Experimental report

03/08/2022

Proposal: 1-01-191 **Council:** 4/2021

Title: SANS study of carbides precipitation kinetics in a high-performance steel designed through computationalthermodynamics and kinetics

Research area: Materials

This proposal is a new proposal

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Samples: Steel

Instrument	Requested days	Allocated days	From	To
D33	1	2	01/09/2021	03/09/2021

Abstract:

Precipitation hardening is one of the most potent strengthening mechanisms for many high-strength alloy steels. Mechanical properties of the alloys can be optimized by carefully controlling the nano-scale precipitation and their sequence, fraction, size and dispersion. However, the bulk quantification of the nano-size precipitates in steels is very challenging due to their small size and volume fraction. Small-angle neuron scattering (SANS) is one of the most powerful technique to tackle this challenge. The objective of this work is to investigate precipitation kinetics in a designed low-carbon low-alloy steel in order to validate the thermodynamic and kinetic modelling. The SANS measurements will help quantitative characterization of precipitation kinetics, which together with other complementary experiments will pave way for computational design of high-performane metallic materials.

Experimental report for:

SANS study of carbides precipitation kinetics in a high-performance steel designed through computational thermodynamics and kinetics

(Proposal number: 1-01-191)

Tao Zhou and Peter Hedström: KTH Royal Institute of Technology, Stockholm

Experimental details and objectives:

The purpose of the proposed SANS experiments was to study the precipitation transition kinetics in a designed high-performance tool steel. The quantitative information of precipitation will be used to validate our modelling of precipitation kinetics. The SANS study, together with our modelling and other experimental work, will pave way for computational design of nanoprecipitation hardened high-performance steels. Another purpose of the SANS experiments was to study the Cu precipitation kinetics during in situ 480 °C ageing of a wire-arc additively manufactured maraging stainless steel, where the Cu precipitation in the solution-treated and as-built conditions were to comparatively studied.

Results:

As an example, Fig. 1 shows the comparative study of Cu precipitation kinetics in the solution-treated and as-built conditions. The Cu precipitation has a finer dispersion in the as-built sample in comparison to the solution-treated sample. In addition, it is interesting that humps on the curves appear at the late ageing stages of both samples, suggesting a bimodal size distribution of Cu precipitates. This is a new research question for our further study.

The experiments have already been used in a published article [1] and will be used in a conference presentation [2].

We would like to thank our local contact Dr. Robert Cubitt, and Nina-Juliane Steinke, Michel Bonnaud and Sébastien Turc for their support before and during the beamtime.

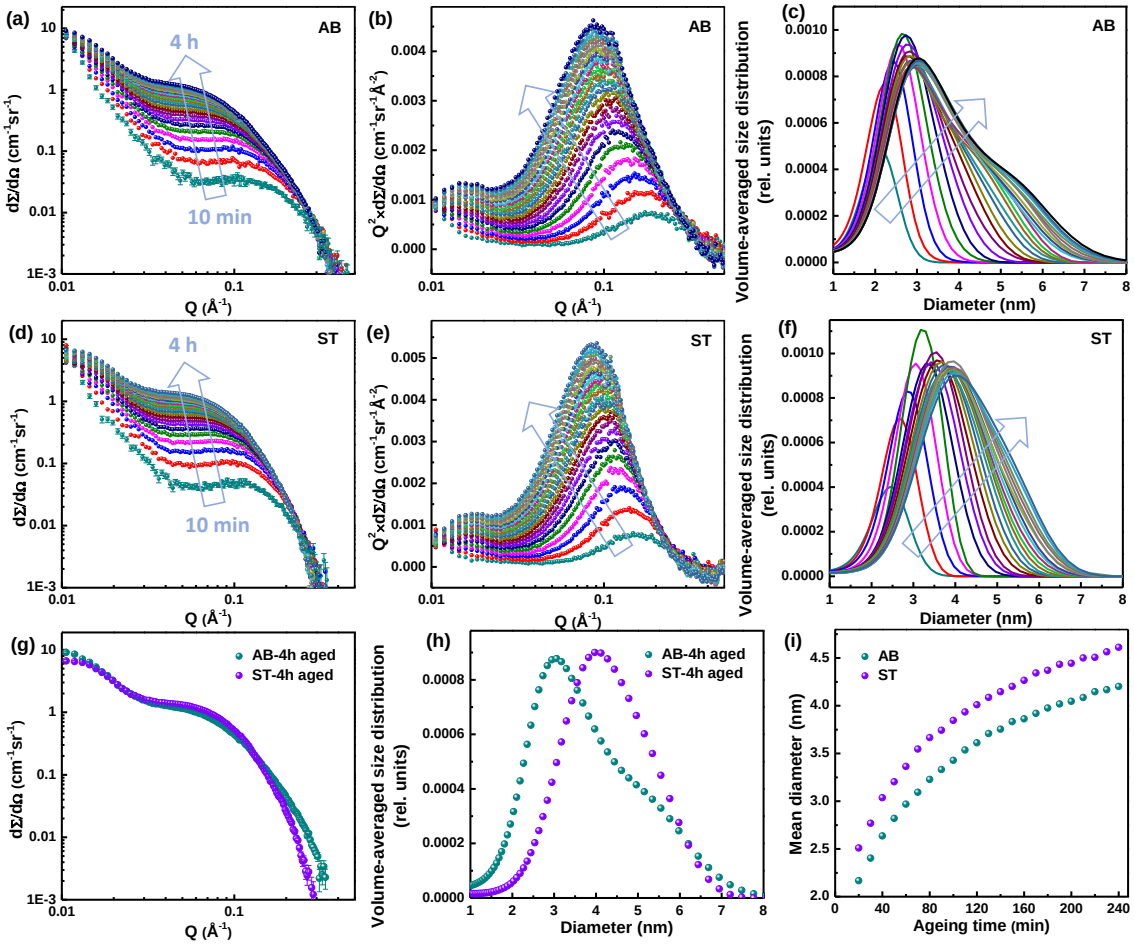

Fig. 1 Time evolution of the dΣ/dΩ after background subtraction as a function of Q measured at 480 ºC up to 4 h for samples of (a) the as-built (AB) and (d) solution treated (ST) at 1200 ºC for 15 h; the calculated dΣ/d$\Omega \cdot Q^2$ as a function of Q for the (b) AB and (e) ST samples; the calculated volume averaged particle size distribution for the (c) AB and (f) ST samples; a comparison of (g) the dΣ/dΩ vs. Q and (h) particle size distribution of the AB-4 h and ST-4 h aged condition; (i) the mean diameter of Cu precipitates as a function of ageing time for the two samples. Results are from Refs. [1, 2].

References:

[1] Tao Zhou, Tao Zheng, Ahmet Bahadir Yildiz, Gabriel Spartacus, Monika Rolinska, Robert Cubitt, Peter Hedström. Microstructure control during deposition and post-treatment to optimize mechanical properties of wire-arc additively manufactured 17-4 PH stainless steel. Additive Manufacturing, 2022, 58, 103047.

[2] Tao Zhou, Tao Zheng, Ahmet Bahadir Yildiz, Gabriel Spartacus, Monika Rolinska, Robert Cubitt, Peter Hedström. Microstructure control during deposition and post-treatment to optimize mechanical properties of wire-arc additively manufactured 17-4 PH stainless steel. Alloys for Additive Manufacturing Symposium, 12th-14th September 2022, Universität der Bundeswehr München.