Towards a thermo-mechanical metallurgical model for TMCP of structural steel for offshore wind turbines

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Abstract

Engineers face a significant challenge in meeting the growing demand for renewable energy to reduce fossil fuel consumption and to lower air pollution. The offshore wind energy sector, both fixed and floating, is currently experiencing significant growth. A key challenge is the need to scale up support structures, such as towers and monopiles, to handle greater load-carrying capacities required by larger nacelle sizes. A key limiting factor is the size dependence of rolled steel plates, particularly when welding. Thermo-mechanical control processing (TMCP) is a well-known technique for enhancing the mechanical properties and microstructure of metallic materials during hot rolling. This paper presents the development of a finite element thermal-metallurgical model as a key driver for the thermal-mechanical model to study the mechanical behaviour and metallurgical mechanism of the steel plate in multi-pass TMCP. Of specific interest is the well-known thickness effect and rate effect on yield and fatigue of rolled steel plate. The model is designed to account for metallurgical phenomena occurring during TMCP, including static and dynamic recovery, dislocation density evolution, static recrystallization, and grain structure evolution, to predict the mechanical behaviour during and after TMCP. A unified physically-based viscoplastic constitutive equation is adopted to model the thermo-mechanical behaviour of the material, incorporating key process parameters, including the number of thermo-mechanical passes, heating- and cooling-rates, dwell times and maximum temperatures on the resulting microstructure, including size and dispersion of the formed fine particles, are determined in this study. The study of the impact of process parameters on the mechanical behaviour of structural steel has been conducted to investigate the effects of TMCP on homogeneity of grain size and texture with respect to large steel plate thicknesses in TMCP. The work also facilitates identification of representative TMCP stress-strain histories for designing Gleeble simulation tests and understanding and analysing of TMCP-induced residual stresses.

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