STRUCTURE OF CARBURIZED Fe–Ti AND Fe–Ti–Cr ALLOYS

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One method for the production of material of a new class is the use of the “ferrite → austenite + carbide” transformation. The transformation occurs under specific temperature-concentration parameters of carburization of low-carbon ferritic “iron – carbide-forming element” alloys. Ferrite decomposes with formation of austenite-carbide colonies similar to eutectoid ones. The colonies are preferentially oriented in the direction of carbon flow, i.e., normal to the carburized surface. Fe–Ti and Fe–Ti–AE alloys, where AE is the alloying element, are of special interest in this connection. Titanium carbide is extremely hard and, when used as an agent reinforcing the surface layer, increases the hardness and wear resistance of the alloy. In addition, TiC dissolves impurities poorly, and therefore in the alloying of Fe–Ti alloys by elements improving their thermal stability or corrosion resistance, its formation will not deplete the matrix. However, the addition of a third component to the Fe–Ti alloy may cause degeneration of the structures of the colonies. The present work is devoted to the effect of different concentrations of chromium on the structure of carburized Fe–Ti alloys.

Structural changes in carburization of ferritic iron alloys alloyed by carbide-forming elements have been investigated earlier [1]. It has been established that under the effect of carbon inflow from the carburizer, ferrite can transform into austenite with formation of carbide. Simultaneous transformation of ferrite into austenite and carbide occurs when the composition of the alloys with respect to carbon corresponds to the vertex of the conode triangle. The formation of austenite and carbide is accompanied by redistribution of the alloy components in them. Austenite and carbide grow cooperatively, forming colonies preferentially oriented parallel to the carbon flow. This is accompanied by carburization and phase transformation. The value of the jump in carbon concentration on the interface of the mother and the growing phases can be determined from an isothermal cross section of the phase diagram of Fe–C–AE. The diagram of the transformation is presented in Fig. 1. The cooperative transformation of ferrite into austenite and carbide is similar to the eutectoid transformation but is caused by supersaturation of ferrite with carbon rather than supercooling.

In the present work we consider the laws governing structural changes in carburization of Fe–Ti and Fe–Ti–Cr alloys and the crystal structure of γ–TiC colonies. The structural transformations in carburization of complexly alloyed Fe–W–Cr–V–Mo alloys were investigated earlier [2]. It was shown that in many alloys austenite-carbide colonies can be formed on the basis of M6C carbide, which comprises all components of the alloy. The solubility of these elements in carbide can exceed their average concentration in the alloy.

When Fe–Ti–Cr alloys are carburized, colonies are formed on the basis of TiC carbide. The equilibrium concentration of chromium in carbide is less than in ferrite and the cooperative α → γ + TiC transformation will be accompanied by the transfer of chromium to ferrite. It is of interest to estimate the effect of this process on the final structure of the alloys.

Colonial structures in Fe–Ti alloys are distinguished by the fact that at the carburizing temperatures used (1000–1200°C) these alloys have a narrow interval of ferrite homogeneity with respect to carbon due to the high carbide-forming capacity of titanium. It was shown in [3] that this interval does not exceed several thousands of a percent (with respect to mass). The production of Fe–Ti alloys with this concentration of carbon requires special refinement techniques. Therefore it is expedient for practical purposes to investigate alloys in which the minimum necessary concentration of carbon can be obtained by methods used in modern metallurgy.

Experimental alloys were melted on the basis of commercial iron in a Tamman furnace in alundum crucibles with continuous supply of purified argon. The chemical composition of the alloys obtained is presented in Table 1. Ingots weigh-
Structure of Carburized Fe – Ti and Fe – Ti – Cr Alloys

Fig. 1. Diagram of cooperative transformation of alloyed ferrite into austenite and carbide in carburizing: F) ferrite; A) austenite; K) carbide; AE) alloying element; h) distance from the surface of the specimen; CF) concentration of the alloying element in ferrite.

Fig. 2. Part of the isothermal cross-section of the phase diagram of the system Fe – Ti – C at 1000°C [3].

Alloy 1 was subjected to carburizing at 1000°C and 1100°C. At 1000°C the alloy in the initial state (before saturation with carbon) was in the binary-phase ferrite-carbide region. In carburizing its composition reached the α – TiC side of the conode triangle, and a certain amount of carbide formed as equiaxial inclusions and a net along the boundaries of ferrite grains. Ferrite was depleted of titanium and acquired the composition corresponding to point a in Fig. 2. In further carburizing, ferrite was supersaturated with carbon and underwent cooperative decomposition, forming colonies of γ – TiC (Fig. 3a). An increase of the carburizing temperature to 1100°C moves the composition of the alloy to the α – TiC side of the conode triangle. There was no or insignificant preliminary formation of carbides in carburizing. Ferrite decomposed with formation of γ – TiC colonies.

Fig. 3. Microstructure of carburized layers of Fe – Ti alloys 1 (a – e) and 2 (f): a, f) for a carburizing temperature of 1000°C; b – e) 1100°C; a, b) × 250; c) × 15,000; d) × 41,000; f) × 100; e) electron diffraction pattern, [100]F || [100]TiC.