EXPERIMENTAL INVESTIGATION INTO THE EFFECT OF GAS TUNGSTEN ARC WELDING ON Ti-6Al-4V

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ABSTRACT- An experimental investigation of enhancing mechanical properties of pulsed and non pulsed frequencies like 2, 4, 6, 8 Hz using Gas Tungsten Arc Welding on Ti-6Al-4V is presented. Butt welding of 2mm thickness titanium sheets is prepared by TIG Welding using argon gas as shielding gas. Evaluating weld ability of Ti-6Al-4V by welding conditions such as welding pass, amount of shielding gas and welding time interval is done. Experimentswere performed on titanium using destructive, non destructive tests and tensile tests are done so as to determine the ultimate tensile strength, yield strength and % elongation.

Index Terms –Welding, NDT, Shielding gas, Titanium

I.INTRODUCTION

Welding of titanium structures is a cost effective manufacturing methods for numerous components used in aerospace applications. Titanium has high specific strength and excellent corrosion resistance and is extensively used in aerospace, missiles and marine applications. Titanium grade 5 is the most commonly used alloy which is considered to be alpha-beta alloy The dual phase, i.e. alpha + beta alloys offer a combination of excellent ductility and strength when proper heat treatment is given, which makes them stronger than alpha-phase and beta-phase. With the increased use of Ti, the joining of titanium has become more and more important. Welding of titanium alloy is difficult because titanium is chemically reactive at high temperatures. The studies have shown that during welding, titanium alloys pick up oxygen and nitrogen from the atmosphere easily .With the development of titanium in industries, Tungsten Inert Gas (TIG) welding is the most commonly used welding method for titanium.

The welded joint significantly affects the mechanical properties of the welded zone depending on the welding materials, welding conditions and welding environment. Like most titanium alloys, Grade 5 has outstanding resistance to corrosion in most natural and many industrial process environments.

II. EXPERIMENTATION

In this experimental investigation Ti-6Al-4V i.e., four number titanium grade 5 sheets of 150 $mm\ x\ 300mm$ dimension and thickness of about $2mm$ are taken. They are subjected to Gas tungsten arc welding.

1. Ti sheets

Titanium gr-5 sheets are rarely available. They are cut according to the dimension mentioned by wire cut EDM carefully .No. of sheets used for welding are four.

2. Filler metal

For welding titanium Gr-5 of 2mm thickness by TIG welding process, a filler metal must be used and its composition is usually matched to the grade of titanium being weld. Filler metal in straight length with 150 mm long and 2 mm diameter was used for the experiment.

3. Shielding gas

Usually argon and helium are used for shielding in welding titanium. Argon is more widely used, since it is readily available and less costly. In this study Argon is used as shielding gas with flow rate at 10L/min.

4 Joint preparation :

Since the welding was carried out outside the welding chamber, without using travelling cup the joints were carefully designed so that both the top and the underside of the weld can be shielded. Groove was selected as 70° as the thickness of the base metal was $2mm$

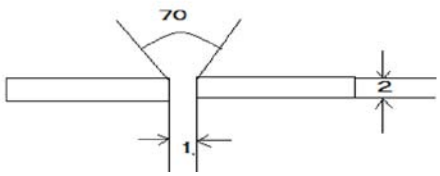


Fig.1 V groove angle

5 Welding

In this experiment, the welding of titanium was carried out using thorium electrode. Welding is carried out on a C clamp arrangement on which titanium sheets are welded and welding parameters are considered.

Fig.2 Welding of Ti-6Al-4V sheets

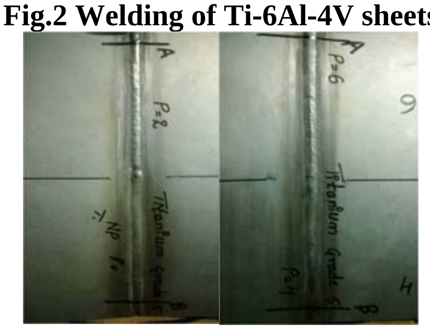


Fig.3 Welded pieces of Ti-6Al-4V

Table 1. Chemical composition of titanium

Aluminum	Iron(Fe)	vanadium	oxygen	titanium
6	Max 0.25	4	Max 0.2	90

III.NON DESTRUCTIVE TESTING

The main purpose of NDT is the detection of different material properties, especially non-homogeneities or defects, without mechanical damage of a tested object.

Methods of NDT USED

Most commonly used methods are:

1. Penetration testing
2. Radiography

1. Radiography:

Radiographic testing is a non destructive testing method of inspecting materials for hidden flaws by using the ability of short wavelength electromagnetic radiation to penetrate various materials. An x-ray machine can be used to detect the flaws in the specimen. Areas of the film exposed to less energy remain lighter. Therefore, areas of the object where the thickness has been changed by discontinuities, such as porosity or cracks, will appear as dark outlines on the film.

Fig.4 Radiography testing equipment

2. Dye Penetrant

It is a widely applied and low-cost inspection method used to locate surface-breaking defects in all non-porous materials. In this method a liquid penetrant is applied to the surface of the product for a certain predetermined time, after which the excess penetrant is removed from the surface. The surface is then dried and a developer is applied to it. The penetrant which remains in the discontinuity is absorbed by the developer to indicate the presence as well as the location, size and nature of the discontinuity.

Table-2 Parameters taken into consideration while conducting DP

PARAMETER	DESCRIPTION
Material	Titanium
method	Visible, Solvent removable
Dwell time and temperature	15 min at room temperature
Acceptable standard	ASTM-E-165
Developer	M/s. The oriental chemicals work

3. TENSILE TESTING

Tensile testing is a fundamental test in which a sample is subjected to a controlled tension until failure. The most common testing machine used in tensile testing is the universal testing machine.

Fig.5 Tensile specimens of Ti-6Al-4V

IV. RESULTS AND DISSCUSSION

Table 3-Basic parameters noted while welding

Frequencies	Electrode	Peak Current(IP)	Shielding Gas L/min	Base current(IB)	Weld time Min	Welding speed Cm/min
Non pulsating	thorium	86	10	40	2:06	12.5
2 pulse	Thorium	90	10	39	1:30	12.5
4 pulse	thorium	89	10	35	2:27	12.5
6 pulse	thorium	86	10	40	1:29	12.5

Porosity and Cracks

According to the ASME SEC XI slandered with film size of 4o cm and focal spot size of 2×2 mm and density at about 1.8 to 3 $g/cm3$.Ti-6Al-4V is given for radiography to check for flaws and detects if any. Finally the results showed that the test pieces are acceptable that means the flaws are within the acceptable limit.

Fig.6 X-Ray of the titanium gr-5 after radiography

Table 4 Radiography Test Results

Sl.No.	Pulsed/non pulsed welding	Frequency Hz	Physical observation
1	Non - pulsed	-	No defect seen
2	Pulsed	2	No defect seen
3	Pulsed	4	Acceptable
4	Pulsed	6	Acceptable
5	Non - pulsed	-	Acceptable
6	Pulsed	2	Acceptable
7	Pulsed	4	No defect seen
8	Pulsed	6	No defect seen

Cracks in the Weldments

According to the ASTM E-1417 [23], the Dye-Penetrant (DP) test was conducted on these weldments. The test results are shown in table 12. The experimental results show that no cracks were observed in the weldments of this alloy in non-pulsed current and pulsed current welding.

Table – 5 Die penetration test results

Sl. No.	Pulsed /non pulsed welding	Frequency *(Hz)*	Physical observation
1	Non - pulsed	-	No defect observed on welded area
2	Pulsed	2	NDOWA
3	Pulsed	4	NDOWA
4	Pulsed	6	NDOWA
5	Non - pulsed	-	NDOWA
6	Pulsed	2	NDOWA
7	Pulsed	4	NDOWA
8	Pulsed	6	NDOWA

Note : NDOWA-No defect observed on welded area

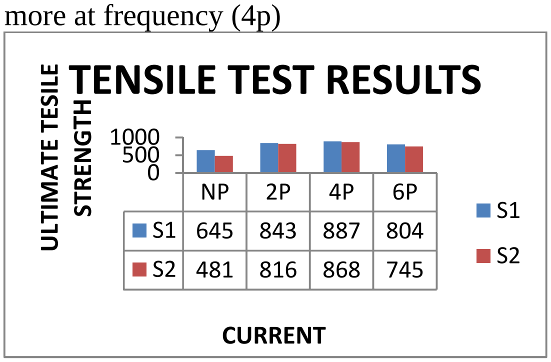
Table -6 Tensile test results

Specimen description	Yield stress Mpa	Tensile strength $n/mm2$	% elongation
2 pulse sample no.1	640.6	843.5	3
2 pulse sample no.2	642.6	816.3	3
4 pulse sample no.1	768.7	887.5	3
4 pulse sample no.2	683.2	868.2	2
6 pulse sample no.1	630.9	804.2	2
6 pulse sample no.2	593.9	745.3	2
Non pulse sample no.1	509	645	1
Non pulse sample no.2	380	481.4	2

The tensile specimens were failed inside the weldments Non pulse and 6p (sample 2). The effeciency is calculated from ultimate tensile strength (UTS) of weldments in comparison to the base metal UTS. The results presented were best values obtained from two trails.

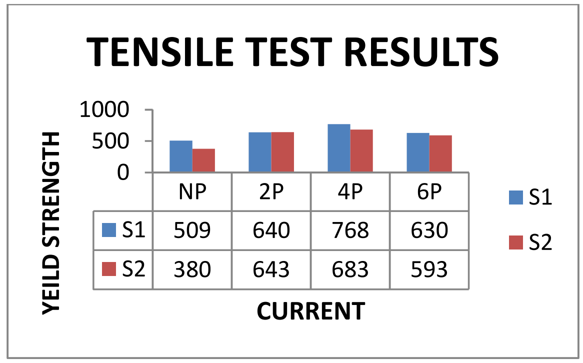
❖ Effect of Current on Tensile Strength

The Filler wire 4p produced maximum ultimate tensile strength i.e., 887.21Mpa. From the graph, it is observed that the ultimate tensile strength is more at frequency (4p)



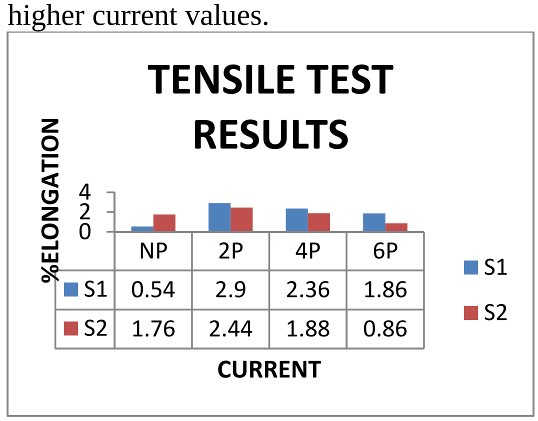
❖ Effect of Current on Yield Strength

The Filler wire 4p produced maximum yield strength i.e., 768 Mpa. The various comparisons of current are shown in the table From the graph, it is observed that the yield strength is low at frequency (np).



❖ Effect of Current on % of Elongation

The effect of filler wire on % elongation is shown in Figure 4.5. From the graph, it is observed that at 2 pulse current has maximum % of elongation when compared to the other currents .The maximum % of elongation value is 2.90. The maximum % of elongation produced at lower current because at lower current there are no much vibrations of torch and less heat produced when compared to higher current values.



CONCLUSIONS

From the experimental results, the following conclusions are drawn:

Porosity and Cracks

Results show that at 2 pulse two pores are present in the Welding area but they are within the acceptable limit of ASTM Standards. There are no surface cracks observed in he weld zone.

Ultimate tensile strength The 4 pulse produced maximum ultimate tensile strength.

The pulsed current has produced more tensile strength than non pulsed current.

Yield strength

The 4 pulse produced maximum yield strength. The pulsed current has produced more yield strength than non pulsed current.

% of elongation

The 2 pulse has maximum % of elongation i.e., 2.90 %. The maximum % of elongation produced at lower current because at lower current there are no much vibrations of torch and less heat produced when compared to higher current values.

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