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Optimization of Titanium Welding used in Aircrafts

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Abstract - *At Present Titanium is most preferred metal for Aircraft Industries including Fighter Aircrafts due to its useful properties like high Corrosion resistance and High strength to density ratio. These Aircraft Industries uses TIG (Tungsten Inert gas) welding for joining Titanium components. These Welding are generally done on Automatic welding machines but, as these machines are Automatic then too we have to provide the Voltage as well as Current depending on thickness of component or sheet to be welded as Inputs to the welding machine Currently these inputs are used on basis of welders skill and predefined values. But using those values of current and voltage have developed crack formation and decrease the life of welded joint of component up to some extent. Therefore in this Project we Aim in finding the Optimized values of the following Inputs i.e. Current and Voltage so that we can minimize as well as prevent the Crack Formation in those Precise components.*

***Key Words*: Titanium, Welding, Current, Voltage, Optimize, Cracks, Components**.

1. INTRODUCTION

Welding has become one of the most common fabrication techniques, which is extensively used to obtained good quality weld joints. The present trend in the fabrication industries is to automate welding processes to obtained high production rate. Arc welding, which is also called as Heat-Type is one of the most important manufacturing operations for the joining of structural elements for various applications, which includes Aircrafts, trains, bridges, building structures, automobiles. It requires a continuous supply of either Direct current (DC) or Alternating electric current (AC), which create an electric arc to generate enough heat to melt the metal and form a weld.

In this Project we have consider the Titanium Welding process which is used in our Fighter Aircrafts. The Component which we are considering here is the Central Panel of Aircraft which is also called as Lower Panel fitted to the bottom of the Aircraft. This panel is supporting the Fuel tak of that aircraft So this Central Panel has to be Leak proof i.e. Crack Proof So welding used here should be Precise.

Here, In this Project we have firstly gone through all the parameters which are affecting the welding process which include the welding Speed, Gas Flow rate, Current, Voltage, Feed rate. We have taken the values from actual Automatic Welding Machine at Industry.

As welding Titanium is not similar to normally used welding process. These Includes some Special procedure as Titanium can react with the oxygen to form Oxide layer which can reduce the Strength of Component therefore Welding of Titanium is to carried out in Vacuum Chamber under Shielding gas Influence. In Automatic welding machine the Welding Arc is Shielded with Shielding Gas which is generally Argon Gas. These gas is allowed to shield Arc and avoid Oxidation[1] . In below we will see the Special process needed for welding Titanium metal.

1.1 T.I.G welding process:-

Tungsten Inert gas Welding (TIG) or also called as Gas Tungsten Arc (GTA) welding is an arc welding process. In which for high thickness welding molten pool is produced by heating the work piece with an electrical arc struck between a tungsten electrode and the workpiece. The electrical discharge generates a plasma arc between the electrode tip and the work piece to be welded. The arc is normally generated by a power source with a high frequency producer.

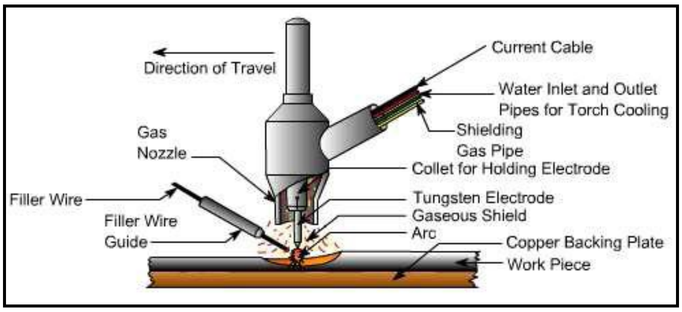


Fig -1: TIG Welding Process

The arc generates high-temperature of approximately 6200°C and melts the surface of base metal i.e. work-piece to form a molten pool. A welding gas or shielding gas (argon or helium) is used to avoid atmospheric contamination of the molten weld puddle. The shielding gas displaces the air and avoids the contact of oxygen and the nitrogen with the molten metal or hot tungsten electrode. As the molten metal cools and the parts are joined. The resulting weld is smooth and thus requires minimum finishing.

1.2 Types of welding current used for TIG:

1. DCSP- Direct Current Straight Polarity - (the tungsten electrode is connected to the negative terminal). This type of connection is the most widely used in the DC type welding current connections. With the tungsten being connected to the negative terminal.The resulting weld will have good penetration..

2. DCRP- Direct Current Reverse Polarity - (The tungsten electrode is connected to the positive terminal). This type of connection is used very rarely because most heat is on the tungsten, thus the tungsten can easily overheat and burn away. DCRP produces a shallow profile. This type of current is mainly used on very light material that too with very at low amps.

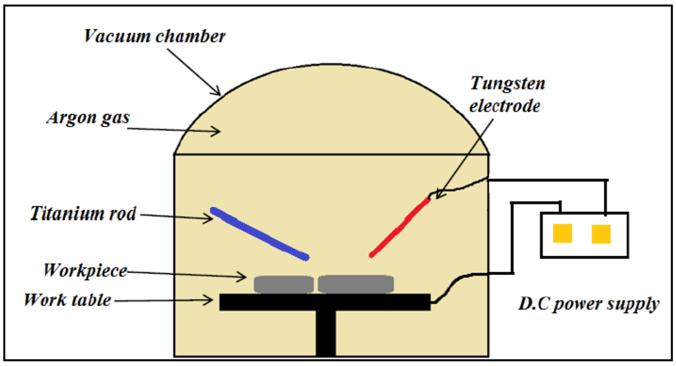
3. AC – Alternating Current – Alternating Current is the most preferred welding current for most white metals, e.g. titanium, aluminium and magnesium.

2. CONDUCTION OF ACTUAL T.I.G WELDING PROCESS AT AIRCRAFT INDUSTRIES

During TIG welding, an arc is maintained between a tungsten electrode and the work piece in an inert atmosphere

Fig -2:Schematic TIG Welding Process in Vacuum Chamber

(Argon, Helium or mixture of both). This atmosphere is created because the heat affected zone reacts with oxygen and nitrogen present in atmospheric air and produces dark blue colour titanium oxide or nitride, which is brittle in nature and ultimately reduces the strength of the welded joints. Depending on the weld preparation and the work-



piece thickness, it is possible to work with or without filler. The filler can be introduced manually or automatically with regarding two types of process. The process itself can be manual, partly mechanized, fully mechanized or automatic. The welding power source delivers direct or alternating current.

2.1 Three Dimensional Model of TIG welding Component:

For Analyzing stresses on the Component we have made a 3D model of Component. By using these we can Analyze Component for various Forces. So that we can Estimate the Life of Welded component. All this Analysis will be done by using "Ansys Software"

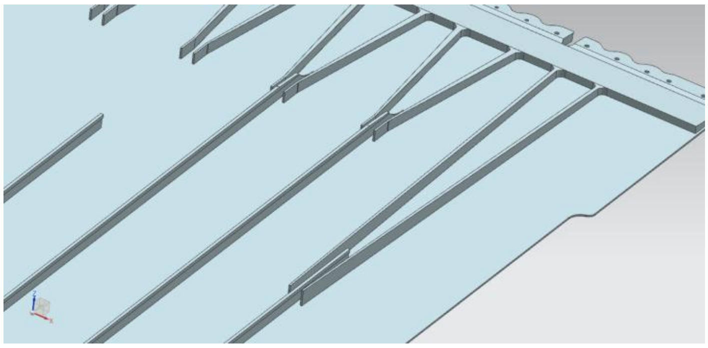


Fig -3: 3D- View of Welding portion.

As we can see in above Diagram the Ribs are welded over the plain Sheet. All the material used here is Titanium including sheet as well as Ribs. This welding procedure is carried out in Automatic Welding machine where ribs to be welded are placed in Fixtures there are total 16 Ribs which are at 90° to Plain Sheet. Then a plain sheet of Titanium is placed on this Fixture and the Automatic Welding machine is allowed to Weld from the backside of the Flat Titanium Sheet the arc is covered with shielded gas and is allowed to pass from the backside of the Sheet so as it Penetrates the plate creates a molten pool and thus the vertical rib gets welded on the sheet creating strong Weld.

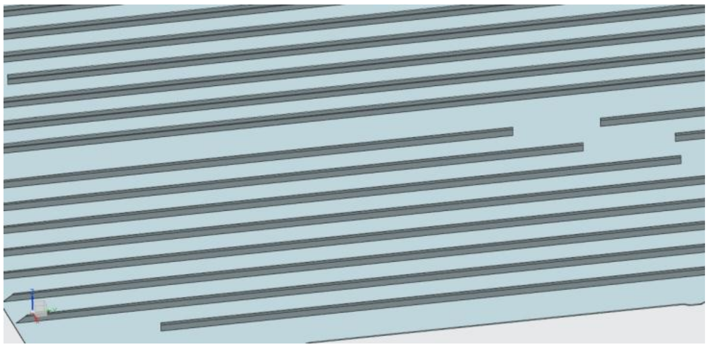


Fig -4: 3D- View of Welded Ribs over the Flat Titanium Sheet.

3. PARAMETERS IDENTIFICATION

The Input parameters which affects the output parameters are many such as :
1.Welding Current
2. Welding Voltage
3. Welding Speed
4. Shielding Gas

Out of these parameters three parameters are chosen for experimental purpose. The following parameters are selected:
1.Welding Current
2. Welding Voltage
3. Welding Speed

Parameters	Units		Ranges Specified
T- Joint Profile	-		Dimension 1.5 mm - 2.5 mm
Shielding Gas Flow Rate (Argon Gas)	m3 /sec	G	7.4 Lit/ min = 0.000123333 m3/sec
Welding Speed	mm / sec	mm / sec	1.66 mm / sec
Arc Voltage	Volt	V	10V - 16V
Current	Ampere	I	220 amp - 360 amp

Table -1: Required Parameters and Range

4. EXPERIMENTAL PROCEDURE

As we have selected Titanium for analysis. It is welded by following parameters. Welding voltage is varied as 10, 11, 12 V. Welding Current is varied as 220, 240, 260 amp. Welding Speed or Travel speed is varied as 1.33, 1.50, 1.66 mm/sec.

We are performing Experiment on nine work-piece and then we will Test it on Universal Testing Machine for getting Experimental Strength value. Considering all the parameters, this Study, purposes "an Optimization " using orthogonal array, ANOVA to optimize welding to get Maximum Tensile Strength.

Here we are using Titanium wire as Filling material Experimental layout design is shown in Table - 3

Table -2: Parameters and their Levels

Parameter	Symbol	Unit	Level - 1	Level - 2	Level - 3
Welding Current	I	Ampere	220	240	260
Welding Voltage	V	Volts	10	11	12
Welding Speed	C	mm / sec	1.33	1.50	1.66

Using L9 orthogonal array, only 9 experiments were performed required for study of the selected welding parameters

The loss function of the higher the better quality characteristic can be expressed as:

Mean Square Deviation,

$$\mathbf{MSD} = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{y_i^2}$$

where, y_i are the observed data (or quality characteristics) at the i^{th} trial, and
n is the number of trials at the same level.
The overall loss function is further transformed into the signal-to-noise $\frac{S}{N}$ ratio.

In the Taguchi method, the $\frac{S}{N}$ ratio is used to determine the deviation of the quality characteristic from the desired value. The $\frac{S}{N}$ ratio (η) can be express as

$$\eta = -10 \log \text{MSD}$$

Table - 3: Experimental Layout using an L- 9 Orthogonal Array

Experiment No.	Welding Voltage (Volts)	Welding Current (amp)	Welding Speed (mm / sec)
1	10	220	1.38
2	10	240	1.50
3	10	260	1.66
4	11	220	1.38
5	11	240	1.50
6	11	260	1.66
7	12	220	1.38
8	12	240	1.50
9	12	260	1.66

5. RESULTS

Results are shown in Table below:

Table - 4: Experimental Results for Tensile Strength

Experiment No.	Factors			Results
	Welding Voltage (volts)	Welding Current (Amp)	Welding Speed (mm/ sec)	Tensile Strength (N/ mm²)
1	10	220	1.38	427
2	10	240	1.50	422
3	10	260	1.66	420
4	11	220	1.38	427
5	11	240	1.50	430
6	11	260	1.66	426
7	12	220	1.38	427
8	12	240	1.50	418
9	12	260	1.66	417

5.1 Interpretation of Plots:

The following graphs are been obtained by using "MINITAB - 17" software:-
1. Main Effect plots for Means for Tensile Strength shown in Chart no.1

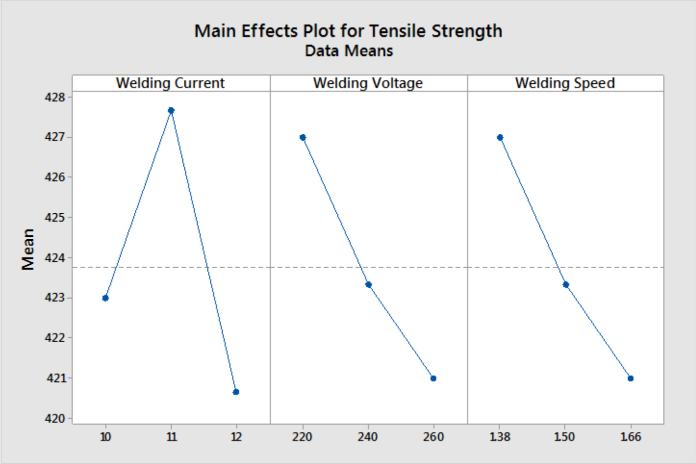


Chart - 1: Main Effect plot for Means

Influence of Parameter:

The Influence of Parameter is Listed Below

Table - 5: Result of Analysis for Tensile Strength

Sr. no	Factor	%
1	Welding Voltage	29.17
2	Welding Current	57.14
3	Welding Speed	13.04
4	Error	0.65
5	Total	100

6. CONCLUSIONS

The above work, experimentally verify that the combined approach of Taguchi and ANOVA gives us the optimal parameters of TIG Welding using optimum set of parameters. The most affecting parameter having Impact of **57.14%** is Welding Current latter welding Voltage and Travel Speed or welding Speed

The remaining Percentage for Influence on this Experiment will be related to other welding Condition and Parameters.

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