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ANALYSIS OF MECHANICAL AND MICROSTRUCTURAL PROPERTIES OF PULSED CURRENT GAS TUNGSTEN ARC WELDED DUPLEX STAINLESS STEEL

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***Abstract*—** Studies The Demand is increasing for Stainless Steel alloys, due to high strength, good welding properties, increased wear and corrosion resistance and high strength-to-weight ratio. Duplex Stainless Steel is widely used in aerospace applications; Ship building, Automobile Industry, Rail Cars and Pressure Vessels.

Pulse Current Welding process has many advantages over Constant Current Welding, including enhanced arc stability, increased weld depth/width ratio, narrower HAZ range, reduced hot cracking sensitivity, refined grain size, reduced porosity, low heat input, lower distortion of gas by weld pool and better control of the fusion zone. Pulsed current welding technology has been widely used in fabrication of high pressure air bottles, high pressure gas storage tanks, rocket motors, structures in aerospace applications such as aircrafts, rockets and missiles. Switching between predetermined high and low level of welding current can be used to produce pulsed current gas tungsten arc welds. Some progress is done on pulsed current GTAW of Duplex Stainless Steel. So far the pulsed current welding is used to study the effect of pulse current, shielding gas composition, weld speed and bead shape, the incidence of welding defects, joint strength, Duplex Stainless Steel, to study the microstructure and weld bead geometry flows.

***Index Terms*— duplex stainless steel, GTAW, HAZ,**

1. INTRODUCTION

In the present context of advancement of technologies and researches, new alloys with exceptional properties are made every day. Due to this, the importance of fabrication or joining of these alloys is also increasing. Latest researches on Stainless Steel lead to invention of its alloys with remarkable properties such as high strength-to weight ratio and ability to resist wear and corrosion. Structural components made from Stainless steel and its alloys are vital to the aerospace industry and ship industry is important in other areas of transportation and structural materials.

Advantages of invention of new Stainless steel alloys can be utilized efficiently only by using proper fabrication process. So the project aims to find the best possible method to join an advanced Stainless steel alloy without sacrificing much of its remarkable properties and to evaluate the mechanical and microstructural properties of the weldment and to compare it with the same of the base metal. This types of stainless steel is a mixture of microstructure of austenitic and ferritic steel (in a 50/50 percentage).It contains a higher amount of chromium and a lower amount of nickel. As it is a mixture of the two types of stainless steel, it is tough, resistant to corrosion, stress and may also show some magnetic properties. 'Super duplex' is the best quality of stainless steel and is widely used as it has the highest corrosion resistance properties among all types of stainless steel.

Chemical Composition of Duplex Stainless Steel

C	Si	Mn	S	P	Cr	Ni	Mo	Cu	N	Fe
0.028	0.65	0.71	0.006	0.027	22.16	5.66	3.33	0.14	0.24	Bal

Mechanical Properties of DSS

Property	Value
Tensile Strength (MPa)	741
Shear Strength (MPa)	348
Elongation (%)	32.2
Hardness (BHN)	223

Physical Properties of DSS

Property	Value
Density	7.805 g/cm^3
Melting Point	1500°C
Modulus of Elasticity	200 GPa
Electrical Resistivity	0.058×10^{-6} Ω.m
Thermal Conductivity	19.0 W/m.K
Thermal Expansion	25×10^{-6} m/K

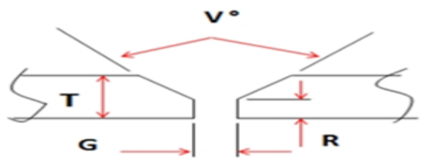
Gas tungsten arc welding (GTAW) is an arc welding process that produces coalescence of metals by heating them with an arc between a non-consumable electrode and the base metal. GTA welding process is generally used for stainless steel welding of stainless steel alloys. TIG welding is widely used for welding, and it produces welds of good appearance and quality. A constant current AC power source with a continuous high frequency is used with water or air-cooled TIG torch and an externally supplied inert shielding gas. The AC process is used to provide a degree of cleaning of the stainless steel surface during the electrode positive cycle though this is not a substitute for proper cleaning of the base material. The tungsten electrode diameter is usually about 2.4 mm and the method can be used with or without filler metal.

2. METHODOLOGY

The base metal employed is 9.1 mm thick plate of Duplex Stainless Steel. Filler material used is 309 L (including ER 309 Lsi), 308 L(including ER 308 Lsi), 347 grade SS, CG-12, CF-8M, CF-3M . The selection of filler material is based on the mechanical properties and resistance offered during welding process.

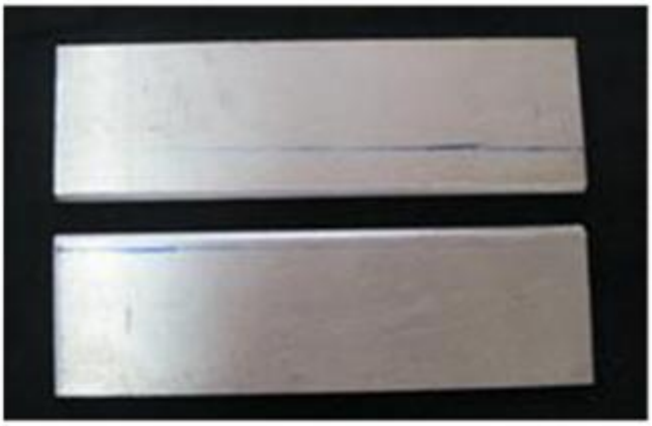
Work Piece Preparation

On the basis of literature review conducted, a single V butt weld joint is prepared. The weld joint and its particulars are shown below



Single V butt welding joint with particulars

Thickness (T) = 6.3 mm, Root Gap (G) = 1.5mm, Root Face (R) = 2 mm, Bevel Angle (V) = 75°



Work piece with Single V butt joint

Working Range of Process Parameters

Trial runs have been carried out on 6.3 mm thick plates of 6360 Duplex Stainless Steel to find out the feasible working limits of PCGTA welding parameters. Different combinations of pulsed current parameters (Peak current and Base current) have been used to carry out the trial runs. The bead contour, bead appearance and weld quality have been inspected to identify the working limits of the welding parameters.

The trials conducted are as follows,

Trail 1- When peak current is 290 A, excess melting of filler metal, melting off of base metal, increased HAZ & improper bead contour has been observed.

Trail 2- When peak current is reduced to 230A, Insufficient melting of filler metal & insufficient penetration was experienced.

Trail 3- When peak current is 270 A, excess melting of filler metal & improper bead contour occurred.

Trail 4- When peak current is 250 A, Sufficient melting & fusion of base metal and filler metal, perfect bead contour & penetration and moderate HAZ has been observed.

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image.

Tensile properties are the most important indication of strength in a material. The force necessary to pull the specimen is determined, along with how much the material stretches before breaking. Tensile test, in a broad sense is a measurement of the ability of a material to withstand forces that tend to pull it apart and to determine to what extend the material stretches before breaking. Tensile testing machine of a constant rate of crosshead movement is used. It has a fixed or essentially stationary member carrying one grip, and a movable member carrying a second grip. A controlled velocity drive mechanism is used. Test specimens are prepared in many ways. The specimens may be prepared by machining operations from materials in sheet, plate, slab or similar form.

GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminium, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc and as a result is often automated.

3. RESULTS AND DISCUSSIONS

The results to beobtained from the various test conducted on the pulsed current gas tungsten arc welded specimens is revealed in this chapter. Mechanical and Microstructural evaluation of the weldment as well as the base metal is also included.

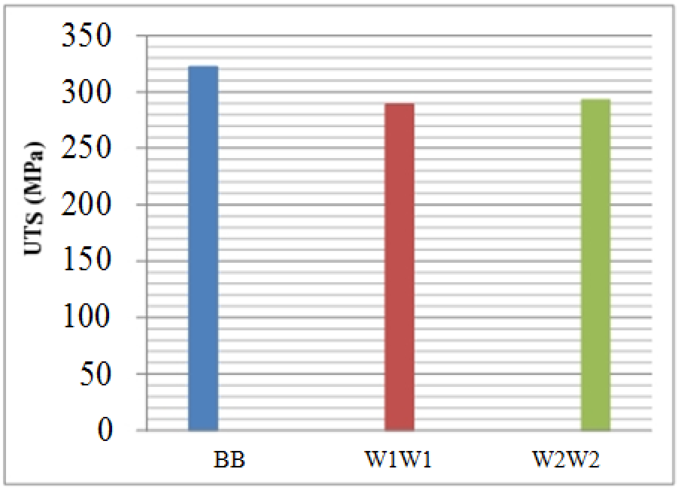
The welded samples are tested to determine its mechanical properties like micro hardness, ultimate tensile strength and % elongation. One tensile test specimen from the base metal and two from welded samples are tested. Microstructural analysis was also done to determine the grain structure. The results obtained were as shown.

Ultimate Tensile Strength (UTS)

Specimens for tensile testing were taken from the middle of all the joints and machined to ASTM E8 standards. Tensile test was conducted using a computer- controlled universal testing machine with a cross head speed of 1 mm/min. All the welded specimens were failed in the heat affected zone. It was observed that maximum tensile strength of 322.07 MPa is obtained for the base metal (BB) while weld samples W1W1 and W2W2 marked UTS of 289.61 MPa and 293.82 MPa respectively. From the above observations it's clear that ultimate tensile strength of the base metal is about 9.4 % more compared to that of base metal. The reasons for this drop in UTS can be revealed by conducting a detailed micro structural study and SEM imaging.

Ultimate Tensile Strength (UTS) of tensile specimens

Expt. No.	Material	UTS (MPa)
1.	Base metal (BB)	322.07
2.	Weld sample (W_1W_1)	289.61
3.	Weld sample (W_2W_2)	293.82



% Elongation Test

Specimens for % elongation testing were taken from the middle of all the joints and machined to ASTM E8 standards. The test was conducted using a computer- controlled universal testing machine with a cross head speed of 1 mm/min. The result shows that the base metal (B) elongated 15.90% of its actual length while weld samples W1W1 and W2W2 elongated only 12.79% and 12.83% respectively. The reasons for drop in % elongation and cause of brittle fracture of the weld samples may be disclosed by conducting a detailed micro structural study and SEMimaging.

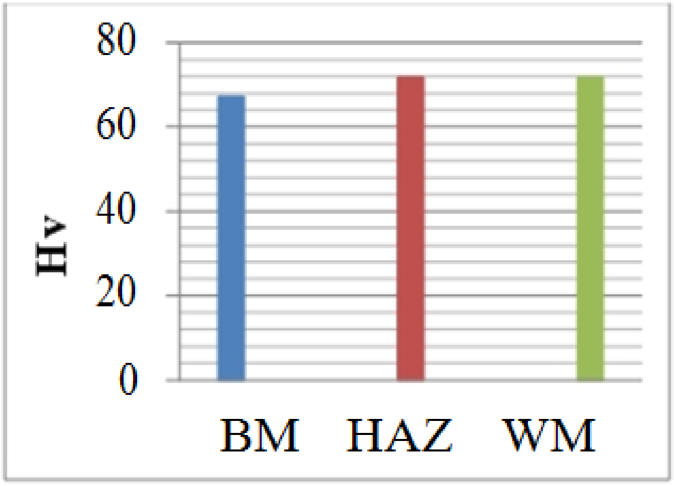
Expt. No.	Material	% Elongation
1.	Base metal (BB)	15.90
2.	Weld sample (W_1W_1)	12.79
3.	Weld sample (W_2W_2)	12.83

Micro Hardness Test

The term hardness is defined as the ability of a material to resist permanent indentation or deformation when in contact with an indenter under load. Three samples (Samples A, B & C) for micro hardness test were cut along the traverse direction to that of the weldment. For hardness measurement Vickers micro hardness tester with 0.3 kg load was used. It contains a square-base pyramid indenter. It contains an optical arrangement to view the indentation without disturbing the specimen. This facilitates the researcher to investigate the hardness at prescribed distances from the previous one. The face angle between of the indenter is 136^0. In this test, the force was applied smoothly, without impact and held in contact for 30 seconds. After that, the force was removed slowly such that the indentation is not affected. The measurements were taken across the diagonals of the square and the hardness value corresponding to the readings was obtained from the chart.

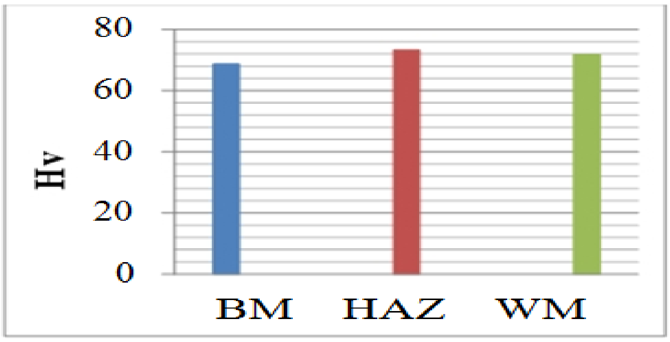
Micro hardness test result of sample A

	Base metal	HAZ	Weldment
Hardness value	67.2	71.8	71.8



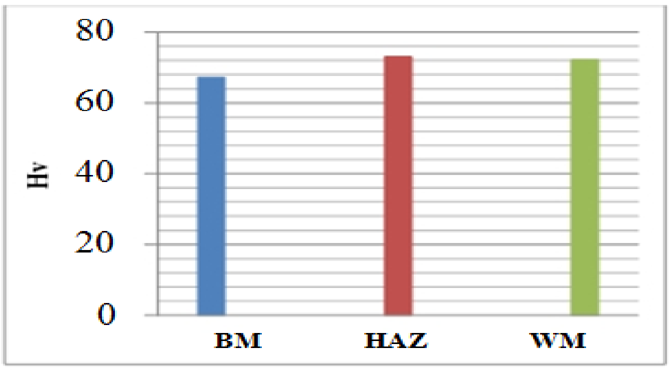
Micro Hardness Test (Sample B)

	Base metal	HAZ	Weldment
Hardness value	68.7	73.2	71.7



Micro Hardness Test (Sample C)

	Base metal	HAZ	Weldment
Hardness value	67.2	73.1	72.1



4. CONCLUSION

Pulse Current Welding process has many advantages over Constant Current Welding, including enhanced arc stability, increased weld depth/width ratio, narrower HAZ range, reduced hot cracking sensitivity, refined grain size, reduced porosity, low heat input, lower distortion of gas by weld pool and better control of the fusion zone. Pulsed current welding technology has been widely used in fabrication of high pressure air bottles, high pressure gas storage tanks, rocket motors, structures in aerospace applications such as aircrafts, rockets and missiles. Switching between predetermined high and low level of welding current can be used to produce pulsed current gas tungsten arc welds

The effect of pulsed current gas tungsten arc welding (PCGTAW) on mechanical and Microstructural properties such as ultimate tensile strength (UTS), percentage elongation, hardness (Hv) & Microstructural details of duplex stainless steel weldment welded filler material has been studied and the following conclusions are made.

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