

Austenization stasis in Fe-12Cr-0.1C martensitic stainless steel

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Residual ferrite, a common sub-product of the austenization process in martensitic stainless steels (MSS), has serious detrimental effects on the mechanical properties of these alloys [1]. Due to its technological relevance, austenization is one of the most well-known phase transformation in material science. For high-Cr steels, a transformation in multiple stages is often reported. However, the mechanisms dictating the onset of the different transformation rates are not entirely clear [2].

Here, using both experimental and simulation techniques, we show that the austenization reaction in MSS occurs in three stages: (1) fast growth of austenite driven by Cr diffusion in ferrite and partial dissolution of $M_{23}C_6$, (2) soft-impingement and reaction stasis, (3) slow austenite growth driven by Cr homogenization in austenite.

The moving boundary model in DICTRA is used to study the transformation. Based on experimental observations, austenite is set to nucleate from ferrite grain boundaries and to grow towards the $M_{23}C_6$ particle, which is initially embedded in the ferrite matrix. DICTRA calculations are in good agreement with dilatometric experimental data, which show the presence of residual ferrite even after prolonged holding time in the austenite temperature range. An analysis of the Cr profiles in the simulation domain shows that the transformation stasis is caused by soft-impingement between $M_{23}C_6$ / α and α / γ interfaces in the residual ferrite matrix.

Next, the effect of heating rate and initial $M_{23}C_6$ particle size are investigated to optimize the process parameters. For heating rates greater than 1°C/s, simulations predict ferrite growth, which immediately follow the point of maximum austenite volume fraction. Based on thermodynamic considerations, this phenomenon is qualitatively explained with ThermoCalc. Moreover, as the initial carbide size is reduced, the volume fraction of austenite transformed before soft-impingement increased. Finally, a set of process parameters are optimized with the objective function of minimizing time while maximizing the final volume fraction of austenite.

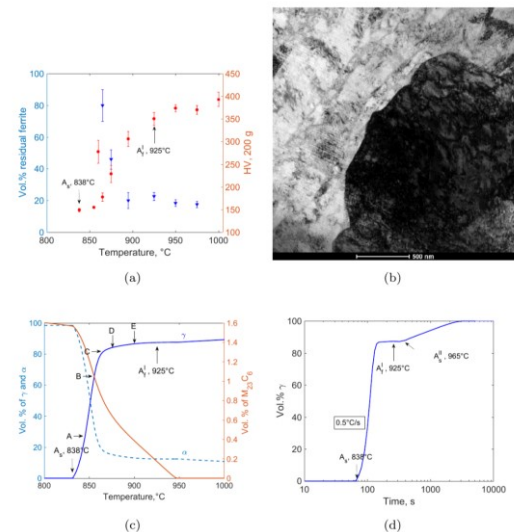


Figure 1. Experimental observations of (a) dilatometry samples reveal the presence of 15 to 20 Vol.% of residual ferrite, darker phase in (b). This is predicted by DICTRA simulations (c-d), which show a three stages transformation kinetics.

References

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Biographical Note

Alvise Miotti Bettanini holds a Master of Science degree from KTH of Stockholm, where he graduated in 2014. He's currently a PhD student at IMAP department at UCLouvain under the joint supervision of Prof. Pascal J. Jacques and Prof. Laurent Delannay. His project, in partnership with APERAM and CBMM, contributes to the development of high strength stainless steels for automotive structural applications.