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Effect of Shielding Gas on Titanium CP (Gr- 2) by using Gas Tungsten Arc Welding

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***Abstract*- This work presents a comparison between different techniques of shielding gas supply for commercially pure titanium grade- 2(as per the AWS D10.6M) by using Gas Tungsten Arc Welding (GTAW) with respect to mechanical properties of weld metal and cost of welding processes. In this work, four type of shielding gases are used, that is pure argon, pure helium, premixed gases of (Ar+He) 75: 25% respectively and alternative gas supply of Argon and Helium. This technology of alternate supply of shielding gas improves every aspect of quality of arc welding. The dynamic motion (stir motion) take place in the weld pool due to various ionization properties of alternate gases supply. The technology of alternate shielding gas supply will improve the strength of the weld metal, welding speed, ductility and reduce crack, porosity, of the welding processes.**

Keywords: Titanium grade-2; GTAW; Shielding Gases.

I. INTRODUCTION

1.1 INTRODUCTION OF TITANIUM

Titanium is not just an ordinary structural material. This metal together with its alloys process a combination of properties which make it suitable for several special purpose application.(Titanium and its alloys have excellent corrosion resistance and a high strength-to-weight ratio, because of which they extensively used in chemical, marine, aviation, space and military fields).

Titanium has a strong chemical affinity for oxygen and a stable, tenacious oxide layer form rapidly on a clean surface even at room temperature on heating this affinity for oxygen increases greatly and at elevated temperatures Titanium has high solubility not only for oxygen but for nitrogen and hydrogen as well.

At temperature near the melting point, Titanium has the property to dissolve discreet amount of its own oxide into solution, these element dissolve intestinally in Titanium small amount of dissolved oxygen and nitrogen significantly increase the hardness of the metal, while dissolved hydrogen reduces the toughness for these reasons titanium requires the use of protective shielding of high purity inert gas lead to contamination of the weld and there by the properties would also be affected.

It has been planned to study the effect of variations in shielding quality on the mechanical properties of the welds commercially pure Titanium.

Titanium and its alloys are classified depending upon the phases it contains. The phases present at room temperature mainly depends upon the interstitial and substitutional alloying elements. Those alloying elements are classified as alpha stabilizers or beta stabilizers depending upon their ability to stabilizer the phase

	Substitutional alloying elements	Interstitial element
α stabilizer	Al	O2, N, C
Beta stabilizer	Cr,Cb,Cu,Fe,Mn,Mo,Ni,Pd, Si, Ta, W , Va	H2
Neutral	Sn,Zr	

TABLE 1.1 Show Alpha Stabilizers And Beta Stabilizers.

II. PROPERTIES OF TITANIUM

Pure titanium is a silver coloured metal. It has a density of about 4.5gram/cc between that of aluminium and steel and is considered a light metal. Its melting point is 1668 c. it undergoes an allotropic transformation from cph (alpha) to bcc (beta) at 855 c on heating. It has resistance to oxidation up to 593 c but is a reactive metal that can pickup and dissolve interstitially, the element H2, o2, and N2. It has a very low thermal conductivity of about 16 W/mk and coefficient of thermal expansion 8.4*10-6 m/mc. Its % elongation treatments are given to modify structure and properties.

Commercially pure titanium usually contain Fe, C, N,O and it as impurities. Depending upon the impurity content, it has a tensile strength varying from 300-700 Mpa. Its young's modulus is 103 Gpa.

2.1 MECHANICAL PROPERTIES

The tensile strength of titanium range from 186 to 586 Mpa, to over 1379 Mpa for its alloys. Titanium and its alloys are as strong in compression as they are in tension for commercially pure titanium compression yield strength, while T-5Al-2.5Sn exhibit slightly higher strengths in compression then in tension Shear strength of titanium and its alloy is normally 60 to 70 % of ultimate tensile strength. The bearing yield strength of titanium and its alloys sheet is roughly 1.2 to 1.6 X tensile strength for an E/D value of 1.5 (ratio of the edge distance E from the centre of the hole to the diameter D of the hold). It is about 1.7 to 1.95X tensile strength for an E/D of 2.0 ultimate tensile strength for an E/D of 1.5 and 0.8 to 2.1X ultimate tensile strength for E/D of 2.0.

Under normal atmospheric conditions the endurance limit of wrought, annealed titanium and its alloys is 0.5 to 0.65X ultimate tensile strengths as determined by rotating beam fatigue tests on un notched bar specimens for 10 million tests. The above value does not take into account the presence of stress raisers, such as corners, notches, holes, rough surface and other discontinuities which reduce fatigue strength appreciably. E.g. under notched conditions (Kt=3.9) the endurance of annealed Ti-6Al-4V is reduced to about 0.2X ultimate tensile strength for 10 million cycles. The hardness of the wrought titanium is usually less than 120Bhn for the highest purity grade. The hardness of other cp grades ranges from 200 to 295 for wrought material and 200 to 220 for castings. The hardness of the annealed titanium alloys is in the range of 32 to 38Rc. Alloys Ti-5Al-2.5Sn and Ti-6Al-4V have hardness of 320Bhn in the as cast condition. The ELI version of the latter alloy has an as cast hardness of 310Bhn.

The tensile modulus of elasticity for cp titanium is in the range of 14.9*106 psi (1.03*105 to 1.07*105 Mpa).

Most titanium alloys have a tensile modulus of 1.1*105 to 1.17*105 Mpa in the annealed condition. Exceptions are Ti-13V-11Cv-3Al 9.79*104 Mpa and Ti-8Al-1Mo 1.27*105 Mpa. Age harden able alloys have a slightly higher tensile modulus in the aged condition. Compressive modulus is equal to or slightly higher than the tensile modulus.

The impact resistance and fracture toughness of titanium and its alloys are inversely affected by increasing strength levels and interstitial content. Charpy V-notch impact strength is in the range of 11 to 40 FT-1b(15 to 54.2J) for cpw roght titanium and about 3 to 8 Ft-1b (4.0 to 10.8J) for tTi-5Al-2.2Sn and 15 to 17 Ft-1b (20.3 to 23) for Ti-6Al-4V. a number at titanium alloys show a high degree of fracture toughness or resistance to creaked propagation. Ti-6Al-4V is an extremely tough material in the annealed condition as shown by notched to unnotched concentration factor up to Kt=10.

The hardness of the cp wrought titanium is usually less then 120Bhn for the highest purity grade. The hardness of other cp grade range from 200 to 295 Bhn for wrought material and 200 to 220Bhn for casting. The hardness of the annealed titanium alloy is in the ranger from 32 to 38Rc.

2.2 ELECTRICAL AND THERMAL PROPERTIES

The electrical resistivity of cp titanium is in the range of 48 to 60 micron-cm at room temperature and increases with increasing temperature reaching 135 to 146 micron-cm ;between' 811 to 1033K. At room temperature the electrical resistivity of titanium alloys is considerably. Higher ranging from 92 micron-cm for Ti-8Mn to 199 micron-cm for Ti-8Al-1mo-1V with most alloy having intermediate valves. The resistivity of titanium alloys also increase with increasing temperature up to a certain point, but at slower rate than cp in the 800 to 1200F (700 to 922K) range resistivity, generally rate with increasing temperatures.

The thermal conductivity of cp titanium is K 9*10 Btu/hrs/sq Ft/F/Ft(15.6 to17.3 w/mk which is similar to that of austenitic stainless steels and is relatively un affected by increasing temperature. The thermal conductivity of titanium alloy is roughly half that of the unalloyed metal and increase with increasing temperatures. The thermal expansively of titanium its alloy is virtually low, ranging from 4.8*10-6in/in/F (8.6*10-6m/m/K) at 32 to 212F(58 to382K) and 5.3*10-6 in/in/F.

2.3 WELDABILITY OF TITANIUM

The weld ability of titanium alloys is closely related to the type of alloy (alpha, alpha+ beta, beta) under consideration. Unalloyed can alpha titanium alloys are usually welded in the annealed condition and appear to present no particular difficulty.

In alpha- beta alloys, the base material consists of small equiaxed alpha grains with in a beta matrix. In the as welded condition the yield and ultimate tensile strength exceeds that the base metal, but accompanied by low fusion zone ductility, particularly with increasing amount of bête-stabilizers. Post weld heat treatment may be used to obtain the required mechanical properties, but it has not always met with success.

During welding weld metal and the HAZ both are take to temperature beyond the beta- transits. Cooling rates from these temperatures and the resulting microstructures and all depends upon the welding process and procedure. The extremely rapid cooling experienced in processes like laser and EBW are likely to result in a fine acicular entirely martensitic microstructure. As the cooling rate decrease, there is an increasing amount of diffusion controlled

Alpha precipitation at prior beta grain boundaries. Some beta may also be retained as the weld metal cools to room temperature. Thus the as welded microstructure may certain alpha, alpha- prime (marten site) and meta stable Beta 9 ° C /sec is the critical cooling rate for Ti-6Al-4V alloy below which no alpha- prime is formed.

Typically the as welded condition is characterised by high strength and low ductility. The latter is attributed to the course prior beta grain size and the largely martensitic microstructures mentioned above, post weld heat treatment can be applied to increasing the ductility but it will decrease the strength. Higher temperature aging of about 900 ° C or even higher arc required if ductility is to be sensibly improved. Higher temperature heat treatment under vacuum may also be beneficial by eliminating small amounts of contaminating elements such as hydrogen in to weld region.

It has been shown may times that processes such as electron beam welding that are characterised by rapid cooling would be advantageous on account of the small fusion zone grain size. Any advantages, however, must be weighed against possible detrimental effect in rapid cooling on non- equilibrium transformation products and thus may actually enhance ductility. It has been shown in the case of Ti-6Al-6V-2Sn weld metal that slower cooling rates promote the nucleation and growth of larger alpha plates, this a enriches the beta phase with beta stabilizers. So that the temperature is lowered and the beta tends to be retained at room temperature such microstructures have better toughness.

Metastable beta- titanium alloys exhibit properties highly desirable in a formable sheet material. Despite an elastic module slightly lower than that of the alpha- beta alloys, good fabric ability in the solution heat- treated condition and an excellent aging response to high strength levels render those alloys ideal candidates for a variety of aerospace structural applications.

The fusion and near HAZ are characterised by a ductile low strength retained beta structure. The weldments contain large columnar grains equiaxed grains in the HAZ. As might be expected , the cooling rates associated with welding and the high proportion of beta- stabilizing elements (such as Mo, V, C, Fe) combine to promote the retention of beta in those regions in the joint which were taken above the super- transus temperature, during welding.

Post weld heat treatment promotes both heterogeneous and homogeneous alpha precipitation in all regions of the weldments. Increased aging temperature render the alpha coarse.

As welded the material has low yield and tensile strength and ductility compared to solution heat treated base material. Aging of the weldments significantly increases strength and corresponding decreases ductility. In general higher aging temperature results in decreased yield strength and increased ductility as well as a trend from trans granular to inter granular fracture.

2.4 APPLICATIONS OF TITANIUM

Titanium and its alloys are used in the following fields:

i. Aircraft gas turbine.
ii. Aircraft skins.
iii. Aircraft body structure.
iv. Steam turbine.
v. Submarine body.
vi. Aircraft landing gear.
vii. Spacecraft structure.
viii. Chemical and petrochemical heat exchangers.
ix. Electrode in fuel cells.
x. Anode for chlorine generation.
xi. Vessels to contain reactive chemicals.
xii. Chemical pumps.
xiii. Helicopter rotor assemblies.

III.EXPERIMENTAL WORK

3.1 BASE METAL

In this work carryout in titanium grade 2 materials to produce quality weld with low cost.

Tungsten inert gas welding is the process that is most widely used for joining titanium and titanium alloys. Titanium is highly reactive and welding must be carefully shielded to prevent H absorption of gases from the atmosphere. Titanium has a strong chemical affinity for oxygen and a stable, tenacious oxide layer forms rapidly on a clean surface, even at room temperature.

At temperature exceeding 500°C, the oxidation resistance of titanium decreases rapidly.

TABLE 3.1 Compositions of the Base Material.

C	O_2	N_2	H	Fe	Ti
0.10%	0.25%	0.03%	0.015%	0.30%	Balance

3.1.1 WORKPIECE GEOMETRY

Material thickness =6 mm

Material length = 150 mm

Material width = 200 mm

Groove type = single V

Groove angle = 70°

Root face = 0.5 mm

Root gap = 1.6 mm

Weld type = butt joint

The following figure () shows base metal of titanium grade 2 setup before welding.

Fig 3.1.1 Titanium work piece

3.2 FILLER MATERIAL

For welding titanium thicker than about 1.6 mm by TIG welding process, a filler metal must be used and its composition is usually matched to grade of titanium being weld. Filler metal is straight length with 800 mm long, 1.6 mm diameter, and composition of filler metal as per AWS classification ERTi-2 was used.

TABLE 3.2 Compositions of the Filler Material.

C	O_2	N_2	H	Fe	Ti
0.03%	0.08- 0.16%	0.015%	0.008%	0.12%	Balance

3.3 WELDING MACHINE

The following details coped from that gas tungsten arc welding machine.

Torch type = water cooled

Electrode type = gray colour (2% ceriated)

Electrode size = 2.4 * 150 mm (AWS A5.12M)

Welding mode = manual

Fig 3.1 GTA welding machine.

3.4 CLEANING

To obtain a good weld, the joint and the surface of the work piece must be cleaned. Solvent cleaning was done for this purpose.

This method is useful for heavier cleaning of stubborn stains. Fold the lens tissue as described in the “brush” technique above, and grip it with your fingers instead of the hemostat. Applying a uniform pressure on the optic edge, slowly wipe across the optic’s face

3.5 WELDING PARAMETERS

Welding parameters too important such as current, voltage, polarity, etc, when increasing current the penetration will increase, and the arc length increase the voltage also will increase automatically.

TABLE 3.3 The Following Parameters Observed When Make Welding With 100% Argon As A Shielding Gas
For Titanium Grade 2

No OF PASSES	CURRENT IN AMPERE (A)	VOLTAGE IN VOLTS (V)	WELDING TIME IN min	SHIELDING GAS PRESSURE
1	120 to 128	10 to 11	3.56	40 lpm
2	130 to 142	11 to 12	2.12	40 lpm
3	146 to 158	10 to 12	3.48	40 lpm

TABLE 3.4 The Following Parameters Observed When Make Welding With 75%Ar + 25% He As A Shielding Gas.

NO OF PASSES	CURRENT IN AMPERE (A)	VOLTAGE IN VOLTS (V)	WELDING TIME	SHIELDING GAS PRESSURE
1	100 to 107	10 to 11	2.56 min	40 lpm
2	110 to 120	11 to 14	2.12 min	40 lpm
3	110 to 115	10 to 15	3.28 min	40 lpm

TABLE 3.5 The Following Parameters Observed When Make Welding With Alternate (Frequency 2.2) Shielding Gas.

NO OF PASSES	CURRENT IN AMPERE (A	VOLTAGE IN VOLTS (V)	WELDING TIME	SHIELDING GAS PRESSURE
1	100 to 120	10 to 12	3.29 min	Ar ; 10 lpm +He; 5 lpm
2	155 to 159	11 to 15	2.50 min	Ar ; 10 lpm +He; 5 lpm
3	150 to 160	14 to 16	1.53 min	Ar ; 10 lpm +He; 5 lpm

TABLE 3.6 The Following Parameters Observed When Make Welding With 100% Helium As A Shielding Gas

NO OF PASSES	CURRENT IN AMPERE (A)	VOLTAGE IN VOLTS (V)	WELDING TIME	SHIELDING GAS PRESSURE
1	60 to 70	10 to 11	2.56 min	40 lpm
2	105 to 110	11 to 12	1.52 min	40 lpm
3	120 to 128	10 to 13	2.28 min	40 lpm

IV. RESULT AND DISCUSSION

4.1 NON- DESTRUCTIVE TESTS

Non – destructive testing of welding structures is mainly used for detecting small flaws or cracks, presence of inclusions or slag and porosity. The most widely used methods are: dry penetrate test, magnetic crack detection, x- ray radiography, etc.

The other three methods are suited for detecting internal flows. X- ray and gamma ray methods use electromagnetic radiations from X- ray tube and radioactive isotopes (co, for instance) respectively, for detection. The rays after passage through the welded structure fall on either a photographic film or a fluoroscopic screen. The fluoroscopic method is less expensive and can be used for routine examination of large number of pieces.

The welding of Titanium grade 2 using four types of shielding gas technique was successfully made with radiographic quality.

4.2 TENSILE TEST FOR WELD STRENGTH ANALYSIS

The transverse butt weld specimen has the tensile axis across the weld. The plastic deformation and failure are usually extended to both the weld metal and the base metal because the gage length can be longer than the weld region. If the weld metal is stronger than the base metal, most of the plastic strain occurs in the base metal with resultant necking and failure outside of the weld area. In such a case, the test indicates that the weld strength is above the ultimate tensile strength achieved in the specimen but not give any indication of the weld quality.

When strength of the weld is lower than that of the base metal, most of the plastic strain occurs in the weld. The result will show low values of elongation, as the deformation is localised in a small portion of the gage length. Therefore, in either case, the transverse weld specimen does not provide a measure of weld ductility. It is mainly employed for determining the joint efficiency in terms of ultimate tensile strength.

The above mentioned radiographic quality welded Titanium plates were prepared for transverse tensile test so as to test the mechanical property of the welds made using four different techniques. The tensile specimens were prepared as per the AWS standards. The tensile specimen dimensions were shown in the diagram.

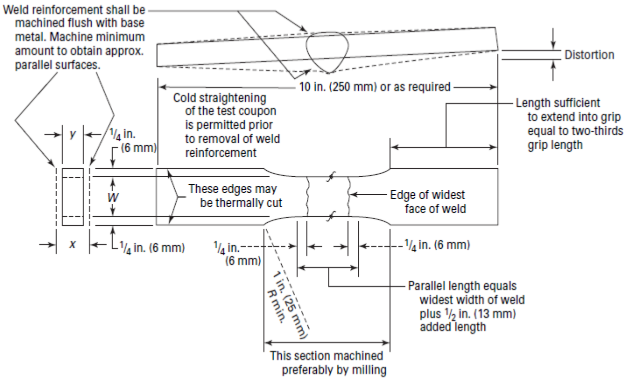

Fig 4.1 tensile test specimen details according ASME IX

The following figure shows work piece for before making tensile specimen.

Fig 4.2 welded job for making tensile test specimen, when alt gases used as a shielding gas.

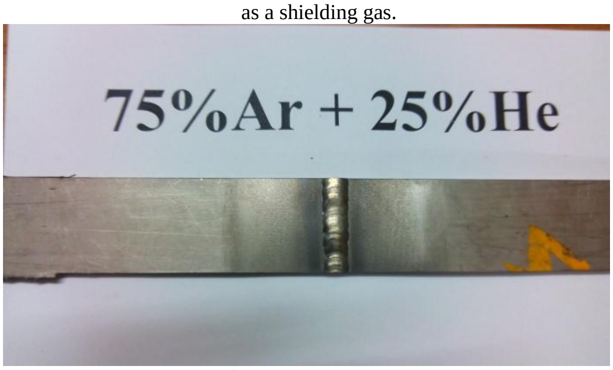

Fig 4.3 shows welded job for making tensile test specimen, when 75% Ar + 25% He used as a shielding gas.

Fig 4.4 welded job for making tensile test specimen, when 100% Ar used as a shielding gas.

Fig 4.5 welded job for making tensile test specimen, when 100% He used as a shielding gas.

4.3 MECHANICAL PROPERTIES

The tensile test results of all four types of shielding gas techniques were tabulated in table (4). It was evident from the table (4) that the tensile strength i.e. weld strength of all four welded Titanium plates were merely same. Thus all the four type of shielding gas techniques produced sound welds.

4.4MICROSTRUCTURALCHARACTERIZATION

Polyhedral interpolation can establish the following approximate co- efficient of hardening caused by impurities within the range of their content in technical-grade titanium.

0.05% oxygen by increase ultimate strength by 60 Mpa
0.05% nitrogen increase ultimate strength by 125 Mpa
0.05% carbon increase ultimate strength by 35 Mpa
0.05% iron increase ultimate strength by 10 Mpa
0.5% silicon increase ultimate strength by 130 Mpa

The test plates produced using the GTA welding processes with different shielding gases were sectioned transverse to weld direction for general microstructure characterization. A metallographic technique was used for preparing the titanium samples for microscopy. This involved polishing with various grades of silicon carbide papers followed by polishing using 15ηm diamond grift. A final polishing was carried out with colloidal silica containing 2% of hydrogen peroxide and 2% of ammonia. The samples were etched with either Kroll's regent (5% nitric acid and 1% hydrofluoric acid in water) which gave a tint etch. The samples were examined using optical microcopy.

The mechanical performance of the weldment particularly with reference to its strength and toughness will depend upon the type of microstructure obtained in weld metal and the HAZ.

The figure shows micro structure of commercially pure titanium of base metal, interface b/w base metal and weld metal and weld metal for shielding gas of100%Ar, 75%Ar+25%He, alternative Ar: He and ,100% He. Which is explain fine grains appeared in the weld metal and heat affected zone (HAZ) with help of alternative shielding gas then the other three shielding methods. Fine grains have more strength then the coarse grain due to more grain boundaries

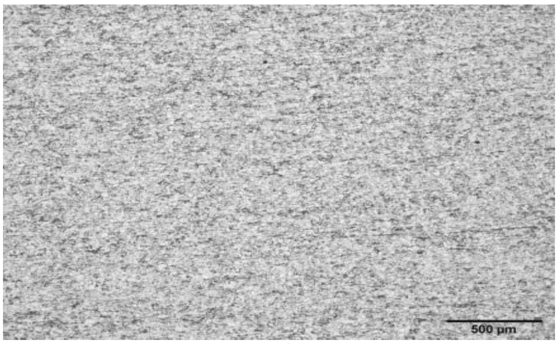

Fig 4.6 microstructure of pure titanium grade 2

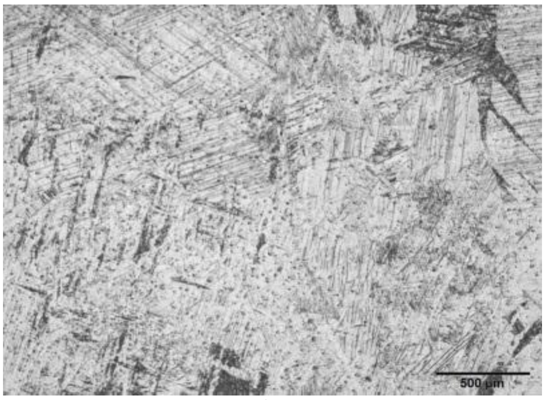

Fig 4.7weld metal microstructure of pure titanium grade 2 with 100% Ar as shielding gas.

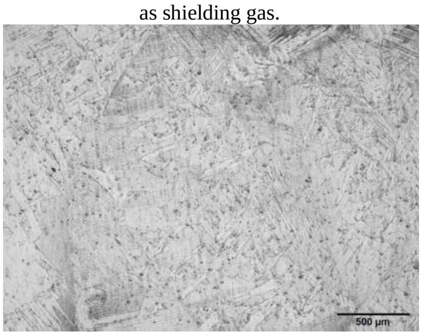

Fig 4.8 weld metal microstructure of pure titanium grade 2 with 75%Ar + 25% He as shielding gas

TABLE 4.1 Mechanical Properties Of Welded Joint By Using Different Shielding Gas

MECHANICAL PROPERTIES				
SHIELDING GASES	*100% Ar*	*75%Ar +25%He*	*ALT Ar:He*	*100% He*
ULTIMATE TENSILE STRENGTH IN Mpa	626	649	670	606
YIELD STRENGTH IN Mpa	596	590	610	552
PRECENT ELONGATION	10	12	12	11
PERCENT REDUCTION OF AREA	26	21	7	25
LOCATION OF FRACTURE	BASE METAL	BASE METAL	BASE METAL	BASE METAL

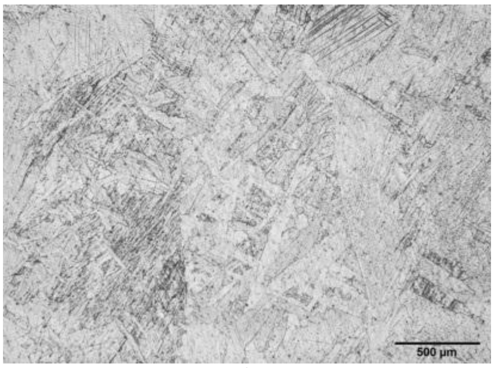

Fig 4.9 weld metal microstructure of pure titanium grade 2 with alt gases as shielding gas

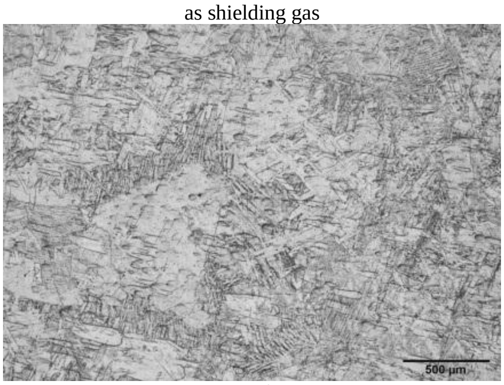

Fig 4.10 weld metal microstructure of pure titanium grade 2 with 100% He as shielding gas

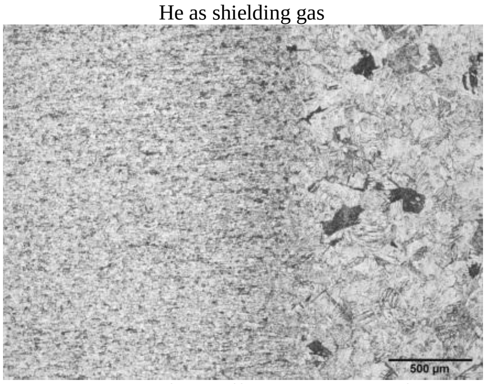

Fig 4.11 microstructure of heat affected zone (HAZ) for 100% Ar as shielding gas

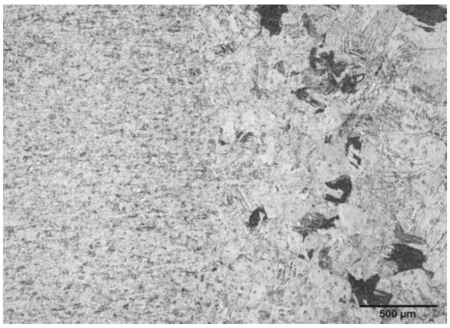

Fig 4.12 microstructure of heat affected zone (HAZ) for 75%Ar + 25% He as shielding gas

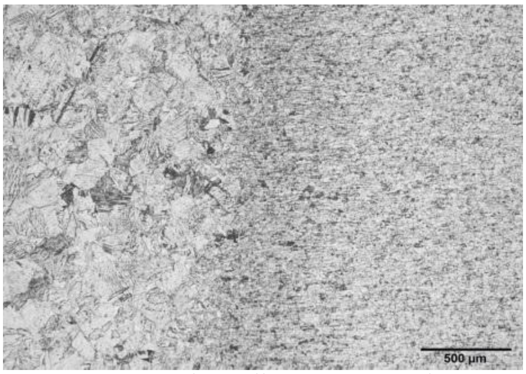

Fig 4.13 microstructure of heat affected zone (HAZ) for alt gases as shielding gas

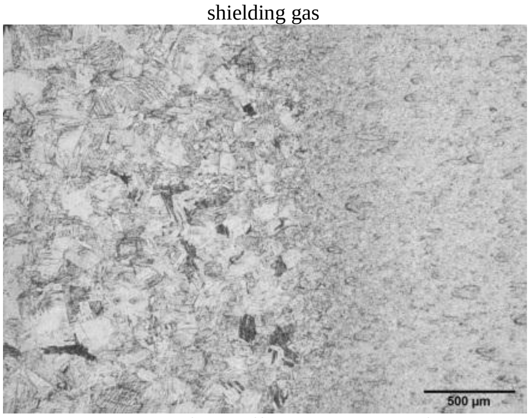

Fig 4.14 microstructure of heat affected zone (HAZ) for 100% He as shielding gas

4.5 GAS CONSUMPTIONS

The cost evaluation of the all four shielding gas techniques was done so as to compare these four techniques. Since the all other factor deciding the cost of weld like man power cost, power supply cost, filler wire cost, Base metal cost, Welding machine depreciation cost are same for all four shielding gas techniques; the cost of shielding gas consumed was the deciding factor of the cost of weld.

For the total volume of gasses used the cost of shielding gas techniques were evaluated and given in table.

TABLE 4.6 Amount of Gas Consumed When Made Weld

TYPE OF GASES	AMOUNT OF GAS IN LITERS
100% ARGON	315
75%Ar+25%He	102 Ar &34 He
ALT Ar:He	40 Ar &20 He
100%HELIUM	222

V. CONCLUSION

The possibility of using alternate shielding gas technique in Titanium Grade 2 welding was stated. It was evident from the tensile results that the all four shielding gas techniques including alternate gas technique produce good quality welds.

It is obvious from the table (14) that the amount of alternate shielding gas technique was lower that of the 100% helium used as shielding gas.

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