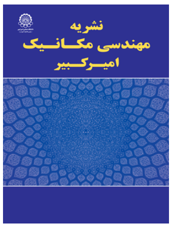

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Evaluation of Microstructure and Mechanical Properties of Dissimilar Joining of Inconel 718 Superalloy to 316 Austenitic Stainless Steel

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ABSTRACT: In this study, the microstructure and mechanical properties of dissimilar joining of Inconel 718 superalloy to AISI 316 austenitic stainless steel were investigated using the tungsten-gas arc welding method with two filler metals 718 (ERNiFeCr-2) and 625 (ERNiCrMo-3). After welding, the microstructure and mechanical properties of different joint areas were evaluated using an optical microscope and scanning electron microscope. The precipitates in the interface and their chemical composition were determined using energy-dispersive spectroscopy analysis. Also, the mechanical properties of the joint were evaluated using tensile, impact, and microhardness tests. Microstructural investigations showed that the freezing structure of filler metal 718 has an austenitic microstructure with a dendritic network along with carbide distribution and filler metal 625 has also created an austenitic microstructure with a dendritic network. In the tensile test, filler metal 718 has the highest tensile strength of 528 MPa and the failure of all tested samples occurred in the area of the austenitic stainless steel base metal 316. The results of the impact test showed that the maximum amount of fracture energy is 50J for filler metal 625. The micro-hardness test also determined that the 718 filler metal has the highest hardness of 214 Vickers.

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1- Introduction

Dissimilar joints are of interest to industrialists due to the reduction of material costs and flexibility and change in mechanical properties. In a dissimilar joint, suitable filler metal can prevent the formation of harmful phases, hot cracks, and melting and freezing cracks. In dissimilar welding of nickel base alloys and austenitic stainless steel, nickel base filler metal or stainless steel filler metal is usually used due to chemical similarities to prevent freezing cracks. Also, the issue of the different thermal expansion coefficients of these two alloys should be considered and the filler metals should have the appropriate flexibility to withstand internal stresses. Ramkumar et al. [1] investigated the joining of nickel-base alloys to austenitic stainless steel, specifically, nickel-base superalloy Inconel 718 to low carbon austenitic stainless steel 316 with tungsten gas arc melting process with three filler metals ERNiCrMo-4, ER2594, ERNiCrMo-1 they paid. The results of the research showed that the ERNiCrMo-4 filler metal has a higher impact energy. The necessity of the present research is due to the microstructural similarities and high-temperature tolerance of these two alloys and providing a combination of desirable properties. According to the report of Ramkumar et al. [2], the dissimilar joint of these two alloys has more strength than the similar joint. Therefore, the practical application of this joint can be referred to Ferretti's report [3], on the joint of Inconel 718 connector to alloy SS316 tube for ammonia transfer in the space station and Henderson et al.'s report [4], on the use of this joint in a gas turbine engine and good resistance to pitting corrosion. Prabaharan et al. [1], mentioned the use of this joint in a gas turbine engine, which uses Inconel 718 in high-pressure stages and 316 stainless steel in low-pressure stages. In short, the study of the dissimilar welding of these two alloys is to improve the joint performance between these two alloys by using suitable filler metal.

2- Methodology

In this research, two dissimilar sheets of superalloy Inconel 718 and SS316 were used, and according to schematic Fig. 1, welding was performed with a current of 90 A, a voltage of 11.7 V, a welding speed of 1 mm/s and an electrode diameter of 2.5 mm. The meter was done.

The welding of the samples was done with the butt-to-butt joint scheme according to Fig. 1. Samples were prepared by wire cutting in the dimensions of 100 mm × 50 mm × 3 mm. Before welding the samples, the unevenness on the surfaces was removed using sandpaper, and to remove oxide layers and surface contamination, the joint was degreased with a wire brush and acetone.

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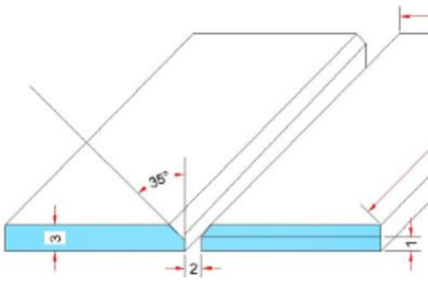

Fig. 1. Joint schematic

In order to evaluate the microstructure, different areas of the alloy to be connected including; The base metal, weld metal, and heat-affected zone were taken from the radiographed parts, and using the radiography results from the various parts of the joint, metallographic samples without defects with dimensions of 30 × 10 mm were prepared by wire cutting and sanded with 100 to 1500 sandpaper and They were finished by 0.3-micron alumina powder. The hydrochloric acid solution, nitric acid, and acetic acid were used for appearance. In order to characterize and examine the microstructure in more detail, an electron microscope model MIRA3 made by TE-SCAN company equipped with X-ray energy diffraction spectroscopic analysis was used.

In order to evaluate the mechanical properties of the joint, tensile, impact, and hardness tests were used. Before performing mechanical tests, with the help of radiographic results, tensile test samples were prepared according to the ASTM E8 standard to determine the tensile strength. Loading was done with a strain rate of 2 mm/min by the INSTRON-4486 machine. The impact resistance test of 3 samples welded with Inconel 718 filler metal and 3 samples welded with Inconel 625 filler metal was performed according to ASTM E23 standard by SANTAM-SIT300 machine and at ambient temperature.

Vickers hardness test was also performed 3 times in each area with each filler metal according to ASTM E92 standard and with 300grf weight for a loading time of 5 seconds. The hardness test was performed on the weld zone, the heat-affected zone, and the base metal of the samples, and their information was recorded.

3- Results and Discussion

The most important influencing elements in the equilibrium distribution during freezing are the presence of elements such as niobium, molybdenum, iron, and carbon. An equilibrium separation coefficient of less than one will cause a temperature decrease in front of the interface and increase the tendency to redistribution during freezing, and as a result of further freezing, the interface no longer has a planar state and changes to dendritic. The concentration gradient created in the structure can reduce the mechanical properties [5]. The niobium element cannot eliminate the concentration gradient due to its low diffusion coefficient and appears as niobium carbide in the space between the dendrites. Carbon also forms carbide phases due to its equilibrium distribution ratio in the range of 0.21-0.27 due to its separation. The higher amount of iron affects the equilibrium distribution ratio of niobium and molybdenum and causes it to decrease. Therefore, niobium dissolves in a small amount in the melt and separates it. The microstructure of the weld metal at the interface plays a fundamental role in determining the properties of a joint, which can be eliminated or reduced by analyzing the interface. According to Fig. 2, the presence of an unmixed region in the interfaces can be caused by factors such as the chemical composition not being the same, the melting point of the filler metal is different from the base metal, the heat input, the rate of cooling, the type of joint design and fluid flow in the melt. Tensile, impact, and microhardness tests were used to check the mechanical properties (Figs. 3 and 4), and Table 1.

Table 1. Average fracture energy of base metals and weld metals

alloy	average impact energy (J)
SS316 base metal	52±2
Inconel 718 base metal	31±3
Inconel 625 weld metal	50±1
Inconel 718 weld metal	27±2

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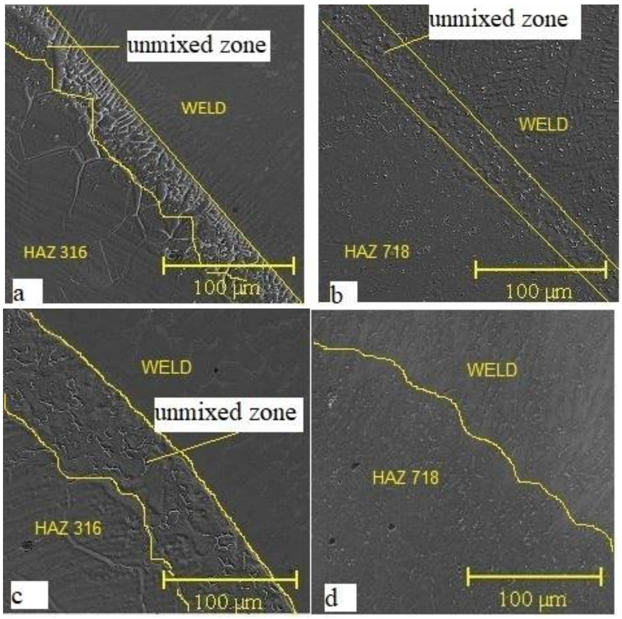

Fig. 2. Unmixed zone a And b: Inconel 625 Filler Metal c And d: Inconel 718 Filler Metal

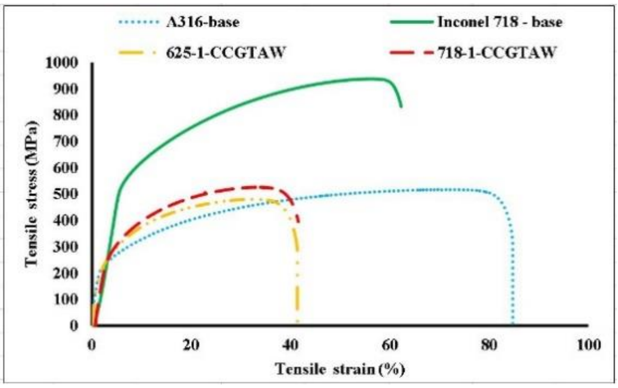

Fig. 3. Stress-strain diagram filler metal and base metal

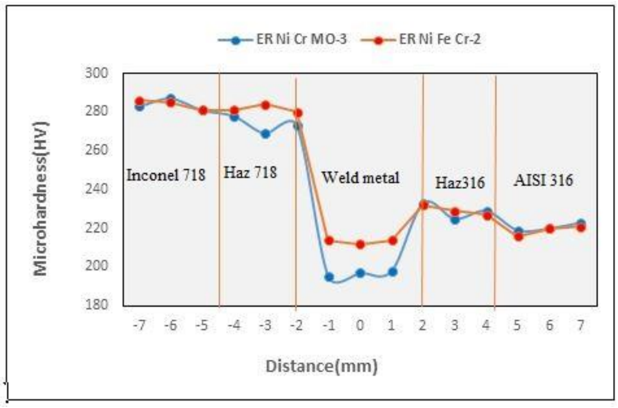

Fig. 4. Microhardness profile in different joint areas

4- Conclusions

1. An unmixed zone was observed at the interface of the Inconel 718 weld metal with the stainless base metal, but there was no lack of mixing on the side of the Inconel 718 base metal. Also, in the junction of Inconel 625 with both base metals (Inconel 718 and SS 316), the unmixed area was observed.

2. According to the tensile test results, Inconel 718 weld metal showed the highest tensile strength with an average of 528 MPa.

3. According to the results of the Charpy impact test, Inconel 625 weld metal showed the highest resistance to impact with an average of 50J.

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