CHALLENGES IN THE PHASE IDENTIFICATION OF STEELS USING UNSUPERVISED CLUSTERING OF NANOINDENTATION DATA

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Cluster analysis tools are used in data interpretation to separate information without the bias of a user. In the current study we investigate two techniques, the elbow method and K-means clustering to achieve a phase classification for a dual phase (DP) and a high strength low alloy (HSLA) steel by using hardness and reduced Young's modulus from nanoindentation tests as input variables. For the DP steel the contrast in hardness of the two phases ferrite and martensite is high, while for the HSLA steel the hardness contrast between ferrite and bainite is small, as seen from the corresponding load-displacement curves (Fig. 1). The elbow method, which provides the minimum number of clusters needed to categorize the data, indicated the optimal number of clusters only for the DP steel. Electron backscatter diffraction (EBSD) measurements were used to correlate the clustering result with the microstructure. The correlation between the calculated clusters and the microstructure showed a good separation of polygonal ferrite, martensite and indents located on grain boundaries or next to martensite islands. On the other hand, K means clustering did not reveal a phase separation of the HSLA constituents after comparing the clustering results with selected grains. After comparing the hardness level of the selected HSLA grains and the minimum distinguishable hardness level at the DP steel, it is assumed that the K-means input variable have to differ from each other by at least 10%. A further sample was heat treated to produce large polygonal ferrite grains. Four selected grain pairs were tested perpendicular to the high angle grain boundaries (HAGB). The goal was to investigate the impact of indentation near grain boundaries between two adjacent grains with similar mechanical properties on the cluster determination and K means clustering. We could show that the optimal number of clusters was not identical for all grain pairs to achieve the best separation. With our study, we were able to determine the limiting factors to obtain a phase classification by using K means clustering based on nanoindentation input variables for the HSLA steel. We could show that the magnitude of the mechanical contrast of the phases, grain and phase boundaries and microstructural inhomogeneities can prevent successful clustering without additional information.

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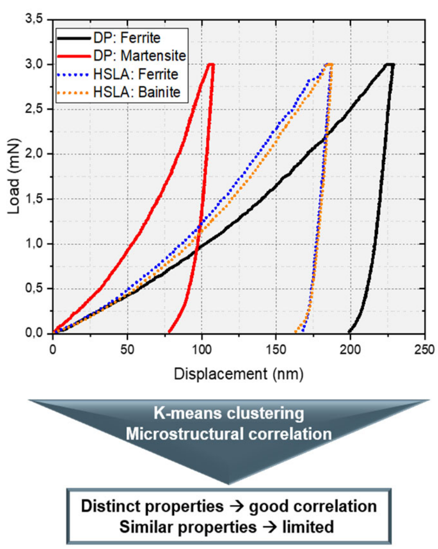

Fig.1 Representative load and depth curves of the tested DP and HSLA steel and its individual constituent.