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Evaluation of Mechanical and Metallurgical Characteristics of the Butt-Welded Mild Steel SA 266 GR.2 & SS 316 Stainless Steel by Gas Metal Arc Welding Process

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A B S T R A C T

Click here and insert your abstract text. Gas metal arc welding in butt joint is made with SA 266 GR.2 and SS 316 using the gas metal arc welding process. Comparing the mechanical properties and metallurgical properties of Butt joint made by varying the welded joints in mild steel to mild steel (SA 266 GR.2) & stainless steel to stainless steel (SS 316) & mild steel to stainless steel (SA 266 GR.2 & SS 316) grades in both similar and dissimilar welded joints with various parameters. To analyze the mechanical behavior of the weld Tensile test, Charphy impact test, Bend test and Vickers hardness are conducted. To analyze the metallurgical behavior microstructure and macrostructure examinations and welding chemical compositions are done in the different zone of weld joint.

Keywords: Tensile test, Charphy, Vickers, microstructure, macrostructure

1. Introduction

In engineering Stainless steel and its alloys are widely used in aerospace, automotive and building industries due to its good ductility, resistance to corrosion, high strength and low cost. Conventional fusion welding of stainless steel and its alloys involves melting of the material which results in the modification of the microstructure to modify the mechanical properties. Therefore, liquid state welding is preferable for the welding of stainless steel and its alloy. Gas metal arc welding (GMAW) is a semi-automatic or automatic arc welding process in which a continuous and consumable wire electrode and a shielding gas are fed through a welding gun. In case of GMAW, a constant voltage DC power supply is most commonly used, however a constant current AC power supply can also be used. In gas metal arc welding, the heat is produced by an electric arc incorporating a continuous feed consumable electrode that is shielded by an externally supplied gas. The process of GMAW requires a welding gun, a source of electric power supply, an electrode wire feed unit, and a source of shielding gas. The welding gun guides the electrode wire, current wire and shielding gas tube. In GMAW, the self-regulation of the arc length is maintained by a constant voltage power supply with a constant wire feed speed unit. MIG is similar to MMA in that heat for welding is produced by forming an arc between a metal electrode and the work piece; the electrode melts to form the weld bead. The main differences are that the metal electrode is a small diameter wire fed from a spool and an externally supplied shielding gas is necessary. As the wire is continuously fed, the process is often referred to as semi-automatic welding. The shielding gas performs a number of important functions in GMAW. Higher deposition rates, Better production efficiency, easily automated for these advantages GMAW process is preferred for this experiment.

In this study SA 266 GR.2 and SS 316 were joined in different ways using the Gas Metal Arc Welding process has investigated to find the better joint for the applications. The current, voltage and travel speed are constant for all different joints. 180A to 220A current, 25V volt and travel speed of 40 cm/min. The length of 50cm and breadth of 25cm plate of each are machined and then welded with given parameters.

2. Experimental Procedure

In this study the SA 266 GR.2 and SS 316 of 5mm plates are welded using GMAW process was carried out using GMAW welding machine. The specimen was prepared in the dimensions 500mmx250mmx50mm. The chemical composition and mechanical properties of SA 266 GR.2 and SS 316 is tabulated in table. Welding was carried out with the current, voltage and travel speed mentioned above. The weld was performed with three different joints SA 266 GR.2 and SA 266 GR.2 & SS 316 and SS 316 & SA 266 GR.2 and SS 316. The filler rod used here is Filler Rod-ER308L-Si. After the welding the specimens were prepared using the wire cut EDM for various tests to get the mechanical properties. Tensile test was carried out using INSTRON 8801 UTM according to ASTM E8/E8M standards for sub size specimen and evaluates the yield tensile strength, ultimate tensile strength and percentage elongation. In the macro examination the different zones present in the specimen were observed such as stir zone or weld zone, TMAZ (Thermo Mechanically Affected Zone), HAZ (Heat Affected Zone) and base metal or parent metal. The microstructural examination was carried out using metallurgical microscope using etchant as with etching time of 10 sec and magnification of 100x to find the microstructure of various zones. Micro hardness was done using Vickers micro hardness tester with load 100gf and dwell time of 10 sec.

Table 1 chemical composition of base metal SA 266 GR.2 and SS 316 in weight %

Elements	Fe %	Si %	C %	Mn %	P %	S %	Cr %	Mo %	Ti %	V %	Cu %	Nb %	N %
SA 266 Gr.2	96.73 5	0.61 6	0.10 9	1.23 9	0.02 3	0.01 6	0.04 8	0.00 1	0.00 7	0.00 6	0.04 7	0.18 3	0.83 9
SS 316	69.03 4	0.44 5	0.03 4	1.14 0	0.01 8	0.00 9	18.48 2	0.22 7	0.00 1	0.03 6	0.05 6	0.37 2	0.21 3

Table 2 Mechanical properties of base metal SA 266 GR.2 and SS 316

PROPERTIES	SA 266 GR.2	SS 316
Yield tensile strength (MPa)	485 - 655	500 - 700
Ultimate tensile strength (MPa)	250	240
Percentage elongation	20	35
Hardness Vickers (HV)	210	200

The Chemical composition of the both base material in weight % of the alloying elements are mentioned in the Table 2.1. The Mechanical properties of the base material is also mentioned in the table 2.2.

Table 3 Process Parameters

S, No	Material 1	Material 2	Current (A)	Voltage (V)	Traveling Speed (cm/min)
1	SA 266 GR.2	SA 266 GR.2	200	25	40
2	SS 316	SS 316	200	25	40
3	SA 266 GR.2	SS 316	200	25	40

Fig. 1 – Welding of (a) SA 266 GR.2 & SA 266 GR.2 (b) SS 316 & SS 316 (c) SA 266 GR.2 & SS 316

The fig 2.1 shows the picture of welded samples of different joints. After the weld the material machined for various test according to the standard measurements.

3. Results & Discussion

Various tests are carried out for the material. The results are compared to get that which combination of the weld have greater mechanical properties.

3.1 Tensile Test

Table 4 Tensile test result of weld samples

Sample	Tensile strength (MPa)	Yield strength (MPa)	Elongation	Fracture Location
SA 266 GR.2 & SA 266 GR.2	496.39	387	10	HAZ
SS 316 & SS 316	536	443	11.50	HAZ
SA 266 GR.2 & SS 316	541.97	432.67	14	HAZ

Fig 2 Trail 1 & 2 tensile results samples of (a) SA 266 GR.2 & SA 266 GR.2; (b) SS 316 & SS 316 (c) SA 266 GR.2 & SS 316

Each sample undergone 2 trails both trail value are taken and the above mentioned value are the average of 2 trails. The maximum tensile strength is obtained in dissimilar combinations of the weld with the value of 541 MPa than similar weld combinations.

3.2 Bend Test

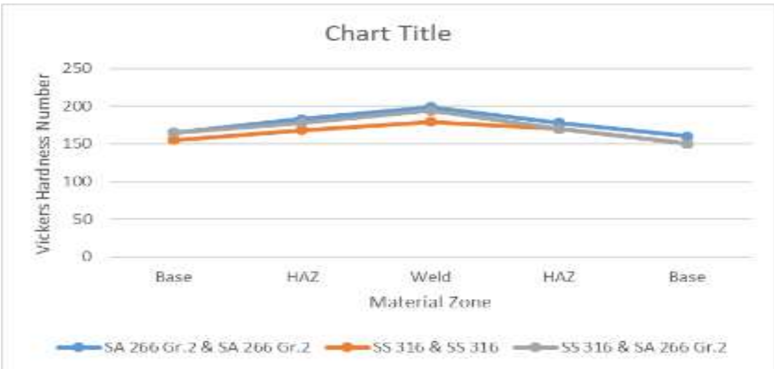
The bend test is one method for evaluating ductility, but it cannot be considered as a quantitative means of predicting service performance in all bending operations in mandrel in four times of thickness in welded samples. Testing of 2 trail sample none of the samples are fractured or cracked. So all the samples are having greater ductility.

Fig 3 Bend test samples

3.3 Microhardness Survey

Table 5 Hardness survey of welded samples

Combination	Base	HAZ	Weld	HAZ	Base
SA 266 Gr.2 & SA 266 Gr.2	165	183	199	178	160
SS 316 & SS 316	155	168	179	170	150
SS 316 & SA 266 Gr.2	165	178	194	170	150



Graph 1 shows a Vickers hardness survey of the welded samples

3.4 Impact Test

The Charpy impact test is to determines the amount of energy absorbed by a material during fracture. The impact test temperature is (+20°C) and sample dimension are 10x10x55mm.

SA 266 Gr.2 & SA 266 Gr.2 **SS 316 & SS 316** **SS 316 & SA 266 Gr.2**

Fig 4 Impact test samples

Table 6 shows the Impact values of the weld samples

Combination	Base (J)	HAZ (J)	Weld (J)	HAZ (J)	Base (J)
SA 266 Gr.2 & SA 266 Gr.2	156	193.33	234	192	155
SS 316 & SS 316	193.33J	126.67J	176.67J	125	193
SS 316 & SA 266 Gr.2	118J	105.33J	173.33J	169.33J	231.33J

3.5 Microstructural Evaluation

The sample are prepared for the microstructural evaluation under metallurgical microscope. The specimen first polished and then etchant is applied on the surface of the specimen for the dwell time of 10sec. The etchant used is 4% Nital & Glyceregia. The microstructures are carried under 100x magnification. In the weld interdendritic structure formed. In the HAZ microstructure shows complete fusion between weld & base.

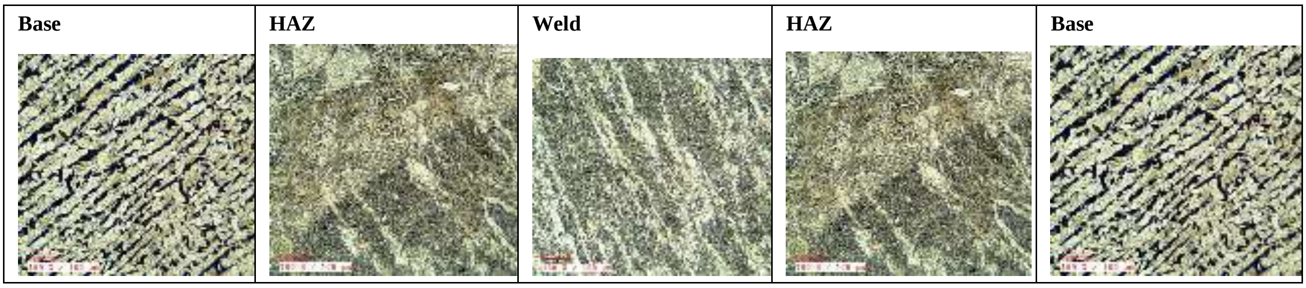


Fig 5 shows SA 266 Gr.2 & SA 266 Gr.2 Weld microstructure

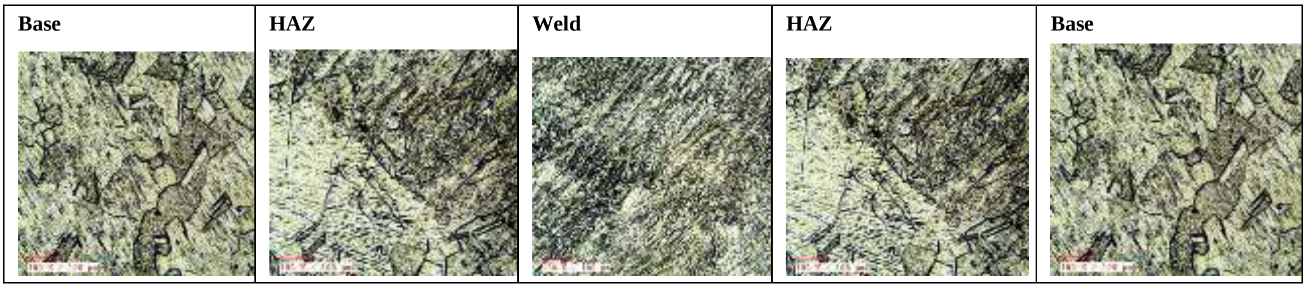


Fig 6 shows SS 316 & SS 316 Weld microstructure

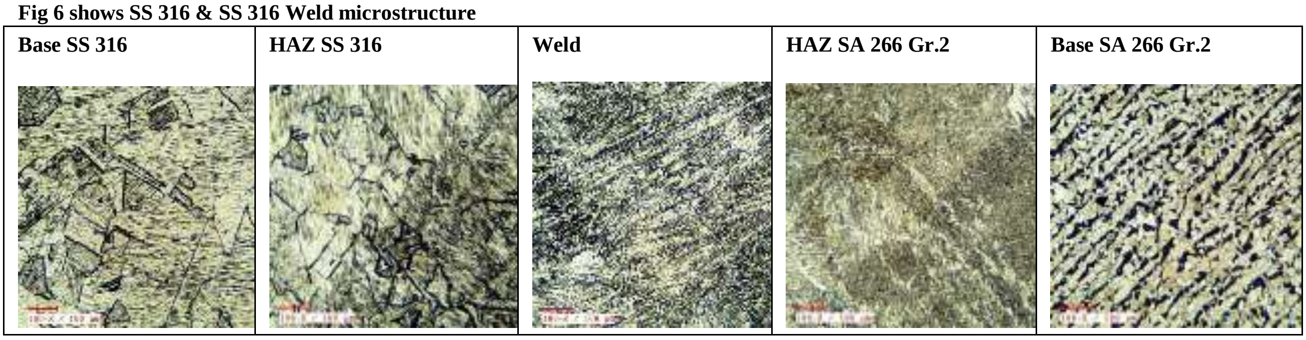


Fig 7 shows SS 316 & SA 266 Gr.2 Weld microstructure

3.6 Macrostructure Evaluation

The macro etched sample examined visually and followed by stereo microscope under 10X magnification reveals, free from macro defects like crack, pin hole, porosity, flute, gassy, tear, splash, pattern and flakes. ASME SEC IX in macro like weld defects in SA 266 Gr.2 and SS 316 Different welded materials.

ROOT-SA 266Gr.2 & SA 266Gr.2 **ROOT-SS 316 & SS 316** **ROOT-SA 266 Gr.2 to SS 316**

FACE -SA 266Gr.2 & SA 266Gr.2 **FACE -SS 316 & SS 316** **FACE- SA 266 Gr.2 to SS 316**

Fig 8 The Macrostructure pictures of the welded samples

4. Results & Discussions

The study of effect process parameter of GMAW welded SA 266 Gr.2 and SS 316 is studied. From that the following conclusions are made.

- The highest tensile strength is obtained in dissimilar weld of SA 266 Gr.2 and SS316. The Tensile Strength is 541 MPa.
- The bend test is conducted for all the samples. In the all samples no crack is observed. So the weld sample has more ductility.
- The Vickers Hardness number is also high in the dissimilar weld SA 266 Gr.2 and SS316. The maximum Vickers hardness numbers 196 in the weld zone. This implies the bonding is stronger than the base metal.
- In the charpy impact test observed that weld is strong in similar weld of SA 266 Gr.2 than dissimilar weld of SA 266 Gr.2 and SS 316 with the average value of 234J.
- In the microstructure evaluation of the welded samples is studied to conclude that interdendtritic structures are formed.
- In the macro examination of the GMAW joint the different zones are viewed and studied from that the weld is crack free, pinhole, porosity.
- The chemical composition test also conducted to check the material grade matches with the standard. The values of samples are perfectly matched with standards

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