Material Characterization on Dissimilar Weldments of Aisi 316L/317L Austenitic Stainless Steels with Inconel 825 Alloy

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The micro structure and mechanical properties of AISI 316L/317L austenitic stainless steels with Inconel 825 alloy were investigated in this work. Two types of filler materials 316L and ERNiCrMo-3 were used to obtain dissimilar weldments using TIG welding. The comparative evaluation initially studied on cutting parameters using unconventional machining process (hereby Water jet machining is considered for cutting process) and impact test is carried on all machined specimens. The impact test results for all specimens exhibits ductile fracture. A detailed micro structural observation was made on all dissimilar joints using SEM analysis. At last it was concluded that ERNiCrMo-3 filler material was the best choice for the joint AISI 317L austenitic stainless steel and Inconel 825 alloy.

Keywords: Austenitic Stainless Steels, ERNiCrMo-3, SEM Analysis

Introduction

Stainless steel also known as inox steel or inox from French "inoxydable", is a steel alloy with a minimum of 10.5% chromium content by mass. Stainless steel does not readily corrode, rust or stain with water as ordinary steel does. It is not fully stain-proof in low-oxygen, high-salinity, or poor air-circulation environments. There are different grades and surface finishes of stainless steel to suit the environment the alloy must endure. Stainless steel is used where both the properties of steel and corrosion resistance are required. Grade 316L, the low carbon version of 316 and has very high immunity from sensitization (grain boundary carbide precipitation). It is extensively used in the oil and gas and chemical industries for its cost effective corrosion resistance and ease of fabrication. Chemical composition of 316L grade is shown in Table 1. Alloy 317L (UNS S31703) is a molybdenum-bearing austenitic stainless steel with greatly increased resistance to chemical attack as compared to the conventional chromium-nickel austenitic stainless steels. Chemical composition of 317L grade is shown in Table 1. INCONEL alloy 825 is a nickel-iron-chromium alloy with additions of molybdenum, copper and titanium. The nickel content is sufficient for resistance to chloride-ion stress-corrosion cracking. The nickel, in conjunction with the molybdenum and copper, also gives outstanding resistance to reducing environments such as those containing Sulfuric and phosphoric acids. The molybdenum also aids resistance to pitting and crevice corrosion. Hajiannia et al.1 discussed the preparation of microstructure and mechanical properties of AISI 347 austenitic stainless steel/ASTM A335 low alloy steel dissimilar joint were investigated. For this purpose, two filler metals including ER309L and ERNiCr-3 were selected to be used during the gas tungsten arc welding process. Studies are available2-10 and discussed for the preparation and evaluation of mechanical and welding properties of ERNiCrMo-3 filler material which is used in Gas Metal Arc Welding (GMAW) and Gas Tungsten Arc Welding (GTAW) of Inconel 601, Inconel 625, Inconel 825 and a range of high alloy austenitic and super austenitic stainless steels. Dissimilar welding applications include joining Inconel alloys, Inconel alloys, low-alloy steels, stainless steels and carbon steels.

Experimental analysis

TIG welding

Tungsten Inert Gas (TIG) welding is the most versatile welding process used today. It is a popular process in the area where a high degree of quality and accuracy is required. Moreover, TIG welding is more preferable than Submerged Arc Welding (SMAW) and Metal Inert Gas (MIG) process because of the lower heat input. The lower heat input results in faster cooling rates which helps overcoming the problem of sensitization, thus leading to a remedy to the problems of inter granular

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corrosion (IGC) and inter granular stress corrosion cracking (IGSCC).

However, this process has relatively shallow penetration capability and low productivity, particularly in single-pass welding operations in the welding of large components, compared to other welding processes. The welded region for two dissimilar metals is as shown in Figure 1.

**Welding parameters**
- Welding is done by keeping voltage about 225V AC throughout welding process.
- Size 6 torch cup is used for welding process.
- Welding Region is maintained at temperatures of 58°C-70°C.

Current values in amperes have been changing from layer to layer in welding process and those variations are shown in Figure 2, Table 2.

**Water jet machining**
Water jet machining is one of the nontraditional ways of machining process which is used to cut very precise and complex shapes. This process uses a high velocity narrow jet of a liquid (water) to cut materials. The jet of liquid velocity is about 2000 ft/sec. Material is eroded from the work piece at the impact location of the liquid jet. An important benefit of this machining process is the ability to cut material without interfering with the material's inherent structure as there is no "heat-affected zone". The specimens are prepared by using the following parameters were as shown in Figure 3(a) & 3(b).
- Pressure of water from nozzle is kept constant 50,000 Psi (350Mpa) i.e. high pressure flow is set in the system.
- A constant feed rate of about 13% is fixed for the cutting so as get a very smooth surface finish.
- Jet movement speed is about 20-25 sec per piece of cut.

**Results and Discussion**

**Impact test (Charpy Method)**
The pendulum impact test indicates the energy to break standard test specimens of specified size under stipulated parameters of specimen mounting, notching, and pendulum velocity-at-impact. With some materials, a critical width of specimen may be found below which specimens will appear ductile, as evidenced by considerable drawing or necking down in the region behind the notch and by a relatively high-energy absorption, and above which they will appear brittle as evidenced by little or no drawing down or necking and by a relatively low-energy absorption. Since these methods permit a variation in the width of the specimens, and since the width dictates, for many materials, whether a brittle, low-energy break or a ductile, high energy break will occur, it is necessary that the width be stated in the specification covering that material and that the width be reported along with the impact resistance. In view of the preceding, one should not make comparisons between data from specimens having widths that differ by more than a few mils. Experimental values of mechanical properties are shown in Table 3. The bent angles for machined specimens were calculated after Charpy test are as shown in Figure 3(c) & 3(d).

Calculations:
- Area of specimen=55*10=550mm²
- 316L austenitic stainless steel & 316L filler wire
- Impact energy on specimen= 80 J

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<th>Grade</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>P</th>
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Fig.1 — Welded Region

Fig. 2 — (a) Before cutting, (b) After cutting
Fracture toughness= impact energy/area
= 80/550=0.14545 J/mm² = 145.45 KJ/m²
- Impact energy on specimen= 100 J
Fracture toughness= impact energy/area
= 100/550= 181.81 KJ/m²
- Impact energy on specimen= 110 J
Fracture toughness= impact energy/area
= 110/550= 200 KJ/m²
- Impact energy on specimen= 90 J
Fracture toughness= impact energy/area
= 90/550 = 163.63 KJ/m²
- Impact energy on specimen= 105 J
Fracture toughness= impact energy/area
= 105/550 = 190.909 KJ/m²
- Impact energy on specimen= 120 J
Fracture toughness= impact energy/area
= 120/550 = 218.18 KJ/m²

**Microstructural analysis**

A Scanning Electron Microscope provides details surface information by tracing a sample in a raster pattern with an electron beam. A variety of detectors are used to attract different types of scattered electrons, including secondary and backscattered electrons as well as x-rays. SEM produces black and white, three-dimensional images. Heat affected zone (HAZ) before impact and after impact are analysed using SEM as shown in Figure 4(a) to Figure 4 (d).
Conclusions
The results of this investigation have shown that austenitic stainless steels can be welded to Inconel alloys using filler materials 316L and ERNiCrMo-3. Impact energy (max. observed value = 120 J) is applied more on ERNiCrMo-3 joint. Fracture toughness values are (max observed value = 218.18 KJ/m²) is observed more on the filler joint of ERNiCrMo-3 compared with 316L joint. It can be concluded that for dissimilar 317L Stainless Steel to Inconel 825 alloy steel with ERNiCrMo-3 filler material has observed optimum mechanical properties.

References