Retained austenite decomposition in low-alloy steels

Grace Fidler, Kun Yan, Matt Dear, Ed Pickering

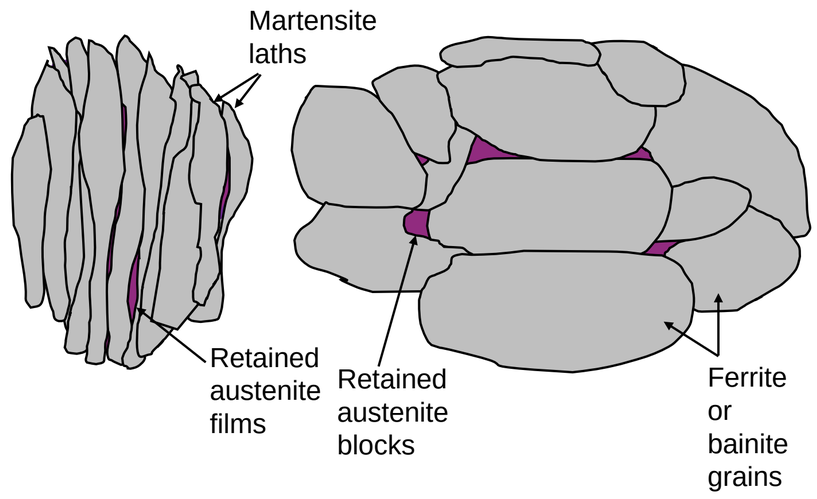
The University of Manchester

advanced metallic systems

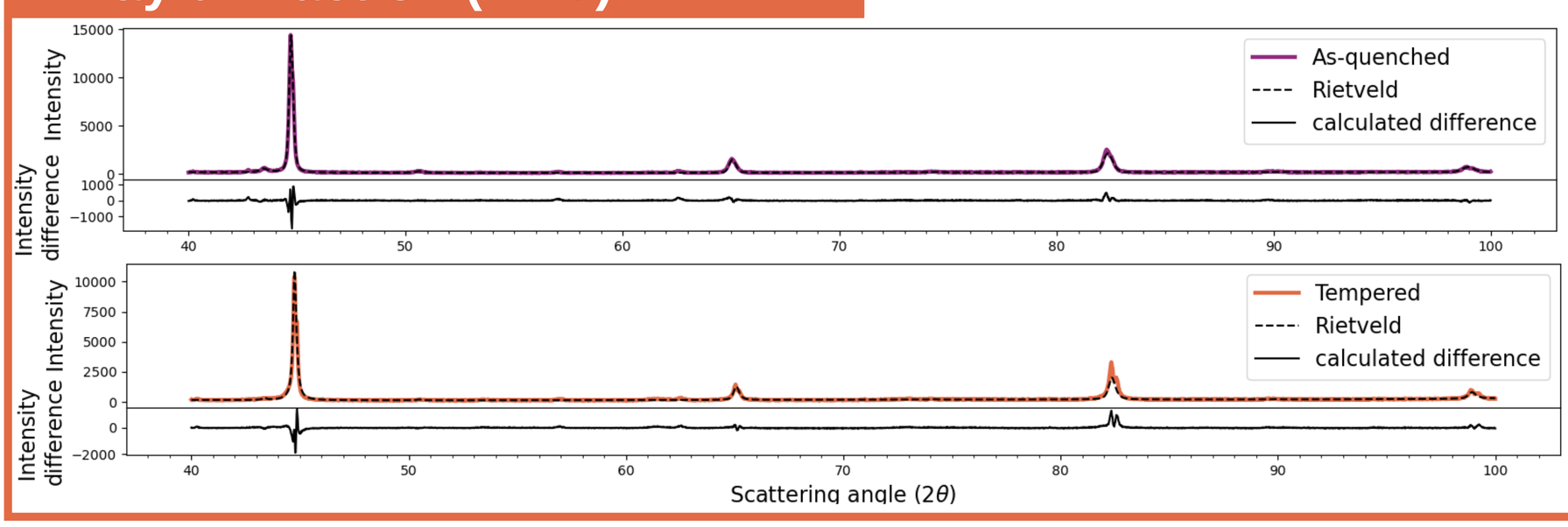
Rolls-Royce

Introduction

Many low-alloy steels are heat treated using a three-step process involving austenitisation, quenching and tempering. Retained austenite (RA) is the austenite phase that is retained to room temperature after quenching from austenitisation. It's often seen as either blocks between ferrite grains or thin films between martensite laths. In low-alloy steels the proportion of RA can be very small (<5% after quenching [1]) and is in theory fully decomposed after tempering [2]). Therefore, a major difficulty in understanding its decomposition in low-alloy steels is measuring it. Synchrotron X-ray diffraction is conventionally the most precise way of measuring RA volume fractions, but is not very accessible. Alternatives include lab-based XRD and EBSD, but both have limitations. Dilatometry can also be used to estimate austenite decomposition in tempering.



X-Ray diffraction (XRD)

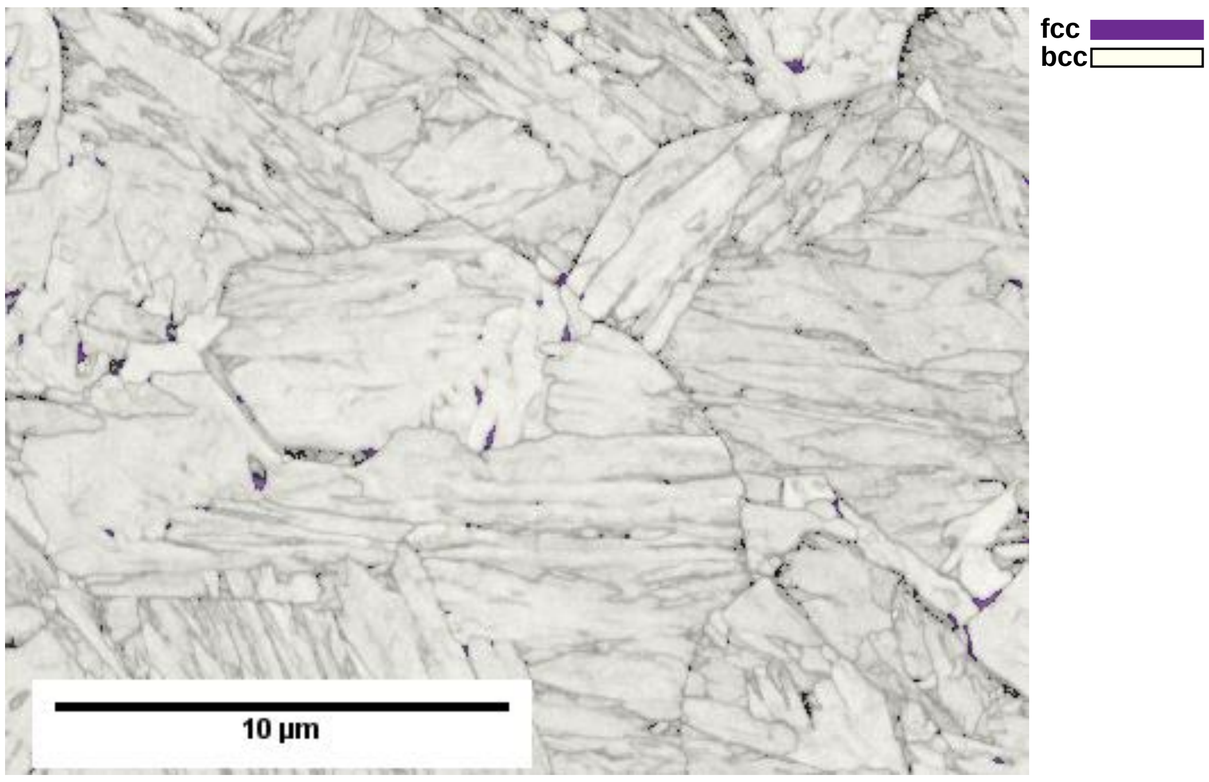


CuKα X-Ray source measuring as-quenched and tempered samples.

- 8% RA as-quenched.
- 2% RA tempered.
- Peak splitting at higher angle in tempered sample, suggesting change in symmetry, likely from carbon diffusion.

Electron backscatter diffraction (EBSD)

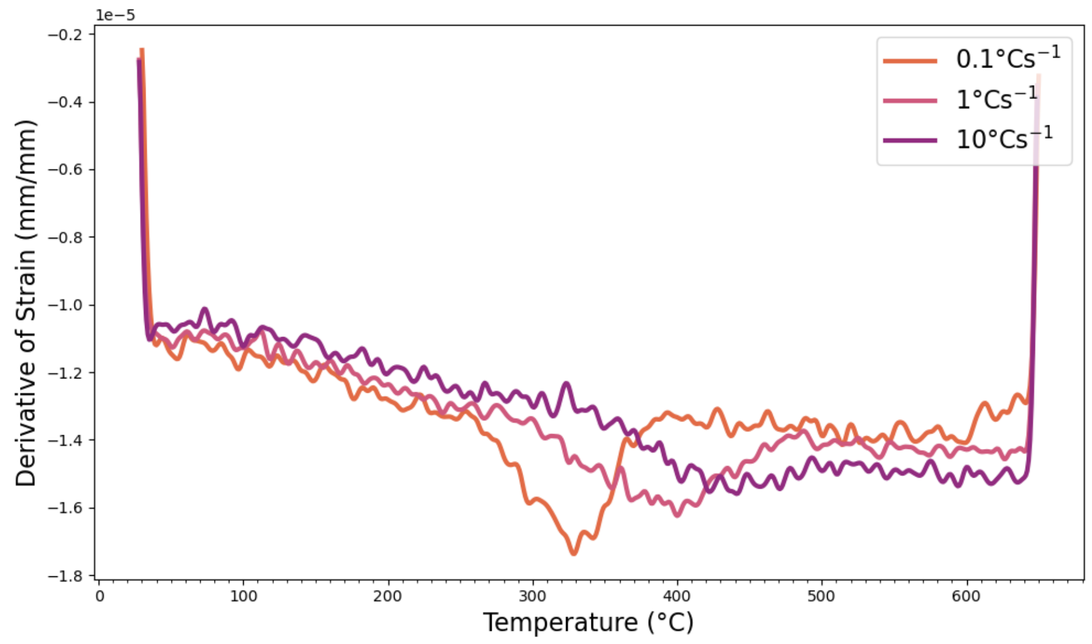
EBSD map of an as- quenched sample using accelerating voltage of 15 kV, beam current of 3.2 nA and sample tilt of 70°, showing phase fraction and band contrast map.



- Approaches the limits of EBSD spatial resolution.
- Rough idea of grain sizes.
- 0.4% volume fraction RA indexed, far lower than XRD, likely finer RA is not being indexed.

Dilatometry

Samples were subject to a tempering up to 650˚C at three heating rates. The derivative of the strain during the heating has been plotted with a smoothing factor



- Reduction in derivative of strain may signify RA decomposition.
- Slower heating rates make start of decomposition temperature lower.
- Deeper trough in slower heating rates, suggesting larger austenite decomposition

Conclusion

Retained austenite has been observed with three methods, each providing unique advantages and disadvantages. The small volume fraction of RA in steels can make it difficult to obtain reliable or accurate results. It is recommended that a combination of the mentioned techniques be used to measure RA. EBSD tilt angle and dictionary-based indexing will be explored in future work.

- XRD measured the highest volume fraction of RA and provided some insight into lattice symmetry.
- EBSD measured a far lower volume fraction but was able to show austenite is retained at boundaries.
- Dilatometry could not quantify RA volume fractions but can be used in-situ to measure its decomposition.

[1] E. J. Pickering, J. Collins, A. Stark, L. D. Connor, A. A. Kiely, and H. J.Stone. In situ observations of continuous cooling transformations in low alloysteels. Materials Characterization, 165, 7 2020.
[2] G. Yan, L.Han, C.Li, X. Luo, and J. Gu. Characteristic of retained austenite decomposition during tempering and its effect on impact toughness in SA508 Gr.3 steel. J. Nucl. Mater. ,483:167–175, 1 2017.