EXPERIMENTAL CHARACTERIZATION OF INCONEL-718 BY GTAW PROCESS USING DIFFERENT SHIELDING GASES

[1]C. VenkateshwarReddy, [2]P. Thrilochan Sharma, [3]G. Sainithin.
[1]Asst.prof., Department of Mechanical Engineering, Matrusri Engineering College, Saidabad, Hyderabad.Telangana, India.
[2&3]Students, Department of Mechanical Engineering, Matrusri Engineering College, Saidabad, Hyderabad,Telangana,India.

Abstract: In the present study effect of shielding gases in welding process which results in weld bead characteristics of metal was studied. The welding was carried out by using the GTAW(Gas Tungsten Arc Welding)/TIG (Tungsten Inert Gas) process. GTAW is very commonly used in the areas such as rail, car manufacturing, automotive and chemical industries. The materialInconel718 is a nickel-based super alloy generally used at elevated temperature applications including turbine engines and power generation because of its superior mechanical properties. In the present experimentation, An attempt was made to study the weld characteristics of Inconel718alloy weld samples with different shielding gases of Argon and Argon-hydrogen gas.

Key words: GTAW, shielding gases, Hardness, NDT, Ultrasonic Test.

I. INTRODUCTION

Inconel718 alloy is a high-strength, corrosion-resistant nickel chromium material suitable for service at temperature ranges from -423° to 1300°F. The easy and economy with which Inconel718 alloy can be fabricated with similar and dissimilar metals. Its good tensile, fatigue, creep, and rupture strength have resulted in its use in a wide range of applications. These components are used for rings, casings and various sheet metal formed parts for aircraft and land-based gas turbine engines and cryogenic tanks. It is also used for fasteners and instrumentation parts. The age-harden able alloy can be readily fabricated, even into complex parts. Its welding characteristics are resistance to post weld cracking results in many applications.

GTAW is a process in which the source of heat is an arc formed in between non-consumable tungsten electrode and the base metal. The arc and the molten weld pool are protected with shielding gas from the atmospheric contamination. The inert gases such as argon, helium, or argon helium mixture are used in this welding process. It is accepted that GTAW is the one of the advanced high- quality metal joining process. The weld quality is effectively recognized by the weld bead geometry, the mechanical properties of welded joints are determined by the dimensions of weld bead. It is very essential to select the welding process parameters for obtaining most favorable weld bead characteristics. Ultrasonic Testing (UT) is the most preferred Non-Destructive Testing(NDT) technique for characterization of material properties. The material is volumetric in nature the ultrasonic examination can give an idea about the bulk material properties. The ultrasonic testing parameters are significantly indicate the changes in micro structural or mechanical properties of materials.

II. SAMPLE PREPARATION

2.1 Selection of input parameters and their range:

Based on previous studies, the effect of welding process parameter on weld bead profile characters, the following TIG welding process parameters are considered as input parameters. They are Welding Current (I), Welding Voltage (V), Welding Speed(S), and Shielding Gas (G). The welding process parameters and their ranges are shown in Table 1.

Table 1: Welding Parameters.

Welding Parameter	Notation	Value
Welding Current (Amp)	I	90
Welding Voltage(Volts)	V	50
Welding Speed (mm/s)	S	2
Shielding gas	G	1.Argon 2.Argon (95%)+H2(5%)

Table 2. Welding Process parameters.

Process Parameter	Constant Value
Gas Flow Rate (l/min)	15
Electrode Diameter (mm)	2.4
Electrode Material type	2% Thorated

The nickel based alloy Inconel718 alloy was received from M/S Ashtavinayaka metals was used as a base metal. The thickness of the base metal is 3mm.size is 5mmx5mm.The below table shows the chemical composition of the alloy at laboratory level.

Table 3- Chemical Composition of Inconel718

Alloy Elements	Percentage	Alloy Elements	Percentage
Nickel (plus Cobalt)	50.00-55.00	Aluminum	0.20-0.80
Chromium	17.00-21.00	Cobalt	1.00 max.
Iron	Balance*	Carbon	0.08 max.
Niobium (plus Tantalum)	4.75-5.50	Manganese	0.35 max.
Molybdenum	2.80-3.30	Silicon	0.35 max.
Titanium	0.65-1.15	Phosphorus	0.015 max.
Copper	0.30 max.	Sulfur	0.015 max.
Boron	0.006 max.		

The welding joints have been fabricated by using an automatic TIG welding machine both in continuous mode and pulsated modes. Before welding, the Inconel 718 alloy plates was cleaned to remove the rust, dirt and any surface impurities with the help of acid and wire brush. The edge preparation is made as per the standard procedure. The samples were welded in accordance with the combination of TIG process parameters with Argon as shielding gas and Argon-Hydrogen shielding gas. The thickness of base metal is 3mm a single weld pass procedure is performed to fabricate the test specimens. The photographs of fabricated test specimens are shown in fig 1.

Fig1(a) specimen welded with Argon

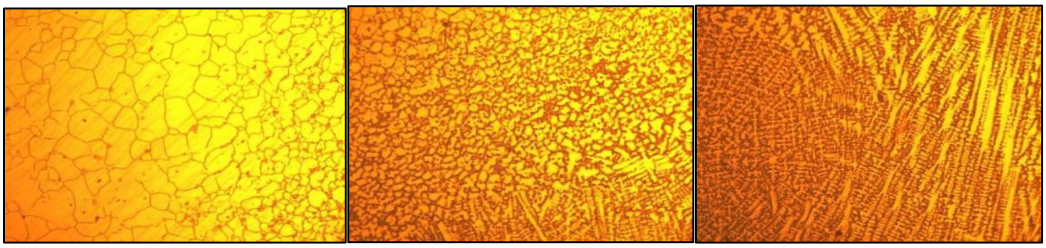
Fig1 (b) specimen welded with Argon-hydrogen

Then the welded samples were cut in small pieces by using abrasive cutting wheel and then some of samples were mounted using cold mounting process. These mounted samples were used to observe micro and macro structural analysis and to perform micro hardness test.

III.RESULTS & DISCUSSION:

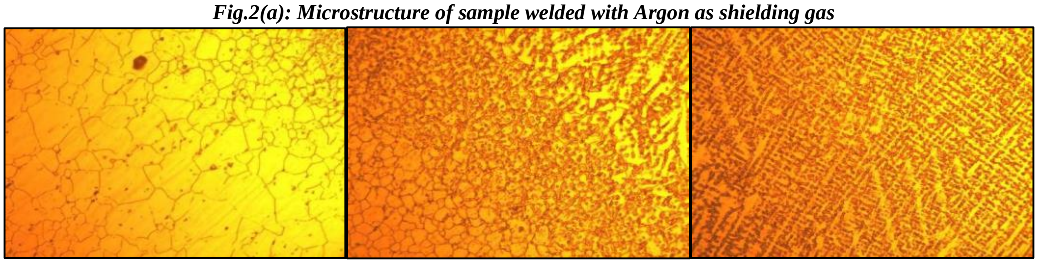
3.1. Microstructure :

The Inconel718 samples welded with Gas Tungsten Arc Welding (GTAW) in two different shielding conditions was studied with standard metallographic techniques and then evaluated using optical microscope with 200X. Microstructure of weld specimens in the weld zone was studied at different regions. Heat input increases when argon-hydrogen is used as shielding gas. Significant grain refinement was observed in HAZ with increases in heat input. It was also found that average dendrite length and inter dendritic spacing in weld zone increases with increase in heat input which is the main reason for observable changes in the microstructure of weld joints welded with different shielding gases.



(a) Base metal (b) HAZ (c) Weld

Fig.2(a): Microstructure of sample welded with Argon as shielding gas



(a) Base metal (b) HAZ (c) Weld

Fig.2(b): Microstructure of sample welded with Argon-hydrogen as shielding gas

3.2. Macrostructure:

To compare the bead size of the both the specimens, their macrostructure was captured at 7X. These bead profile specimens were polished using disc polisher with different grades (320 – 1200 grit sizes) emery papers of different grit sizes and final polishing was done with diamond paste. To expose the bead profile characters the specimens are deeply etched with oxalic acid. Bead Depth (BD) and bead width (BW) were measured using 3D profile projector (make: Sipcon) based on illustration of bead profile shown in Fig. 4. The measured values of WD, WW and DW are presented in Table 4. Then weld bead width and weld penetration are calculated using IMAGE J software from the obtained macrographs of the weld samples.

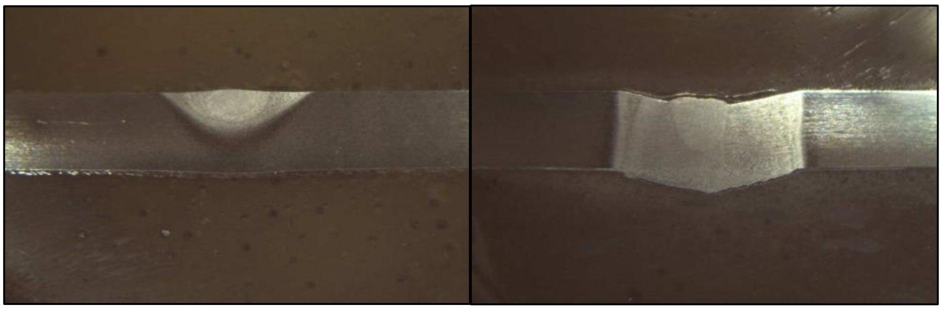


Fig 3. Macrostructure of weld (a) with Argon shielding gas (b) with Argon-Hydrogen shielding gas

Comparing the bead size of the both the specimens, we observed a broader bead along with a deeper penetration in the case of the sample welded with Argon-Hydrogen as shielding gas. Addition of Hydrogen to Argon changes the static characteristic of the welding arc, increases arc power and consequently the quantity of material melted. In GTAW welding with 10% increase in the quantity of hydrogen, melting of parent metal increased by four times. Thus, we get a wider weld bead when we use Argon-Hydrogen as the shielding gas. Ionization potential of Argon-Hydrogen shielding is more than only Argon shielding, resulting a deeper penetration.

Table 4: Bead width of test specimens welded with Argon and Argon-Hydrogen as shielding gas

Shielding Gas	Weld penetration (cm)	Weld Bead width (cm)
Argon	1.8	3.2
Argon-Hydrogen	2.8	2.7

3.3. Micro Hardness:

After the samples were prepared using standard metallographic techniques, they are evaluated using Vickers Micro hardness testing The Micro Vickers hardness test method consists of indenting the test material with a diamond indenter in the form of a right pyramid with a square base and an angle of 136˚ between opposite faces. The test piece was subjected to a load of 500 gm-f, applied for a dwell time of 10 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load were measured using microscope at 50X magnification. Using the MINUTEMAN software the length of the diagonals of indent was measured. And hence using these values the Vicker's Hardness of the specimen is determined at varied positions (at micron distances) along the weld surface ranging from the weld region to the base metal and Hardness Vs distance graph is plotted.

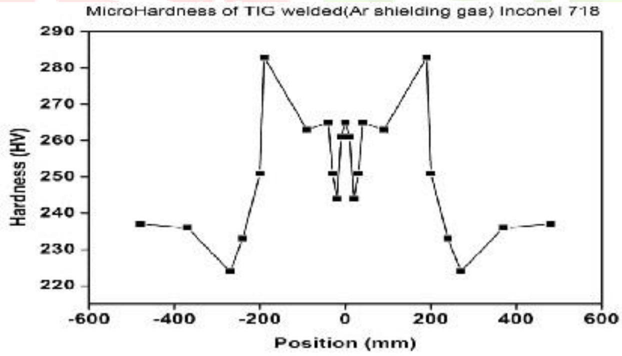


Fig.4 (a) Micro Hardness using Argon Gas

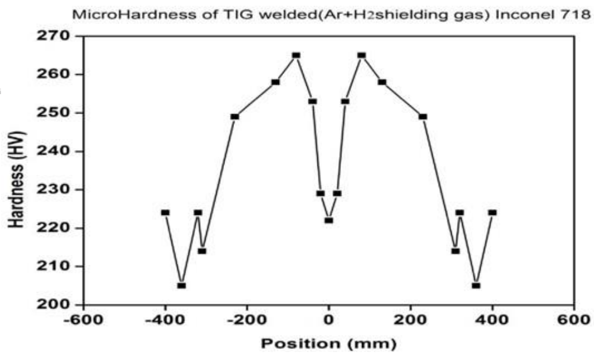
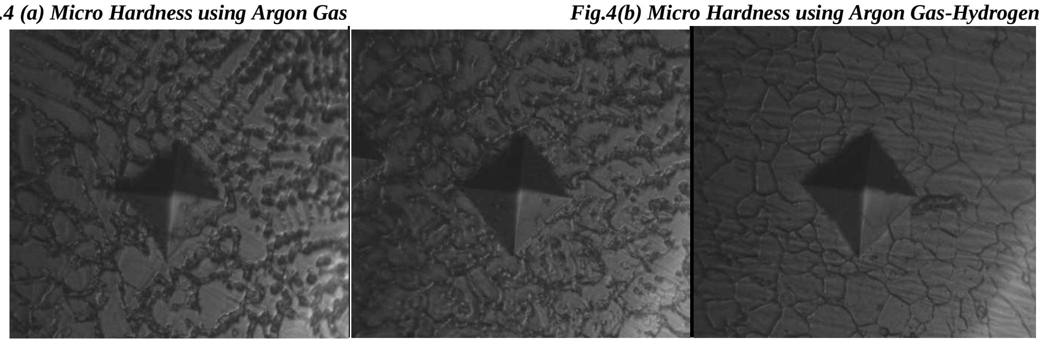
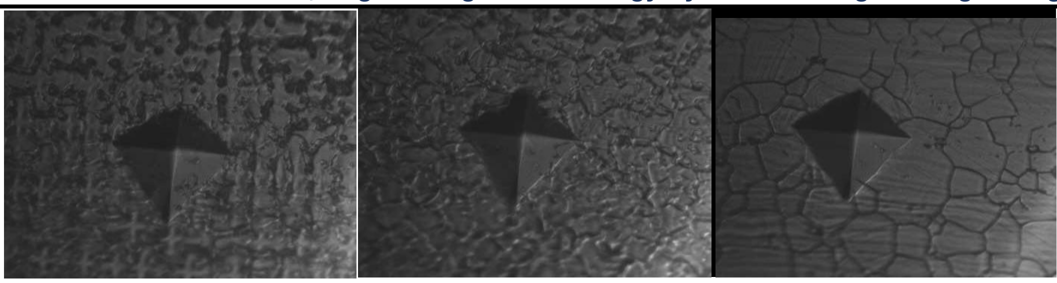


Fig.4(b) Micro Hardness using Argon Gas-Hydrogen Gas



Weld HAZ Base metal

Fig 5: (a)Indentation by vicker's hardness tester on Ar welded samples.



Weld HAZ Base metal

Fig 5: (b)Indentation by vicker's hardness tester on Ar-H_2 welded samples.

The results shows that hardness variation in HAZ is much greater than weld and base metal areas. Analysis of the results showed that each of the experimental variables and interactions had statistically significant effects on one or more of the hardness value measured. It was found that the mechanical properties of the joint in welds were made under the conditions of higher heat input in the case of Argon-Hydrogen shielding, because of which it has lower hardness than the other case.

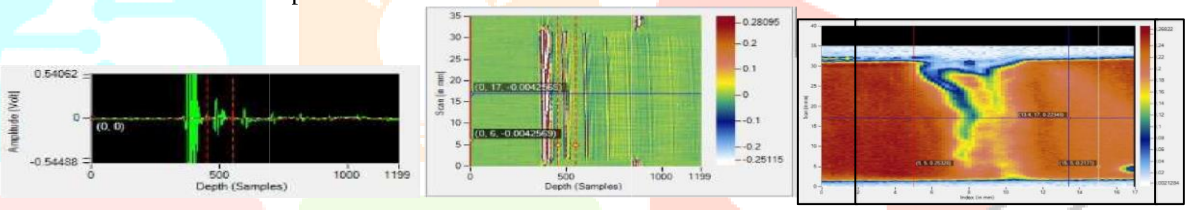
3.4 Ultrasonic Testing:

Ultrasonic data can be collected and displayed in a number of different formats. The three most common formats are known in the NDT world as A-scan, B-scan and C-scan presentations. Each presentation mode provides a different way of looking at and evaluating the region of material being inspected. Modern computerized ultrasonic scanning systems can display data in all three presentation forms simultaneously.

A-Scan Presentation: The A-scan presentation displays the amount of received ultrasonic energy as a function of time. In the A-scan presentation, relative discontinuity size can be estimated by comparing the signal amplitude obtained from an unknown reflector to that from a known reflector.

B-Scan Presentation: The B-scan presentations is a profile (cross-sectional) view of the test specimen. From the B-scan, the depth of the reflector and its approximate linear dimensions in the scan direction can be determined.

C-Scan Presentation: The C-scan presentation provides a plan-type view of the location and size of test specimen features. The plane of the image is parallel to the scan pattern of the transducer. The C-scan presentation provides an image of the features that reflect and scatter the sound within and on the surfaces of the test piece.



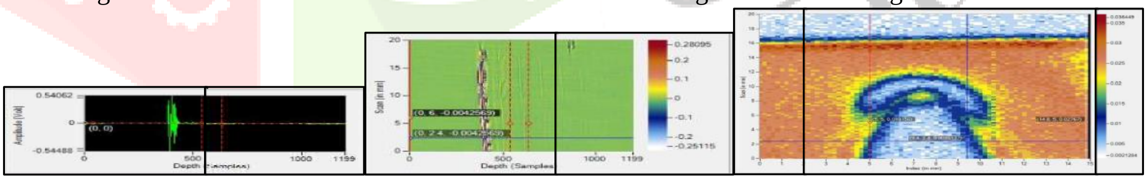
6(a) Ultrasonic A Scan **6(b) Ultrasonic B Scan** **6(c) Ultrasonic C Scan**

Fig.7Observations of Ultrasonic Test for weld specimen using Argon Gas.

Fig 7 (a)shows the absence of defect echo and hence we conclude that there is no defect in the welded specimen.

Fig 7(b)does not characterize the location of the defect as it is not present in the specimen.

Fig 7(c) highlights the base metal region in orange, the HAZ region in pink and the weld in yellow. The blue color highlights the variation in thickness in the weld region because of insufficient heat accumulation in that region as the welding had been started in that area.



7(a) Ultrasonic A Scan **7(b) Ultrasonic B Scan** **7(c) Ultrasonic C Scan**

Fig.8Observations of Ultrasonic Test for weld specimen using Argon Gas- Hydrogen Gas.

Fig 8(a) shows the absence of defect echo and hence the absence of any defects in the weld specimen.

Fig 8(b) characterize the location of the defect as it is not present in the specimen.

Fig 8(c) highlights the base metal in orange, the HAZ in yellow and the weld region in blue colour.

The uniformity in color in the weld region describes the absence of any irregularities and characterizes a continuous weld being done.

$$V_L = \sqrt{\frac{E(1-\upsilon)}{\rho(1+\upsilon)(1-2\upsilon)}} \qquad V_T = \sqrt{\frac{G}{\rho}}$$

Where V is the speed of sound, C_{ij} is the elastic constant in the given direction, E is Young's modulus (or the modulus of elasticity), ν is Poisson's ratio, ρ is the density, and G is the shear modulus, V_L is the longitudinal velocity and V_T is the shear velocity.

Table 5:Weld and base metal characteristics obtained from Ultrasonic A Scan

Shielding gas	Region	Poisson's Ratio	Shear Velocity (m/s)	Longitudinal Velocity (m/s)	Young's Modulus (MPa)	Shear Modulus (GPa)
Argon	Base	0.28	3100	5607.4	36.18	79.28
	Weld	0.225	3100	5405.4	36.81	79.28
Argon-Hydrogen	Base	0.234	3100	5263	37.212	79.28
	Weld	0.196	3100	5042	37.6214	79.28

Shear waves, particles oscillate at right angle to the direction of propagation. They require an acoustically solid material for their propagation and relatively weaker than longitudinal waves. In longitudinal waves, the oscillation occurs in the direction of wave propagation. Compression and expansion forces are active in these waves and they are also called "Density waves, as material density fluctuates as the wave moves. These are the velocities of the ultrasonic rays.

IV. CONCLUSION

From the experimental results, it is observed that the weld properties changed with change in shielding gases while carrying out GTAW welding. The grain size in HAZ region is dendrite length and spacing in weld region is more and deeper weld penetration and a wider bead was observed with Argon-Hydrogen as shielding gas as compared to Argon gas. A shallow penetration and narrow bead was observed from the macrostructure using Argon as shielding gas. Hardness of samples welded with Argon-Hydrogen shielding gas is lower. From Ultrasonic Testing it was found that there are no defects in the weld region. Observing the results of Ultrasonic A scan, the Young's modulus of the weld region is more that of the base metal whereas the Poisson's ratio for the base metal is higher than the weld region. Young's modulus of the specimen welded with Argon is less than that welded with Argon-Hydrogen.

III. REFERENCES

[1] Hirose A, Sakata K, Jobayashi KF (1998) Microstructure and mechanical properties of laser beam welded Inconel 718. Int.J Mater Prof Technol 13 (1-2) : 28-44.

[2] M or tezaie A, shamanian M (2014) An assessment of microstructure, mechanical properties and corrosion resistance of dissimisa welds between Inconel 718 and 310s. austenitic stainless steel. Int J press ves pip 116: 37-46.

[3] James L (1978) Fatigue- crock growth in Inconel 718 weldments at elevated temperatures weld j res suppl 57(1) : 17s -23s.

[4] Wang.H, ileuchi, K, Aritoshi, M, Takahashi, M and Ikeda, A. 2008. Microstructure forming in friction weld of Inconel 718 alloy. Quart J Jpn weld soc, 26(2): 159-166 (In Japanese).

[5] M. Sundararaman and P. Mukhopadhyay, "Carbide precipitation in Inconel 718", High Temperature Materials and Processes, 11 (1993), 315-368.