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Abstract

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STUDY OF THE PHASE COMPOSITION OF IRON-VANADIUM AND IRON-CHROMIUM ALLOYS

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According to literature data ([1,2]), the phase diagrams of iron–vanadium and iron–chromium contain a region of the σ-phase, which at temperatures $> 1234^{\circ}$ for Fe–V alloys and 820° for Fe–Cr alloys passes into the region of solid solutions of the α-phase. However, the abrupt change in the properties of alloys within the single-phase regions of both the σ- and the α-phase indicates a more complex character of the phase transformations. Thus, for example, brittleness is sharply manifested after annealing at temperatures of 400—550° in alloys which, according to the phase diagram, belong to the single-phase region of the σ-phase. The ductility in this case falls to zero, which limits the practical use of the alloys. Lena and Hawkes ([3]) consider that the strengthening of Fe–Cr alloys at low tempering temperatures is explained by the separation of a solid solution rich in chromium. A similar point of view is held by Williams and Paxton ([4]), who, on the basis of their experimental investigation, came to the conclusion that in the Fe–Cr system at temperatures below 600° there are two eutectoid transformations.

A change in properties not corresponding to a single-phase structure of the solid solution is also observed ([6,7]) at temperatures above the temperature of the σ- to α-phase transformation. This change in properties is difficult to explain by a process of atomic ordering, which is assumed by some investigators both at low and at high temperatures ([7]).

The purpose of the present investigation was to study the structure of iron-vanadium and iron-chromium alloys after heating at various temperatures in the range 1400—600°, followed by quenching in water.

The alloys were prepared from electrolytic iron, electrolytic chromium, from vanadium reduced from vanadium oxide and containing 99.6% V and 0.08% C, and from aluminothermic vanadium containing $\sim 1\%$ Si.

Alloys of Fe with 49.5 at.% V and Fe with 50 at.% Cr were prepared by the method of crucibleless melting. Alloys of Fe with 28.5, 43, and 74 at.% V and alloys of Fe with 35, 42, and 48 at.% Cr were prepared from vanadium containing Si as an impurity.

The investigation was carried out by the method of X-ray diffraction in a polycrystal and by microscopic analysis. After casting, the alloys were homogenized at a temperature of 1300° for from 20 to 100 hr and quenched from this temperature in water.

Structure of iron-vanadium alloys. After heating an alloy specimen at the selected temperature and quenching in water, the microstructure of the alloy was studied; then powder for X-ray examination was filed from the surface of the specimen. The filed powder was sealed in evacuated capillaries and additionally heated, followed by quenching at the same temperature at which the heating was carried out.

To the article by Zakharova, Ignatova, Semenova, and Khatanova, p. 498

Fig. 1. X-ray diffraction pattern of an iron alloy with 42% chromium after homogenization at 1300° for 100 hours, followed by quenching in water

Fig. 2. Microstructure of an iron alloy with 42% chromium after homogenization at a temperature of 1300°, followed by quenching in water. 160×

β phase

$(111)K_\beta$ $(111)K_\alpha$ $(200)K_\alpha$ $(220)K_\alpha$ $(113)K_\beta$

α phase

$(110)K_\beta$ $(110)K_\alpha$ $(200)K_\beta$ $(200)K_\alpha$ $(112)K_\beta$ $(112)K_\alpha$

Fig. 3. X-ray diffraction pattern of an iron alloy with 42% chromium after annealing the alloy at 1000° for 4 hours, followed by quenching in water

To the article by Smirnov, p. 508

Fig. 2. X-ray diffraction pattern of polystyrene (filtered copper radiation)

Fig. 3. X-ray diffraction pattern of mercurated polystyrene II (filtered copper radiation, exposure 40 hours)

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of the specimen. The duration of heating of the specimen was varied from 15 min to 2 h at a temperature of 1400° and from 5 to 170 h at 600°. Annealing was ended when an increase in the heating time no longer led to a change in the structure.

X-ray patterns were taken using chromium radiation. The results of the investigation showed that after homogenization at 1300° and quenching, iron-vanadium alloys with vanadium contents from 28.5 to 74% are not single-phase (as they should be according to the Weber and Ellinghausen phase diagram), but two-phase. Microscopic examination revealed that, against a background of crystals of the α-phase with a hardness of ~250 kg/mm^2, crystals of another phase with a hardness of ~750 kg/mm^2 are visible. The amount of the second, harder phase increases with increasing vanadium content in the alloy. X-ray analysis confirmed the microscopic data. Two systems of lines appeared on the X-ray pattern, one of which corresponded to the body-centered cubic α-phase, and the other to a face-centered phase, which we designated the β-phase. From the intensity ratio of the lines of the α- and β-phases by the method of homologous pairs, it was determined that the alloy with 28.5% V contains 5% β-phase, and the alloy with 74% V contains ~80% β-phase. The lattice constant of the β-phase for the alloy Fe with 43% V is 4.12 Å. With a change in the vanadium content, the constant changes by hundredths of an angstrom.

After investigation of the structure at a temperature of 1300°, the same specimens were annealed and quenched from temperatures of 1400, 1200, and 1150°; the structure of all Fe—V alloys proved to consist, just as after quenching from 1300°, of two phases—α and β. At a temperature of 1150° the structure of Fe alloys with 28.5, 42, and 49.5% remained two-phase when the annealing time was increased to 60 h.

A different picture was observed after annealing Fe—V alloys at 800°. At this temperature, already after 5 h of heating and quenching, the Fe alloy with 28.5% V consists of one α-phase; alloys with 43, 49.5, and 74% V consist of two phases —α and σ. After annealing at a temperature of 600°, the α-phase structure is preserved in the alloy with 28.5% V; in the alloy Fe with 43% V there is a structure of α- and σ-phases; in the alloy with 49.5% V the crystals of the α-phase have disappeared, and the structure consists only of the σ-phase.

Consequently, in iron–vanadium alloys from 28.5 to 74%, when the temperature is lowered from 1400 to 600°, the phase transformations proceed by a more complex path than follows from the phase diagram available in the literature, namely:

$$(\alpha + \beta) \to \alpha \to (\alpha + \sigma) \to \sigma.$$

On reheating the alloys from 600 to 1300°, the σ-phase transforms into α- and β-phases, which indicates that the β-phase is an equilibrium phase and that Fe alloys with 28.5–74% V at temperatures above the temperature of transformation of the σ-phase into the α-phase consist of α- or $\alpha + \beta$-, or β-phases.

Structure of iron–chromium alloys. Heat treatment of Fe—Cr alloys was carried out in the same way as for Fe—V alloys, by homogenization at a temperature of 1300° followed by quenching in water. After microscopic and X-ray investigations, the same specimens were annealed and quenched at temperatures of 1400–900°. Microscopic and X-ray investigations showed that after quenching from a temperature of 1300° the structure of Fe alloys with 35, 42, and 48% Cr consists of crystals of α- and β-phases. The amount of β-phase decreases with decreasing temperature. Thus, in the Fe alloy with 42% Cr at a temperature of 1400° there is 100% β-phase; at 1300°, approximately 90% β-phase (Fig. 1).

The microstructure of this alloy after quenching from 1300° consists of crystals of the α-phase against a background of crystals of the β-phase (Fig. 2). After annealing the alloy at a temperature of 1000° for an hour, only about 10% β-phase remains in the alloy (Fig. 3). After the annealing time is increased until equilibrium is established at 1000°, the alloy consists of one α-phase. The lattice constant of the β-phase of the Fe alloy with 42% Cr is 3.65 Å.

Consequently, in alloys of iron with 35-48% chromium, as also in allo—

in iron alloys with 28.5-74% V, the phase transformations consist not only in the polymorphic transformation of the σ-phase into the α-phase, but also in the transformation of the α-phase into the body-centered cubic lattice of the β-phase.

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REFERENCES

[1] F. Wever, W. Lellinghaus, Mitt. Kais. Wilhelm. Inst. Eisenforsch., **12**, 317 (1930). [2] F. Adcock, J. Iron and Steel Inst., **124**, 99 (1931). [3] A. I. Lena, M. F. Hawkes, J. Metals, **6**, AIME Trans. 200 (1954). [4] R. O. Williams, H. W. Paxton, J. Iron and Steel Inst., **185**, 3 (1957). [5] I. I. Kornilov, V. S. Mikheeva, DAN, **104**, No. 1, 88 (1955). [6] A. G. Lesnik, N. P. Plotnikova, Problems of Physical Metallurgy and Metallography, No. 5, 123 (1954). [7] P. Bastien, G. Pomey, C. R., **239**, 1636 (1954); E. Josso, C. R., **240**, 776 (1955).

Note: Figure translations are in progress. See original paper for figures.