PHASE TRANSFORMATIONS

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EFFECT OF MAGNETIC FIELDS ON ISOTHERMAL MARTENSITIC TRANSFORMATION IN ALLOY N24G4

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The effect of constant magnetic fields on isothermal martensitic transformation and structure of alloy Fe – 14% Ni – 4% Mn is studied. A C-diagram of the isothermal martensitic transformation and volume kinetic diagrams in a stationary magnetic field are plotted.

INTRODUCTION

Magnetic field is an external factor that substantially affects phase transitions if at least one of the phases participating in the transformation is ferromagnetic. As applied to phase transformations in steels the first experimentally detected effect of magnetic field was determined for the transformation of paramagnetic austenite into ferromagnetic martensite. This effect was studied in great detail for alloys with an athermal type of martensite transformation [1]. This is explainable by the fact that the specific features of athermal martensitic transformation, primarily the absence of diffusion and the high rate of occurrence, have made it possible to replace the use of stationary magnetic fields by much stronger pulse magnetic fields, the technique of creation of which under laboratory conditions is well-developed. The short time of the action of a pulse (10^{-4} – 10^{-5} sec) makes it possible to influence only athermal transformations, because the time of growth of a martensite crystal is about 10^{-7} sec. The effect of magnetic field on isothermal martensitic transformation has been studied less, which is explainable by the kind of occurrence of this transformation. Isothermal martensitic transformation develops for a long time in a specific temperature range in the process of isothermal hold and exhibits an obvious dependence of the rate of transformation on the temperature, which has the form of a curve with kinetic maximum. This circumstance explains the fact that studies of the effect of magnetic field on isothermal martensitic transformation had to be performed in a stationary magnetic field. In order to obtain appreciable effects the study should be made in strong enough stationary magnetic fields, which are obtainable with certain engineering difficulty and require special equipment. In recent years such installations have become available for metal scientists, and this allowed them to perform research in this direction. The aim of the present work consisted in studying the effect of a stationary magnetic field on isothermal transformation in alloy N24G4.

METHODS OF STUDY

We studied a classical alloy N24G4 (0.03% C, 23.6% Ni, 3.6% Mn, remainder Fe) with isothermal kinetics of martensitic transformation during cooling. The specimens were air hardened from 1420 K from vacuum. The magnetic field was induced using a NPMSS-XL (Quantum Design) installation that produces stationary fields with intensity of up to 4.0 MA/m (50 kOe) in a wide temperature range (from room temperature to the temperature of liquid helium) with automatic recording of the variation of the specific magnetization as a function of the temperature and of the hold time. The changes in the specific magnetization were used to determine the fact of martensitic transformation and its degree.

The microstructure of the specimens after various modes of magnetic treatment was studied by the metallographic method under an “Épitip-2” light microscope. The fine structure of the martensite was studied using a “JEM-200CX” electron microscope under accelerating voltage of 160 kV for foils prepared by a standard method.

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RESULTS AND DISCUSSION

After hardening from 1420 K alloy N24G4 at room temperature has an austenitic state, which is preserved after conventional cooling to the temperature of liquid nitrogen as well as after subsequent rapid enough heating to room temperature. If the heating is performed slowly in liquid nitrogen vapor, 4 – 5% phase appears. At very slow cooling the rate of the transformation near the martensite point (about 220 – 210 K) is extremely low and the process develops very slowly, attaining a maximum rate near 130 – 140 K and then damping progressively with decrease in the temperature. In the range 200 – 180 K the martensitic transformation develops very slowly, i.e., 1 – 2% α-phase forms in 1 h.

Preliminary certification of alloy N24G4 in the initial state, i.e., after magnetization of specimens at room temperature in a field with intensity of up to 2.4 MA/m (30 kOe), showed that the austenite possessed a certain magnetic susceptibility that increased gradually upon growth in the intensity of the magnetic field. The growth was fully reversible, i.e., when the specimen was withdrawn from the range of action of magnetic field its magnetic susceptibility acquired the initial value. This means that martensite did not form in the alloy under the mentioned action of magnetic field. The change in the magnetization was the same for all the specimens studied, which confirmed their identity. Similar behavior of the magnetic properties of austenite has been determined in [2, 3], where it was shown that some steels possessed superparamagnetic properties in austenitic state due to the existence of small single-domain ferromagnetic cluster regions in the austenite. The presence of the clusters was also associated with the comparatively high value of the initial magnetization and with the susceptibility of the alloys to the action of magnetic field on the γ → α transformation. Thus, the austenite of alloy N24G4 possesses a superparamagnetic property like high-nickel alloys.

Figure 1 presents some curves describing the variation of the magnetization of specimens as a function of the temperature of imposition of stationary magnetic fields of different intensities (a) and a part of a curve of reversible variation of magnetization (b): ▼) 0.4 MA/m (5 kOe); △) 1.92 MA/m (24 kOe); □) 4 MA/m (50 kOe).

Figure 2. Position of martensite points in alloy N24G4 as a function of the intensity of the stationary magnetic field.