Better identification of dual phase steel constituents by combined EBSD and high resolution EPMA carbon measurements

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The mechanical properties of multiphase steels depend on various factors such as the composition, fraction of the different phases/constituents and internal strain level. Precise measurements are required to understand steel behaviours as well as to establish reliable prediction models. In this project, EBSD and EPMA measurements are combined to obtain a complete characterization of dual phase and TRIP steel samples as well as to overcome some ambiguities encountered when only one of these two techniques is used. In the present work, carbon measurements were performed on a field emission electron microprobe (JEOL JXA8530F) to assist the EBSD evaluation (JEOL JSM7000F with TSL OIM). SEM images after chemical etching are also performed to validate the results.

The lattice deviations between ferrite, bainite and martensite are too small to significantly change their interplanar angles; hence they cannot be indexed as different phases by an EBSD software. As reported by many authors including Ryde (2006), ferrite and martensite can be differentiated based on the quality of the diffraction patterns (Figure 1a). Despite its dependence on the crystal orientation, the diffraction quality is predominantly reduced by the crystallographic defects in martensite. This segmentation is further confirmed by EPMA where martensite regions have a carbon concentration between 0.8-1.2 wt% in the measured samples (Figure 1b).

The discrimination between ferrite and bainite using the diffraction quality is however more ambiguous. Zaefferer et al. (2008) utilized the higher concentration of dislocations in bainite, measured using the kernel average misorientation (KAM), to segment out bainitic regions from ferrite grains. However, in dual phase steels, potential ferritic regions with high density of transformation induced dislocations near martensite islands complicates the identification of bainite. Both have high local misorientation. High resolution carbon measurements performed with a microprobe can resolve this ambiguity. Bainite can be identified as regions of high misorientation values containing carbon, whereas dislocation regions will have a carbon content similar to the one in ferrite grains.

Figure 2 and 3 illustrates the differentiation between a bainitic and transformation induced dislocation region, respectively. A quantitative carbon line scan is first performed followed by an EBSD mapping over the area covered by the line scan. The KAM profile is then extracted from the EBSD dataset and compared with the one of the carbon measurement. In Figure 2, the presence of carbon in the two high KAM regions (left and center) indicates that these regions are bainite. The region on the right is a martensite island due to its low image quality. In Figure 3, the absence of carbon in the high KAM region on the right of the martensite island (white arrow in Figure 3b) confirms that this region is not bainitic and can therefore be identified as a high dislocation density region.

Figure 1: Martensite region identified (a) using EBSD as a region with a low image quality value and (b) using EPMA with a distinguishable amount of carbon.

Figure 2: Line scan over two bainitic regions (left and center) and one martensite island (right). (a) image quality (b) kernel average misorientation (KAM) using a kernel of 300 nm and a maximum misorientation of 3° (c) comparison of the KAM and carbon profile.

Figure 3: Line scan over a martensite island (center) and dislocation region (white arrow). (a) image quality (b) kernel average misorientation (KAM) using a kernel of 300 nm and a maximum misorientation of 3° (c) comparison of the KAM and carbon profile.