Microstructure evolution in high performance martensitic stainless steel during/after heat treatment using high energy SXRD

THE INDUSTRIAL CHALLENGE

voestalpine Precision Strip AB produces martensitic stainless steel with excellent corrosion and mechanical properties, ideal for demanding applications such as valves. The steel's microstructure, composed of multiple carbides and austenite phases, is highly sensitive to heat treatment and difficult to optimize. To effectively control the microstructure, a deeper understanding of the formation process is needed.

WHY USING A LARGE SCALE FACILITY

Traditional XRD can detect carbides in steel, but its accuracy is impaired by low signal-to-noise ratio, questionable results, and a lack of standards. On the other hand, high-energy synchrotron X-ray diffraction (SXRD) offers improved accuracy by producing higher quality data, better signal-to-noise, and higher resolution. Additionally, high-energy SXRD have better penetration on steel and allows for better averaging from the entire material thickness, whereas traditional XRD methods only average from the near surface (less than 10 µm).

HOW THE WORK WAS DONE

Fifty samples with thickness less than 200 µm were prepared and subjected to post-processing. High-energy SXRD experiments were then carried out at the P07 beamline of Petra III in Germany. The experimental setup of the beamline is shown in Figure 1a. To capture the dynamics of phase transformation and carbide phase evolution during heat treatment, some measurements were performed in-situ using a special furnace with selected heat treatment cycles (Figure 1b), while others were performed ex-situ at room temperature (Figure 1a). Altogether, a total of six in-situ experiments and 50 ex-situ measurements were performed. A full profile refinement method like Rietveld analysis was used for result evalution, along with conventional peak fitting-based analysis. Additionally, lab-based XRD and SEM tests were conducted at Swerim and voestalpine to validate some of the observations.

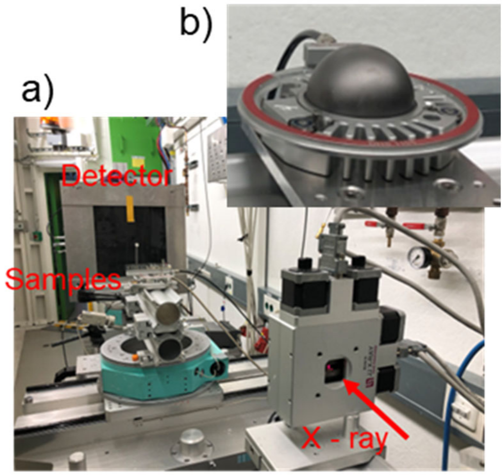

Figure 1 a) The ex-situ measurement setup with samples; b) the furnace used in the in-situ study

THE RESULTS AND EXPECTED IMPACT

The ex-situ measurements successfully determined the quantity of carbides and austenite phases in the system and could validate the accuracy of lab-XRD and SEM studies. Also, the carbide determination routine in the lab could be confirmed as reliable. The shown high-throughput capabilities of SXRD technique make them useful for efficient bulk metallic material characterization. However, the in-situ experiments were less successful due to a technical issue with the furnace which limited the maximum temperature to 500 ºC. To improve future experiments, the furnace's heating capability needs to be checked and calibrated. Despite this limitation, valuable insights were gained into the dynamics of phase transformation and the effects of heat treatment on the microstructure of the steel, which is crucial for the development of advanced alloys and optimizing properties for industrial applications. The team gained valuable experience for future in-situ analyses and avoiding similar issues.

SWERIM voestalpine ONE STEP AHEAD.

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