

5-6 Towards Higher-Performance Steels

— Elucidating the Microstructural Formation Mechanism via Electron and Neutron Beams —

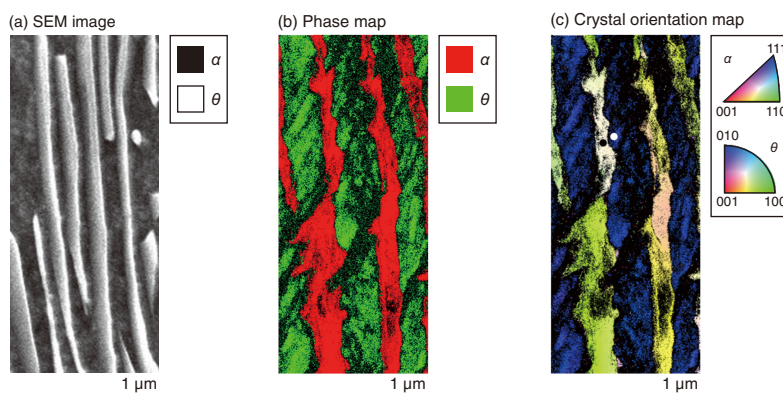


Fig.5-15 Microstructural characteristics of pearlitic steel

(a) SEM imaging of pearlitic steel, where the lamellar structure consists of α (black) and θ phases (white). (b) Phase map of the pearlitic steel obtained by the EBSD method, where the α (red) and θ (green) crystal phases are identified in the pearlite structure. (c) Crystallographic orientation distribution map of the α and θ phases in the pearlitic steel obtained by the EBSD method.

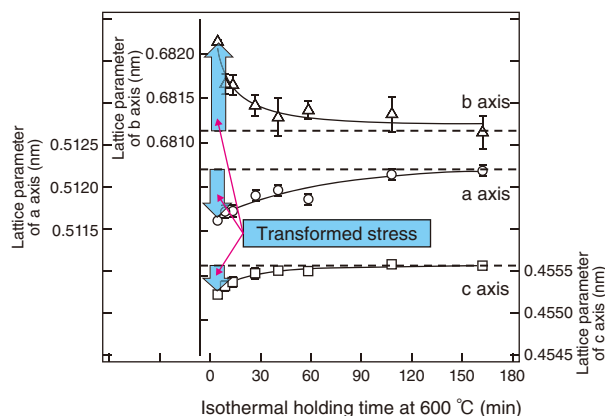


Fig.5-16 Evolution of the lattice parameter of pearlitic steel during isothermal holding

In-situ neutron diffraction confirmed the continuous evolution for the crystal cell structure of the α phase during isothermal holding. The curved and dashed lines correspond to the real-time changing structure parameters and the final structure parameters after holding for 180 min, respectively. The weakening deviations from the final structure parameters marked with dashed lines showed the transformed stress in the pearlite structure was gradually relieved.

Steel is a kind of important structural material which is indispensable for our daily lives and presents in a variety of places, from ordinary office items to social infrastructure including long-span bridges and ultrahigh-rise buildings. The strength and ductility of steels can be controlled by optimizing the microstructural parameters including the grain size and crystal morphology. It is therefore valuable to elucidate the microstructure formation mechanism to develop higher-performance steels with high fracture resistance and good manufacturing capacity, which are highly expected for the continuous development of large social infrastructure, such as ultrahigh-rise buildings. Here, the microstructural formation mechanism of a pearlitic steel was investigated using an electron scanning microscope (SEM), electron backscatter diffraction (EBSD), and neutron diffraction.

Pearlitic steel has a lamellar microstructure, consisting of a body-centered cubic crystal structure (α phase) and a simple rectangular crystal structure (θ phase), as shown in Fig.5-15(a). The phase identification and crystal orientation maps of this steel were evaluated using EBSD. The obtained constituent phase and crystal orientation maps of the pearlitic steel are shown in Figs.5-15(b) and (c), respectively. In general, a crystal grain only shows a crystal orientation (mono color) like a single crystal. However, with a lamellar structure, the color label

corresponds to a gradient change in the crystal orientation. Here, a large shift in the crystal orientation was confirmed in the α phase.

A neutron diffraction experiment was then performed using the TAKUMI (Beamline No.19), a high-resolution, high-intensity time-of-flight (TOF) neutron diffractometer at the Materials and Life Science Experimental Facility (MLF) of J-PARC. The evolution of the triaxial crystal cell parameters of the θ phase after the pearlite transformation is shown in Fig.5-16 as a function of the isothermal holding time at 600 °C. The cell structure parameters along crystal axes a, b, and c of the rectangular crystal structure of θ phase changes with increasing isothermal holding time. This indicates that the stress that occurred during the pearlite formation (Fig.5-15(c)) was gradually released over a long isothermal holding treatment.

Hence, this stress is suggested to have an important influence on the microstructural formation of pearlitic steels. Such information is valuable in developing higher-performance steels.

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Reference

Amemiya, Y., Morooka, S. et al., Dynamic Accommodation of Internal Stress and Selection of Crystallographic Orientation Relationship in Pearlite, *Tetsu-to-Hagane*, vol.105, no.2, 2019, p.314-323 (in Japanese).