Report of MERIT Internship (Japan)

Graduate School of Engineering, Department of Materials Science and Engineering
Nanbu Laboratory, Doctor course, 1st year / MERIT 8th
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Outline of internship

Place of internship: Dr. Ikumu Watanabe, High Strength Materials Group, NIMS (National Institute for Materials Science)

Period: November 9, 2020 - December 11, 2020

Theme: Construction of a three-dimensional model which represents bainite microstructure and its analysis by Finite element method

Outline of Research

The bainitic transformation of steel is a displacive transformation with the partitioning of carbon. Since austenite, which is a highly ductile phase, can be stably retained even at room temperature, the structure can be multi-phase composed of bainite and austenite. These bainite-austenite based multi-phase steels attract attention for its high strength and high ductility.

Attempts to improve mechanical properties in multiphase steels by controlling the volume fraction and morphology of the high-strength phase have been made for a long time. It has been reported that the multiphase steels have higher strength and ductility when the high-strength phases are connected, or when they are oriented in the tensile direction. However, most of these

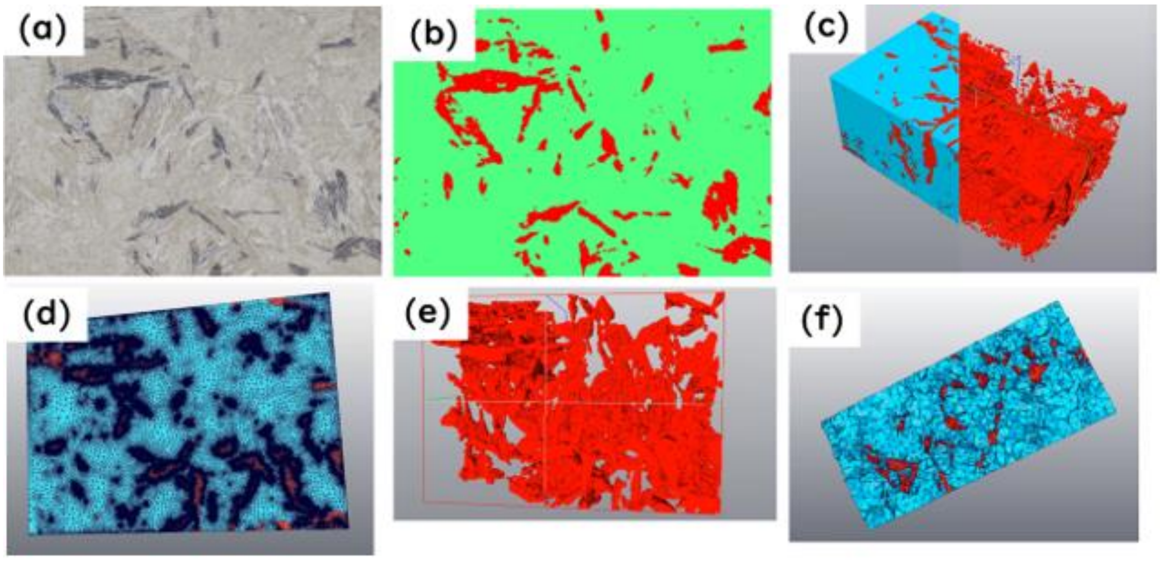

Fig.1 The process of making and meshing the 3dimensional image of tempered martensite. (a) optical microscopy image, (b) binary image (c) 3D image of tempered martensite before cleanup (d) meshing result of c (e) 3D image of tempered martensite after cleanup (f)meshing result of e.

investigations are two-dimensional, and even in three-dimensional investigations, the modeling and analysis are based on simple morphologies, such as random arrangement of spheres at a specific volume fraction. Bainite has a plate or lath microstructure with a large aspect ratio, but there are few studies about these shapes with various ways of distribution.

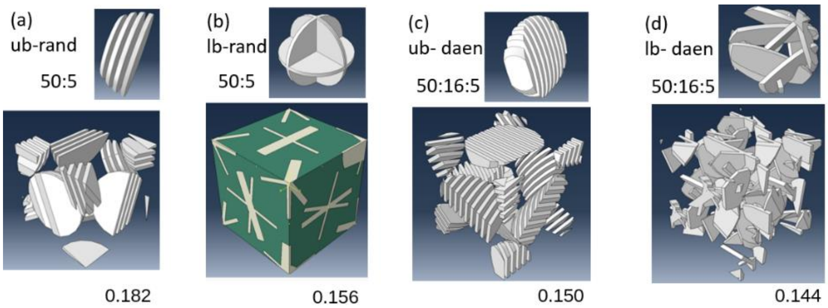

Fig.2 Typical images of the models calculated in this study.

In this internship, I studied the method of constructing 3D model structures and analyzed the structures using Finite element method (FEM), which is the simulation method to calculate the stress/strain distribution and macroscopic mechanical properties, under Prof. Ikumu Watanabe, who is an expert in FEM.

To construct the 3D model, serial sectioning (a technique in which observation and polishing are repeated several hundred times) was used to obtain hundreds of images, followed by binarization and meshing using 3D image analysis software as shown in Fig.1.

In addition, as shown in Fig. 2, we analyzed the effect of morphology on the mechanical properties by creating virtual models using CAD. I learnt a lot about the model construction, mesh size, element settings, and other aspects that are not covered in the papers, as well as points that need to be taken into account in the calculations. The results of the simulation showed that the strength and ductility, especially uniform elongation, were improved when the hard phase had connectivity. When the hard phases distribute relatively uniformly, the mechanical properties were improved without the connectivity of the hard phase.

Acknowledgments

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