austenite grain boundary, block and packet boundaries) as well as within laths and at low angle boundaries (lath boundaries) by tempering. TEM observation has revealed that finer cementite is dispersed more uniformly in the rapidly heated specimen than in the slowly heated specimen. It is considered that the temperature where cementite precipitation starts is raised by increasing the heating rate to tempering temperature, resulting in a higher nucleation rate and a finer dispersion of cementite.

(cf. *ISIJ Int.*, **44** (2004), 1937)

Mechanical Properties

Development of high strength hot-rolled sheet steel consisting of ferrite and nanometer-sized carbides

Y.FUNAKAWA et al.

A ferritic steel precipitation-strengthened by nanometer-sized carbides was developed to obtain a high strength hot-rolled sheet steel having tensile strength of 780 MPa grade with excellent stretch flange formability.

Manganese in a content of 1.5% and molybdenum in a content of 0.2% were added to 0.04% carbon Ti-bearing steel in order to lower austenite–ferrite transformation temperature for fine carbides and to retard generating of pearlite and large cementites, respectively. Tensile strength of hot-rolled sheet steel increased with titanium content and it was achieved to 800 MPa in a 0.09% Ti steel. Microstructure of the 0.09%Ti steel was ferrite without pearlite and large cementites. Fine carbides of 3 nm in diameter were observed in rows in the ferrite matrix of the 0.09% Ti steel with transmission electron microscope. The characteristic arrangement of the nanometer-sized carbides indicates that the carbides were formed at austenite–ferrite interfaces during transformation. By energy dispersive X-ray spectroscopy, the carbides were found to contain molybdenum in the same atomic concentration as titanium. Crystal structure of the nanometer-sized carbides was determined to be NaCl-type by X-ray diffractometry. The calculated amount of precipitation-strengthening by the carbides was approximately 300 MPa. This is two or three times higher than that of conventional Ti-bearing high strength hot-rolled sheet steels.

Based on the results obtained in the laboratory investigation, mill trial was carried out. The developed hot-rolled high strength sheet steel exhibited excellent stretch flange formability.

(cf. *ISIJ Int.*, **44** (2004), 1945)

Elastic strains of cementite in a pearlite steel during tensile deformation measured by neutron diffraction

A.KANIE et al.

Lattice plane strain, *i.e.*, elastic strain, in cementite plates embedded in the ferrite matrix was measured by *in situ* neutron diffraction during tensile deformation for a hypereutectoid pearlite steel. The employment of time-of-flight method and microstructure control enable us to measure the shift of cementite peaks along tensile and transverse directions at the applied stress up to 1.6 GPa. The highest elastic strains of cementite determined was approximately 0.015. Heterogeneous plastic deformation between ferrite and cementite as well as among ferrite blocks are discussed.

(cf. *ISIJ Int.*, **44** (2004), 1952)