SUMMARY

題 目 Transformation-thermo-mechanical Analyses on Size Effect in Polycrystalline TRIP Steels based on Crystal Plasticity Finite Element Method
（結晶塑性有限要素法による多結晶 TRIP 鋼における寸法依存性の変態・熱・力学解析）

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The excellent mechanical properties of the transformation-induced plasticity (TRIP) steels can be generated by the strain-induced martensitic transformation (SIMT) behavior in microstructures. Basically, in TRIP steels, martensitic transformation (MT) is characterized by the rearrangement of atomic structures with both the geometric and crystallographic patterns. At the crystal scale, a formation of microscopic shear bands plays a very important role on martensitic nucleation during SIMT. Because there are still difficulties to understand SIMT fully only by an experimental approach, several numerical methods have been developed to express the microstructure during MT. However, the shear band structures have not been described explicitly yet so that they are still challenges to deal with the nucleation process.

On the other hand, the shear band is formed by concentrating plastic deformation in a band-like structure. The width of shear bands as well as the size of martensitic nuclei has a significant influence on SIMT as a length scale effect. Additionally, MT introduces a great amount of shear and volume change accommodated by the generation of dislocations around the transformed regions. For decades, numerical modelling methods based on the crystal plasticity theory have been developed to study the plastic deformation and behavior of materials at such microstructural levels with MT. However, the size dependency should be considered in crystal plasticity for a deeper investigation. The novelty of this study relies on a development of a numerical model to describe SIMT with an explicit expression of the shear band structure. It provides a simple and easy implementation, and an effective method. To solve the problems above, the dissertation is organized as follows.

First of all, the development of the numerical models for SIMT in TRIP steels as well as the length scale effect on evolution of dislocations are reviewed in Chapter 1. In Chapter 2, the constitutive model based on the framework of crystal plasticity finite element method (CPFEM) coupling with a cellular automata approach is introduced. The details of the derivation process and the numerical model with introducing periodic boundary conditions are presented. The computational results in both mono and polycrystal TRIP steels are shown to discuss SIMT caused by the formation of shear band structure as well as martensitic nuclei from the viewpoint of the length scale effect. Next, in Chapter 3, a new size-dependent hardening model based on a notion of the microforce, which can naturally include the free energies by dislocation density, is proposed within the framework of CPFEM. From the obtained results, a discussion on the size-dependent crystal plasticity in metastable austenitic steels is done in both single and polycrystal models. Finally, in Chapter 4, the main findings of the study are summarized. Then, the views and propositions on the future work are provided.