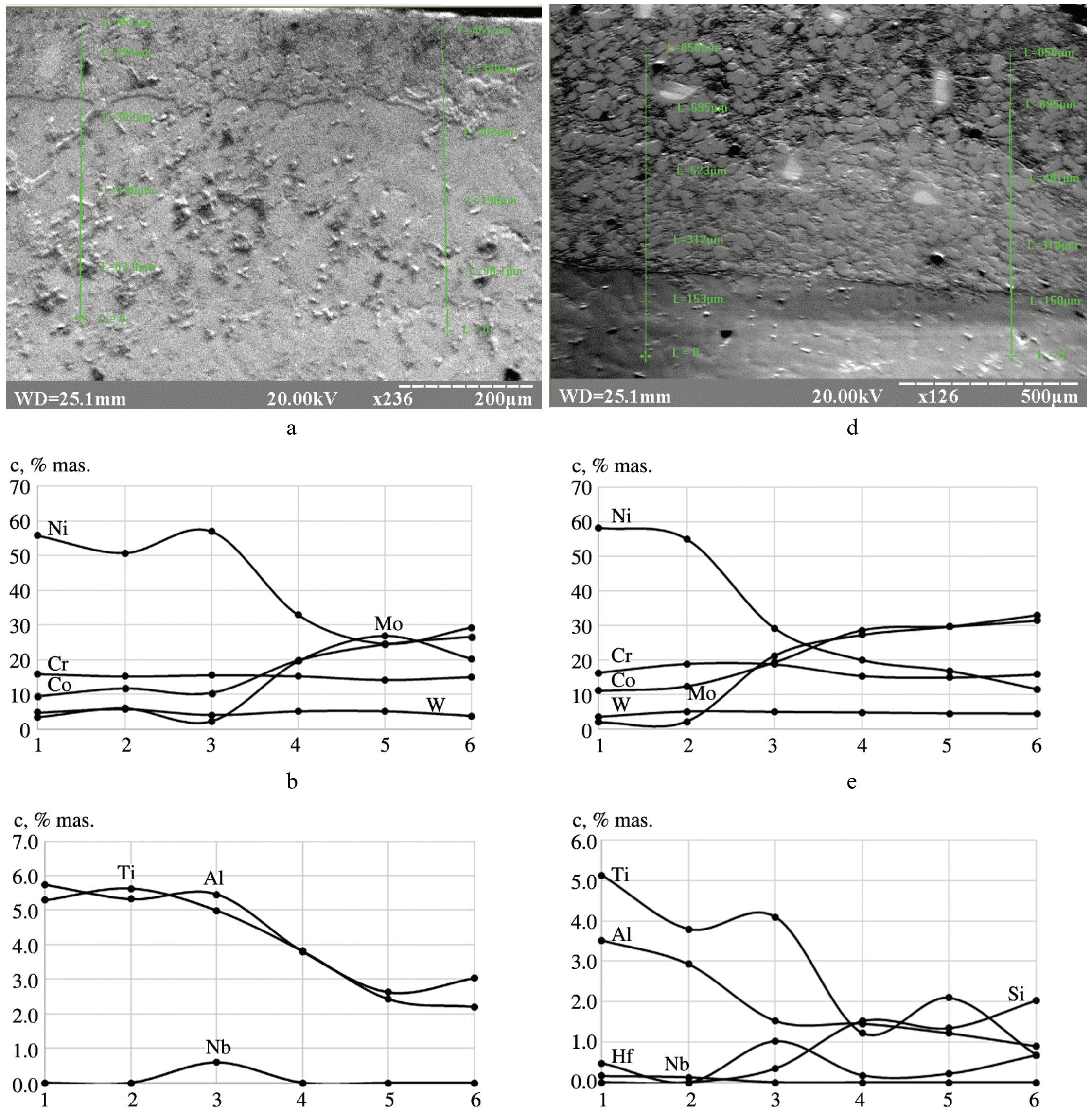

Fig. 2. Microstructure and the separation of the chemical elements at the area of the interaction of the alloys KMX (*a, b, c*) and KMXC (*d, e, f*) with the heat-resistant alloy CM88Y at temperature 1190°C.

tion of Al is decreasing at the pass from the base metal up to the deposited metal up to 1.5-1.7% mas It is not changed during 700 micrometers. Si is concentrated at fusing up to 4-5% mas.

The interaction of the alloys KMX and KMXC with the heat-resistant alloy CM88Y at 1190°C (see Fig. 2, a-f) occurs more actively. The chemical elements of the alloy CM88Y begin to saturate the deposited metal as the result of the intensification of the processes dissolution. The separation of the chemical elements with the combination of the alloy KMX is shown in Fig. 2, a-c. The mass part of Ni at the line of the alloying is 32-37%, and at fusing it is 25-29% at the distance of 150 micrometers from the line of fusion. The concentration of Cr in the base metal is 15-16% mass in the deposited metal it is 14-15% mas. The content of Co in the base metal is in accordance with the nominal.

At the joint it is increasing up to 19-20% mas., at the fusion, at the distance of 150 micrometers from the joint, there is 23-26% mas. and it does not achieve the nominal value on the whole height of the fusion. Mo is 2.8-3.5% mas. in the base metal at the distance of 300 micrometers from the line of alloying. It is exceeded the output volume (1,96% мас.), at the area of the joint it is 14-19% mas., and at the area of the fusing it is 23-29% mas., depending on the phase. W is divided uniformly on the analysis line, and its medium value of the concentration is near 5% mas. Al diffuses actively into the fusion (near 3% mas.) on the whole height. Ti does the same, the medium concentration of it at the fusion is 2.4-2.7% mas. Nb and Hf are at fusion in the separate points, in the concentration up to 0.5% mas.

The interaction of the alloy KMXC with the heat-resistant alloy CM88Y at 1190°C (see Fig. 2, d-f) occurs more actively. During this, the equalization of the concentration of the alloying elements takes place in the adjacent to the line of fusion volumes of metal. The deposited metal continues to enrich actively by Ni, W, Al and Ti, which move from the base metal as the result of the intensification of the processes of its dissolution and the further diffusion.

During the excessive heating of the samples at temperature up to 1250°C, which is near to the melting temperature of the alloy CM88Y, there is the dangerous interaction of the deposited metal and the base metal. In these conditions, the researched alloys are melted fully with the base metal and the mutual uniform equalization of the alloying elements concentration is executed on the whole area of the fusion up to the averaged values. In the structure there are the discrete eutectic inclusions, which are enriched by Si, Ti and, probably, by B, the concentration of it didn't specify in this work.

In our previous work, the processes of the heat-temperature interaction of the alloys KMX and KMXC with the alloy ВЖ98 [12] were researched. In whole, during the passage from the alloy ВЖ98 up to the alloy CM88Y, the intensity of the interaction processes of the deposited materials, with the base increases. This is due to the increasing of the number and quantity of the interactive between themselves alloying elements, in accordance with the possibility of the availability of the additional eutectic reactions. This position is illustrated clearly by the form of the line of the materials extension, which are deposited, on the surface of the heat-resistant alloys. At temperature 1190°C the alloy KMXC is spreading easily on the surface of the heat-resistant alloy ВЖ98, and it interacts very weakly. In these conditions the alloy KMXC interacts actively with the base metal CM88Y: the depth of the dissolution is increasing from 0.16 mm up to 0.29 mm, the angle of wetting is increasing from 13 up to 26 degrees, which leads to the enrichment of the deposited metal by the alloying elements of the base and the partial loss of its working characteristics, for example, the hardness and the wear-resistance.

This regularity leads to the impairment of the characteristics of the wetting and the spreading of the materials KMX and KMXC, at their coating on the boundary alloying heat-resistant and heat- and - corrosion – resistant alloys on the base of Ni base of the type CM88Y, with the simultaneous intensification of the processes of the base material dissolution. For the confirmation of this position, we defined the specific squares of the spreading of the most active alloy KMXC, at its interaction at the researched temperature range with the alloys ВЖ98 and CM88Y. The results are shown in Table 3.

The analysis of the specified results in Table 3 confirmed the progressive increase of the adhesive activity at the fusion of the materials KMX and KMXC at the whole researched temperature interval, at the passage from the alloy ВЖ98 to the alloy CM88Y [12].

Table 3. Specified square of the spreading of the composition KMXC with the alloys ВЖ98 and CM88Y at different temperatures

Grade of the alloy	Specified square of the spreading, Ssp, mm^2/mg		
	1175°C	1180°C	1210°C
ВЖ98	0.40	0.41	1.20
CM88Y	0.19	0.20	0.79

The specified peculiarities must be taken into account at the choice of the temperature of the covering of the compositions KMX and KMXC on the real parts. An excessive increase of the heating temperature of the base material will have the negative influence on the operational characteristics of the compositions, which are fusing. The analysis of the obtained results has shown that the heating temperature of the base material at the fusion must not exceed the fusion temperature of the coating compositions. Thus, for the KMX alloy the optimal heating temperature of the base metal at its fusion must not exceed 1185^{+5} °C, and for the KMXC alloy it is 1165^{+5} °C. At the same time, it is necessary to minimize the time stayed at this temperature.

In connection with this, during the development of the real technology it is necessary to precisely control the heating temperature of the parts, which are strengthen and minimize the use of adhesive materials, which are fusing.

Conclusions

1. An excessive increase of the heating temperature of the base metal, at fusing, negatively affects the operative characteristics of the compositions KMX and KMXC due to their enrichment by the chemical elements of the base.

2. It is necessary to limit the heating temperature of the base metal at fusing, it should not exceed the melting temperature of the fused compositions. For the KMX alloy, the optimal temperature of the heat of the base metal must not exceed 1185^{+5} °C, and for the KMXC alloy it must not exceed 1165^{+5} °C. At the same time, it is necessary to lead to the possible minimum time to stay at this temperature.

3. During the transition from the alloy ВЖ98 to the alloy CM88Y, which has a boundary level of alloying, there is the intensification of the interaction processes of the materials, which are fusing, with the base at the whole temperature interval. The depth of the dissolution of the base metal and the wetting angles are increasing approximately two-fold proportionally the heating temperature. It is explained by the increase of the number and the quantity of the interacting alloying elements which increses the possibility of the additional eutectic reactions.

მასალათმცოდნეობა

CM88Y შენადნობისა და Co-Mo-Cr-Si-B სისტემის მაღალტემპერატურული ურთიერთქმედების პროცესების შესწავლა

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ნაშრომის მიზანია Co-Mo-Cr-Si-B სისტემის მაღალტემპერატურული ურთიერთქმედების პროცესების შესწავლა თბომედეგი CM88Y ნიკელის შენადნობთან, გემის აირტურბინული ძრავის ფრთების საკონტაქტო ზედაპირების გაძლიერების ტექნოლოგიის განვითარებასთან მიმართებაში. ნაშრომში გამოყენებულია მიკრორენტგენის სპექტრული ანალიზის მეთოდები და ელექტრონული მიკროსკოპია. შესწავლილია შენადნობების ადჰეზიური აქტივობა. აღმოჩნდა, რომ ექსპერიმენტის მასალებს აქვს მაღალი ადჰეზიური აქტივობა 1190-1250°C ტემპერატურაზე მაღალი რეზისტენტობის ნიკელის შენადნობებთან შედარებით. ეს კი ქმნის ხელსაყრელ პირობებს გემის აირტურბინის ნაგებობაში მათი გამოყენებისთვის.

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