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Report:

Maraging steels are low-carbon martensitic steels developed in the 1960s for specific applications requiring ultra-high strength combined with good fracture toughness (e.g. surgical knifes and razor blades) [1]. Their remarkable properties are obtained through a process of martensite formation plus annealing in the range of 673-873 K to allow precipitation of very fine intermetallic phases in martensite [2]. Martensitic transformations are diffusionless. During this process, the austenite face-centred cubic (fcc) structure transforms to the martensite body-centred cubic (bcc) or body-centred tetragonal (bct) structure, depending on the steel composition. In iron-based alloys most of the observed martensitic transformations occur virtually instantaneous when the temperature is lowered below the martensite start temperature. In some cases however, a time-dependent isothermal martensitic transformation is found to occur at a constant transformation temperature. Despite continuous world-wide efforts, the mechanisms involved in the isothermal martensitic transformation are still not understood in detail.

Previous experiments on a Fe-12Cr-9Ni maraging steel (12 wt.% Cr, 9 wt.% Ni, 4 wt.% Mo, 2 wt.% Cu, 1 wt.% Ti, <0.01 wt.% C) using magnetization, laboratory XRD, and metallographic measurements showed that the martensitic transformation in this steel is isothermal with a highest transformation rate of about 24 hours at 233 K [3]. Recently, we found in magnetisation measurements that the transformation rate increases by several orders of magnitude in applied magnetic fields up to 9T [4]. In order to obtain a physical insight in this isothermal martensitic transformation we have performed time-resolved high energy X-ray diffraction measurements in constant applied magnetic fields up to 8 T. The high energy makes it possible to probe the bulk of the sample, while the use of microbeams allows to monitor individual reflections resulting from a limited set of illuminated grains. Thanks to the use of relatively large applied magnetic fields, workable transformation times become accesible.

Samples with a surface area of 5×5 mm^2 and a thickness of 0.45 mm were mounted in the 8 T horizontal cryomagnet of the University of Warwick and cooled to a fixed temperature of 233 K to start the isothermal martensitic transformation in a constant field. The samples were irradiated by a microbeam of hard X-rays with an energy of 80 keV on beam line ID15A in order to record the diffraction patterns from the sample on the 2D detector (placed 40 cm behind the sample) as a function of time. The magnetic field was applied parallel to the X-ray beam. Time-resolved measurements with two beam sizes of 40×40 μm^2 and 60×60 μm^2 have been performed ensuring that about 50 individual austenite grains were observed in one exposure. During the 5 s exposures the sample (and cryomagnet) was rotated continuously over an angle of 0.4 degrees around the vertical rotation axis covering a total angular range from -3.2 to +3.2 degrees. The two beam sizes make it possible to check whether the complete grain is illuminated by the beam. In that case the total integrated intensity of an individual diffraction spot is proportional to the grain volume.

As shown in Fig. 1 the diffraction patterns contain individual peaks from the original austenite (fcc) matrix and the newly formed martensite (bcc). As the martensite is formed in randomly orientated plates with a relatively small volume it results in a continuous powder ring on the 2D detector.

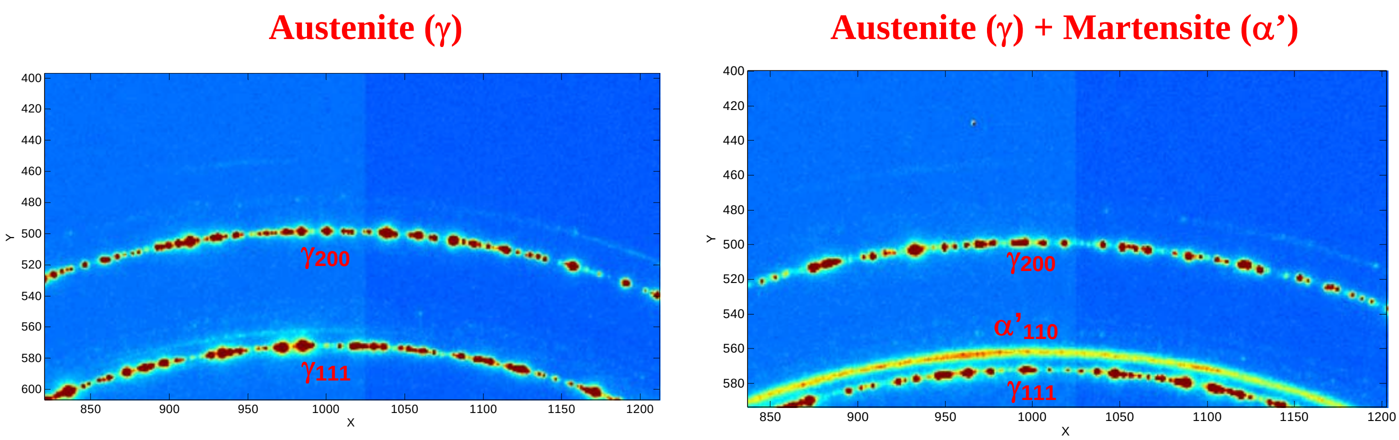

Fig. 1: Section of the 2D diffraction pattern of maraging steel before (left) and after (right) the isothermal transformation for 8 hours in an applied magnetic field of 8 T at a temperature of 233 K. The γ_{111} and γ_{200} austenite reflections of the individual metastable grains have partially transformed into martensite plates, resulting in the α'_{110} martensite powder ring observed at the end of the transformation.

The isothermal transformation kinetics of the metastable austenite was monitored in zero field and in constant applied magnetic fields of 4 and 8 T for a period of 8 hours. A powder analysis of the data indicate, as expected, that the overall transformation was significantly accelerated by increasing the applied magnetic field. No significant texture effects induced by the applied magnetic field were however detected. The analysis of the isothermal transformation of individual metastable austenite grains is currently in progress. First results indicate that the transforming austenite grains show a gradual decrease in grain volume over a relatively wide time scale.

References

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