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Gas Metal Arc Welding of Clad Plates API 5L X-60/316L Applying External Magnetic Fields during Welding

Authors : Blanca A. Pichardo, Victor H. Lopez, Melchor Salazar, Rafael Garcia, Alberto Ruiz

Abstract : Clad pipes in comparison to plain carbon steel pipes offer the oil and gas industry high corrosion resistance, reduction in economic losses due to pipeline failures and maintenance, lower labor risk, prevent pollution and environmental damage due to hydrocarbons spills caused by deteriorated pipelines. In this context, it is paramount to establish reliable welding procedures to join bimetallic plates or pipes. Thus, the aim of this work is to study the microstructure and mechanical behavior of clad plates welded by the gas metal arc welding (GMAW) process. A clad of 316L stainless steel was deposited onto API 5L X-60 plates by overlay welding with the GMAW process. Welding parameters were, 22.5 V, 271 A, heat input 1,25 kJ/mm, shielding gas 98% Ar + 2% O_2, reverse polarity, torch displacement speed 3.6 mm/s, feed rate 120 mm/s, electrode diameter 1.2 mm and application of an electromagnetic field of 3.5 mT. The overlay welds were subjected to macro-structural and microstructural characterization. After manufacturing the clad plates, a single V groove joint was machined with a 60° bevel and 1 mm root face. GMA welding of the bimetallic plates was performed in four passes with ER316L-Si filler for the root pass and an ER70s-6 electrode for the subsequent welding passes. For joining the clad plates, an electromagnetic field was applied with 2 purposes; to improve the microstructural characteristics and to assist the stability of the electric arc during welding in order to avoid magnetic arc blow. The welds were macro and microstructurally characterized and the mechanical properties were also evaluated. Vickers microhardness (100 g load for 10 s) measurements were made across the welded joints at three levels. The first profile, at the 316L stainless steel cladding, was quite even with a value of approximately 230 HV. The second microhardness profile showed high values in the weld metal, ~400 HV, this was due to the formation of a martensitic microstructure by dilution of the first welding pass with the second. The third profile crossed the third and fourth welding passes and an average value of 240 HV was measured. In the tensile tests, yield strength was between 400 to 450 MPa with a tensile strength of ~512 MPa. In the Charpy impact tests, the results were 86 and 96 J for specimens with the notch in the face and in the root of the weld bead, respectively. The results of the mechanical properties were in the range of the API 5L X-60 base material. The overlap welding process used for cladding is not suitable for large components, however, it guarantees a metallurgical bond, unlike the most commonly used processes such as thermal expansion. For welding bimetallic plates, control of the temperature gradients is key to avoid distortions. Besides, the dissimilar nature of the bimetallic plates gives rise to the formation of a martensitic microstructure during welding.

Keywords : clad pipe, dissimilar welding, gas metal arc welding, magnetic fields
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