INFLUENCE OF HEAT-RESISTANT COATINGS ON THE STRUCTURE OF ALLOYS ZhS6K

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The article investigates the influence of heat-resistant coatings based on nickel monoaluminide with additions of chromium, tungsten, silicon, carbon on the composition and structure of the alloy ZhS6K after it has been coated and subsequently held for a long time at a high temperature.

When nickel alloys are coated at temperatures exceeding 1050°C with heat-resistant metallike substances, it may bring about a substantial change of their structure throughout the bulk. For instance, when the alloy ZhS6K is held at 1050-1200°C for 4 h or more, γ'-phase and the carbide M6C of globular and acicular shape are segregated in it structure. As a result the mechanical properties of the alloy (ductility and thermal fatigue strength) are impaired and can be restored only by additional heat treatment, viz., holding at 1220°C 4 h [1].

Both in the formation of heat-resistant coatings and in operation of the finished product intense interdiffusion between the protective coating and the matrix occurs, and this leads to the resorption of the coating and also to a change in the composition and structure of the alloy in the diffusion zone [2].

There are published data on the influence of silicon on the intensity of segregation of secondary phases in nickel base alloys. For instance, when the content of Si is increased from 0.2 to 1.3% in the nickel alloys É1929, ÉP202, and ÉP109, the amount of secondary phases increases from 2-4 to 6-12% after holding at 900°C 1000 h [3]. When aluminum coatings on the alloy ZhS6K are alloyed with silicon, an acicular phase in the diffusion zone of the alloy forms and coagulates with great intensity [4].

In the present work we investigated the composition and structure of the alloy ZhS6K after it had been provided with a heat-resistant coating with the composition 59.5% NiAl + 30% Cr + 5% W + 5% Si + 0.5% C [2] and was then held for a long time at a high temperature.

The coating was obtained by the powder baking technology at 1200°C for 10 min in a vacuum furnace at a residual pressure not exceeding 133·10⁻³ Pa on plates of alloy ZhS6K 10 × 10 × 4.5 mm in size. The coating was 200-300 μm thick. Additional holding was carried out in air at 1100°C for 160 and 500 h.

The specimens were investigated by local x-ray spectrum analysis (LXSA) on a microanalyser Camebax. The silicon content of the phases of the alloy was ascertained by the method of varying the accelerating voltage, which makes it possible to determine the mass fraction of one component without full quantitative analysis of the phase for its entire composition [5]. The accuracy of quantitative LXSA was ±10 rel.%. Stereometric analysis was carried out on a linear structure analyzer Epiquant.

Metallographic investigation showed that as soon as the coating is applied, secondary phases with globular shape, 1-10 μm in size, are segregated along the grain boundaries. Additional holding at 1100°C leads to the formation of acicular secondary phases more than 15 μm long and mostly 1-2 μm thick in the body of the grain. Qualitative investigation of the structure of the alloy by LXSA showed that the content of Mo, W, Si in the acicular phase is higher than in the matrix of the alloy (Fig. 1).

According to [1] the segregating secondary phases (both globular and acicular) are tungsten and molybdenum carbides alloyed with elements of the alloy.
With LXSA we ascertained that the elements of the coating (Al, Si, Cr) diffuse to considerable depth with great intensity into the protected alloy. After build-up of the coating the diffusion zone was 35-50 μm thick, after additional heat treatment at 1100°C for 160 and 500 h its thickness increased to 250-350 and 400-500 μm, respectively. The technical possibilities of the instrument were unfortunately such that diffusion of carbon could not be investigated.

The results of the determination of the silicon content of the matrix and the acicular phase of the alloy are presented in Fig. 2. The acicular phase was investigated on thickened needles 8-10 μm in size. It can be seen that in secondary phases with acicular shape the silicon content is always higher than in the matrix of the alloy. Consequently silicon, causing segregation of secondary phases, also concentrates predominantly in them. Beyond the diffusion zone the silicon content in the matrix and in the acicular phase is almost independent of the length of heat treatment and is equal to 0.25 and 0.5%, respectively. In the diffusion zone of the alloy the silicon concentration increases upon approach to the coating: in the matrix imperceptibly, to 0.4%, in the acicular phase substantially, after additional heat treatment at 1100°C for 160 and 500 h to 2.0 and 3.2%, respectively. Consequently, almost all the silicon diffused into the alloy from the coating is concentrated in the acicular phase and not in the matrix of the alloy.

Additional holding at 1100°C leads to segregation of secondary phases with acicular shape throughout the bulk of the alloy. It was established by stereometric analysis that in the alloy beyond the diffusion zone the volume fraction of the acicular phase is 2.5%. Diffusion of the elements of the coating into the alloy intensifies the process of segregation of the secondary phases: near the coating their volume fraction increases to 7.5%, and at the same time the needles about double in length (Table 1).

It should be noted that the diffusion of elements of the coating into the protected alloy causes irreversible changes of the composition and structure of the alloy in the diffusion zone, impairing its mechanical properties [1]. Restoration of the structure of the alloy beyond the diffusion zone (elimination of the consequences of overheating) is possible in principle but the heat treatment required for that (1220°C 4 h [1]) greatly impairs the protective properties of the coating because at 1220°C a liquid phase forms in the coating, and that causes intense resorption of the coating, reduction of the proportion of nickel aluminate in it, and that is the component ensuring high heat resistance of the composite [2].