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Role of Vanadium in welding of flat products in High-Strength Low-Alloy Steel: microstructure and mechanical properties

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High-Strength Low-Alloy (HSLA) steels are widely used in structural applications, requiring a thorough microstructural analysis to optimize the strength and toughness of welded joints. During multi-pass welding, thermal cycling leads to the formation of a complex Heat-Affected Zone (HAZ), consisting of sub-regions with diverse microstructural constituents, including brittle phases that influence the static and cyclic mechanical resistance of HSLA steel joints. This study evaluates the effect of Vanadium (V) addition on the HAZ microstructure in 15 mm thick S355 steel welds produced by robotic GMAW welding. A steel variant micro-alloyed with both V and Niobium (Nb) was also considered. The results are compared to a standard C-Mn S355 steel without micro-alloying elements to assess the impact of V and Nb on weld microstructure and mechanical performance. The results reveal a heterogeneous microstructure with ferrite of several morphologies, bainite, and martensite/austenite (M/A) islands. The presence of vanadium reduces the solubility of carbon during phase transformations, favoring the formation of ultrafine precipitates (~11 nm) and reducing the M/A phase in the high vanadium (0.1 wt%) variant compared to the vanadium-free material. Nevertheless, the micro-alloyed variants improve mechanical strength (yield and ultimate strength) without loss of ductility or fatigue resistance. The combined presence of both hard and soft microstructural constituents in HAZ allows a stress-damping behavior, which, together with the presence of very fine precipitates, promises improved resistance to crack propagation under different loading conditions.

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