

Investigation on the Improvement of Hydrogen Embrittlement Resistance in 4130X Microalloyed Steel by Rare Earth Elements

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Abstract Rare earth elements have a significant impact on the mechanical properties of microalloyed steels, including hydrogen embrittlement resistance. This study investigates the mechanism by which rare earths affect the hydrogen embrittlement sensitivity of 4130X steel using electrochemical hydrogen permeation, thermal desorption, slow strain rate tensile testing, EBSD characterization of fracture microstructures, and TEM characterization of carbides. After adding rare earth elements (La+Ce content of approximately 0.04 wt.%), the hydrogen embrittlement sensitivity significantly decreases, with the hydrogen diffusion coefficient reducing from $1.19 \times 10^{-6} \text{ cm}^2\text{s}^{-1}$ to $0.86 \times 10^{-6} \text{ cm}^2\text{s}^{-1}$. The saturated hydrogen concentration and hydrogen trap density increase from $2.78 \times 10^{-6} \text{ mol}\cdot\text{cm}^{-3}$ and $5.92 \times 10^{19} \text{ cm}^{-3}$ to $5.92 \times 10^{19} \text{ cm}^{-3}$ and $9.82 \times 10^{19} \text{ cm}^{-3}$, respectively. The increase in hydrogen trap density is mainly attributed to the increased proportion of high-angle grain boundaries and the changes in the type, morphology, and distribution of carbide precipitates in the steel. Regarding the hydrogen embrittlement suppression mechanism, rare earth elements reduce the size of the original austenite grains and bainitic laths, enhancing the crack propagation resistance of the steel matrix. More importantly, rare earths promote the dispersion of nanoscale spherical M_3C carbides within the bainitic laths and inhibit the formation of long strip-shaped M_7C_3 carbides, thereby weakening the accumulation of hydrogen at grain boundaries and reducing the hydrogen embrittlement sensitivity of the steel.

Keywords Rare Earth Elements; Hydrogen Embrittlement; CrMo Steel

Reference

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