A Multi-Phase-Field Simulation of Carbon Steel under Actual Conditions of a Hot Rolling Process

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ABSTRACT

It had been well known that mechanical properties such as yield stress, tensile strength and elongation of hot rolled steels were related to grain size and transformed structure. Therefore, mathematical models to predict those representative microstructural characteristics of hot rolled steel have been investigated for many years. Generally, these models predict macroscopic metallurgical information such as average grain size and a volume fraction of each transformed phase considering metallurgical phenomena such as deformation, recrystallization and transformation. Then, mechanical properties are calculated by an empirical model which explains effects of the macroscopic metallurgical information to the mechanical properties as well, and studied from both theoretical and experimental side. Furthermore, due to the difficulty of observation of microstructural evolution during the process, theoretically based simulations have strong expectation in this area. In recent years, a phase-field method has received much attention as a mesoscopic scale simulation tool which calculates the morphological change during growth of precipitated structure. Many investigations with experimental conditions have been carried out and reported to show its capability. However, few were focused on its application to an actual hot rolling process conditions.

This time, we employed a multi-phase-field method²⁾ to caluclate metallurgical phenomena during the cooling process of the hot rolling. Simulations of the phase transformation from the austenite (γ) to the ferrite (α) in a low carbon steel were performed using in-house code. Not only a macroscopic data, but also a growth of transformed phases were visually obtained. As the α grain grows, the carbon concentration increases at the γ/α boundary because the equilibrium value of the carbon concentration in α -phase is lower than that in γ -phase, and the diffusivity of carbon in α phase is much higher than γ -phase. Finally, grain growth is disrupted due to the impingement. As the initial carbon concentration increases, the curve of temperature-ferrite fraction becomes gradual. These results are explained by the retardation of the growth of the α -phase due to soft impingements induced by increase of carbon concentration. On the other hand, a temperature path is known as the one of the primary factors on the formation of transformed structure. Therefore, actual temperature transitions of the hot rolling process such as cooling start at finish mill delivery and end at coiling temperatures, cooling speed patterns, and a temperature drop in edge parts of a strip were considered in simulations and those effects on the final microstrucute were investigated.

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