MODIFYING THE PHASE TRANSFORMATION MECHANISM IN A HIGH CARBON STEEL USING A HIGH MAGNETIC FIELD

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Introduction

Several researchers[1-2] have shown that the application of a high magnetic field can alter the Gibbs free energy of the Fe-C phase diagram such that the austenite/ferrite phase boundary becomes a function of the applied field. Because the magnetic susceptibilities of ferrite and austenite are substantially different, the magnetization of the material coupled with the applied field alters the free energy and, therefore, phase stabilities. In steel, the magnetic field promotes the formation of ferromagnetic ferrite and destabilizes the paramagnetic austenite.

In previous work[3], thermocouple measurements were used to measure the temperature of a 1045 steel specimen undergoing phase transformation during continuous cooling with and without a magnetic field. Because the release of latent heat associated with austenite decomposition is readily observed in temperature measurements[4], a phase transformation can be associated with specific times and temperatures during cooling. It was shown that a 30T magnetic field can raise the transformation temperature by approximately 90°C.

Experimental

Experiments were performed using a 32 mm diameter bore, 33T resistive magnet with a specially designed and fabricated bore insert for rapidly heating and cooling specimens. A high carbon 52100 steel was continuous cooled after annealing at 850°C for 30 minutes. Specimens were cooled at ~40°C/s with and without a 30T magnetic field. Specimens were examined using a Hitachi 4700 scanning electron microscope.

Results and Discussion

The microstructures obtained from continuous cooling experiments are shown in Figure 1. SEM images for the material cooled a) without and b) with a 30T magnetic field are shown. For ambient magnetic field, the microstructure is predom-inantly martinsitic with spherical cementite carbides present and probably some retained austenite. In contrast the 30T sample shows a pearlitic microstructure and spheroidized cementite. Recalescence observed in temperature measurements indicates that the martensite formed at temperatures below 250°C, while the pearlite formed at temperatures greater than 600°C.

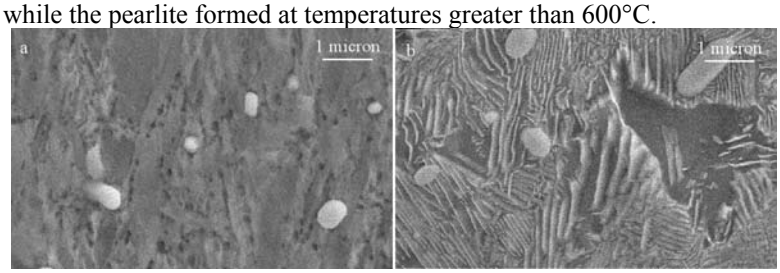

Figure 1. SEM images showing a) martensitic microstructure obtained without magnetic field and b) pearlite obtained with a 30T magnetic field applied during cooling.

Conclusions

These results clearly show that for a fixed chemistry and cooling rate, a 30T magnetic field can alter the transformation mechanism in a 52100 steel. SEM analysis revealed a martensitic microstructure for cooling without an applied magnetic field. This transformation product is obtained by shear or displasive transformation mechanism. In contrast, the material cooled with a 30T magnetic field had a pearlite microstructure which is the product of a diffusive transformation. These results indicate that a wide range of microstructures is possible for a given chemistry and cooling rate by modifying the strength of the applied magnetic field.

References

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[4] Lee, K.J., Scripta mater., **40**, 735-742 (1999).