Ambient Temperature High Magnetic Field Processing Conversion of Retained Austenite (%RA) in SAE 52100 Steel

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Introduction

Our prior research [1] has shown that the application of high magnetic fields during the quenching process can alter the microstructure and phase transformations in medium and high carbon steels. The application of magnetic fields at ambient temperature as a method of reducing retained austenite in as-quenched SAE 52100 steel is based on the thermodynamic argument that paramagnetic austenite is destabilized in the presence of a large magnetic field. The goal of this study was to determine the effect of applying a magnetic field at room temperature after quenching on the amount of retained austenite.

Experimental

These experiments utilized the 20 Tesla, 195 mm bore resistive magnet facility at the National High Magnetic Field Laboratory. All samples were heated to 850° C using a custom designed induction coil [1] and held for 30 minutes to insure full transformation into austenite. The samples were then quenched to 25° C using helium gas. Magnetic fields with strengths ranging from 0 to 20 T were applied immediately after the quench at room temperature. Retained austenite data were determined using conventional x-ray diffraction methods (ASTM Standard E-975-95).

Results and Discussion

Table I lists the amount of retained austenite and hardness as a function of applied magnetic field for the samples examined.

Table 1. Experimental Results of %RA and Hardness versus Magnetic Field Strength

Magnetic Field (Tesla)	% Retained Austenite	Hardness (VHN)
0	11	845
10	9	870
20	6	875

The influence of magnetic field (MF) can be incorporated into the classical Koistinen-Marburger equation for martensite transformation kinetics to estimate the volume fraction of retained austenite after MF processing. This effect is explicitly introduced as an increase in the martensite start, Ms, temperature (227°C for this alloy and austenitization temperature). Based on these experimental data, such a relationship is given in the equation below:

$$f^{\gamma} = e^{-0.011\left(\mathrm{Ms}+\Delta\mathrm{Ms}-25^{\circ}\mathrm{C}\right)}. \qquad [1]$$

Here, f^{γ} is the volume fraction of austenite, and ΔMs is the apparent increase in Ms due to the magnetic field.

Conclusions

X-ray measurements of retained austenite in annealed and quenched SAE 52100 steel indicate that room temperature application of a magnetic field can reduce the amount of retained austenite which can reduce the energy consumption requirements during subsequent heat treatment applications and enhance material performance.

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References

[1] R.A. Jaramillo, et al, in "Solid-to-Solid Phase Transformations in Inorganic Materials 2005", Vol. 1: Diffusional Transformations, (Eds. J.M. Howe, D.E. Laughlin, J.K. Lee, U. Dahmen, W.A. Soffa), TMS, PA, pp. 893-898 (2005).