IF steel recrystallization: nucleation stage linked to internal misorientation parameters

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Abstract

Microstructure evolution during deformation and recrystallization can be followed by several misorientation parameters, deduced or calculated from EBSD data, such as: BC (Band Contrast), GOS (Grain Orientation Spread), GND (Geometrically Necessary Dislocation density) and KAM (Kernel Average Misorientation). Recrystallization includes nucleation and growth of nuclei until the consumption of the deformed matrix. In this work, we propose an internal misorientation parameter, based on KAM values, to characterize recrystallization in an IF steel, especially the nucleation stage. By definition, KAM of a pixel is the mean value of misorientation between this pixel and its neighbors in a grid of (NxN) pixels in grain interior. It is well known that nucleation starts in grains that have the highest stored energy of deformation, and then progresses in grains that have lower stored energy. It was found that the new misorientation parameter is quite sensitive to the state of material. This presentation will discuss the relation between this parameter, orientation gradients and the stored energy, as well as the possibility of using its values to identify nucleation sites.

Keywords: recrystallization, nucleation, stored energy, KAM, IF steel.

Introduction

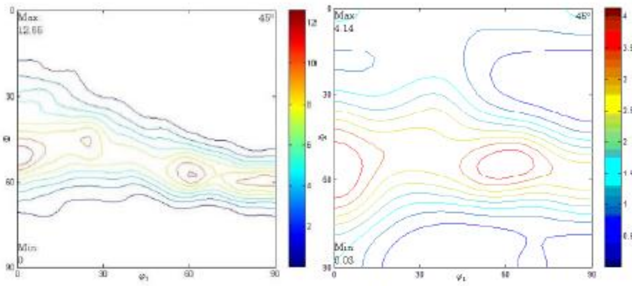
The progress that has been made in the Orientation Imaging Microscopy (OIM) has contributed significantly to the understanding of the recrystallization texture in low carbon and interstitial free (IF) steels. Currently, several misorientation parameters deduced from EBSD data are used to follow the evolution of microstructure in deformation and recrystallization such as: Grain Orientation Spread (GOS), Kernel Average Misorientation (KAM), Grain Average Misorientation (GAM). The GOS for a grain is the mean value of misorientations between all pixels of the grain and the average orientation of the grain. However, a KAM value for a pixel is obtained by averaging the misorientations between it and each of its first neighboring pixels in the same grain of this pixel. The modification to KAM that we propose in this paper is to not avoid calculation of misorientation between two pixels which do not belong to the same grain.(i.e. consideration of misorientations between pixels located on either side of the grain boundary).

The annealing texture of IF steels with moderately cold rolling reductions is controlled by the orientation of nuclei [2]. The dominant nucleation process is the formation of γ-fiber grains in highly deformed regions of γ-fiber orientations. This occurs near prior grain boundaries [3,6] and inside the deformed grains at deformation bands [7]. Regions near grain boundaries and triple points present a higher degree of orientation variation and higher dislocation density compared with the interiors of the grains [4,8]. The increased dislocation densities and orientation variation in these grain boundary regions makes them potent sources of nuclei [9]. In addition, subgrains having a high stored energy and high angle grain boundaries are the most likely nucleation sites [1]. The modification of the KAM is proposed for better taking into account these changes in the vicinity of the grain boundaries and to adjust the stored energy

in these potential nucleation sites. The relation between this internal misorientation parameter and the stored energy, as well as the possibility of using it to identify nucleation sites will be discussed.

Results

It is observed that the texture after cold rolling consists of the α-fiber and γ-fiber orientations with an almost uniform intensity along these two fibers. The maximum intensity is located in γ-fiber with a large spread. It should be noted the presence of a secondary maximum on the {001}<110> component of the α-fiber. For the recrystallized sample (630°C, 180 mn), the texture consists mainly of a strong γ-fiber with a relatively large spread around it, especially in the α-fiber direction (i.e. for ϕ_1=0°). Inside this γ fiber, the density is approximately evenly distributed with a slight peak around the orientation {111}<110> (Figure 1a).



(a) (b)

Figure 1.φ2 = 45° sections of ODF for : (a) recrystallized state (630°C, 18 mn) ; (b) nuclei (GOS≤0.5°) at early stage of recrystallization (630°C, 5mn).

In order to understand the texture evolution during recrystallization in the 75% cold rolled IF steel and an eventual role of oriented nucleation, the microstructure and texture were analyzed in early stage of recrystallization (630°C, 5 mn). By using a severe criterion GOS ≤ 0.5° to partition the recrystallized grains (nuclei), the recrystallized volume fraction is ~ 4%. The nucleation texture (only orientation of nuclei) is shown in Figure 1b. It shows a strong γ-fiber, it is qualitatively similar to that of the recrystallized state (Figure 1a). Therefore texture development in this case can be considered to be nucleation controlled (oriented nucleation).

When considering the textures of pixels having the lowest values of the modified KAM (representing 25% of the total number of pixels) and pixels with the highest values of the modified KAM (representing also 25% of the total number of pixels) of the 75% cold rolled sample, it appears that the orientations of high KAM pixels are more concentrated in the γ-fiber and the maximum intensity of the ODF corresponds to {111}<112> component. This probably leads to the texture evolution seen previously in the experimental study, due to nucleation of orientations belonging to γ-fiber which based on the high stored energy mechanism.

Conclusion

In this paper, a misorientation parameter deduced from EBSD data is used as an semi quantitative indicator for the stored energy level in a 75% cold rolled IF steel. It consists of a modification of the KAM that does not exclude misorientation between neighbors located on either side of the grain boundary. By comparing texture of the deformed state, especially that of pixels with high modified-KAM values and textures of early stage of nucleation and fully recrystallized states, it was found that nucleation consists mainly of γ-fiber orientations that possess a relatively high values of the modified KAM (i.e., high stored energy). Therefore, KAM is a good parameter to detect nuclei which could develop during recrystallization of IF steels.

References

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