STUDY ON TENSILE PROPERTIES OF AISI 304L GRADE AUSTENITIC STAINLESS STEEL JOINTS BY GTA WELDING

Amudarasan N V.[1], Palanikumar K.[2], Shanmugam K.[3]

[1]Research Scholar, Department of Mechanical and Production Engineering, Sathyabama University, Chennai, India.
[2]Department of Mechanical Engineering, Sri Sairam Institute of Technology, Chennai, India.
[3]Department of Manufacturing Engineering, Annamalai University, Chidambaram, India.
Email: [1]vsamudhui@sify.com

Abstract

The present study is concerned with the effect of filler metal austenitic stainless steel (AISI 308L) on tensile properties of the austenitic stainless steel conforming to AISI 304L grade. Because of their mechanical properties, 304L austenitic stainless steel is used widely in industry. Gas tungsten arc welding is most widely used as a joining process for sheet materials. Tensile properties and microstructure of the joints fabricated by austenitic stainless steel filler metal (AISI 308) were evaluated and the results were reported. Rolled plates of 3 mm thickness were used as the base material for preparing single V butt welded joints. Yield strength, Ultimate tensile strength and percentage of elongation across the weld has been reported. The tensile properties of the welded joints have been evaluated using Electro mechanical controlled Universal Testing Machine. The welding microstructures and tensile test results were analyzed using an optical microscopy and stress – displacement curves.

Key words: Tensile properties, Austenitic stainless steel, Gas tungsten arc welding, Microstructure.

I. INTRODUCTION

Austenitic stainless steel constitutes the largest stainless family in terms of alloy type and usage (1). The standard austenitic stainless weld metals contain two phases (austenitic + ferrite) similar to an ‘as cast’ microstructure (2). Austenitic stainless steel is widely used as a structural material in chemical, petrochemical, power engineering, transportation and aviation industries. In general, austenitic stainless steels are easily weldable (3). Type 304L is used where extensive welding is to occur; it has lower levels of carbon to reduce the tendency toward carbide precipitation at the grain boundaries during welding (4). The use of fusion welding for manufacturing can cause localized variations in the composition of materials, which can alter the stability of the passivation layer and its corrosion performance (5,6). In addition, from the metallurgical and micro structural point of view, the formation of delta ferrite is an important parameter due to its influence on the mechanical behaviour of welding (7,8).

Gas tungsten arc welding (GTAW) is the most important joining techniques in almost all types of manufacturing industries. GTAW is suitable for welding thin materials when good quality and surface finish are required. Thick materials require full penetration welds with one of the major problems being the weld pool geometry of cast-to-cast variations in the composition of certain residual elements (9,10). Dursun Ozyurek investigated the effect of weld current and weld atmosphere on the resistance spot weldability of 304L ASS and found that optimum weld quality was obtained by using 9 kA peak weld current in nitrogen atmosphere (11). Woei-Shyan Lee et al. investigated the impact properties of 304L stainless steel GTAW joints evaluated by strain rate of compression tests and found that the impact properties and fracture characteristics of the tested weldments depend strongly on applied strain rate (12). Ibrahim made a comparative evaluation of impact behaviour of different stainless steel weldments at low temperatures and found that remarkable decrease was observed for the duplex stainless steel compared with 304L and 316L (13). Jun yan investigated the microstructure and mechanical properties of 304L SS joints by Tig, laser and laser-TIG hybrid welding and found that laser-TIG hybrid welding showed high welding speed and excellent mechanical properties (14).

Most of the reported literature focused on different types of welding methods, heats input and weld bead, etc., Hence the present investigation was carried out to study the effect of austenitic stainless steel filler metal on mechanical properties, microstructure and stress- strain variation of GTA welded austenitic stainless steel joints.

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II. MATERIALS AND METHODS

A. Samples of experiment

In this study, AISI 304L stainless steel plate with 3 mm thickness in annealed condition was used. The chemical composition (wt.%) of stainless steel was C 0.020, Mn 1.470, P 0.044, S 0.006, Si 0.436, Cr 18.31, Ni 8.00, Ti 0.003, Mo 0.155, Cu 0.356 and Fe as the balance.

B. Welding process

Gas tungsten arc welding (GTAW) was employed to join the plates together. The welding processes were performed with AISI 308 stainless steel filler metal and form a single V butt joint. The initial joint configuration was obtained by securing the plates in position using tack welding. Necessary care was taken to avoid joint distortion and the joints were made with applying clamping devices. Selective parameters were voltage (V) 14, current (A) 90, welding speed (mm/sec) 1.4, heat input (J/mm) 900, gas flow (lit/min) 10, electrode diameter (mm) 2.0 and shielding gas (%) argon 99.99, basis of thickness of plate, type of alloy and type of welding process.

C. Preparation of samples

In order to study the tensile behaviour, a part of the weld metal was cut. To compare the tensile behaviour of the weld metal and the base metal, some of the samples were prepared with austenitic stainless steel filler metal with the welding procedure. Using power hacksaw the welded joints were machined to the required dimensions for preparing tensile specimens as shown in Fig.1 and photographs as authenticated in Fig. 2. Mechanical properties of GTA welded joints were evaluated by tensile tests. Tensile testing was performed at room temperature using an electro mechanical controlled universal testing machine (UNITEK-94100) as shown in Fig. 3. ASTM E8M-01 specifications were followed for preparing and testing the specimens. Hence the plate thickness is small, sub sized specimens were prepared for tensile tests.

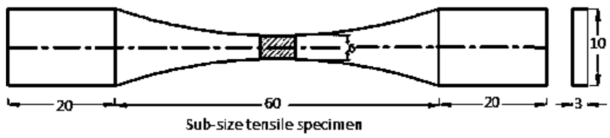


Fig. 1. Dimensions of sub-sized tensile test specimens

Fig. 2. Photograph of tensile test specimens

Fig. 3. Photograph of Universal Testing Machine (UNITEK-94100)

D. Structural characterization

Micro structural examinations was carried out with a light optical microscope (LEITZ, West German) incorporated with an image analyzing software (Metal Vision). The specimens for metallographic tests were sectioned to the required size from the joint comprising base metal and weld metal regions were polished using different grades of emery papers. Final polishing was done using the diamond compound in the disc polishing machine. The specimens were etched with 5 ml HCL acid, one gram picric acid and 100 ml methanol applied for few seconds.

III RESULTS AND DISCUSSION

Tensile properties such as ultimate tensile strength, yield strength and percentage of elongation of the un-notched tensile specimen joints were evaluated. For this experiment, three specimens were tested, and the results were presented in Table 1.

Table 1. Tensile Properties of Base Metal and Welded Joints.

Joint	Ultimate stress KN/mm^2	Yield strength KN/mm^2	Displa-cement at Fmax mm	Break-ing Load KN	Max. Displa-cement mm	Elonga-tion %
BM	0.556	0.425	22.408	2.578	24.816	45.120
GTASS-1	0.531	0.406	21.400	2.462	23.700	43.091
GTASS-2	0.493	0.391	20.700	1.508	23.100	42.000
GTASS-3	0.540	0.400	21.300	2.363	23.600	42.909

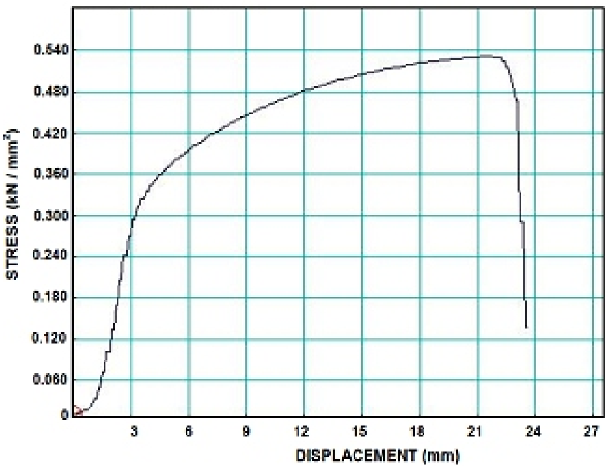


Fig. (a) GTAASS-1

The yield strength and tensile strength of unwelded base metal are 0.425 KN/m^2 and 0.556 KN/m^2, respectively. But the yield strength and tensile strength of GTAASS-1 (fabricated using austenitic stainless steel filler metal) joints are 0.406 KN/m^2 and 0.531 KN/m^2, in GTAASS-2 joints the yield strength and tensile strength are 0.391 KN/m^2 and 0.493 KN/m^2 and in GTAASS-3 joints the yield strength and tensile strength are 0.400 KN/m^2 and 0.540 KN/m^2 respectively.

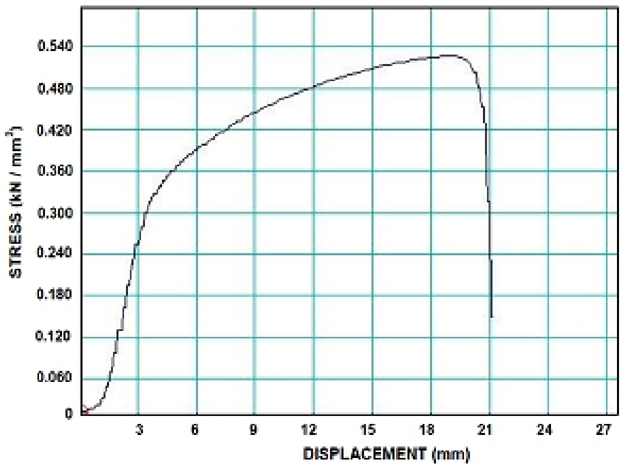
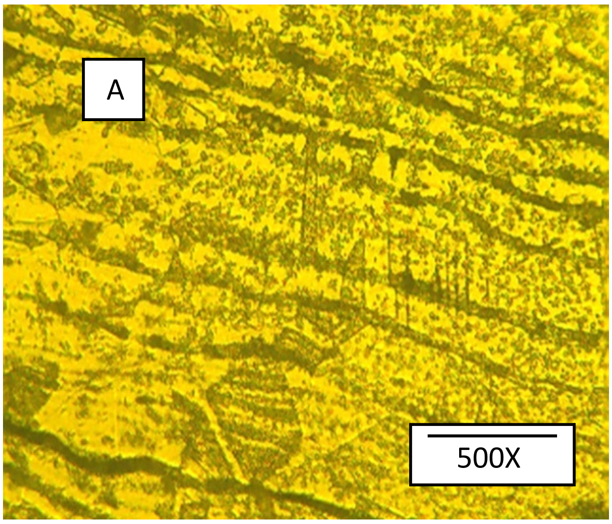


Fig. (b) GTAASS-2

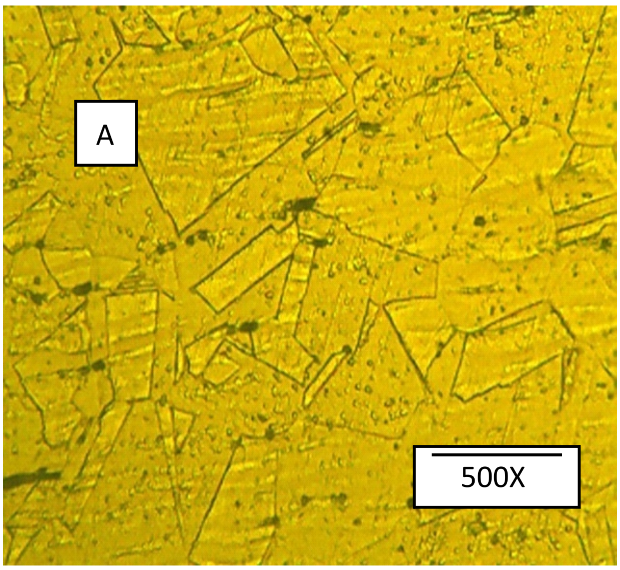
Fig. (c) GTAASS-3

Fig. 4. Stress – Displacement Curve for the Three Specimens

This indicates that GTAASS-1 specimen is 5% reduction in strength compared to base metal strength, GTAASS-2 specimen shows 9% reduction in strength compared to base metal strength and GTAASS-3 specimen is 6% reduction in strength compared to base metal strength. Of the three joints, specimen GTAASS-1 joints exhibited higher strength values compared with the other two specimens.



(a) Base Metal (304L)



(b) Base Metal with Filler Metal (304L + 308L)

Fig. 5 Optical Micrographs of ASS Weldments

The elongation of un welded base metal is 45.120%. But the elongation of GTAASS-1 joint is 43.091%, GTAASS-2 joint is 42.000% and GTAASS-3 joint is 42.909%. This suggests that there is a 4-6% reduction in ductility compared to the base metal. Of the three joints, specimen GTAASS-1 joints exhibit higher strength value compared with the other two specimens.

The stress-displacement curves for all three specimens desired from the samples are given in Fig. 4. Microstructure was examined such as base metal and base metal with filler metal is displayed in Fig. 5. The joint fabricated by ASS filler metal contains solidified dendrite structure of austenitic. The variation in tensile strength, yield strength and percentage of elongation of austenitic stainless steel joints is caused by the two important characteristics of weld metal (i.e.) chemical composition of the weld metal and microstructure of the weld metal. But here the chemical composition is same, so the deviation in their values is mainly by the welding speed and filler metal ratio. Hence GTAASS-1 joint exhibits higher yield strength, tensile strength and percentage of elongation.

IV CONCLUSION

From this investigation, following important conclusions are derived.

- Of the three specimens, GTAASS-1 shows higher yield strength and tensile strength compared to the joints GTAASS-2 and GTAASS-3, respectively.
- The percentage of elongation shows higher in GTAASS-1 compared to the joints GTAASS-2 and GTAASS-3 respectively.

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N.V. Amudarasan was born in Attur, Tamil Nadu, India in 1974. He received his bachelor degree in Mechanical Engineering from Madras University, Tamil Nadu and Master degree in Production Engineering from Annamalai University, Chidambaram, Tamil Nadu, India. He is presently a research scholar in the Department of Mechanical and Production Engineering, Sathyabama University. He has fifteen years of teaching experience. He is a member in ISTE, IWS and IIPE.