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A Comparative Study of Welding Characteristics of Stainless Steel AISI 321 and Aluminum Alloy 65032 using GTAW

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Abstract: - TIG welding is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. Fixing of the input parameters plays a significant role in getting the quality weld joint. Generally, all welding processes are used with the aim of obtaining a welded joint with the desired mechanical properties with minimum distortion. The present study is to investigate some aspects of TIG welding. In this study of non destructive testing and tensile test of weldments have been carried out on a aluminium alloy 65032 and stainless steel alloy AISI 321 using GTAW with non pulsed different currents. The radiography, liquid penetrant test and tensile test have been carried out on the weldments of the above two materials having thicknesses (i.e., aluminium alloy 65032 of 3mm an stainless steel alloy AISI 321 of 2.4 mm). The aim of this study is to compare the various characteristics of weldments at different currents levels. The experimental results examine different welding parameters for aluminium alloy 65032 and stainless steel AISI 321 using non pulsed currents GTAW.

Key-Words :- Aluminum Alloy 65032, Stainless Steel 321, Tungsten inert gas Arc Welding , Radiography Test, Penetrant Test, Ultimate Tensile Strength.

1 Introduction

There is a great demand for aluminium alloy and alloy steel welded structure and products where a high standard of quality is required, such as in aerospace applications. The aluminium alloy and alloy steel can be easily welded by conventional arc welding like Tungsten Inert Gas Welding (TIG) and Metal Inert Gas Welding (MIG) [1]. The Gas Tungsten Arc Welding (GTAW) process has proved for many years to be suitable for welding of 65032 aluminium alloy and stainless steel alloy AISI 321 since it gives best quality welds. The AC and Straight polarity GTAW process is used in this study for 65032 aluminium alloy and direct current straight polarity GTAW process for stainless steel alloy AISI 321 [2].

TIG welding is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. Fixing of the levels of the input parameters plays a very important role in getting the quality of a weld joint. Generally, all welding processes are used with the aim of obtaining a welded joint with the desired mechanical properties with minimum distortion [3].

2 Experimental Setup

A turbocharger consists of a compressor wheel and exhaust for this experiment the TIG welding set up [3] is available at DRDL, Kanchanbagh, Hyderabad (India). The grinding was done on the tungsten electrode to prepare it for the welding. The used tungsten electrode having 2% Thoriated tungsten (EWTh-2) of Red strip with 2.4 mm diameter. During this process welding parameters like gas flow rate, inert gas used, and the number of passes of the welding to be kept constant for all trails. But the welding current was used as a varying parameter. At the different value of welding current the mechanical properties of the welded joints are determined. The inert gas used for the experiment was Argon. Flow rate of the gas was kept constant during the welding of the specimen. The filler wire selected for the process of welding of the grade as ER347 of diameter 1.6 mm for SS321 and 4043 of diameter 2.4 mm for AA 65032 (H20) were used for the welding process.

Before setting a TIG welder there is some preparation work that needs to be done first. The weld joint must be absolutely clean. That means no rust, paint, oil or anything else. Absolutely nothing but bare shining metal. Although TIG is an excellent welding process, it must be stressed most emphatically that the joint must always be clean - pristine! Additionally, Tungsten electrodes need to be sharpened to a fine point for all metals except Aluminum. Clean joint and clean sharp Tungsten rods are always needed [4].

The torch body has four main parts plus the Tungsten electrode for set-up. The torch body holds the collet body, collet, back cap, and cup. All of these parts are what hold and shield the Tungsten electrode.

The set-up of the torch requires proper size collet and body to match the Tungsten size that will be used. The cup size is chosen based on the size of weld that will be done and the back cap is what tightens the Tungsten. Once these are the Tungsten to stick-out just enough to keep the weld shielded from the air and far enough to see the arc. This is something that every welder does differently [5].

Gas flow rate is regulated in CFH "Cubic Feet per Hour". Set-up of the gas flow rate varies depending on the cup size and any draft or wind conditions. If you are in a shop that has no drafts, a rate of 5 CFH may be enough. However, 60 CFH may not be enough if weldings done outdoors. . A higher gas flow rate is not good either because it causes turbulence that will pull air into the weld.

3 Experimental Procedure

3.1 Selection of materials:

The following materials were selected for this study. ***Aluminum Alloy 65032(H 20)*** plate of thickness 3mm and length by width of 200x100mm was selected as shown in the figure 1 below.

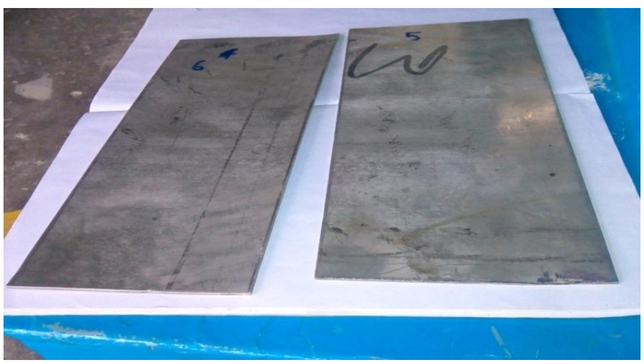

Figure 1: AA 65032(H20) Work Pieces

Stainless Steel Alloy (SS 321) plate of thickness 2.4mm and length by width of 200x100mm was selected as shown in the figure 2 below.

Figure 2: SS 321 work pieces

3.2 Chemical Analysis:

The selected materials were sent for the chemical analysis to detect the chemical composition of the selected materials.

3.3 Cutting of Materials:

Selected raw materials were needed to cut down to required size and shape before proceeding to other works in the process. For this purpose , a hand hack saw was employed to cut the aluminum sheets into plates, whereas a machine hack saw was used to cut down the steel sheet into plates of required size , as latter was stronger than the former one and is shown in figure 3.

Figure 3: Manual Cutting Machine

3.4 Surface Cleaning:

The plates thus obtained had sharp, rough and irregular edges and also stains due to corrosion and other incorrect handling during the process. These sharp edges were deburred using a rough and smooth files whereas the surface was cleaned using a rough grade sand paper initially and then with a soft graded paper. This removed the surface impurities from both the plate's surface and is shown in figure 4.

Figure 4: Surface Cleaning

3.5 V-Groove Formation:

Groove (chamfering) was then performed on the deburred and surface cleaned plates for welding purpose. Then the plate surfaces were cleaned chemically ACETONE was used for this purpose. This is done to get the surfaces free from any chemical depositions or oxide deposition as they may affect the welding process and the weld strength and is shown in figure 5.

Figure 5: Chemical Cleaning

3.6 Welding Fixture:

Welding fixture is used to support the plates during welding process. A weld fixture is shown in figure 6 and made up of mild steel welding fixture is used for the following purpose:

- To hold the pieces in the position.
- To avoid misalignment of the plates during the welding.
- To avoid bending of plates due to melting of the plates during the welding process.
- To provide for the purging gas for underside of plates being welded to avoid oxidation.

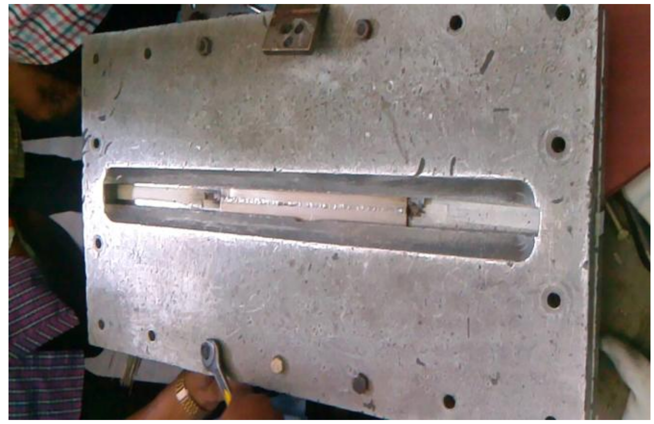

Figure 6: Welding Fixture

3.7 Welding Process:

After fixture has been readied, the plates were fixed in the position. The shielding gas and purging gas lines were opened and their line pressures were checked. Then the welding on the plates has been carried out. This was done in following phases:

1. Tack Welding: During these phases tacks (i.e temporary weld bead) are placed in the gap (obtained by groove) between the plates at regular distances in order to hold the plates and check for any misalignment or bending of plates.

2. Total Welding: During this the total surface of plates is TIG welded from one end to other end, stopping at regular interval of 100mm distance.

The welding on the plates were carried for 2 passes as shown below figures 7 & 8. The plates were once again treated with “ACETONE SOLUTION”, to make the surface free of any chemical residue, before sending it to further tests.

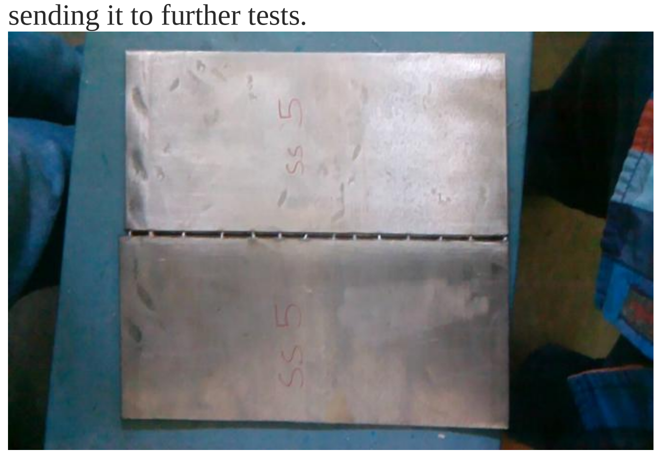

Figure 7: Tack Welding

Figure 8: Full Welding

3.8 Dye Penetrant Tests:

A dye penetrant test was conducted to detect any welding surface defects such as hairline cracks, surface porosity, and fatigue cracks. The plates were tested in the following steps:

- Firstly the plates were applied with red color penetrant and allowed for dwelling time.
- Next the plates were then cleaned using a cleaner base.
- Finally the plates were coated with a developer base and allowed for developing time

After developing time, the red color penetrant seeps out onto the surface from the cracks through capillary action and this shows us the defective spots as shown in figure below. The plates were then sent for the radiography test.

3.9 Radiography Test:

The plates after coming from die penetrant tests were sent for radiography test, where the plates are inspected for hidden flaws such as cracks, improper penetration of weld bead by using the ability of short wavelength electromagnetic radiation (high energy photons) to penetrate various materials. The test was performed and the test films were obtained as shown in fig. Most of the plates have passed the test with no or minimal defects except for few pieces which were rejected.

3.10 CNC Machining:

The plates obtained after radiography test were into tensile specimen coupons in a 3-axis CNC machine. For this purpose the radiography films were studied and the plates with regions no defect were marked and the tensile test coupons were cut to test for tensile strength as shown below:

Tensile Test:

The tensile specimen coupons obtained from CNC machine were then sent for tensile strength test. For this purpose a UNIVERSAL TESTING MACHINE (INSTRON) of maximum capacity of 250KN was selected and the load was applied with a speed of 1mm/min [6]. The machine is shown below figures 9 & 10. The coupons broke during the test and the load at which coupons broke was noted down by a digital interface mounted on the device and a graph was generated and shown in Table 1 & 2.

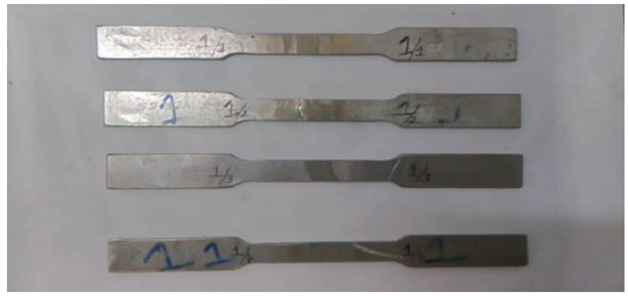

Figure 9: Stainless Steel Alloy (321) test coupons

Figure 10: Aluminum Alloy 65032(H 20) test coupons

TABLE 1
WELDING PROCEDURE PARAMETERS FOR STAINLESS STEEL 321

SAMPLE NO	WELD LAYER	PROCESS	FILLER METAL		CURRENT		VOLTAGE volts	SPEED mm/sec
			CLASS	DIA (mm)	POLARITY	CURRENT RANGE(amp)	VOLTS	
01	1	TIG	ER 347	1.6	STRAIGHT	55-56	7.5-7.6	0.71
	2	TIG	ER 347	1.6	STRAIGHT	55-56	9.0-9.9	0.61
02	1	TIG	ER 347	1.6	STRAIGHT	65-66	7.5-8.7	0.47
	2	TIG	ER 347	1.6	STRAIGHT	65-66	8.6-9.2	0.69
03	1	TIG	ER 347	1.6	STRAIGHT	75-76	8.4-9.0	1.02
	2	TIG	ER 347	1.6	STRAIGHT	75-76	8.7-9.6	0.95
04	1	TIG	ER 347	1.6	STRAIGHT	85-86	8.3-9.2	1.51
	2	TIG	ER 347	1.6	STRAIGHT	85-86	9.0-9.8	1.28

TABLE 2
WELDING PROCEDURE PARAMETER FOR AA 65032 (H 20)

SAMPLE NO	WELD LAYER	PROCESS	FILLER METAL		CURRENT		VOLTAGE	SPEED mm/sec
			CLASS	DIA (mm)	POLARITY	CURRENT RANGE (AMPS)	VOLTS	
01	1	TIG	4043	2.4	STRAIGHT	110-111	12.6-13.1	1.47
	2	TIG	4043	2.4	STRAIGHT	110-111	13.5-14.1	1.64
02	1	TIG	4043	2.4	STRAIGHT	120-121	12.5-13.4	1.72
	2	TIG	4043	2.4	STRAIGHT	120-121	13.4-14.0	2.47
03	1	TIG	4043	2.4	STRAIGHT	130-131	13.6-13.7	1.93
	2	TIG	4043	2.4	STRAIGHT	130-131	13.7-14.3	2.61
04	1	TIG	4043	2.4	STRAIGHT	105-106	12.5-13.2	0.69
	2	TIG	4043	2.4	STRAIGHT	120-122	13.7-14.4	1.76

4 Results and Discussions

4.1 Chemical analysis of the Work Pieces:

First the work pieces were selected for the experiment to perform welding, to check the chemical composition of the materials, the materials were sent for chemical analysis. The chemical analysis of Aluminum alloy 65032 (H20) and stainless steel 321 is given below table 3 & 4.

TABLE 3
CHEMICAL ANALYSIS OF ALUMINIUM ALLOY 65032(H20)

SPECIMEN	SPECIFICATION	EXPECTED MATERIAL	REMARKS
Aluminium	IS: 737 65032	Al ALLOY 65032	THE SAMPLES ARE AGREEING WITH 65032 SPECIFICATIONS.

TABLE 4
CHEMICAL ANALYSIS REPORT OF STAINLESS STEEL 321 ALLOY

SPECIMEN	SPECIFICATION	EXPECTED MATERIAL	REMARKS
Stainless Steel	AISI - 321	S.S 321	THE SAMPLES ARE AGREEING WITH AISI 321 SPECIFICATIONS WITH SLIGHTLY HIGH CARBON.

4.2 Effect of Current on Porosity and Cracks*:*

Dye penetrant test results*:*

The liquid penetrant (LP) test was conducted on these weldments. During this test no cracks were observed in the weldments which are welded at different currents.

Radiography test results:

The effect of different currents on the porosity observed during radiography .These results show that no weld defects were present and all the welded samples were acceptable.

Tensile test results:

Tensile test of the welded joint was performed with universal tensile testing machine (Instron) with maximum load capacity 250 KN. Load give with a speed of 1 mm/min. The following figures 11 & 12 shows the tensile strength value for all the welded joints produced at different welding speed and current.

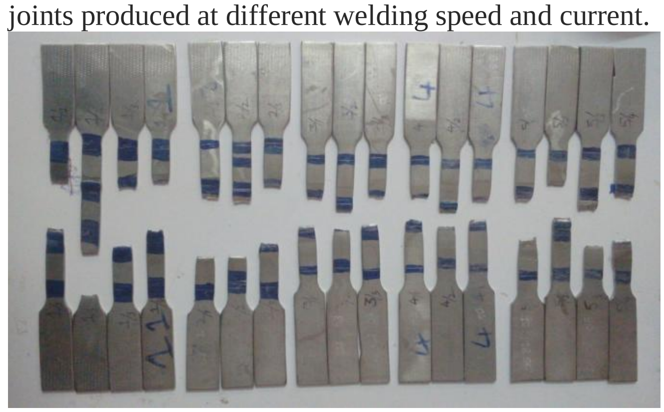

Figure 11: Tensile test coupons of SS 321

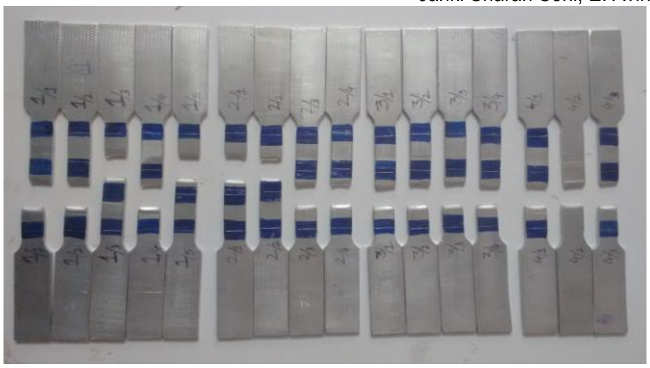

Figure 12: Tensile test coupons of AA 65032 (H20)

The results analyses are shown below figures 13(a) to 13(f):

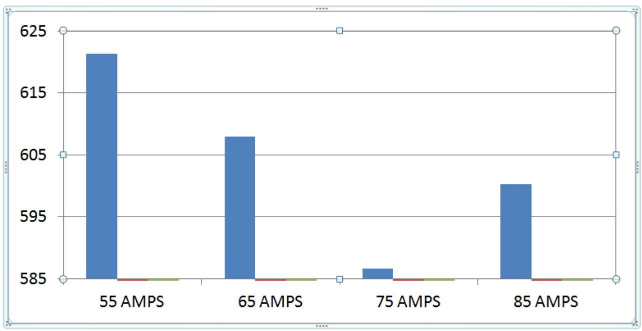

Figure 13(a): CURRENT (Amps) Vs UTS (MPA) (SS 321)

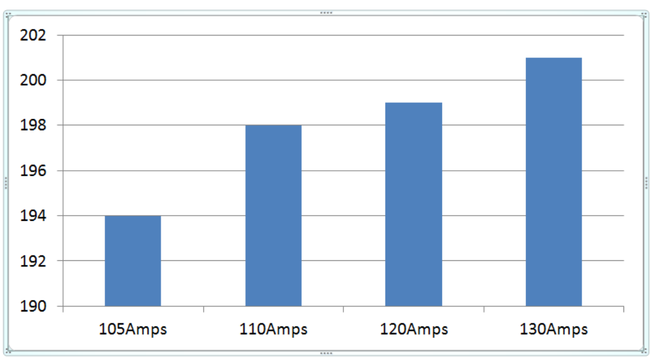

Figure 13(b): CURRENT (Amps) Vs UTS (Mpa) (AA 65032 (H20))

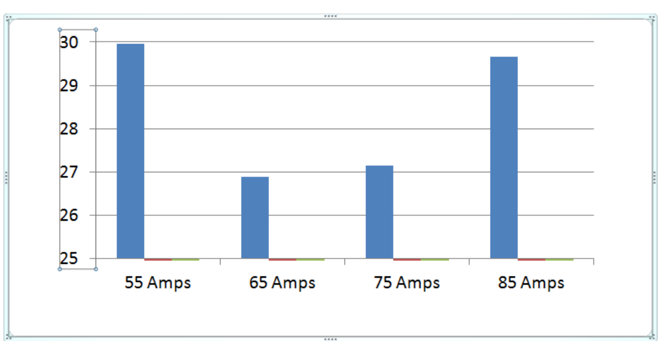

Figure 13(c): CURRENT (Amps) Vs % EL (SS 321)

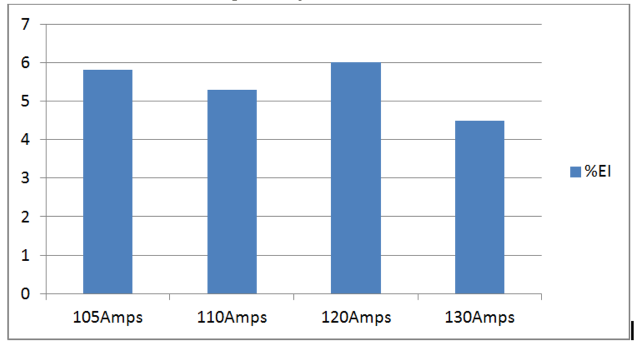

Figure 13(d): CURRENT (Amps) Vs %EL (AA 65032 (H20))

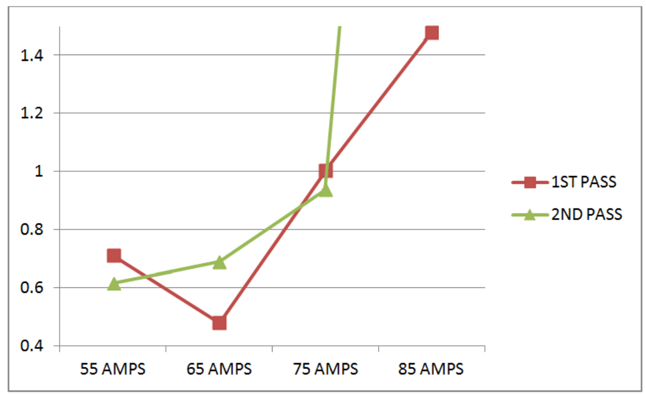

Figure 13(e): CURRENT (Amps) Vs SPEED (mm/sec) SS 321

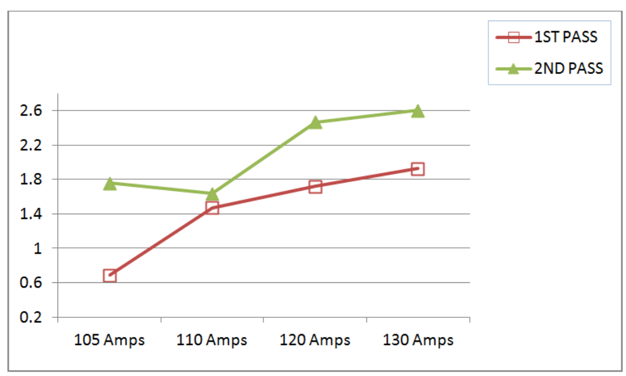

Figure 13(f): CURRENT (Amps) Vs SPEED (mm/sec) AA 65032(H20)

From the graphs it can be concluded that for both the materials with the increase of currents the speed of the welding also increases and there was increase in speed in second pass compared to first pass.

5 Conclusion

By using TIG welding process uniform welding of aluminium alloy possible. The important parameters affecting the output responses have been identified as speed and current. Selection and preparation of welding joint greatly affect the welding strength, microstructure etc. To improve welding quality of aluminium pre and post welding precaution must be taken during welding process. By optimizing and controlling welding parameters (like welding current, welding speed) welding defects get totally avoided. As welding current was increased the average weld speed of two passes was found to increase for both the materials. The joints were defects free during visual inspection.

DP Test: There are no surface cracks observed in the weld zones. X-ray radiography results show that almost all the samples are passing through X-ray radiography test with „no significant defect" remarks. i.e. that there were no pores and cracks in the weldments.

For Aluminium Alloy 65032(H20) as current was increased from 105 Amps to 130 Amps, it was found that the ultimate tensile strength increases from 194MPa to 201 MPa, whereas for Stainless Steel 321 as current increases from 55Amps to 85 Amps, the ultimate tensile strength was found to be decreasing from 621MPa to 600MPa.

For Aluminum Alloy 65032(H20) as current was increased from 105 Amps to 130 Amps, it was found that the %EL (Elongation) gradually increased from 5.87% to 6.07%, whereas for stainless Steel 321 as current increased from 55Amps to 85 Amps, %EL (Elongation) was found to be decreased drastically from 29.9% to 26% initially but overall %EL was found to be less from beginning i.e. 29.6% at 85Amps.

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