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Analysis of TIG Welding Process Parameters for Stainless Steel (SS202)

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***Abstract*— *The aim of this project work is Analysis of TIG welding parameters of Stainless Steel (SS 202) material used in the manufacturing of Heat Exchanger and Pressure vessel by TIG welding process, in which various input process parameters within the range of value are carried out and characteristics of output parameters are analyzed. Gas Tungsten Arc Welding (GTAW) process is commonly applied to a wide range of metals which uses non-consumable tungsten electrode. Stainless steel specimen (SS 202) of 6mm thickness used in the manufacturing of heat exchanger and pressure vessel is selected. Full factorial Design method is used to formulate the experimental layout to rank the welding input parameters which affects the quality of weld and is influenced by the input parameters such as current, gas flow rate followed by diameter of filler wire. The weldments are studied for tensile test, Bending test, Hardness test to find qualitative properties. The percentage contribution of each input parameter and prediction of tensile strength, bending strength and BHN is found by Full factorial Design.*

Keywords*—*TIG welding, Stainless steel specimen (SS 202), Full factorial Design, Gas flow rate.

I. INTRODUCTION

Gas Tungstan Aragon Welding (GTAW) is an arc welding process that produces coalescence of metals by heating them with an arc between a non consumable electrode and a base metal .It is commonly used for welding thin and medium thickness materials like Stainless steel plates and carbon steel plates and for applications where metallurgical control of the weld metal is critical Since welding is now highly mechanized, the welding procedure must ensure that the weld bead is of good quality and is obtained at minimum cost.

GTAW or Tungsten gas welding is one of the most commonly used in the manufacturing of heat exchanger and pressure vessel. This finds wide application in the field of chemical, oil and petroleum industries. This welding process is commonly used for welding of thin plate or root welding of medium thickness plate. Usually, the desired welding process parameters used in heat exchanger and pressure vessel are based on the ASME SECTION IX, But most of the company having experienced welders who uses the welding parameters depending upon their experience. And set the welding process parameters according to their convenient level but which is also within the acceptable level. These convenient welding input parameters which is also the acceptable level varies from one welder to the other welder, those input parameters of most of the experienced welders, used for the welding of stainless steel material of SS 202 are investigated and using full factorial design welding characteristics are studied by experimentation. In Full factorial experimental design two levels (minimum and maximum) are taken. And three input parameters such as current, inert gas, and diameter of filler wire are set for welding process.[1]

II. TIG WELDING PROCESS

A. Operation

Manual gas tungsten arc welding is often considered the most difficult of all the welding processes commonly used in industry. Because the welder must maintain a short arc length, great care and skill are required to prevent contact between the electrode and the work piece. Similar to torch welding, GTAW normally requires two hands, since most applications require that the welder manually feed a filler metal into the weld area with one hand while manipulating the welding torch in the other. However, some welds combining thin materials (known as autogenous or fusion welds) can be accomplished without filler metal; most notably edge, corner, and butt joints.[2]

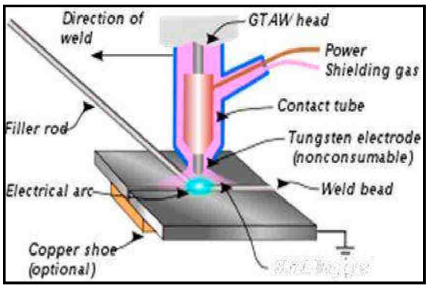

Fig.1: TIG welding process

To strike the welding arc, a high frequency generator (similar to a Tesla coil) provides an electric spark; this spark is a conductive path for the welding current through the shielding gas and allows the arc to be initiated while the electrode and the work piece are separated, typically about 1.5-3 mm (0.06-0.12 in) apart. This high voltage, high frequency burst can be damaging to some vehicle electrical systems and electronics, because induced voltages on vehicle

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wiring can also cause small conductive sparks in the vehicle wiring or within semiconductor packaging.

Vehicle 12V power may conduct across these ionized paths, driven by the high-current 12V vehicle battery. These currents can be sufficiently destructive as to disable the vehicle; thus the warning to disconnect the vehicle battery power from both +12 and ground before using welding equipment on vehicles.

B. Equipments used

The equipment required for the gas tungsten arc welding operation includes a welding torch utilizing a non-consumable tungsten electrode, a constant-current welding power supply, and a shielding gas source.

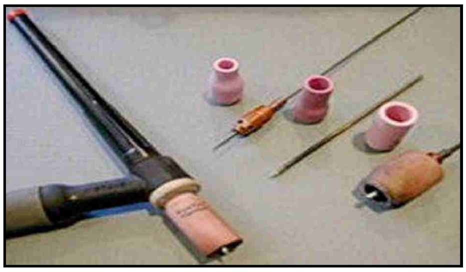

Fig.2: GTAW torch with various electrodes, cups, collets and gas diffusers.

C. Power supply

The preferred polarity of the GTAW system depends largely on the type of metal being welded. Direct current with a negatively charged electrode (DCEN) is often employed when welding steels, nickel, titanium, and other metals. It can also be used in automatic GTAW of aluminum or magnesium when helium is used as a shielding gas. The negatively charged electrode generates heat by emitting electrons which travel across the arc, causing thermal ionization of the shielding gas and increasing the temperature of the base material. The ionized shielding gas flows toward the electrode, not the base material, and this can allow oxides to build on the surface of the weld.

Fig.3: GTAW power supply

D. Shielding gas

Filler metals are also used in nearly all applications of GTAW, the major exception being the welding of thin materials. Filler metals are available with different diameters and are made of a variety of materials. In most cases, the filler metal in the form of a rod is added to the weld pool manually, but some applications call for an automatically fed filler metal, which often is stored on spools or coils.

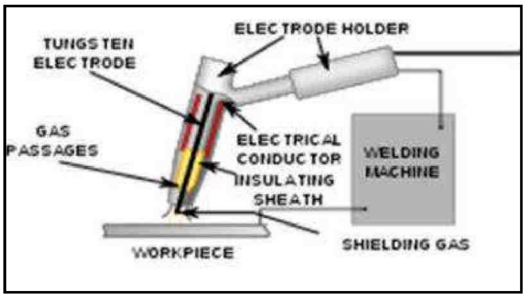

Fig.4: GTAW system setup

As with other welding processes such as gas metal arc welding, shielding gases are necessary in GTAW to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embrittlement if they come in contact with the electrode, the arc, or the welding metal. The gas also transfers heat from the tungsten electrode to the metal, and it helps start and maintain a stable arc.

III. METHODOLOGY AND OBJECTIVE

A. Problem definition

GTAW or Tungsten gas welding is popularly used in manufacturing of heat exchangers and pressure vessels.TIG welding process has different process parameters. The quality of the weld depends on several input variables, like welding speed, voltage, size of filler wire, gas flow rate, nozzle-to-plate distance, torch angle and other factors. By varying these process parameters, yields different characteristics, which affects the mechanical properties. This experiment is carried out to produce no failure so that there is no variation in the input parameters of the welding process to give wrong results.

As the heat exchangers and pressure vessels are subjected to high pressure during working period, this experiment is carried out for the welded specimen to get the best results. Design of experiment is done for TIG welding of the specimen as a test piece where same process for welding is carried out during manufacturing of the products which gives better than the required task. That ensures more safety of the products such as heat exchangers and pressure vessels.[3]

B. Objective

In this dissertation work an attempt has been made to design of experimentation for good strength weld bead required for the pressurized products such as heat exchangers and pressure vessels. For TIG welding process, different input process parameters are used for welding the joints. These welding input parameters have different effect on the weld bead, which affect the weld pool geometry, mechanical properties and microstructure.

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However need for pressurized products are more on safety side. Hence in this dissertation work, mainly mechanical properties are considered to study the characteristics of the input parameters.

To study the mechanical characteristics of the welded joint tensile test, hardness test, bending test is carried out. and corresponding tensile strength, hardness (BHN), and bending strength are analyses to adopt the correct parameter required for the safe operation of the pressurized products, as it is subjected to tensile, bending during the operation of the pressurized Fluid.

C. Methodology

1. Identifying the important process control variables and finding their upper and lower limits.
2. Developing the experiments as per the design matrix and recording the response Parameters.
3. Developing the model and calculating the regression coefficients.
4. Conducting the experiments as per the design matrix and recording the response Parameters.
5. Checking the adequacy of the models.
6. Significance test of factors.
7. Graphical method for identification of significant factors.
8. Estimation and evaluation of effects of parameters.

IV. PROCESS MODELLING

A. Problem definition

A process generally consists of several discrete or continues input factors and some of these factors (May not all) can be controlled or varied during experimentation. Each response (output) is to be expressed, as a function of the input factors. The experimental data are to be used to drive an empirical (approximation) model linking the outputs and inputs and to find out which factors influence a response most. These empirical modes could be either linear or Non-linear in nature.

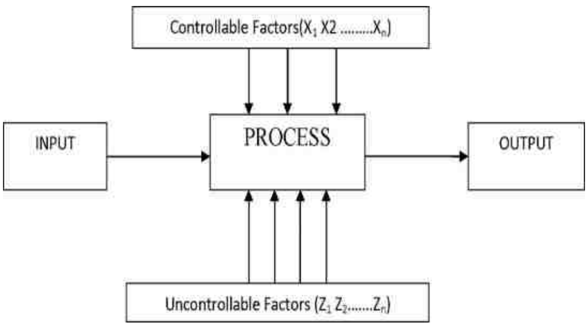


Fig.5: Schematic diagram of manufacturing process model

B. Developing the models and calculating the regression co-efficient

The input-output model or analysis of the process under study is obtained by adding "I" column containing 1s and "$X_1 * X_2$", "$X_1 * X_3$", "$X_2 * X_3$", "$X_1 * X_2 * X_3$" columns to the matrix of 8 trials for a 2^3 experiments.

Table1: shows the model matrix of the 2^3 full factorial experiments.

Trial	I	Factor (X_1)	Factor (X_2)	Factor (X_3)	Factor (X_1xX_2)	Factor (X_1xX_3)	Factor (X_2xX_3)	Factor ($X_1xX_2xX_3$)	Response (Yi)
1	1	-1	-1	-1	1	1	1	-1	Y1
2	1	+1	-1	-1	-1	-1	1	1	Y2
3	1	-1	+1	-1	-1	1	-1	1	Y3
4	1	-1	-1	+1	1	-1	-1	1	Y4
5	1	+1	-1	-1	1	-1	-1	1	Y5
6	1	+1	+1	+1	-1	1	-1	-1	Y6
7	1	-1	+1	+1	-1	-1	1	-1	Y7
8	1	+1	+1	+1	1	1	1	1	Y8

V. TEST RESULTS

A. Significance test of factors

The values of the regression coefficient give an idea as to what extent the control variables affect the response quantitatively. The less significant can be dropped from the response equation, without sacrificing the accuracy. To achieve this, student's t-test is used or graphical methods, such as normal probability plot of effect Pareto chart of effects are used.

B. Working range of process parameters

The range of parameters which is available in RHINO TIG 6400 Gouzing Equipment is as follows:

- Current: maximum - 400 Amps
- Flow rate of inert gas: maximum - 40 lit/min
- Voltage: maximum : 40 Volts
- Diameter of the Filler wire: 01.6 mm - 03.5 mm

As per ASME section-IX, welding Stainless steel material SS 304 of 6mm thickness required range of input parameters are as follows,

- Current: 120-125 amps
- Flow rate of inert gas: 9-10 lit/min
- Diameter of filler wire: 1.6-2.5mm.[4]

C. Orthogonal arrangement for experiment

The following table shows the range of input process parameters used in the welding of stainless steel material of SS 202 specimen. [5]

Table.2: Orthogonal arrangement for experiment.

Ex. No	Current (amps)	Flow rate of inert gas (lit/min)	Diameter of filler wire (mm)
1	120	10	1.6
2	125	10	1.6

3	120	09	1.6
4	125	09	1.6
5	120	10	2.5
6	125	10	2.5
7	120	09	2.5
8	125	09	2.5

D. Machining process

For that milling machining is carried out for the preparation of the specimen according to the dimension required for mechanical testing .In this milling machine large amount of coolant is used for the machining process to eliminate the heat input to the specimen as less as possible.

The specimen after machining process is shown below,

Fig.6: Specimen machined by milling process.

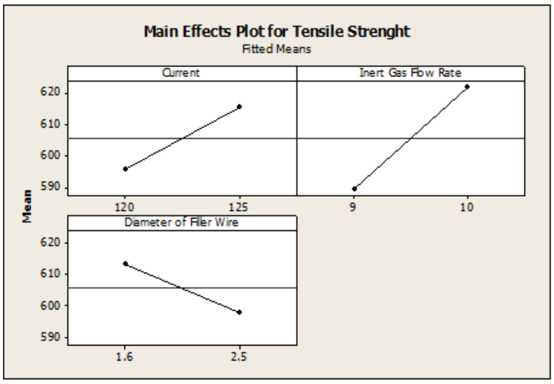
E. Mechanical testing

For Mechanical testing three testing's are carried out as follow

1. Hardness testing
2. Tensile testing
3. Bend testing.

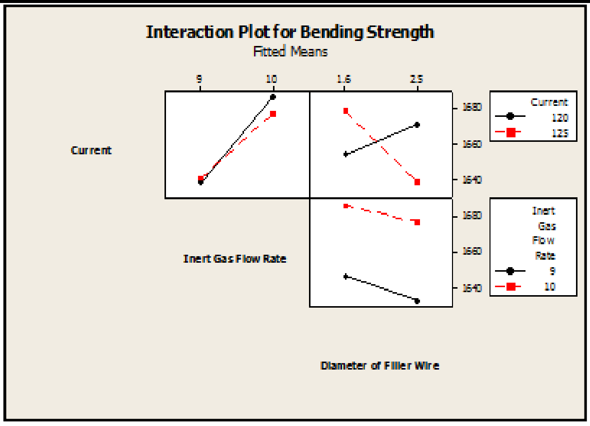
F. Results from main effect plot for tensile strength

Graph 1, Shows the effect of the different main factor on tensile strength and it is found that as the current increases tensile strength increases and as inert gas flow rate increases tensile strength increases, but as diameter of the filler wire increases tensile strength decreases.



Graph.1- Shows the effect plot for tensile strength.

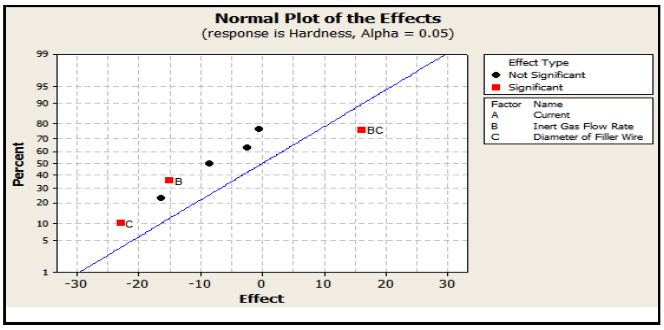
G. Results from Interaction plot for bending strength



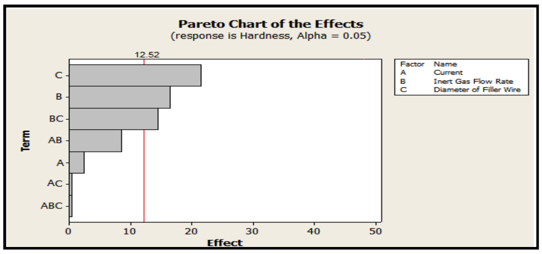
Graph 2-Shows the interaction plot for Bending Strength.

H. Results from Interaction plot for hardness

Interaction plot for Hardness between current and inert gas flow rate shows that hardness increases as gas flow rate increases from 9 lit/min to 10 lit/min at lower current (at 120 amp),and also hardness decreases for inert gas flow rate from 9 lit/min to 10 lit/min at higher current (at 125 amp).

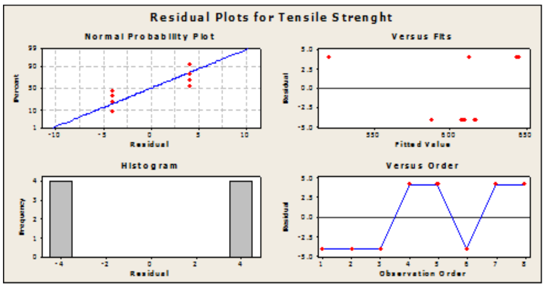


Graph 3- *Normal Plot of the Effects.*

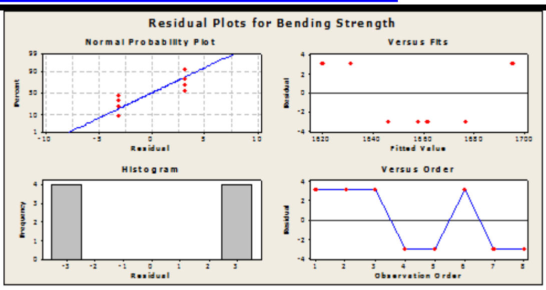


Graph 4 -Pareto Chart of the Effect.

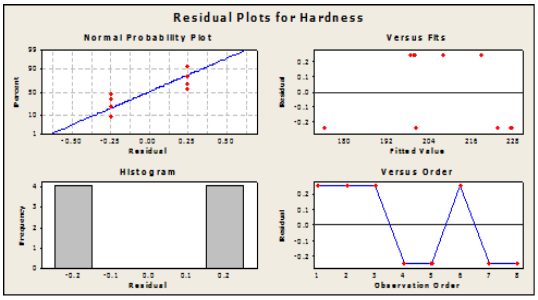
I. Residual strength for different tests



Graph 5- Residual Plots for Tensile Strength



Graph 6- Residual Plots for Bending Strength



Graph 7-Residual Plots for Hardness

VI. CONCLUSION

The project work is carried out successfully for analysis of input process parameters to study the mechanical properties of stainless steel (SS 202) material, which is used in manufacturing of heat exchangers, pressure vessels and chemical industries. The mechanical properties obtained by mechanical testing are analyzed with input process parameters by using mini-tab software. The results were found good and are as per requirements.

In manufacturing of heat exchanger and pressure vessels good strength weld joint is required. The weld joint of the shell as it is being rolled, re-rolled during manufacturing, it must withstand high tensile strength, bending strength and hardness. Thus values obtained from mechanical testing for a given input process parameters are satisfied. To cross check these values for satisfaction, results were compared with the Test certificate of the plate. Also, graphs obtained from full factorial design, it can be concluded for better performance. From main factors effect and interaction effects it clears that high current and high inert gas flow rate with lower diameter of the filler wire give maximum tensile strength and for bending strength low current and lower diameter with higher inert gas flow rate gives maximum bending strength, and for the harness low current, low inert gas flow rate and at lower diameter give maximum hardness. And also from normal probability chart and pareto chart it is clear that Inert gas flow rate and diameter of the filler wire have maximum positive effect on Tensile strength, Bending strength and Hardness of the weld joint. Thus Tensile strength and bending strength decrease as current and Inert gas flow rate increase for a higher value of filler wires and found more strength at low current and low inert gas flow rate for a lower value of filler wire. While hardness of the joint found higher value for maximum current, Inert gas and diameter of the filler wire.

VII. FUTURE SCOPE

This dissertation work is carried out only for characterization of TIG welding process parameters such as current, inert gas flow rate and diameter of the filler wire. Further study is required for other parameters such as voltage, feeding rate of the filler wire, groove angle etc

This project uses base material as stainless steel of SS 202, which is used in heat exchanger and pressure vessel; this can be extended for other materials such as stainless steel, cupron nickel, and super duplex and also for the cladded materials.

Testing of the specimen is carried out only for three types of tests; it can be further studied for the other NDT methods such as radiographic testing, ultrasonic testing etc for better joint analysis as the products are utilized in pressurized industries.

Due to Welding of the test piece distortions occurs the distortions induces stress in specimen. In future study heat treatment of the test to be carried out before it is used for testing and analyzing the test difference between the specimen which is heat- treated with specimen which is not heat-treated.

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