The Ultimate Tensile Strength of A 304l Austenite Stainless Steel Subjected To Tungsten Inert Arc Welding Using 308 Filler Metal.

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Abstract

The aim of this research is to study the ultimate tensile strength (UTS) of 304L austenite stainless steel (ASS) which was subjected to tungsten inert arc (TIG) welding with 308filler. ASS sheets of 304L measuring 60mm x 30mm x 5mm were welded to produce V groove butt weld joints with a roof face of 1mm inclined at 30º and the land face of 2mm. The UTS welded joints were evaluated using tensile testing machine: Monsanto Tensometer of type W based on the experimental data obtained from the tensile tests performed at an interval of 10amperes from 50amperes-90amperes. The result shows that as current increases, UTS decreases and descrease in UTS leads to the failure of the materials. The better specimen is the specimen A with the highest UTS (1804.7MPa) and lowest welding current (50A).

Keywords: *Austenitic stainless steel; 304L; Tungsten Inert Gas welding; Tensile test and Ultimate Tensile Strength.*

1.0 Introduction

Austenitic stainless steel (ASS) have a good mechanical properties, excellent corrosion resistance and it has a wide range of applications in diverts engineering fields, e.g nuclear power plants, gas turbine components, underwater pipelines etc, (Gupta *et al*., 2013). This is as a result of the metallurgical advantages they offer. These steels also do not lose their strength at elevated temperatures as rapidly as ferritic (bcc, body-centred cubic) iron base alloys and the least corrosion-resistant versions can withstand the normal corrosive attack of the everyday environment that people experience, while the most corrosion-resistant grades can even withstand boiling seawater. Hence, ASS are user friendly metal alloys with life-cycle cost of fully manufactured products lower than many other materials, (Oladele *et al*., 2010). ASS 316L also found applications in the field of nuclear science which is used as a manufacturing material for nuclear fuel clad tubes and fuel sub assembly wrappers in fast breeder reactors owing to its superior mechanical properties at elevated temperatures and good compatibility with liquid sodium, (Karthik *et al*., 2011). The most common and abundantly used stainless steels in today industries are the austenitic class and they are over 70% of total stainless steel production. They contain a maximum of 0.15% C, a minimum of 16% Cr and sufficient nickel to retain an austenitic structure at all temperatures, from the cryogenic region where they exhibit high toughness to high temperatures, (Wikipedia, 2011).

TIG welding is a process where the source of heat is arc forms between a non-consumable tungsten electrode and work piece. With a gaseous shield of inert gas such as argon, helium or argon-helium mixture. If filler metal is required, then it will added externally to the arc in the form of bare wire by the welder. Yuan *et al*., (2015) imvestaged on the fact that TIG welding easily welds all stainless steels and is particularly suited for welding stainless steel pipes, with or without an inert or backing ring. It is also used extensively in joining tubes to tube sheets in shell and tube heat exchangers. The following are the equipment's used in TIG welding illustrated in figure I, (Parag *et al*., 2013).

Moslemi *et al*., (2015), studied on the effect of welding current on micro-structure and mechanical properties of ASS 316 in a welded joint using TIG, re-affirmed chromium carbide formation at weld joint due to increase in heat input. This established that increase in welding current causes a raise in heat input. It was also concluded that current of 100A is the most suitable current that gives optimal strength and hardness in welding of ASS304 using TIG welding process.

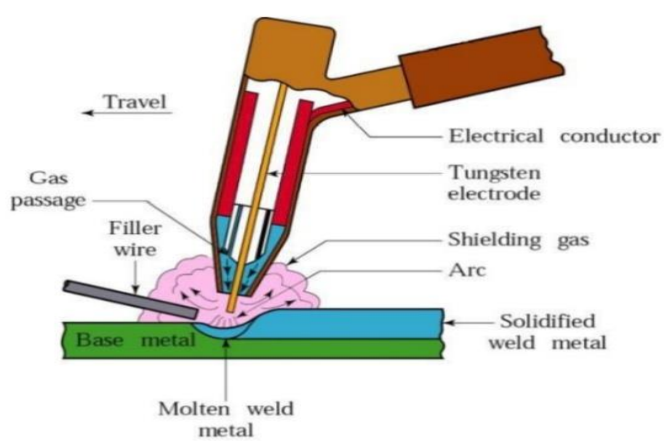


Figure 1: TIG welding process.

ASS 304L with the lowest width of HAZ at a weld current and corresponding temperature have effect on the mechanical properties of strength and hardness and increase in the welding current result to increase in temperature, (Balogun *et al*., 2018). Mechanical properties of ASS strongly depend on chemical composition, heat treatment and the amount of cold work. However, hydrogen embrittlement, sensitisation and formation of different carbides and sigma phase can also influence the mechanical properties. The mechanical properties are ultimate tensile strength (UTS), yield strength (YS), % elongation, strain hardening exponent (n) and strength coefficient (K) and one very essential mechanical property is the tensile strength (Okonji, 2014) which is define as the amount of load or stress that a material can handle until it stretches and breaks. As its name implies, tensile strength is the materials resistance to tension caused by mechanical loads applied to it (can be called UTS or ultimate strength). UTS is generally affected by welding parameters such as welding current, welding voltage and welding speed, which have been described as the most important factors affecting the quality, productivity and cost of weld joints, (Srivastava *et al*., 2010).
Raveendra*et al.,* (2013) carried out an experiment to determine the influence of pulsed current on the characteristics of weldments by TIG welding. The 3mm thick sheet of steel was tested using different frequencies, then Wang *et al.*, (2011) studied on the effect of different parameters like variable welding current, variable welding speed & different plate thickness using TIG welding process, the results were obtained that the heat increase with increasing the current and reduction with the welding speed.

Narang*et al.,* (2011) studied on TIG welding of structural steel plates of different thickness with welding current in the range of 55A to 95A, and welding speed of 15mm/sec to 45mm/sec. To predict the weldment macrostructure zones, weld bead reinforcement, penetration and shape profile characteristics along with the shape of the heat affected zone (HAZ), simulation of TIG welding process was carried out. Also Ghazvinloo and Honarbkhsh (2010) investgated on effect of welding current on the tensile strength of weld metal in low carbon steel using fluxed core arc welding process to illustrate the increase in welding current which lowered the tensile strength and it may cause failure in the material.
Yang et al., (2010) worked on the effects of heat input on tensile properties and fracture behaviour of friction stir welded Mg-Al-Zn alloy, by stir welded 6.3mm thickness of the material. It was established that the highest value of UTS of the weld was achieved with increase in heat input and decrease in welding temperature and current. It was also affirmed that increase in the width of HAZ does not bring about increase in hardness value of the weld and Guo et al., 2014 focused on the ultimate tensile strength (UTS) with respect to welding current in the research and increase in current brings about decreased in UTS.
Several researchers have reported in literatures on the different types of welding methods, heat input and welds bead, etc. But this paper is carried out to determine the ultimate tensile strength of a 304L austenite stainless steel subjected to tungsten inert arc welding using 308 filler metal.

2.0 Materials and Methods

This paper is focused on the detail of the welding procedures & parameters, filler metal and tensile testing. ASS sheets of 304L was measured by 60mm x 30mm x 5mm which were welded to produce single V groove butt weld joints that has 1mm roof face which is inclined at angle 30 and 2mm land face. The chemical composition of the ASS 304L was extracted from the experimental data obtained from the welding process carried out with GYS TIG 250 (Model: AC/DC-HF with dimension 350mm x 640mm x 670mm to produce a V groove butt weld joint. The edge of each cut pieces was cleaned with emery cloth and methylated spirit. Five welding currents ranging from 50A to 90A at ten amperes interval were welded. The table 1 showed the chemical composition while the TIG welding parameters are shown is shown in Table 2. The details of the experimental setup are as mentioned by Balugun *et al*., (2018).

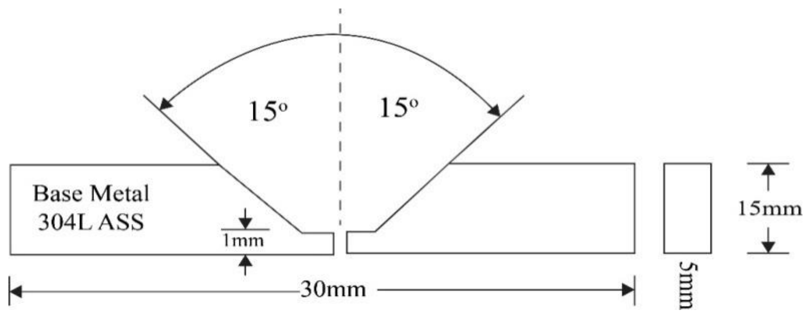


Figure 2: Single V groove butt

Table 1: Chemical composition base metal of 304L ASS

Elements	C	Mn	P	S	Si	Cr	Ni	Mo	Fe
%weight	0.03	2.00	0.045	0.039	1.00	18.04	8.09	0.36	70.38

Table 2: TIG welding parameters

Machine type	Model	Power (hp)	Voltage (V)	Electrode/ diameter (mm)	Filler metal/diameter (mm)	Current (A)	Frequency (Hz)
GYS TIG 250	AC/DC-HF	3	400	EW-Th-2/3.15	Filler 308/3.15	50-90	50/60

2.1 Tensile Test

The welded coupons were cut to 5samples (A-E) for preparing tensile specimens. The schematic illustration of the sub-size tensile specimen is shown in figure 3; using power hacksaw and it was subjected to longitudinal tensile test using a tensile testing machine: Monsanto Tensometer of type W with serial number 10975, UK and Capacity of 300kN maximum load which is located at Kaduna Polytechnic, Kaduna State. The test was carried out following the ASTM E8 Standard procedure for all weld tensile test. The coupons were fitted into the jaws of the testing machine and subjected to tensile stress until they fractured. The experimental results are shown in Table3.
Where R is radius of the groove angle and mm is millimeter.

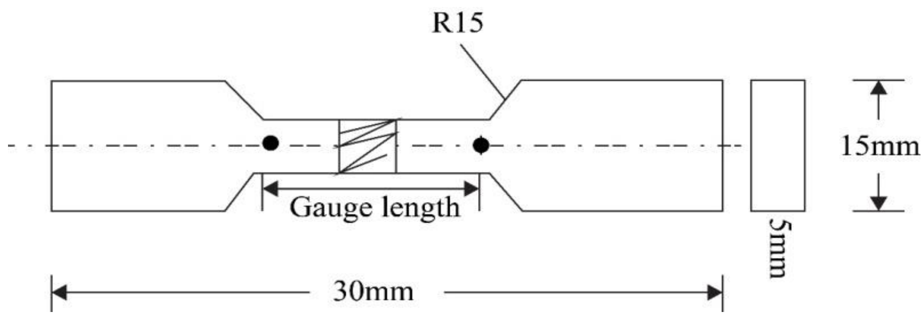


Figure 3: Schematic tensile specimen specification

3.0 Results and Discussion

3.1 Tensile Test Results

Specimens A to specimen B of 304L ASS were tested for each welding process and the results are shown in Table 3.

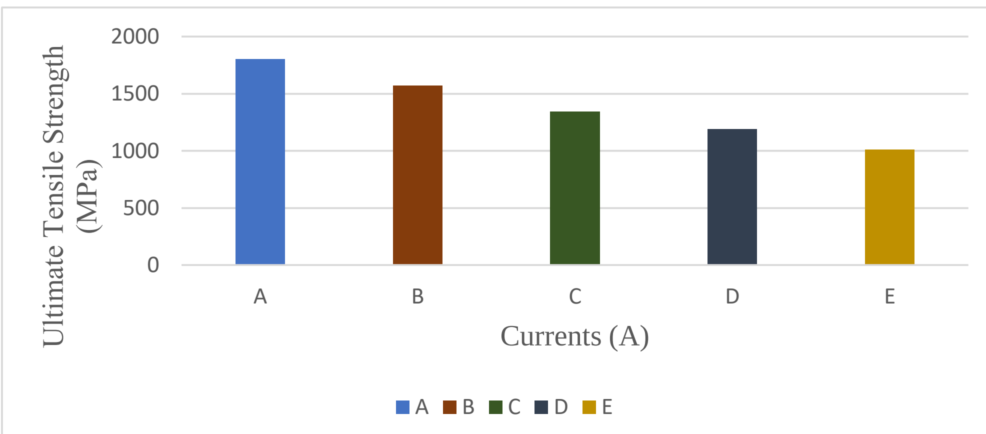
Table 3: Ultimate Tensile Test (UTS)

Specimens	**A**	**B**	**C**	**D**	**E**
Welding current (A)	50	60	70	80	90
UTS (MPa)	1804.7	1573.5	1345.6	1190.2	1012.5
Welding temperature (°C)	100.6	200.2	300.8	400.2	500.6

From table 3, it showed that at specimen A, current was 50A and UTS was 1804.7MPa; specimen B, welding current was 60A while UTS was 1573.5MPa; specimen C showed that at welding current 70A, UTS was 1345.6MPa; at specimen D, welding current was 80A while UTS was 1190.2MPa and at specimen E, the welding current was 90A, UTS was 1012.5MPa.

The result arranged with Konji *et al*. (2015) and Guo *et al*., (2015) that reported that increase in the welding current, increases the welding temperature which result to decrease in the tensile strength of the material. As the tensile strength decreases, it causes material to failure (shortening the life span of the material) and affects the microstructure. The increase in temperature as the result of increase in the welding current of 304L ASS will start to form chromium carbide which causes weld decay and corrosion is the major challenge on a material that researchers are working tirelessly to mitigate it. From the results, it is observed that sample A has higher strength value (its UTS value is higher than the other specimens) and its welding current is lower than the rest specimens.

The bar chart shown in figure IV gives a clearer view of the relationship between welding current specimens and ultimate tensile strength. Specimen A has the highness value of 1804.7MPa and specimen E has the lowest value of 1012.5MPa. The value of ultimate tensile strength increased with decrease in the welding current.



4.0 CONCLUSION

From the research, the following conclusions are drawn:

i. The tensile strength of 304L austenitic stainless steel with 308 filler metal of specimen A is the best in terms of long span of the material and corrosion resistance compared to the other specimens.

ii. For the 5 specimens, the tensile strength under investigation increased with decrease in welding temperatures and currents. That is to say that the UTS are vital in determining the hardness of a material.

iii. Specimen E was the least in terms of effect on the tensile strength. It gave UTS of 1012.5MPa, which implied that it's the specimen that will experience failure in the material earlier than the others.

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