High-throughput investigation of ferrite growth kinetics in graded steels

For decades, the austenite-to-ferrite phase transformation has been largely investigated from both technological and scientific standpoints. Controlling the growth kinetics of this phase transformation is a critical mainstay to tailor the mechanical properties of new high strength steels such as TRIP and DP steels. Despite numerous modelling attempts to accurately describe the effect of solute concentration on ferrite growth kinetics, disputes about the role of substitutional elements and their interaction with the moving interface are still existing among the scientific community. Validation of the developed models requires conducting experimental studies on the effect of processing parameters on growth kinetics. Particularly, studying the effect of composition on ferrite growth kinetics using conventional discrete methods (such as dilatometry and optical microscopy) was shown to be time-consuming and sometimes costly. High throughput approaches represent an adequate solution to accelerate the investigation of large set of parameters on material properties. In this study, we present a complete combinatorial approach for high-throughput mapping of the austenite-to-ferrite phase transformation kinetics dependency on solute composition in steels. The methodology consists on making diffusion couples containing macroscopic gradients of composition and using high energy X-ray diffraction experiments to gather *in situ* the phase transformation kinetics along the composition gradient. The methodology was used to investigate the solute content effect on ferrite growth kinetics in 5 ternary Fe-C-X and 3 quaternary Fe-C-X_1-X_2 systems, where X, X_1 and X_2 are substitutional elements (Mn, Cr, Si, Ni and Mo). As a result, a large database of more than 1500 kinetics describing the effect of different substitutional elements on ferrite growth kinetics was gathered using a very limited amount of samples in a limited time laps (4 days). The obtained results were compared with the predictions of different models describing ferrite growth kinetics in steels. The para-equilibrium and local-equilibrium classical models failed to accurately predict ferrite growth kinetics as a function of composition. A modified version of the ‘three-jump’ solute drag model was proposed and validated in the present contribution. The calculated kinetics using the new model showed a very good agreement with the measured ones over the whole range of solute composition and at different temperatures. Moreover, it was shown that using the same fitting parameters for the ternary systems, the model was able to accurately predict the growth kinetics in quaternary systems. It is noteworthy that this new methodology could be used to study any other phase transformation in any other metallic alloy.