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Experimental Investigation of Dissimilar Weld Characteristics for a TIG Welding with SS410 & SS304L

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Abstract – From 20th century to present, stainless steel is used almost everywhere for both commercial & industrial applications because of their excellent properties such as high corrosion resistance, high cryogenic toughness and high work hardening rate. They are used in gas & steam turbines, valves, gears, pressure vessels, seals, aircraft parts etc. By using dissimilar weld, we can reduce the cost & improve the performance significantly of component production over component made by single material. SS410 can be welded using all conventional welding techniques. It is resistant to hot gases, steam, food, mild acids, alkalies, fresh water and dry air. It has good scaling resistance too, but SS304L has good machinability and excellent corrosion resistance. It doesn't require pre or post heat treatment and it has excellent fusion welding performance for both with and without fillers. In this study we are using TIG welding to weld SS410 and SS304L, because weld joints exhibit better mechanical and metallurgical characteristics such as toughness value and high tensile strength. Then the specimens obtained will be subjected to few mechanical tests for their physical evaluation. The dissimilar welds will be compared with similar weld to find the effective and superior weld.

***Key Words*:** dissimilar weld, TIG welding, stainless steel, SS410, SS304L

1.INTRODUCTION

Aim of this study is to test and evaluate dissimilar welding characteristics for a weld between stainless steels of grade SS410 and SS304L. Stainless steels are basically classified into four types based on their crystalline structure called as austenitic, martensitic, ferritic and duplex. Austenite stainless steels have face-centered cube as their primary structure, martensite has centered tetragonal structure, ferrite has body-centered cubic structure and duplex has both austenitic and martensitic structure in near equal proportions.

Tungsten Inert Gas (TIG) welding or Gas Tungsten Arc Welding (GTAW) is one of the popular arc welding processes. It uses a non-consumable tungsten electrode to produce weld. A layer of inert gas such as argon or helium shields the welding area from getting oxidized or external contamination. A filler material in the form of an electrode is generally used to obtain the weld. It is preferred to obtain thin weld sections for metals such as stainless steels and some aluminium and copper alloys.

Shielding gases play a huge role in TIG welding process to protect welding area from atmospheric pollutants such as nitrogen and oxygen, which causes welding effects such as porosity and brittling of the weld metal when they come in contact with tungsten electrode, arc or the welding material.

Several factors influence the selection of shielding gases such as type of the metal being welded, design of the joint and final desired weld appearance. Argon is most commonly used shielding gas for TIG welding, the shielding gas we are using is 99.97% pure argon.

The stainless steels SS410 and SS304L are welded together in butt joint. It is the most versatile method of joining metals. It can be used to weld pieces of any geometry or any kind of equipment. It is also known as square groove weld.

2. Experimental Setup

2.1. Base Material

SS410 is an austenitic stainless steel and SS304L is a martensitic stainless steel. Both are cold rolled, to find its composition Optical emission spectroscopy test was conducted on them.

It has dimension of 150mm length, 100mm width and 10mm thickness. It is grooved at angle of 30 degree on one side.

2.2 Optical Emission Spectroscopy Test

Optical Emission Spectroscopy (OES) analysis uses a sparking process, which involves applying an electrical charge to the sample, vaporizing a small amount of material. The occurrence of the spark results in the emission of plasma which contains unique chemical signatures, which is used by experts to determine the breakdown of constituent elements

BIARD-DV 6E makes Optical Emission Spectrometer is used for this experiment which works on the principle that when a chemical element is heated by a flame or electric arc it will emit the energy. This energy is in the form of light, the spectrometer separates the light into individual frequencies. Because of the quantum nature of the light and matter, particular elements will emit light at specific frequencies. Therefore, analysis of the output of a spectrometer allows you to identify particular elements.

The standard used to conduct this experiment is IS:9879-1998(RA 2015)

The below tabular column shows the obtained composition of SS410 and SS304L obtained from the spectroscopy test.

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Sample 1 – SS304L

Elements	% by Weight
C	0.041
Si	0.46
Mn	1.08
P	0.026
S	0.014
Cr	18.11
Ni	8.36

Table 1, SS304L composition

Sample 2 – SS410

Elements	% by Weight
C	0.186
Si	0.41
Mn	0.75
P	0.018
S	0.009
Cr	12.44
Ni	0

Table 2, SS410 composition

All the obtained results are according ASME standards.

2.3 Welding Setup

SS410 and SS304L both were machined into plates of length 150mm, width 100mm and thickness of 10mm. A groove at an angle of 30^{o} was machined, which when adjoined gives a total of 60^{o} for the V-butt weld.

When the groove sides were kept adjacent to each other the total dimensions measure 100×150×10mm, after the weld it measures 200×150×10mm.

The configuration is:

- Current type – 2-step DC Voltage
- Shielding gas – 99.97% Pure Argon
- Electrode used – SS309
- Electrode diameter – 0.8mm
- Deposition rate – average of 1.2mm/sec
- Current setting for Root Pass – 131Amps
- Current setting for Soft Pass – 150 Amps
- Current setting for Hard Pass – 171 Amps
- Current setting for Metal Filling – 187 Amps

All the current setting is optimum for that respective fill, for the remaining fills the direction was from left to right and vice versa in zigzag manner.

So, we obtained three types of specimens. Two similar welds, one containing only SS410 (**Fig 1**) and another containing only SS304L (**Fig 2**). The last specimen was dissimilar weld consisting of SS410 and SS304L (**Fig 3**).

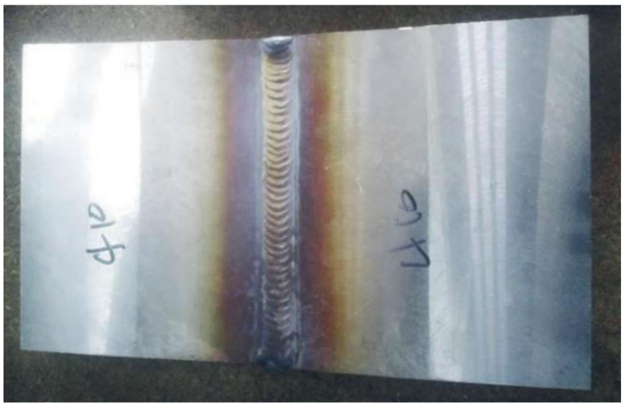

Fig 1, SS410/SS410 weld

Fig 2, SS304L/SS304L weld

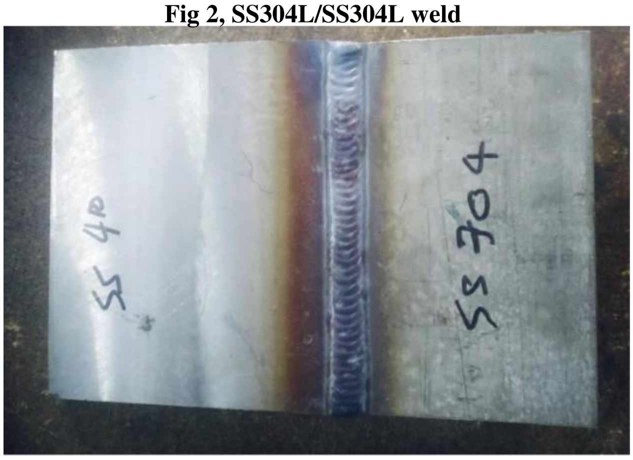

Fig 3, SS410/SS304L weld

2.4 Radiography Testing

To evaluate the weld obtained we subjected it to one of the suitable non-destructive method which is X-ay testing.

A typical X-ray system consists of an X-ray tube, a voltage generator, and console ray control which is usually produced by setting a very high voltage in between the two electrodes. Electrons generated from the filament gets impacted on the target to produce x-rays.

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Specifications of experiment are:

- Source – X-Ray
- Size – 2.0×2.0 mm
- Voltage – 110kV
- Current – 5mA
- Film make & type – AGFA D7
- Test specifications – ASME SEC V ART 2
- Exposure time - 2min
- Film density – 1.8-4.0
- SFD – 24INCH
- IQI type and designation – Wire Type, ASTM 1B
- Technique – SWSI

Observing that there was no significant discontinuity, as per the acceptable criteria of ASME Sec. 9. The weld is acceptable.

2.5 Tensile Testing

It is arguably the most conducted mechanical test for all kind of materials. This test gives how well a weld joint would perform under different loads under different environmental conditions. Elastic Modulus, Ultimate yield strength, deformation type and weld joint's elongation.

A total of three samples were tested, in which two samples were similar welded and another one was dissimilar weld.

Fig 4, Tensile tested samples

I. SS410/SS410

Input data:

Specimen Width – 19.05mm

Specimen Thickness – 10mm

Initial Gauge Length – 50mm

Initial Cross-Sectional Area – 190.5mm^2

Output data:

Loat at Yield – 99.78kN

Yield Stress – 523.780 N/mm^2

Load at Peak – 118.310 kN

Avg. Tensile Strength – 621.050 N/mm^2

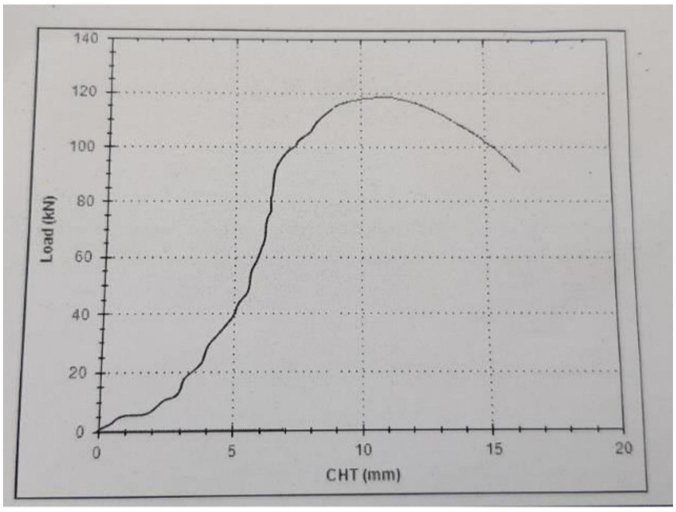

Fig 5, Stress-Strain curve of SS410/SS410 sample

The criteria for tensile to be successful for a welded joint, it should break at HAZ or at base metal. This test piece broke at base metal, which indicates successful weld.

II. SS304L/SS304L

Input data:

Specimen Width – 19.03mm

Specimen Thickness – 10mm

Initial Gauge Length – 50mm

Initial Cross-Sectional Area – 190.3mm^2

Output data:

Loat at Yield – 113.8kN

Yield Stress – 595.796 N/mm^2

Load at Peak – 139.120 kN

Avg. Tensile Strength – 731.056 N/mm^2

The criteria for tensile test to be successful for a welded joint, it should break at HAZ or at base metal. This test piece broke at HAZ, which indicates successful weld.

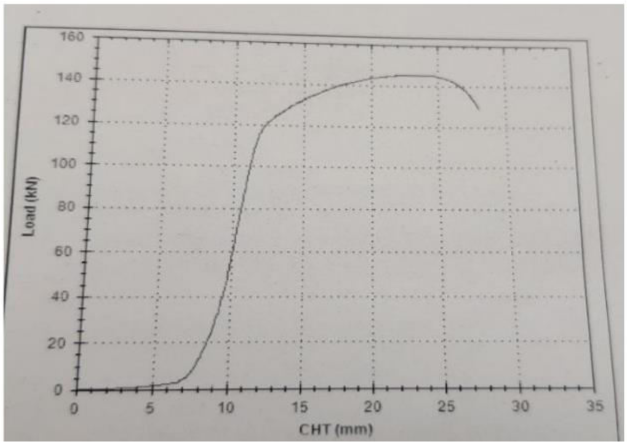

Fig 6, Stress-Strain curve of SS304L/SS304L

The heat caused during the welding process has affected the alloying compound to deconstruct which causes grains to disperse in HAZ region, hence this makes HAZ weaker than base metal.

III. SS410/SS304L

Input data:

Specimen width – 19.07mm

Specimen Thickness – 10mm

Initial Gauge Length – 50mm

Initial Cross-Sectional Area – 190.7mm^2

Output data:

Loat at Yield – 117.74kN

Yield Stress – 617.41 N/mm^2

Load at Peak – 145.350 kN

Avg. Tensile Strength – 762.192 N/mm^2

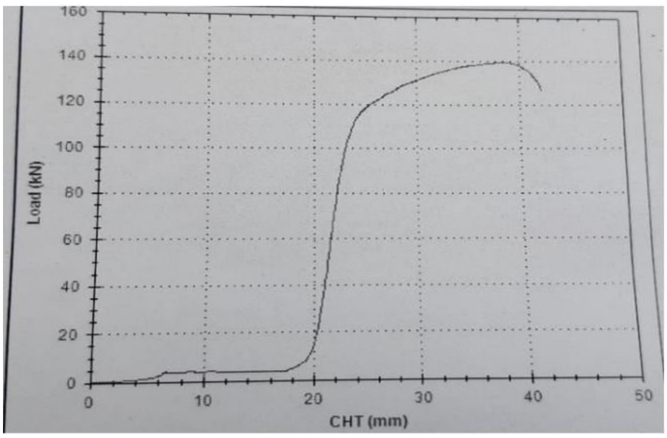

Fig 7, Stress-Strain curve of SS410/SS304L

This test piece broke at base metal, indicating a very successful weld.

2.6 Bend Tests

It is one of the simple and inexpensive qualitative test which can be used to test the ductility of the material. In our case it's a crucial quality control test, which determines the quality of butt-weld when it is bent 180 degrees.

Face bend test is conducted with subjecting weld face to tension, where as root bend test is conducted when weld root is subjected to tension.

Test specifications

- Test reference – ASME SEC IX 2019
- Mandrel Diameter – 4T

	Face Bend		Root Bend	
	Angle of bend	Result	Angle of bend	Result
SS410/SS410	120^o	Crack observed	120^o	Not satisfactory
SS304L/SS304L	180^o	No Crack observed	180^o	Satisfactory
SS410/SS304L	120^o	Crack observed	120^o	Not satisfactory

Table 3, Bend test

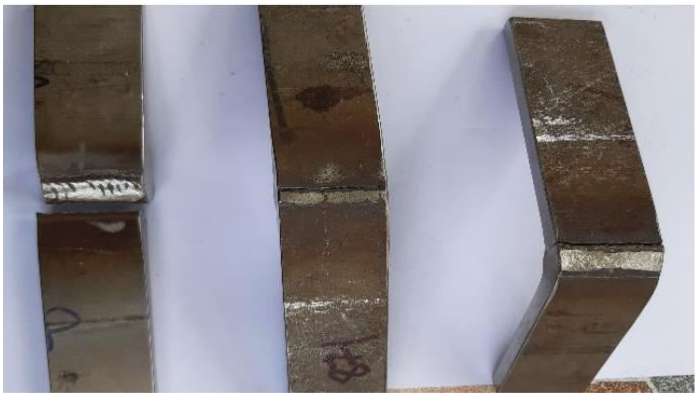

Fig 8, Root bend tested samples

Due to high carbon composition, SS410 failed in bend tests due to its brittle nature.

SS304L is the lower carbon variant of SS304. That makes it more flexible than similar grades o steel. Hence it passes the bend tests.

In dissimilar weld, cracks were observed in SS410 region near 120-degree angle bend. Hence SS410 is less flexible and is to bent only up to 100-degree for better results. Whereas SS304L side can be used for more flexible purposes.

Fig 9, Face bend tested samples *2.7 Simulation*

A Simulation is an approximation which imitates the system's operation or process. Since simulation gives perfect weld and test results, we need to compare the simulation obtained values with experimented values of mechanical tests to know the deviation of real-world results from the ideal ones.

Solid Edge 2020 was used for modelling of the plate. With solid edge's welding assembly feature, plates were welded.

The model was then imported to Ansys's workbench via spaceclaim. SS410, SS304L & SS309 properties were defined using material library.

After applying mesh to the model, using the 'static structural' feature the test was simulates. Equivalent Von-Mises Stress and Total deformation values were obtained for tensile and bend tests.

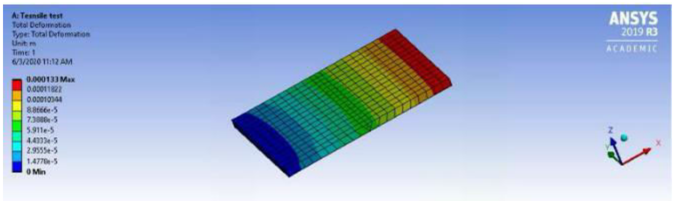

Fig 10, Tensile test simulation

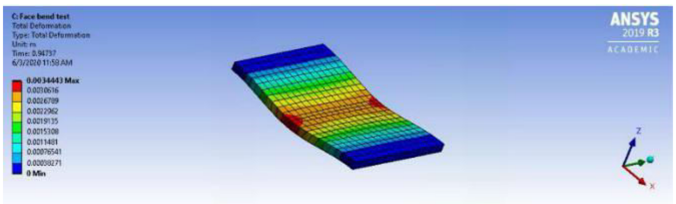

Fig 11, Face bend test simulation

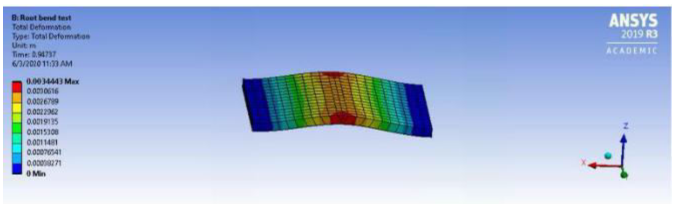

Fig 12, Root bend test simulation

From the obtained values from simulations, we get to know that simulated values are higher than experimented values but are in close quarters.

Since simulation represents a perfectly executed process, we can consider it has an ideal welding process. So, we get to know that the deviation of experimented values and find the errors to perfect the welding to get more efficient material.

3. CONCLUSIONS

The ideology was to reduce cost and increase life span of the stainless-steel usage in industries and automobiles, by using dissimilar weld instead of traditional weld of similar metals. Dissimilar weld was fabricated using SS410 and SS304L with SS309 as filler material. This welded joint was tested to determine its mechanical properties which was compared with mechanical properties of similar metal weld joint. The spectrometer test gave the composition of test pieces, which was agreed ASME standards. The radiography test indicated that there were no significant defects. Mechanical tests we conducted was with the purpose to observe the strength and its ability to satisfy our requirement. In tensile test, SS410 weld and dissimilar weld broke at base metal but SS304L broke at HAZ. Whereas in bend test, SS304L passed the 180-degree bend test and the other two failed. This shows the strength of SS410 and flexibility of SS304L can be brought together with help of dissimilar weld.
Thinner the metal gets it will become much challenging to obtain complete joint penetration. It can be solved by designing a hybrid weld process with TIG.

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