Research on abnormal grain growth in reversely transformed austenite structure

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Control of austenite grain structure is of great importance in heat treatment processes, because the prior austenite grain structure entirely affects the size and morphology of the final microstructure, and thus to largely determine the final mechanical properties of steels. The present study mainly focuses on the abnormal grain growth (AGG) of reversely transformed austenite in 0.2 mass% carbon steel and attempts to control it. The AGG of austenite which leads to extraordinary coarse austenite grains and bimodal grain size distributions degrades final mechanical properties of steels, because an initial variation in prior austenite grain size can result in a coarse and inhomogeneous final grain structures. Hence, AGG in austenite grain structure during the heat treatment processes is very harmful, which is quite worth to be investigated.

AGG has been extensively investigated because of both its technological relevance in the steel industry and scientific interest. In spite of the considerable research effort, there are still some important issues that remain to be resolved. For example, it is unclear whether the initial microstructure of steel, such as ferrite/pearlite (F/P) banded and non-banded structure affect the austenite abnormal grain coarsening or not. Since the banded structure with a great inhomogeneity in alloy elements distribution, it may have a great effect on the austenite abnormal grain coarsening behavior. On the other hand, it is unclear how to control the AGG of austenite during the heat treatment process. Therefore, the purpose of the present study is to investigate the abnormal grain coarsening behavior of reversely transformed austenite and attempts to control it.

The contents of this thesis are described as follows. In Chapter 1, the research background is illustrated. By describing some steel manufacturing processes, the importance of refinement of austenite grains during reheating is emphasized. Moreover, it is explained that the occurrence of AGG of austenite grains degrades the final mechanical properties of steel. The motivation and purpose of present study are also illustrated. Chapter 2 is the review of the literatures related to the AGG of reversely transformed austenite grain structures. The reported mechanisms for the occurrence of AGG and the effects of cold deformation on the austenite grain structure and
precipitation are summarized.

In Chapter 3, the grain growth behavior of austenite reversely-transformed from F/P banded and non-banded steels has been studied systematically. It was found that the grain-coarsening temperature, $T_c$, (the temperature at which abnormal grain growth occurs) of the initially banded F/P steel is quite low compared with that of the non-banded steel. In the F/P banded steel, it was found that the abnormal grains originate from the former ferrite region. The occurrence of AGG is essentially attributable not to the austenite nucleation process during heating but to the grain growth process after the completion of austenizing. It was proposed that the lowered $T_c$ in the F/P banded steel is due to the non-uniform pinning-effect of AlN precipitates between former ferrite and pearlite regions. In chapter 4, the effect of cold deformation on AGG of austenite in F/P banded steel has been investigated. It was found that the low $T_c$ in the F/P banded steel can be increased significantly by applying cold deformation prior to austenitizing. The severity of AGG above the $T_c$ is also largely reduced by the cold deformation. This is attributed to the fine and uniformly distributed AlN precipitates caused by the cold deformation.

In Chapter 5, the effects of cold deformation on AGG of austenite in non-banded steel have been studied. It was found that the effect of cold deformation on AGG of austenite depends on the initial state and distribution of AlN precipitates. When the non-banded steel with aluminum and nitrogen in solution, cold deformation reduces the AGG temperature-range (a temperature range of occurrence of AGG) of austenite. While the non-banded steels are subjected to a long time subcritical annealing treatment making the AlN fully precipitated and growth, the occurrence of AGG can be completely inhibited by applying cold deformation. This can be explained by the size and spatial distributions of the precipitates affected by the cold deformation.

In Chapter 6, the local plastic strain distribution and its effect on the on the austenite grain growth has been studied. It was found that large macroscopic plastic strains with high strain rates lead to steep and narrow distribution profile of local plastic strain. The peak of the local plastic strain profile does not appear at the deformed surface but immediately beneath the surface. The deformation at high strain rates is favorable to localize the plastic strain in the vicinity of the surface. On the other hand, the deformation at lower strain rates makes plastically deformed zone wider. The local plastic strain distribution has a strong effect on the austenite grain growth. The austenite grain structure near the surface can be effectively controlled by the local plastic strain distribution. In Chapter 7, the misorientation manifestations in chemical etching contrast has been studied in cold deformed iron. The chemical etching is performed by using nital. It was found that the chemical etching contrast strongly reflects the crystallographic orientation. The gradual change in chemical etching contrast inside the individual deformed grains gives information of both the
misorientation and local plastic strain within the grains. This method can provide an easy and alternative way to qualitatively understand the misorientation and local plastic strain distributions in the microstructures.

Finally, the important findings in this study are summarized in Chapter 8.