Abstract of Dissertation
論文の内容の要旨

In-situ analysis of the local deformation behavior of lath martensite in steel

（鋼のラスマルテンサイトの局所変形挙動のその場解析）

羅　賢擇

Plastic deformation behavior of low-carbon martensitic steels was observed in-situ in a scanning electron microscope, and their unique local deformation behavior was revealed. Multilayered structure was employed as a tool to acquire sufficient plastic deformation in the lath martensitic steel under uniform tensile loading. In contrast to the case of ferritic steel, a significant grain refinement was observed in as-quenched lath martensite after a strain of only 20%. From the analysis using the electron backscattering diffraction (EBSD), non-uniform crystal rotation behavior within a single block and subblock was clarified. Under the assumption of a simple loading condition, the activation behavior of slip systems in block and subblock were estimated from the classical crystal plasticity model. As the potential factors for the heterogeneous local deformation behavior associated with activation of slip system in lath martensite, effects of grain interaction and dislocation motion were discussed from the results of the local strain measurement using a digital image correlation method and the observation of dislocation structure using a transition electron microscope. The thesis is composed of five chapters.

In the first chapter, research cases on the crystallographic, morphological properties and related deformation behavior of low-carbon martensitic steels are reviewed. Then, objectives of this dissertation are highlighted.

In the second chapter, crystallographic investigation using electron back scattering diffraction coupled with a crystal plasticity model confirmed that activation behavior of slip systems is inhomogeneous even within each martensite block, which leads to nonuniform crystal rotation behavior within the block. In particular, the activation behavior of slip systems are initially affected by initial crystal orientation, however, the effect becomes negligible with increased deformation. In addition, slip systems parallel to the lath plane are preferentially activated (lath constraint mechanism) during elongation. Our results indicate that the nonuniform crystal rotation behavior within individual block induced not only by the grain interaction phenomena but also by the limitation of activation of slip system (lath constraint mechanism) is a key factor that determines the grain refinement behavior in as-quenched lath martensite in steel during deformation.

In the third chapter, the microscopic strain distribution in lath martensitic steel during tensile deformation up to a strain of 10% has been measured in situ through digital image correlation method. Strain localization, which indicates the grain interaction, is clearly observed in the vicinity of subblock boundaries, and it affects the inhomogeneous crystal rotation behavior within block (or subblock), and hence resultant rapid grain subdivision of the lath martensitic steel during elongation.

In the fourth chapter, to elucidate dislocation density and its structure on the plastic deformation behavior of lath martensites in a view of submicroscopic area, tempered martensite, annihilated initial dislocation density with preserving martensite starting microstructure (such as packet, block, subblock, and lath), was obtained and compared with case of as-quenched one. 80% of initial dislocation density of as-quenched martensite was removed after tempering at approximately 520K for 36 x 10^4 s. Majority of newly generated grain boundaries (almost 99%) after elongation were classified as low angle boundary (5˚-10˚). The effect of lath constraint becomes less significant in the tempered martensite compare to the cased of as-quenched martensite. Accordingly, it seems that relatively weak inhomogeneous local deformation behavior was performed in tempered martensite. In addition, it was hard to observe formation of dislocation cell structure in tempered and as-quenched martensites during 20% elongation.

In the fifth chapter, present study is summarized. It is predicted that heterogeneous local deformation due to not only effect of grain interaction associated with complicated initial constituent microstructures but also the lath constraint mechanism, and those effects are relatively stronger than the effect of dislocation rearrangement, general phenomena in severely deformed ferritic steel, for grain refinement in lath martensitic steel during deformation. This is the reason why grain refining can be observed in lath martensite at relatively early stage of plastic deformation.