Transactions of the Materials Research Society of Japan 28 [2] 223-224 (2003)

Effects of High Magnetic Field on Alignment of Reverse-transformed Structure in Fe-based Alloys

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Effects of high magnetic field on reverse transformation (lath martensite to austenite) have been investigated in Fe-based alloys. An Fe-0.4C alloy was solution treated at 900 ℃ for 15 min and water-quenched without magnetic field, which produces the lath martensite single phase structure. Then this specimen was reheated to 750 ℃ or 770 ℃ (ferrite and austenite two phase region) with or without magnetic field and held for 20 min and then rapidly cooled to room temperature by He gas. In this reheating treatment, austenite is formed by the reverse transformation. When specimens are reheated to 750 ℃ without magnetic field, equiaxed austenite grains are formed and distributed homogeneously. With magnetic field, austenite grains and ferrite grains are aligned along the direction of applied magnetic field. On the contrary, when specimens are reheated to 770 ℃、austenite phases are not aligned along the direction of magnetic field and rather formed along the packet or block boundaries of lath martensite.

Key words:lath martensite, reverse transformation, alignment, magnetic field

1.INTRODUCTION

Magnetic field is expected to affect the alignment of product phase and transformed structure per se during solid/solid phase transformations and then affect the mechanical properties of materials. Therefore, it is also expected that any new functions are provided to the material or even a new material can be produced by applying magnetic field during transformations. Therefore magnetic field is considered to be promising for structural or functional control of materials. Steels are very hopeful for such structural or functional control of materials by magnetic field because steels have various kinds of solid/solid phase transformations and therefore various structures. It is expected that the nucleation and growth rates, transformation kinetics, transformed structure and variants are affected by magnetic field since the magnetic moment of parent and product phases are different in these transformations, and also due to the magnetocrystalline anisotropy, shape magnetic anisotropy, induced magnetic anisotropy and magnetostriction.

The meanings of the study of effects of magnetic field on phase transformations are as follows. First, a new aspect of transformation can be explored and the mechanism of nucleation and growth can be clarified. For example, Kakeshita et al[1] studied the effects of magnetic field on martensitic transformation systematically and proposed a model that can explain both the isothermal and non-isothermal martensitic transformation kinetics, and made some important consideration of nucleation. Shibata et a[2] studied the effects of magnetic field, pre-deformation and heat treatment on martensitic transformation, and considered the potential for nucleation. Second, functional control of materials are explored. One of the example is the shape memory alloy that works by magnetic field[3-6]. It is necessary to study the effects of magnetic field on martensitic transformation for developing this type of shape memory alloys. Third, it is expected that a new type of structural control can be developed. For example, a new thermomechanical heat treatment can be established by applying both the magnetic field and thermomechanical heat treatment[7].

So far, we have investigated the effects of magnetic field on martensitic transformation[8,9]recrystallization[10,11], austenite to ferrite transformation[12-15], pearlite transformation[16] and dynamic aging. In this study, the effects of magnetic field on martensitic transformation and its reverse transformation from lath martensite to austenite are reported.

2. EXPERIMENTAL

The specimen used in this study is, Fe-0.41C-0.008Si (mass%), with the dimension of 5X5X1 mm^3. Specimens were austenitized at 900 or 1500 ℃ for 15 min and water quenched. This heat treatment was conducted without magnetic field. The prior austenite grain size was measured to be about 30 and 120 μ m, respectively by linear intercept method. The structure is almost lath martensite single phase after this heat treatment. Magnetic field was increased up to 10T in 27 min, and the specimen was reheated to 750 or 770 ℃, isothermally held for 20 min and then cooled to room temperature by He gas. After this heat treatment, magnetic field was decreased to 0. For the specimen reheated without magnetic field, the same pattern of heat treatment was applied without magnetic field. The surface parallel to the direction of applied magnetic field was observed by optical microscope, so the direction of applied magnetic field is vertical in the figures.

3. RESULTS AND DISCUSSION

The effects of prior austenite grain size and the reheating temperature on the reverse transformation from lath martensite to austenite have been investigated.

First, the experimental results with the reheating temperature of 750 ℃ are shown. Figure 1 is the optical micrographs showing the reverse transformed structure. The specimens were heat treated at 900 ℃ for 15 min before the reheating treatment. Figure 1(a) shows the structure formed without magnetic field, and (b) shows that with magnetic field of 10T. The bright area is ferrite, and the dark area is austenite formed by the reverse transformation and transformed to pearlite by the final cooling. In Fig. 1(a), both ferrite and austenite are equiaxed and randomly distributed, but in Fig. 1(b), both ferrite and austenite are elongated and aligned head to tail along the direction of applied magnetic field. Then the results for the specimens heat treated at 1150 ℃ for 15 min before the reheating treatment were studied. Austenite grains are formed along the grain boundaries, packet and block boundaries of lath martensite, and not aligned along the direction of applied magnetic field. Therefore the prior austenite grain size should be relatively small for the alignment of reverse transformed structure in magnetic field.

Second, the experimental results with the reheating temperature of 770 ℃ were investigated. The curie temperature of ferrite is 770 ℃ , but under high magnetic field of 10T, ferrite has some magnetic moment and is not paramagnetic at 770 ℃ [14]. The specimens were heat treated at 900 ℃ for 15 min before the reheating in magnetic field. No alignment of reverse transformed structure is observed for the specimen heat-treated in magnetic field. Similar results have been obtained for the specimen austenitized at 1150 ℃ for 15 min. Therefore the heating temperature should be relatively low for the alignment of reverse transformed structure.

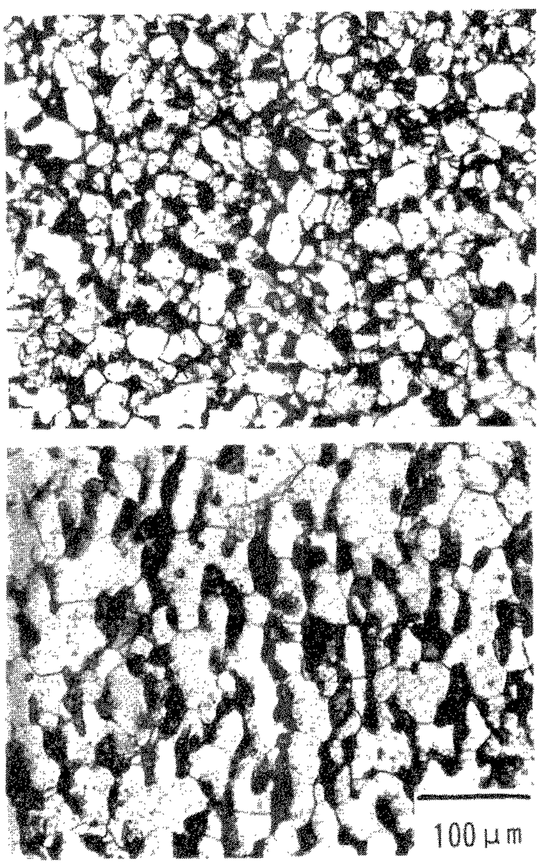

Fig.1 Effects of magnetic field on reverse transformation with small prior austenite grain and low heating temperature (750 ℃). (a) 0T, (b) 10T.

4. SUMMARY

The Effects of magnetic field on lath martensite to austenite reverse transformation have been investigated. Prior austenite grain size should be relatively small and the reheating temperature should be relatively low for the alignment of product phase in high magnetic field.

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(Received December 21, 2002; Accepted March 30, 2003)