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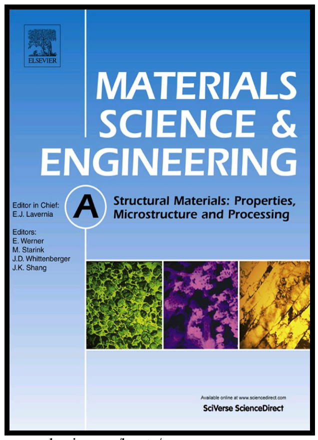

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Kinetics and Microstructural Change of Low-carbon Bainite due to Vanadium Microalloying

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Abstract

Noticeable strength increases, up to 120MPa, have been obtained in hot strip and linepipe bainitic steels by microalloying with vanadium. However, there is no consensus on the mechanisms proposed in the literature to explain this effect. As such, this study has investigated the root cause and various strengthening contributions of vanadium additions to bainitic linepipe steels. Two variants of a X100 linepipe steel with identical compositions but different vanadium contents, i.e. a reference steel with residual amount of vanadium and a microalloyed variant with 0.06wt% vanadium, have been subjected to dilatometric study to determine the kinetics of bainite formation during continuous cooling and cooling-coiling scenarios. Further, a novel in-situ hot compression experiment was developed to determine the strength of fresh bainite (prior to coiling) and its softening during simulated coiling at 450°C. Various microstructural features of the bainite, including the morphology, dislocation density and lath size, as well as the presence of microalloyed carbonitrides have been quantified by TEM characterization. It was found that the kinetics of the bainite transformation during cooling and the tempering of fresh bainite upon coiling simulations were substantially influenced by vanadium microalloying. Vanadium in solution shifted the bainite transformation to lower temperatures (by 30-40°C) during cooling at 1-50°C/s, refining the lath structure and increasing the dislocation density of bainitic ferrite. The V-added steel demonstrated a higher strength of fresh bainite (about 50MPa) compared to the reference alloy. This superior strength has been explained explicitly by accounting for the contributions from the increased dislocation density and the refined lath structure of V-added variant. No evidence of fine VC or VN precipitation occurring during coiling at 450°C was found. Further, the complex TiNbV(CN) particles that were observed were too coarse and too scarce to make any strengthening contribution. The fresh bainite of both X100 variants tends to soften rapidly upon coiling at 450°C; about 110MPa strength drop was noticed for the reference alloy. The implications of the findings for alloy design and processing of advanced linepipe steels are discussed.

Keywords: Linepipe Steels, Strengthening, Phase transformations, Vanadium, In-situ Compression