Tungsten Inert Gas Welding Process of Dissimilar Metals

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Special attention is required when joining two materials with distinct chemical, physical and thermal properties in order to make the joint bond robust and rigid. Welded samples employing ER-309L filler wires had a microstructure consisting of a delta ferrite network in an austenite matrix. The tensile strength experimental results revealed that welding current, followed by GFR, was a highly influential parameter on tensile strength. Weld metals had higher hardness and flexural strength than stainless steel and carbon steel base metals.

dissimilar metal   gas tungsten arc welding   mechanical properties

1. Introduction

Manufacturers are focused on dissimilar materials joining to reduce manufacturing costs and build lightweight components. Steel structures are lighter and more cost effective when their structural components are made of different steels [1]. Chemical, petrochemical, nuclear, power generation, and other industries use a variety of dissimilar steel joints [2][3]. When welding of components, dissimilar joints are unavoidable. Joining dissimilar steels is typically more difficult than joining similar steels [4][5]; this is caused by a variety of causes, including changes in chemical composition and thermal expansion coefficients. Gas tungsten arc welding (GTAW), also known as tungsten inert gas welding (TIG), ref. [6] is an arc welding process that creates an electric arc using a non-consumable tungsten electrode. TIG welding provides outstanding welding with a coalescence of heat generated through an electric arc between a tungsten electrode and the steel [7][8]. TIG welding is a simple, fumeless, and spatter-free process that requires little or no finishing. This will look at the effects of welding current, root gap, gas flow rate, and filler metal type on the welding of the dissimilar metals SS316 stainless steel and AISI 1020 mild steel. Mechanical properties, such as tensile strength, hardness strength, and flexural bending strength, and microstructural properties were used to assess the TIG welding process parameters.

2. Consideration during Welding Dissimilar Metals

Previous studies on the TIG welding of diverse and dissimilar metals can be split into three categories: characterization, parameter optimization, and application. Heat conduction from the molten weld pool to a base metal with a higher thermal conductivity absorbs thermal energy and determines the amount of energy needed to melt the base metal locally [9][10]. During cooling, the differing base metals' thermal expansion coefficients produce tensile in one part and compressive stress in the other part. If the stress is not relieved, the metal deposited under tensile stress may experience hot cracking during welding or cold cracking during service [9][10]. When welding metals with significantly different thermal conductivity, the heat source must provide a thermal differential for proper thermal equilibrium. Heat conduction rapidly from the molten weld pool to the base metal with higher thermal conductivity takes away the thermal energy and affects the energy input required to melt the base metal locally. Thus, the heat source is always directed toward the metal with higher thermal conductivity to balance the heat. Preheating the base metal with a higher thermal conductivity can control heat loss to the base metal and reduce the cooling rate of the weld metal and the heat-affected zone (HAZ) [9][10]. During cooling, the difference in thermal expansion coefficients between the base metals creates tensile stress in one and compressive stress in the other. The metal deposited under tensile stress may experience hot cracking during welding or cold cracking during service if the stress is not released. This is critical in recirculation applications where the seal must operate at high temperatures.

3. Current Studies

Dissimilar welded joints between 92 and AISI 304L austenitic stainless steel were studied in an experimental investigation by Dak and Pandey [11]. The microstructure, mechanical properties, and residual stresses of the material were investigated. The weldment's microstructure and mechanical properties (tensile, Charpy impact, and microhardness) were determined using a scanning electron microscope and an optical, multi-pass gas tungsten arc welding (GTAW) method. A post-weld heat treatment (PWHT) at 760 °C for two hours, followed by air cooling, was used to homogenize the heterogeneous microstructure formed on the P92 side. As a result, this PWHT had no effect on the weld fusion zone or the SS304L heat-affected zone (HAZ) microstructure, but it did change the situation. Khan et al. [12], using shielded metal arc welding (SMAW) and tungsten inert gas (TIG) welding processes, investigated the effects of welding technique, filler metal, and post-weld heat treatment on stainless steel 304 and mild steel AISI 1020 dissimilar welding joints. Tensile and bending tests were performed to determine the best welding and PWHT method for this dissimilar junction. When comparing tensile and bending test results, it was discovered that a PWHT at 630 °C was the best heat treatment procedure for SMAW joints with both MS and SS electrodes. The optimal heat treatment process for TIG welding joints with both MS and SS filler materials was determined to be a PWHT at 600 °C. Ramakrishnan A. [13] experimented on the mechanical characteristics of TIG-welded dissimilar joints between AISI 304 and AISI 316 stainless steel using 308 filler rods. The effect of welding current on TIG welds has been studied before, and several mechanical tests have been carried out to validate the weld's mechanical properties. Researchers chose welding currents of 30, 45, and 60 amps. The chosen welding voltages were 40 V, 60 V, and 80 V. Weld quality was assessed using hardness and tensile tests. The weld zone had the highest hardness rating when compared to the heat-affected zone and base metal. When TIG-welded part with 60A of current, the specimen reached the highest ultimate tensile strength of 528.36 MPa. In an experimental study, Satputaley et al. [14] investigated the effect of TIG welding on the maximum tensile strength for 4130 Chromoly and 7075T6 aluminum. These results show that Chromoly 4130 has the same weld strength as Al 7075T6 (396.69 MPa), resulting in poor weld mechanical characteristics and welding performance. When utilized for high-strength applications, Al 7075T6 has a low weld penetration. TIG welding on Chromoly 4130 results in excellent weld penetration while maintaining the material's properties. Ramadan and Boghdad [15] performed an experimental investigation on the parametric optimization of TIG welding influence with respect to the tensile strength of the dissimilar metals SS-304 and low-carbon steel by using the Taguchi approach and using process parameters such as current and gas flow rate. The weld quality was assessed using tensile strength. The tensile test results, which were welded by a parametric combination of variables, yielded the best value (8 gas flow rate and 120 current amperes). The effective welding parameters are current and gas flow rates were determined using the mean, signal-to-noise ratios, and the ANOVA test. An analysis and investigation on the weld characteristics of TIG welding with respect to the dissimilar metals SS304 and MS1040 was conducted by Vennimalai Rajan et al. [16]. Tensile strength, hardness, and bend tests inspected the weld quality. The results showed that the tensile strength was 507.902 N/mm^2 at a peak load of 49.880 KN, and the bending strength was 31.213 N/mm^2 at a peak load of 3.140 KN. The Rockwell hardness was 78 kgf. Anbarasu et al. [17], used mild steel (IS 2062) as a base material and super-duplex ER2594 as a filler material to investigate the effect of filler material on the hardness of TIG welds. Materials can be created by selecting current, welding speed, and gas flow as process parameters. The Taguchi method of the L9 orthogonal network was used to conduct the test. Microhardness and microstructure were two of the weld quality metrics. Using DOE Taguchi and ANOVA methodologies, Kausar [18] analyzed and studied the weld quality parameters of tungsten inert gas welding on different metal plates with SS316L and IS2062. The process parameters, such as current, voltage, and gas flow are chosen, and weld quality was determined by tensile strength, hardness, and microstructure. The findings demonstrated that voltage has the most significant impact on stiffness, followed by gas flow and current, and that the most important parameter is tensile current, followed by voltage and gas flow. The optimum parameters for hardness are 130 (amp), 60 (volts), and 9 (L/min) airflow, while the optimum parameters for tensile strength are 130 (amp), 50 (volts), and 10 (L/min) airflow. Good flow indicates that the connection is vital when it comes to microstructures. Hazari et al. [19] performed an experimental investigation of TIG welding on AA 6082 and AA 8011 by selecting the welding current, electrode diameter, and gas flow rate. The weld's final quality was validated by its ultimate strength and hardness. The maximum tensile strength increased dramatically as the amperage was raised, but the yield strength improved significantly. By increasing the effectiveness of the shielding gas, the ultimate tensile strength increased according to the gas flow rate. The diameter of the filling material changed little; nevertheless, material soldered with a 2.5 mm diameter filler showed a significant difference. Using the TIG welding process, Sayed et al. [20] conducted a research of different metal welds in stainless steel and mild steel. A. Kumar et al. [21], used the Taguchi technique to conduct an experimental investigation of TIG welding on stainless steel 202 and stainless steel 410. Current, gas pressure and welding speed were the considered process characteristics, and the final tensile strength determined the quality of the weld. The primary impact graphs revealed that current, gas pressure, and welding speed were the significant influencing elements on the ultimate load. With a welding current of 130A, a gas pressure of 10 kg/cm^2, and a welding speed of 2.8 mm/s, the ideal parameter setting for the ultimate tensile strength of 808.3 N/mm^2 was determined experimentally. Devakumar [22] investigated GTAW welds on duplex stainless steel and hot-rolled steel (DSS/HRS) by characterizing the weld microstructure and examining the micro-composition by using energy-dispersive X-ray (EDAX) in order to determine metallurgical properties, and they used a microhardness test, tensile test, and bending test to determine mechanical properties. In contrast to the DSS parent metal, which has a grain austenitic with ferrite, and the HRS parent metal, which only has a long-grain similar to austenitic, the results showed the production of a triangular ferritic microstructure. The DSS/HRS weld was more efficient with fine ferrite grain. The creation of the dendritic delta ferrite microstructure appeared to be the result of the energy-dispersive X-ray analysis (EDAX). L. S. Kumar et al. [23] used the Taguchi technique for TIG and MIG welding to investigate the welding features of AISI 304 and 316. They discovered that, when welding austenitic stainless steels using the TIG method, the hardness value (BHN) at 40A for TIG is 162.3 and 196.54 for MIG. As a result, they concluded that the MIG technique is appropriate for low currents. They also concluded that the TIG welding pattern could sustain a final load of 57600N, whereas the MIG welding pattern could withstand 56160N. As a result, the TIG welding pattern can withstand more load than the MIG welding pattern. Thus, by observing the past work-performed on austenitic stainless steel. Some research focused on application, different grades of material, and welding parameter optimization. However, no attention was paid to SS316 and mild steel (dissimilar metals) in terms of the effect of filler metal type and root gap, as well as to parametric optimization during dissimilar metals welding for weld quality. Various researchers have experimented by considering common process parameters such as welding current, welding voltage, speed, and gas flow rate. Other process variables, such as filler wire and root gap, however, have a considerable impact on mechanical and microstructural qualities. Because the chemical and physical properties of materials differs when the base metals to be welded are dissimilar metals, the filler metals utilized compromise this difference. The gap between the roots is also a key determinant in weld penetration, which has an impact on mechanical properties.

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