An Experimental Study on TIG welded joint between Duplex Stainless Steel and 316L Austenitic Stainless Steel

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Abstract:
An attempt was made to join the two dissimilar material between Duplex Stainless Steel (DSS) and 316L Austenitic Stainless Steel (316L SS) by Tungsten Inert Gas (TIG) welding process. 316L SS was used as filler metal. The microstructures of DSS and 316L SS were evaluated before and after the TIG welding. The various mechanical tests were conducted to evaluate the mechanical properties. Although the welded joint revealed the acceptable mechanical properties, the hardness and impact strength of the welded zone of DSS were higher than the welded zone of 316L SS. In this paper, the focus is on characterization and analysis of the welded joint. The microstructure and chemical composition of the selected metals were also found to play an important role on mechanical properties. The results are summarized to rationalize the relationship between chemical composition, welding conditions, and heat affected zone microstructures, and then mechanical tests such as X- ray test, impact test, hardness test, tensile test and bending test.

Keywords — *Dissimilar metal weld, TIG welding, Duplex Stainless Steel, 316L Austenitic Stainless Steel.*

I. INTRODUCTION

The effect of process parameters of Tungsten Inert Gas (TIG) welding process was investigated by many researchers. Bravo et al [1] investigated dissimilar welding of super duplex stainless steel for offshore applications joined by GTAW process for structural behavior. Poznansky et al [2] analysed the corrosion rate of the duplex and super duplex stainless steels in sea water applications. Honey combe et al [3] carried out an investigation on TIG welding process for optimal parametric combinations and geometry of welded joints using the Grey relational analysis and Taguchi method. Mourad et al [4] carried out a research work to select the optimum process parameters for TIG welding to weld the stainless steel and the optimal weld pool geometry. They have suggested that parameters will vary to metal to metal. However, front height, front width, back height and back width are important factors for the weld pool [4]. Ibrahim et al [5], found that hardness of pure titanium material varies gas flow rate and numbers of welding passes.

Straffelini et al [6], carried out an investigation to find the effect of TIG welding parameters like welding speed, current and flux on depth of penetration and width in welding of 304L stainless steel. From this study, it was observed that flux used has the most significant effect on depth of penetration followed by welding current. Luo et al [7], observed that the use of fluxes, even of extremely simple formulation, can greatly increase (up to around 300%) the weld penetration in TIG welding. Hence, in the current investigation, two dissimilar metals (316L SS vs. DSS) were welded by TIG welding process and its microstructure and mechanical properties were evaluated.

II. METHODS

The two dissimilar metals such as AISI 316L type austenitic Stainless Steel (316L SS) and Duplex Stainless Steel (DSS) were selected for TIG welding. These two materials were surface finished before welding. After welding, the microstructure of heat affected zone of these base metal and weld portion was evaluated by optical microscope. X ray test was conducted to identify the defects in the weld. Tensile test, impact test, hardness test and bend test have been conducted to evaluate the mechanical properties of welded joints..

III. RESULT AND DISCUSSION

A. X-Ray Test

The radiographic examination was done for the three samples at the radiographic size of 3” X 8”. The X- ray test picture is presented in Fig. 1. The results reveal some of the pores within the acceptable level. Hence, the soundness of welding is proven and it can be proceed for further mechanical testing.

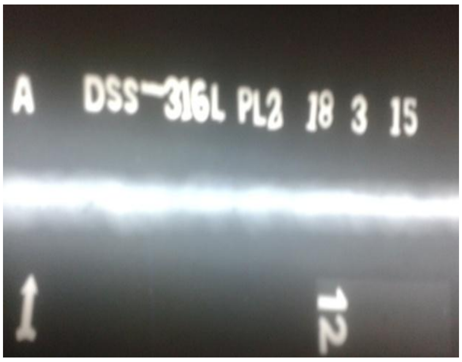

Fig. 1. X-Ray Test on TIG Welded Joint

B. Microstructural Analysis

The base metal microstructure is presented in Fig. 2a and Fig.2b. It reveals that the very fine austenite grain for 316L SS, whereas elongated grains of austenite in a matrix of ferrite (Dark) for DSS. Austenite ferrite ratio measured in DSS base metal using quantitative metallographic image analysis is 50:50. The microstructure obtained after welding gives entirely different grain structure in weld (Fig. 3c) and Heat Affected Zone (HAZ) (Fig. 3a and Fig. 3b). When compared with the base metal. Evolution of the microstructure in the DSS weld zone has been takes place in three stages after welding.

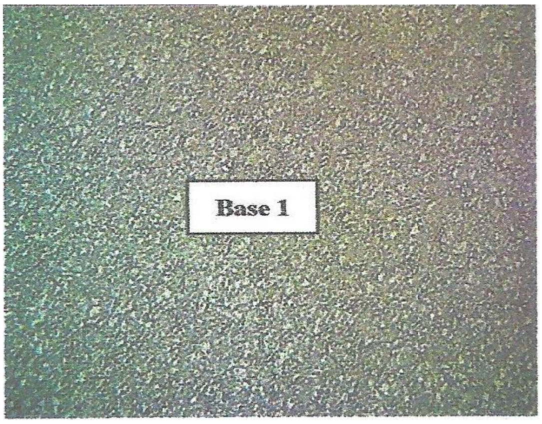

Fig. 2a. Base metal of 316L SS Microstructure shows Very Fine Austenite Grain.

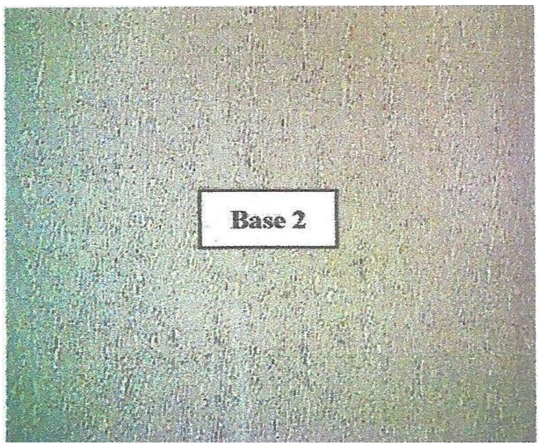

Fig. 2b. Base metal of DSS Microstructure Shows Elongated Grains of Austenite Grains in a Matrix of Ferrite (Dark)

The HAZ is the portion of the weld joint which has experienced peak temperatures high enough to produce solid-state microstructural changes. Every position in the HAZ relative to the fusion line experiences a unique thermal experience during welding, in terms of both maximum temperature and cooling rate. HAZ of 316L SS side shows (Fig. 3a) the fine grains of Austenite whereas HAZ of DSS shows (Fig. 3b) fine grains of Austenite in a matrix of ferrites (dark area). DSS side microstructure nucleates as allotriomorphs at the ferrite grain boundaries. It is due to multi-pass welding, and subjected to reheating. And very less amount of intra-granular austenite particles are absorbed. The microstructure of welded portion (Fig. 3c) shows interdentritic welded portion. This is due to inter-metallic combination of weld metal and filler metal.

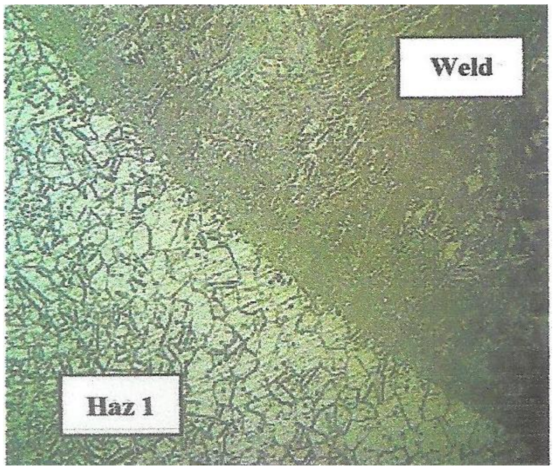

Fig. 3a. Heat Affected Zone of 316L SS Side.

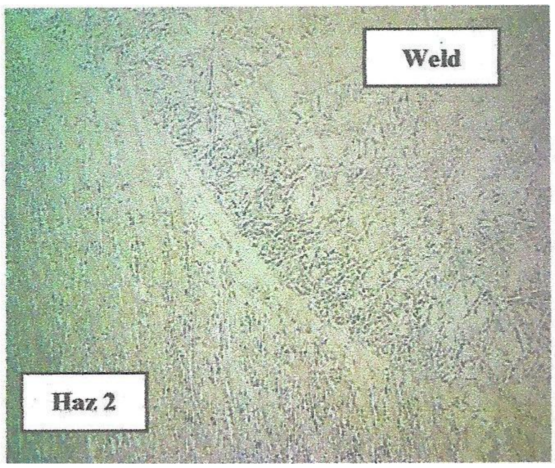

Fig. 3b. Heat Affected Zone of DSS Side.

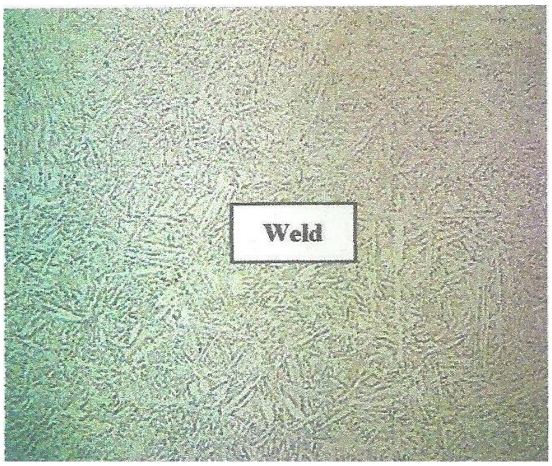

Fig. 3c. Microstructure at Fusion Zone of Weld shows Interdentritic Structure

C. Impact Test

The impact tests were conducted at room temperature for 316L SS, DSS and welded portion. The photographic picture of impact tested specimen is presented in Fig.4. It reveals impact energy at welded portion is increased as 110 joules compared to base metal of 316L SS (63 Joules) and DSS (107 Joules). It is due to relatively high content of delta ferrite in the weld metal than that in the base metal.

Fig. 4. Impact Tested Specimen

D. Hardness Analysis

The sample is polished before hardness test. The hardness is measured at the different locations of base metal, HAZ and weld zone. The values obtained are graphically represented in Fig. 5. Three set of readings were measured in each zone. The weld zone has higher hardness value. It is due to greater in ferrite phase formation than the austenite phase. The hardness of the HAZ of DSS side is higher than that of the base material (DSS) and it is due to strain induced heating and cooling cycle and also due to changes in microstructures such as secondary austenite formation. The strain induced hardening is caused by the compression of the weld region during solidification. Whereas the hardness of the HAZ of 316L SS is slightly lower than that of the base material (316L SS). This is due to decreasing the austenite phases.

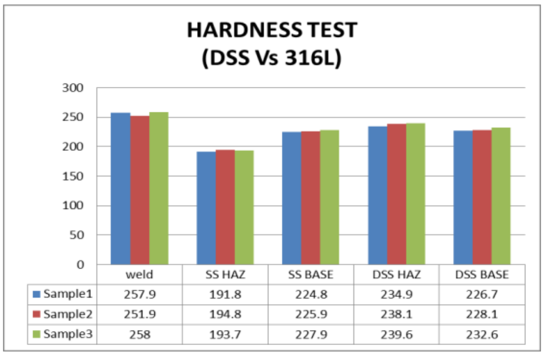

Fig. 5. Hardness Test Analysis

E. Tensile Test

The tensile test was conducted in a standard Universal Testing Machine (UTM) of 100 tonnes capacity. The result is presented in TABLE I and reveals that tensile and yield strength of welded sample is increased heavily with slight reduction in percentage of elongation. The increase of tensile and yield strength is added advantage with respect weld quality. It is improved because of combined metal solidification and heating as well as cooling effect. The photographic picture of tensile tested specimen is presented in Fig.6.

Table I : The Result of Tensile Tests

sample	T.S (Mpa)	Y.S (Mpa)	Elongation in %	Brinell hardness
Base metal-1 (316L SS)	485	170	40	210
Base metal 2 (DSS)	621	450	25	293
After TIG welding	735	610	17	260

Note: T.S- Tensile Strength and Y.S- Yield Strength.

Fig. 6. Tensile Tested Specimen.

F. Bending Test

Since the percentage of elongation is decreased, it is necessary to conduct the bending test to verify the weld quality. The photographic picture of bending tested specimen is presented in Fig.7. The bending test result reveals that bent load was 18.1KN for face bend and 10.3 KN for root bend. It is found that there were no cracks observed. Hence. this welding quality is acceptable.

Fig.7. Bending Tested Sample.

IV. CONCLUSIONS

The TIG welding was successfully done for the selected dissimilar metals (316L SS vs. DSS). The test results recommend as follows,

- X-ray test found that no defects.
- Microstructure of welded portion shows that inter-metallic combination of weld metal and filler and sound.
- Impact test reveals that weld is in acceptable level.
- Tensile test found that improved mechanical properties such as tensile strength and yield strength.
- Hardness test reveals that improved value compared to 316L SS.
- Bending test conclude that welding quality is acceptable.

It is concluded that the selected dissimilar metal is suitable to do TIG welding and recommended for real time applications.

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