EFFECT OF BAINITE MORPHOLOGY ON HYDROGEN TRAPPING IN X70 MICROALLOYED STEEL

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The microstructure/phases present in X70 microalloyed steel can affect the trapping ability of hydrogen within the steel and ultimately influence the mechanical properties. Differences in processing of the steel can result in different microstructural phase(s) such as ferrite, acicular ferrite, pearlite and bainite. The focus of this study will be on the effect of different bainite morphologies on hydrogen trapping capability.

Double-cell electrochemical hydrogen permeation tests were conducted on an X70 steel (same chemical composition) that was processed under different conditions - including number of rough rolling passes, time at temperature and/or the application of laminar cooling - to generate different bainitic microstructures in each sample. The effective diffusion coefficient was obtained from each permeation test using both the lag-time and curve fitting method. The trap density (both reversible and irreversible) was calculated using a model develop by Dong [1]. The reversible trap density was relatively constant for all steels and was independent of the bainitic microstructure morphology. The bainite lath morphology changed with increasing the number of rolling passes and correspondingly decreased the irreversible trap density.

Microstructural analysis was undertaken using optical microscopy (OM), transmission electron microscopy (TEM) and electron backscatter diffraction (EBSD) (boundary misorientation and band contrast). Both lower bainite (LB) and upper bainite (UB) were observed by OM. The presence of both these phases was confirmed with EBSD band contrast mapping. The dominant phase for steels processed without laminar cooling (as determined by band contrast) was lower bainite. Conversely, the steels subject to both rolling and laminar cooling showed a mixture of both lower and upper bainite. In addition, EBSD misorientation measurements showed that increasing the number of rolling passes decreased the fraction of high angle grain boundaries (HAGB) (> 50°). The martensite-austenite (M-A) phase was also detected at upper bainite interlath boundaries. The prior austenite grain (PAG) size for each steel was measured using OM. PAG decreased with increasing number of rolling passes. The fraction of HAGB's increased with increasing PAG size.

The size and number density of (TiNb)(NC) precipitates was measured using TEM. The mean size of these precipitate types increased from ≈96 nm with no rolling passes to ≈121 nm for 5 rolling passes. The (TiNb)(CN) complex precipitates did not exhibit significant irreversible trapping ability. A high irreversible trap density was attributed to high angle grain boundaries (HAGBs) associated with the lower bainite microstructure. In contrast, the primary irreversible traps for the steel exhibiting upper bainite were bainitic lath interfaces (low angle boundaries) where M-A phase occurs.

[1] Dong, C.F., et al., Hydrogen-induced cracking and healing behaviour of X70 steel. Journal of Alloys and Compounds, 2009. 484(1): p. 966-972.