Welding Characteristics of 304, 306, 316 Stainless Steel: A Technical Review

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Abstract—In this paper stainless steel welding review is carried out. Stainless steels are materials with increasing use in industries, because they have good corrosion resistance and mechanical properties. However, these materials require rigorous welding and inspection procedures. Inspection can be done by ultrasonic treatments. They can be readily used in low temperature area like cryogenic applications.

Key words: Stainless steel welding, residual stress, cladding, ultrasonic treatment, cryogenic applications.

I. INTRODUCTION

Stainless steel (SS) does not readily corrodes, rust with water as ordinary steel . It is not fully proof in less-oxygen, high-salt content, or less air-circulation environments. There are various grades stainless steel to suit the environment the alloy must endure. Stainless steel is used because of corrosion resistance.

Stainless steel differs from carbon steel by the amount of chromium occur. Carbon steel rusts readily when exposed to air and moisture. This iron oxide film (the rust) is active and accelerates corrosion by forming more iron oxide. SS contain enough chromium to form a passive film of chromium oxide, which protect further surface corrosion by blocking oxygen diffusion to the steel surface and blocks corrosion from spreading into the metal's internal structure due to the similar size of the steel .

II. LITERATURE SURVEY

A. Based on residual stress

Jinya Katsuyama et al.[1] Welding residual stress is one of the most important factors of stress corrosion cracking (SCC) for austenitic stainless steels of the pressure boundary piping in nuclear power plant. This result indicated that higher loading of bending and axial stresses caused higher relaxation on welding residual stress near piping weld. The dissimilarity in the effect of loading direction was observed. It is known that over loading to piping butt-welds has an influence on the suppression of SCC growth due to the decrease in tensile residual stress at the inner surface.

Dean Deng et al.[2] temperature fields and residual stress states in multi-pass welds in SUS304 stainless steel pipe. According to ABAQUS software, thermal–mechanical three-dimensional (3-D) and two- dimensional (2-D) finite element models are urbanized. The finite element models are working to evaluate the transient temperature and the residual stress fields during welding. In this study, experiments are also carried out to verify the effectiveness of the introduced numerical models. The conclusion of 3-D and 2-D model are in very good with the experimental measurements.

X.K. Zhu et al.[3] Three-dimensional nonlinear thermal and thermo-mechanical numerical simulations are conducted for the friction stir welding (FSW) of 304L stainless steel. The FEA code—WELDSIM, growed by the authors specifically for welding simulation, was utilized. Two welding cases with tool rotational speeds of 300 and 500 rpm are compared. The aim is to study the difference of transient temperature and residual stress in a friction stir welded plate of 304L stainless steel. Comparison with the residual stress fields measured by the neutron diffraction technique shows that the results from the present numerical simulation have good agreement with the test data.

Wei Liang et al.[4] During the course of the welding, high residual stress and distortion occur. This cause the issuse in nuclear power plant components especially where the danger of stress corrosion cracking (SCC) develops. In this, both experiment and the FEM are utilized to investigate the welding residual stress distribution in medium thick-walled austenitic SS pipe. Earlier, the experiments are done to examine the characteristics of the temperature cycle. Finally, the influence of the yield strength of the weld metal on the welding residual stress is clarified by means of numerical simulation.

B. Taljat et al.[5] Residual stresses and strains in a tube with spiral weld cladding were analyzed by the finite element method. The purpose of this work was to find out the residual stress-strain state in the weld clad tube and verify the developed Finite Element model, which might provide for future parametric sensitivity studies of various welding parameters on residual stresses in such tubes. In general, the results obtained in this study are very promising for determining the residual stress patterns of complex welding processes by a Finite Element model. The developed Finite Element model can be subscribed in future parametric sensitivity study to analyze the effect of various welding parameters on the residual stress distribution.

MA Ninshu et al.[6] to evaluate safety of welded joints in chemical tanks before production, the rolling residual stress in steel plate and residual stress welded joint need to be measured.

B. Based on cladding

Wenchun Jiang et al.[7] This paper used finite element method (FEM) to predict the residual stresses in repair weld of a SS clad plate. The results cocludes that large residual stresses have been generated in weld metal and heat affected zone (HAZ). The clad metal and base metal thickness have a great effect on residual stresses. As the base metal thickness increase, this constraint function is established, which tends to an increase in residual stress, which gives a reference for the repair welding of stainless steel clad plate.

W.C. Jiang et al.[8] Stainless steel clad plate is widely used in oil and chemical industries due to its good corrosion resistance and high strength. But cracks are often formed in clad layer during the production, which are often repair by welding. The objective of this paper is to estimate the residual stress and deformation in the repair weld of a

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stainless steel clad plate by finite element method. The effects of heat input and welding layer number on residual stresses and deformation have been studies. Using multiple-layer welding and higher heat input can be useful to decrease the residual stress, which provides a reference for optimizing the repair welding technology of this stainless steel clad plate.

Edmilson O. Correa et al.[9] The effect of clad metal composition on stress corrosion cracking (SCC) behavior of three types of SMAW filler metals (E308L-16, E309-16 and E316L-16), used for cladding components subjected to highly corrosive conditions, was investigated in boiling 43% Magnesium chloride solution. In order to investigate the stress corrosion cracking susceptibility of the top layer, constant load test and metallographic examination in tested SCC specimens were conducted. Their higher SCC susceptibility may be attributed to the presence of continuous vermicular delta-ferrite in their microstructure.

C. Based on ultrasonic treatment

Ramon Ferreira Ferreira et al.[10] Conventional ultrasound techniques are rarely used to evaluate the austenitic stainless steel welds, because it has high attenuation of ultrasonic wave. In this study, the detection of defects is hampered by weak signal to noise relation, cause issue to the inspection. This study was developed to evaluate the phased array ultrasound technique effects austenitic weld, finding a correspondence between microstructure with ultrasonic properties, the ultrasonic beam behavior and a better characterization of welding defects in this inspection.

Gang Tie et al.[11] An ultrasonic evaluation method of echo feature of diffusion bond joint between two dissimilar is discussed. The echo signal was taken by an automatic ultrasonic scan test system. It is find that the intensity of echo and its phase can be used of dissimilar materials bonding can be evaluated by ultrasonic method.

Yashar Javadi et al.[12] Longitudinal critically refracted (LCR) waves are employed to measure the welding residual stress. The acoustoelastic constant is calculated through a hydro test while the pressure vessel is kept intact. The results show good agreement between hole-drilling and ultrasonic stress measurements which is accomplished nondestructively.

Gang Ma et al.[13] Effect of temperature and chloride content on the stress corrosion cracking (SCC) susceptibility of 304 stainless steel welded joints treated by ultrasonic impact treatment (UIT) is investigated. High tensile weld residual stress is important factor contributing to Stress Corrosion Cracking. The results reveal that surface of the samples becomes rougher than the original plate with the increase of the impact duration, which comprise to the pitting corrosion. The level of pitting corrosion is lowered with increase of temperature.

P. Palanichamy et al.[14] Austenitic 316L(N) stainless steel specimens subjected to total strain controlled fatigue and creep-fatigue cycling at 923 K have been investigated to correlate the observed micro structural features with ultrasonic measurements. Models were subjected to ultrasonic velocity. In normal and elevated temperatures. The study is also useful in estimating the elastic properties of the creep-fatigue damaged materials at elevated temperatures through ultrasonic measurements

D. Based on cryogenic applications

R.L. Tobler et al.[15] Cryogenic mechanical property data compiled at the National Bureau of Standards, USA, have been used to analyze the relationship between yield strength and fracture toughness for austenitic stainless steel welds at 4 K. This paper illustrates that there is an inverse linear correlation between yield strength and fracture toughness for the stainless steel welds at 4 K.

E. R. Szumachowski et al.[16] The role of delta ferrite in controlling toughness of austenitic stainless steel weld metals at cryogenic service temperatures was discussed in Part I of this study.1 Data showed that toughness of many grades of stainless steel weld metals deposited by covered electrodes varied inversely with carbon and ferrite substance. High toughness, as measured by Charpy V notch (CVN) impact energy properties and lateral expansion (LE), was obtained when both carbon and ferrite contents were as low as possible.

D. T. Read et al.[17] The effects of ferrite structure, carbon composition and tensile properties of AWS E316L and E316 shielded metal arc (SMA) weldments at 295, 76, and 4 K were investigated. In four of the welds, the delta ferrite content was controlled over the ferrite number range of 0 to 11 through slight variations in the chemical compositions.

S. F. Kane et al.[18] This paper summarizes the development and qualification of an appropriate welding consumable for a demanding cryogenic magnet usage. It begins to start with a review of the research conducted on cryogenic fracture toughness of wrought and welded austenitic SS. This workdone shows that some elements of the composition have a powerful effect upon the steel's fracture toughness at 4 K.

III. CONCLUSION

From this paper it is concluded that SS welding is one of the efficient process. It is widely used in many fields like navy, air force, cryogenic applications. Due to its corrosive resistant property it is preferred. Ultrasonic treatments of SS welds can the detail description of its property.

In future, Cladding materials can be introduced along with SS welding. Hope to reduce the residual stress.

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