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Abstract

Full Text

Chemistry

I. I. Novikov and L. I. Lautova

Dependence of Relative High-Temperature Strength on Composition in the Cu–Ni–Si System

(Presented by Academician A. A. Bochvar, 24 I 1957)

A large number of works have been devoted to the study of the connection between high-temperature strength and the phase diagram. The main types of “high-temperature strength–composition” diagrams have been derived on the basis of investigations of specific binary systems and individual sections of multicomponent systems ^(1–4).

In the studies of A. A. Bochvar and M. V. Zakharov ^(2,3,5), an important role in increasing high-temperature strength is assigned not only to alloying of the basic solid solution, but also to the structure and properties of the excess phase coexisting with this solution.

Fig. 1. Isothermal section of the Cu–Ni–Si system at 700° ⁽¹⁰⁾. The figures in parentheses are the serial numbers of the sections.

In many works by I. I. Kornilov, the determining role of the solid solution is emphasized, and the maximum high-temperature strength is often associated with the limiting saturated solid solution ^(4,6,7).

The accumulated experimental material shows that the character of the dependence of strength properties on composition changes under the influence of various factors, for example, with a change in temperature ^(2,3,8,9).

The influence of the nature of coexisting phases on the character of the dependence of high-temperature strength on composition is conveniently traced along ray sections of a complex ternary system in which various second phases, differing in their properties and structure, border on the basic solid solution. As far as we know,

...therefore, such an approach to studying the dependence of heat resistance on composition had not yet been used.

Fig. 2. Dependence of hourly hardness at 700° on composition for different sections of the Cu–Ni–Si system. The numbers in parentheses are the serial numbers of the sections (see Fig. 1), 0—the Cu–Ni system, 7—the Cu–Si system

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For the investigation the system Cu–Ni–Si was chosen, in which, at 700°, various phases of different nature coexist with the copper-based solid solution: the compound Ni_5Si_2 , the γ -phase (Cu–Si), and the ternary compound σ -phase (Fig. 1) ⁽¹⁰⁾.

Relative heat resistance was evaluated by the method of long-time hardness ⁽¹¹⁾. The hourly hardness was measured at 700°, with a cone made of heat-resistant steel, having an apex angle of 90°, serving as the indenter.

Binary alloys Cu–Ni and Cu–Si and ternary alloys lying on six radial sections were investigated (Fig. 1).

The long-time hardness was determined on specimens cast in a graphite mold without any preliminary heat treatment. This was due to the fact that silicon bronzes are of practical interest as a material for certain cast parts operating at high temperatures.

The test results are presented in Figs. 2 and 3 in the form of “hourly hardness –composition” diagrams.

Microscopic analysis showed that alloys with maximum hourly hardness are sometimes clearly single-phase, and sometimes more or less heterogeneous; in the latter case the second phase is clearly visible at medium microscope magnifications.

Fig. 2. Dependence of hourly hardness at 700° on composition for different sections of the Cu–Ni–Si system. The numbers in parentheses are the serial numbers of the sections (see Fig. 1), 0—the Cu–Ni system, 7—the Cu–Si system.

In Fig. 4 the curves of equal hourly hardness at 700° (isohardness curves) are plotted on the concentration triangle. Also shown there is the microscopically established boundary of the single-phase region for the casting conditions (specimens in a graphite mold).

The different position of the maximum of heat resistance relative to the boundary of the single-phase region can be explained if one takes into account the ratio of the long-time hardness of the second phase and of the copper-based solution.

Fig. 3. Dependence of hourly hardness at 700° on composition along the Cu–Ni₂Si section

Figure 3: Fig. 3. Dependence of hourly hardness at 700° on composition along the Cu–Ni₂Si section

Fig. 4. Curves of equal time hardness (isochrones) at 700° in the Cu–Ni–Si system; a—line of maxima of time hardness, b—boundary of the single-phase region

Figure 4: Fig. 4. Curves of equal time hardness (isochrones) at 700° in the Cu–Ni–Si system; a—line of maxima of time hardness, b—boundary of the single-phase region

Fig. 3. Dependence of hourly hardness at 700° on composition along the Cu–Ni₂Si section.

In the alloys of the first, second, and third sections, in which the maximum heat resistance lies in the two-phase region, the second phase is not the compound Ni₂Si, as was previously thought, but a solid solution based on the silicide Ni₅Si₂ (Fig. 1) ^(10,12). The heat-resistant phase Ni₅Si₂, being located along the dendrite boundaries, exerts a blocking action on the copper solution and increases the heat resistance of the alloy.

Excessive heterogenization of alloys of the first, second, and third sections leads to a decrease in high-temperature strength. This can be explained by the fact that, with an increase in the interphase surface, the action of the solution-precipitation mechanism of plasticity is intensified ⁽⁵⁾. The solubility of nickel and silicon in copper decreases sharply with decreasing temperature ⁽¹⁰⁾, while the compound Ni₅Si₂ itself is capable of dissolving a large amount of copper ⁽¹²⁾.

Fig. 4. Curves of equal time hardness (isochrones) at 700° in the Cu–Ni–Si system; a—line of maxima of time hardness, b—boundary of the single-phase region

With a very high content of Ni₅Si₂ in the alloys, a new rise in high-temperature strength is observed (Fig. 3). The latter is connected with the fact that the decisive role in these alloys is played not by the interaction of two phases, but by the high hardness of nickel silicide Ni₅Si₂, which becomes the basis of the alloy.

In the Cu–Si system, the alloy with a small amount of the γ -phase is the most high-temperature-strength, since this phase is somewhat more heat-resistant than the solution of silicon in copper.

In the fifth and sixth sections, the maximum high-temperature strength lies in the single-phase region of the solid solution. In alloys of these sections, the ternary compound (σ -phase), formed by a peritectic reaction at 915° ^(10,12)

(Fig. 1), borders the copper-based solid solution. The test temperature of 700° is a high homologous temperature for the σ -phase, which, evidently, is not heat-resistant under these conditions. The appearance of the σ -phase in the alloy leads to a decrease in high-temperature strength.

The small second rise on the long-time hardness curves of the fifth and sixth sections is due to the premature appearance, during nonequilibrium crystallization, of the γ -phase, which is somewhat more heat-resistant than the σ -phase.

A large influence on the level of the values of the time hardness of the alloys, including alloys with a heat-resistant second phase, is exerted by the degree of alloying

of the basic solid solution. The relation of heat resistance to the alloying of the copper-based solid solution is clearly revealed in the following comparison. Silicon in the binary Cu–Si system increases the heat resistance of the solid solution less than nickel in the binary Cu–Ni system (compare curves 0 and 7 in Fig. 2). At the same time, the position of the isoclines in Fig. 4 shows that partial replacement of nickel in the solid solution by silicon (at constant copper content) leads to an increase in heat resistance. Here the positive role of complex alloying of the solid solution is manifested⁽¹³⁾.

Thus, the maximum of heat resistance on radial sections of the ternary system is located, in the general case, either in the two-phase (and also three-phase) region, or in the region of an unsaturated solid solution. **Coincidence of the maximum of heat resistance with the boundary of the solid solution is a special case.** The position of the maximum of heat resistance relative to the boundary of the single-phase region is strongly influenced by the ratio of the strength properties of the solid solution (the base of the alloy) and of the excess phase.

To the three schemes of M. V. Zakharov for the dependence of heat resistance on composition⁽²⁾, it is necessary to add a fourth scheme, very important for practice: an increase in heat resistance to a maximum **located in the heterogeneous region**, then a decrease in heat resistance to a shallow minimum, and a new increase in heat resistance up to the composition of the second phase (Fig. 3).

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CITED LITERATURE

1. M. V. Zakharov, *Izv. AN SSSR, OTN*, No. 1, 124 (1949).
2. M. V. Zakharov, *DAN*, **65**, No. 3, 337 (1949).
3. M. V. Zakharov, *Investigation of Non-Ferrous Metal Alloys*, collection 1, Izd. AN SSSR, 1955.
4. I. I. Kornilov, *DAN*, **96**, No. 4, 721 (1952).
5. A. A. Bochvar, *Izv. AN SSSR, OTN*, No. 5, 649 (1948).
6. I. I. Kornilov, *DAN*, **67**, No. 6, 1037 (1949).
7. I. I. Kornilov, R. S. Mints, S. D. Onoprienko, *DAN*, **88**, No. 4, 683 (1953).
8. A. A. Bochvar, *Izv. AN SSSR, OTN*, No. 5, 743 (1946).
9. I. I. Kornilov, L. I. Pryakhina, *DAN*, **87**, No. 6, 971 (1952).
10. I. I. Novikov, L. I. Dyatova, *Collection of Scientific Works of the Physico-technical Institute, Academy of Sciences of the Kazakh SSR*, **1**, 1957.
11. A. A. Bochvar, *Izv. AN SSSR, OTN*, No. 10, 1369 (1947).
12. M. Okamoto, *Nippon Kinzoku Gakkai Si*, **3**, No. 9, No. 10, No. 11, 336, 365, 411 (1939).
13. K. A. Osipov, *DAN*, **60**, No. 6, 1535 (1949).

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