Phase transformation and hydrogen content in metastable austenite

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1. Introduction

Stable austenitic stainless steels are said to be relatively unaffected by hydrogen, however their cost-strength ratio makes them expensive to deploy in hydrogen infrastructure on a large scale. Metastable austenitic stainless steels might be more suitable cost-wise, but martensitic transformation is an issue in the context of hydrogen embrittlement. To evaluate the parameters influencing phase transformation, a metastable austenitic stainless steel with varying grain sizes and varying hydrogen gas exposure pressures was subjected to cold-rolling. Strain-induced martensite transformation is then discussed in relation to the above parameters.

2. Material and procedure

A metastable austenitic stainless steel, close to SUS304 in composition was used: Fe-16Cr-10Ni. After 90% cold-rolling to a thickness of 1.5 mm, the material was fully martensitic. It was then annealed to induce reverse transformation of martensite back into austenite. The annealing temperatures were 923K, 1023K and 1173K, and annealing times were 10 and 30 minutes, followed by air cooling. The resulting grain sizes varied from 1 to about 20 μ m. Regardless of the grain size, the resulting material was fully austenitic.

Hydrogen exposure was conducted in hydrogen gas at 10, 40 and 100 MPa, at 543K for 72 hours. Following hydrogen exposure, cold-rolling was conducted at room temperature to induce martensite transformation.

After cold-rolling, the samples were analyzed using magnetic saturation measurements, X-Ray Diffraction (XRD) and a Scanning Electron Microscope (SEM) with an Electron BackScattered Diffraction (EBSD) camera. All measurements were used to measure the volume percentage of martensite (α' and ε) as well as austenite (γ).

3. Results and summary

Steel that was not exposed to hydrogen transformed to martensite in similar proportions regardless of grain size, i.e. for uncharged metastable austenite, the mechanical stability of austenite is independent of grain size.

Conversely, hydrogen exposure affected the strain-induced phase transformation. In this case also, there was no observable effect of grain size on the volume fraction of transformed martensite. However, increasing hydrogen exposure pressures delayed the onset of phase transformation, so much so that at a true strain of 0.1, there was no martensite in any steel exposed to 100 MPa hydrogen gas (for all grain sizes, Fig. 1).

Evaluation of the formed martensitic variants from partially transformed grains showed that in the presence of hydrogen, specific variant packets formed predominantly: once a martensite variant packet started to form in a sample, its proportion would increase until being about 50% of all martensite variant packets in the sample.

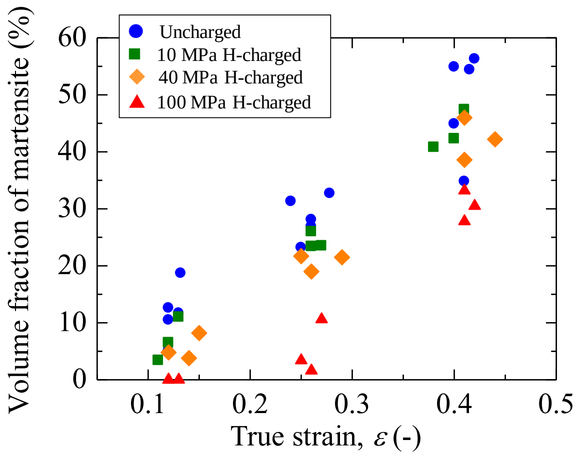

Fig. 1 Evolution of the volume fraction of martensite with true strain for different hydrogen exposure conditions (as there is no effect of grain size, they are not differentiated)

This research showed that increasing hydrogen contents will increase the mechanical stability of metastable austenite and delay the formation of strain-induced martensite. The transformation from austenite to α'-martensite appeared to be similar to previously explained mechanisms [1], with the only difference being that hydrogen affected the slip systems, which resulted in fewer martensite embryos.

References

[1] G.B. Olson, M. Cohen, (1972) A mechanism for the strain-induced nucleation of martensitic transformations, Journal of Less Common Metals, 28 (1972) 107-118.