RECRYSTALLIZATION OF PHASE-HARDENED IRON-NICKEL AUSTENITE

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An increase in the density of structural defects during heating cycles and their possible interaction can change substantially the recrystallization temperature of phase-hardened austenite. The aim of the present work is to investigate the processes of austenite recrystallization in iron-nickel alloys after repeated cyclic heat treatment (CHT) accompanied by forward and backward $\alpha \rightarrow \gamma$ transformations and subsequent recrystallization.

Many investigations have been devoted to the structural state of phase-hardened alloys strengthened as a result of forward $\gamma \rightarrow \alpha$ and backward $\alpha \rightarrow \gamma$ transformations. The results of the investigations are generalized in [1–5]. Alloys on an iron-nickel base are preferentially strengthened as a result of several $\gamma \rightarrow \alpha$ transformations. For this reason the majority of the authors restricted themselves to studying their properties after the $\gamma \rightarrow \alpha$ transformation. However, even after repeated $\gamma \rightarrow \alpha$ transformations occurring by the shift mechanism the structure of the reversed austenite exhibits considerable changes caused by possible accumulation and subsequent interaction of structural defects in the course of the transformations [6]. By decreasing the heating rate in the region of backward $\alpha \rightarrow \gamma$ transformations researchers created new features in the formation of the structure of reversed austenite associated with the increased role of the diffusion component of the mechanism of the martensite transformation [4–7].

We investigated austenite alloys N31 (0.04% C, 30.7% Ni) and 50N25 (0.5% C, 24.8% Ni) melted in an hf electric furnace. In order to obtain coarse crystalline grains the melt was slowly cooled to $1100^\circ$C and then quenched in cold water. Cylindrical single-crystal specimens 0.8–1.0 mm in diameter were cut from austenite grains for an x-ray investigation. The forward $\gamma \rightarrow \alpha$ transformation in the alloys was conducted by cooling the specimens in liquid nitrogen, and the backward $\alpha \rightarrow \gamma$ transformation was conducted by holding the specimens in a bath with molten salts. An x-ray investigation of single crystals was conducted in an RKV-86M1 chamber in cobalt $K_\alpha$ radiation. The temperature ranges of cyclic heat treatment were determined by the magnetometric method. The microstructure was investigated on an Epiquant light microscope.

When the alloys are heated in the range of the backward $\alpha \rightarrow \gamma$ transformation at a rate exceeding the critical one ($v_h > v_{cr}$), the phase transformation occurs preferentially by the shift mechanism, which provides predominant restoration of the orientation of phase-hardened austenite crystals [8]. However, the austenite single crystal breaks into fragments. This is detected as an azimuthal propagation of diffraction spots on the x-ray diffractograms of single crystals (Fig. 1). Repeated CHT increases the disorientation angle between the fragments. The diffraction spots corresponding to martensite formed in the phase-hardened austenite also spread in the azimuthal direction. The maximum disorientation angle in martensite under all CHT regimes (different numbers of heat cycles, different cooling rates in the range of the $\gamma \rightarrow \alpha$ transformation, and different heating rates in the range of the $\alpha \rightarrow \gamma$ transformation) is always smaller than in austenite (Fig. 2). This indicates that the most disoriented austenite regions are stable with respect to the martensite transformation. After a certain number of $\alpha \leftrightarrow \gamma$ transformations the Debye rings are filled completely, i.e., the single crystal actually turns into a polycrystal.

When quenched single crystals of alloy 50N25 were heated at a rate $v_h < v_{cr}$, the diffractograms exhibited reflections both from austenite crystals with restored initial orientation formed by the shift mechanism and from finely dispersed crystals having a random orientation and formed by the diffusion mechanism. These crystals represent the polycrystalline component (PC) of the reversed austenite [7].

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The diffractograms from a single crystal of alloy N31 subjected to repeated CHT are represented by continuous Debye rings. They appear due to progressive fragmentation of the initial single crystal. At the same time, the diffractograms of carbon alloy 50N25 exhibited reflections from a crystal of the initial orientation and from a polycrystalline component.

Phase-hardened alloys were successively heated in a salt bath (τ = 5 min) to different temperatures of the γ-region in order to conduct an x-ray investigation of the recrystallization processes. The x-ray method (under the given conditions of photography) gives diffraction patterns showing individual point reflections on the Debye rings only if the grain size exceeds 10 μm. By the data of [4, 6] austenite grains formed in the initial stages of recrystallization have a size an order of magnitude smaller. This means that the appearance of sharp point reflections on the Debye rings can only allow us to judge the temperature of the beginning of secondary recrystallization (t_r).

In alloy 50N25 sharp reflections are observed only on continuous Debye lines of the polycrystalline component of austenite (Fig. 3). On the azimuthally spread reflections of a single crystal with restored initial orientation such reflections are absent. The dependence of t_r on the number of γ → α transformations for alloy 50N25 turned out to be nonmonotonic (curve 2 in Fig. 4).

The temperature at which we were able to detect sharp reflections in the diffractograms of austenite of alloy N31 after the first γ → α → γ transformation was about 75°C higher than that for alloy 50N25. Intense cyclic heat treatment (ten or more heat cycles) causes a decrease in t_r in both alloys (Fig. 4). It should be noted that defined reflections in the initial stages of the CHT for alloy N31 appear for the most part on the “tails” of azimuthally spread spots of reversed austenite; only in certain cases did we observe individual reflections on the spots themselves. Moreover, the number of

![Fig. 1. Azimuthal propagation of a diffraction spot (111) from phase-hardened austenite alloy 50N25: a) initial state; b, c) after CHT with 1 and 40 cycles respectively.](image1)

![Fig. 2. The maximum angle (φ) of disorientation of fragments of austenite (1) and martensite (2) in 50N25 alloy as a function of the number of heat treatment cycles. The heating rate in the region of the α → γ transformation ν_h = 60°C/sec.](image2)

![Fig. 3. Fragments of diffractograms showing fluctuations from austenite in alloys 50N25 (a) and N31 (b) after recrystallization annealing.](image3)

![Fig. 4. Recrystallization temperature t_r as a function of the number of heat treatment cycles in alloys N31 (1) and 50N25 (2).](image4)