

Dtesting and Analysis of Weld Bead Profile of TIG Welded Duplex Stainless Steel by Using Taguchi Method

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ABSTRACT: The aim of the project is to study the effects of TIG welding on Duplex Stainless Steel welds. The aim of the project is to study the effects of Tungsten Inert Gas Welding (TIG) on duplex stainless steel (DSS). Here butt joint is done on this type of welding. The weld bead is cut in a transverse manner. The weld bead geometry is finally measured that is hardness and the percentage of ferrite. Using TIG welding butt type of joint is usually preferred for DSS. Weld bead geometry has great influence on mechanical strength. Welding speed, current and gap flow rate are some of the parameters which influence the welding process. Then the experiment is done by using Taguchi method. Duplex stainless steel is a common structural material in the oil and gas industries, and has special applications in chemical, wastewater and marine engineering fields. The fabrication of metal structures requires the extensive use of TIG welding process welds. Generally, the single pass TIG welding with argon as shielding gas is limited to a 1.5 mm depth for the butt joint of stainless steels. One of the most notable techniques is to use activating flux with TIG welding to achieve single pass weld. If the weld current increases or the travel speed decreases, the weld bead becomes excessively wide with relatively little gain in the penetration capability. Therefore, it is necessary to improve the penetration capability and manufacturing productivity of TIG welding. TIG welding process are conducted for similar materials of 6mm thickness plates. The duplex stainless steel joined using automatic TIG welding machine. Single pass, autogenous, bead on plate TIG welds were made along the center line of the test specimens. A water cooled thoriated tungsten electrode rod with 45 degree angle.

KEYWORDS: Tig Welding, Welding geometry, Taguchi method.

I. INTRODUCTION

TUNGSTEN INERT GAS (TIG WELDING)

Tungsten inert Gas Welding is a welding process, in which heat is generated by an electric arc struck between a tungsten non consumable electrode and the work piece. The weld pool is shielded by an inert gas (Argon, helium, Nitrogen) protecting the molten metal from atmospheric contamination. The heat produced by the arc melts the work pieces edges and joints them. Filler rod may be used, if required. The welding produces a high quality weld of most of metals. Flux is not used in the process. Gas Tungsten Arc Welding (GTAW) more commonly referred to as TIG (tungsten inert gas) welding is an arc welding process that uses a non consumable tungsten electrode to produce the weld. In TIG welding, a shielding gas is used to protect the weld area against atmospheric contamination.

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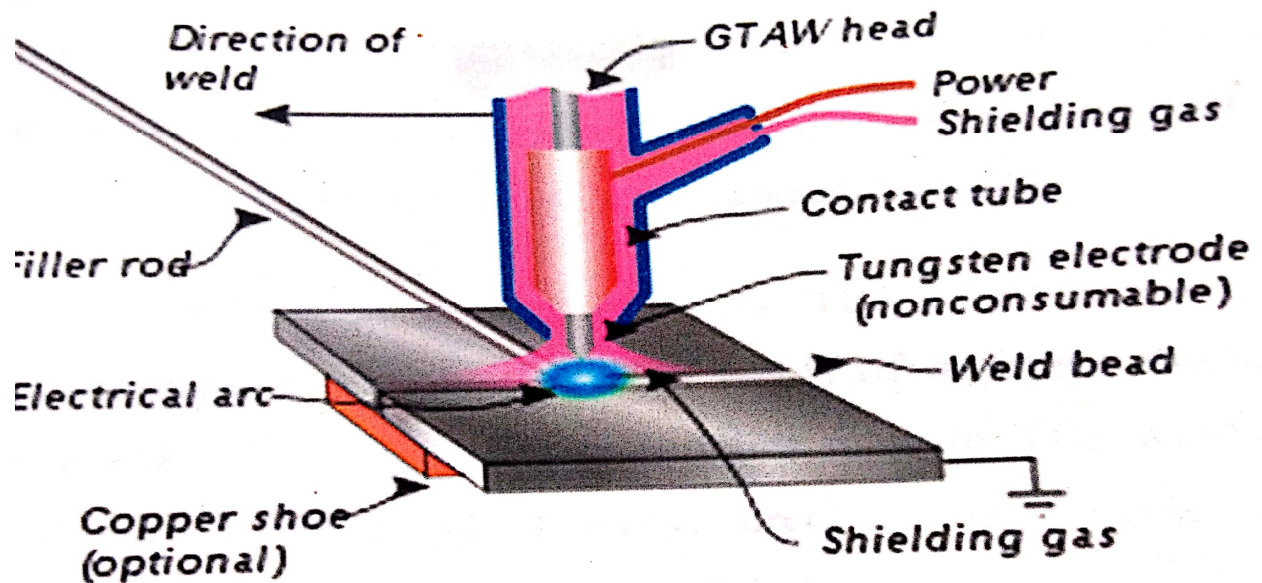


Figure 1- TIG Weld Area

Energy is supplied by a constant-current welding power supply and the end result is a conduction of highly-ionized gas and metal vapors (also known as plasma) across the welding arc. This energy is then transmitted over the arc, which forms a weld pool that connects the two metal pieces together.

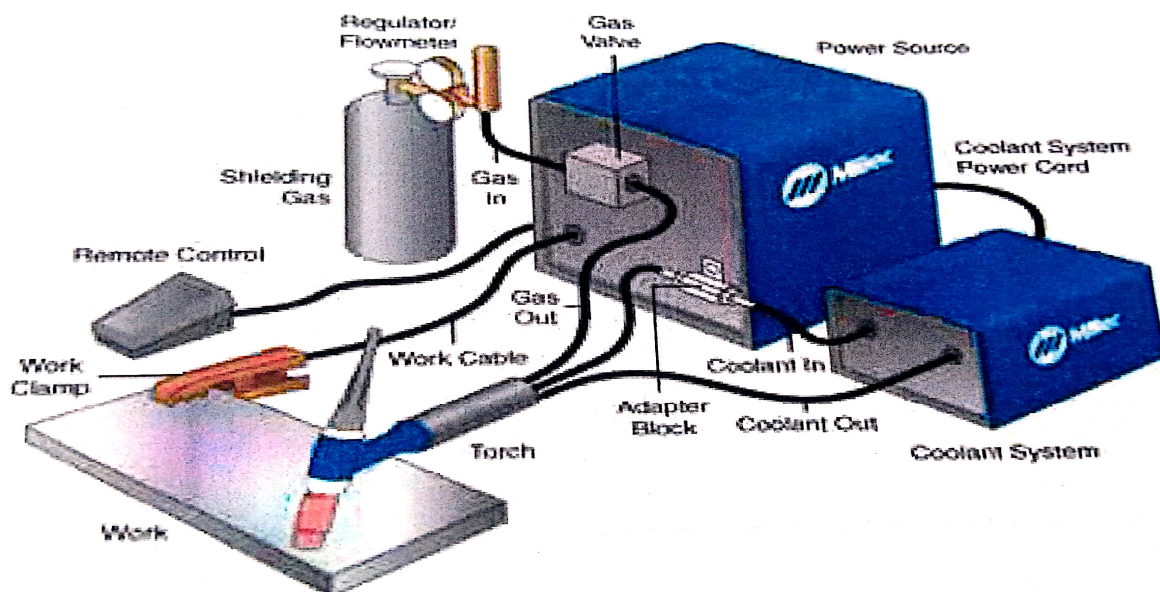


Figure 2- Process of TIG Welding

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II. WORKING

TIG welding is a welding process that uses the heat produced by an electric arc created between non consumable tungsten electrode and the weld pool. This electric arc is produced by the passage of current through a conductive ionized inert gas that also provides shielding of the electrode, molten weld pool and solidifying weld metal from contamination by the atmosphere.

The process may be used with or without the addition of filler metal using metal rods. Basic TIG welding process shown in fig4.

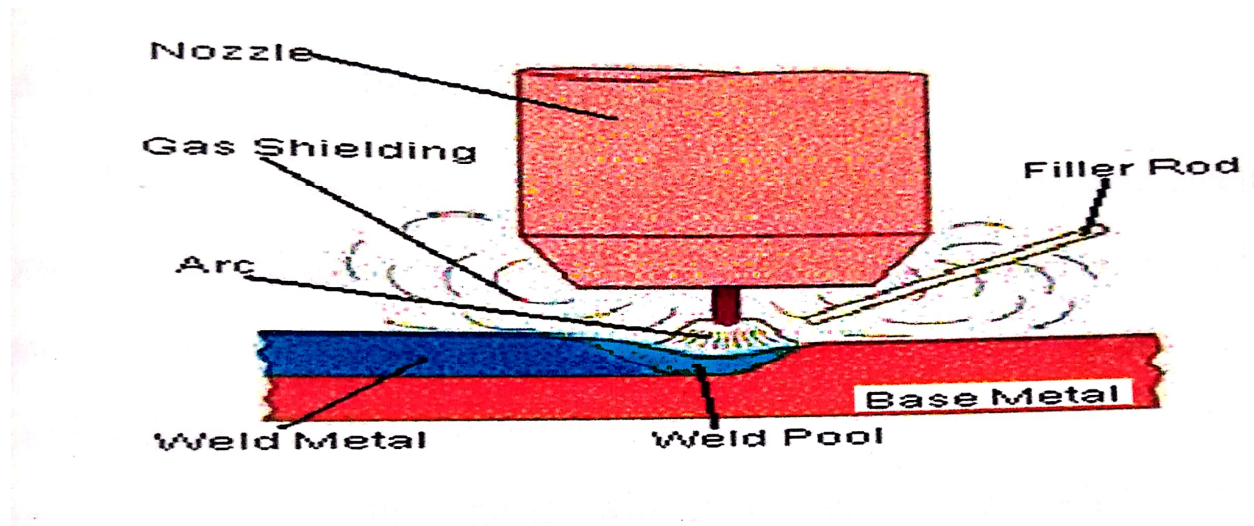


Fig 4 TIG Welding Process

1.1 EQUIPMENT IN TIG WELDING MACHINE

- Power sources
- TIG torch
- Regulators
- Shielding gas

Power Sources

The preferred polarity of the TIG system depends largely the type of metal being welded. Direct current with a negatively charged electrode is often employed when welding steels, nickel, titanium, and other metals. 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, and this can allow oxides to build on the surface of the weld. A TIG power source can be of the AC or DC types.

The principle of electric circuits will apply to only DC power sources. This means 70% of the heat is always on the positive side.

TIG Torch

TIG welding torches are designed for either automatic or manual operation and are equipped with cooling systems using air or water. the manual torch has a handle while the automatic torch normally comes with a mounting rack

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The automatic and manual torches are similar in construction, but. Air cooling systems are most often used for low current operations up to about 200A, while water cooling is required for high current welding up to about 600A.

The torches are connected with cables to the power supply and with hoses to the shielding gas source and where used, the water supply. The internal metal parts of a torch are made of hard alloys of copper or brass in order to transmit current and heat efficiency. Ports around the electrode provide a constant flow of shielding gas. Collets are sized according to the tungsten electrode and to hold the electrode.

Regulator

A welding regulator is necessary to monitor the flow of shielding gas to the welding puddle. Gas must come out smoothly and controlled the welding arc. If you were to skip the regulator and hook up a hose directly to pressurized gas bottle, the gas could be released entirely in seconds. The regulator does just what it sounds like, it regulates the gas flow.

The pressure can then be set to usable and less wasteful level. The rate of flow can be adjusted by twisting a knob one way or the other to increase or decrease flow. Most TIG welding regulators will have two gauges which is shown in fig6 one to show the flow rate, the other to show the gas bottle pressures.

The gas bottle pressure reading will let you know how much gas is left in the bottle. As the gas is used, as the gas is used, the pressure will drop and the reading on the gauge will thus indicate.

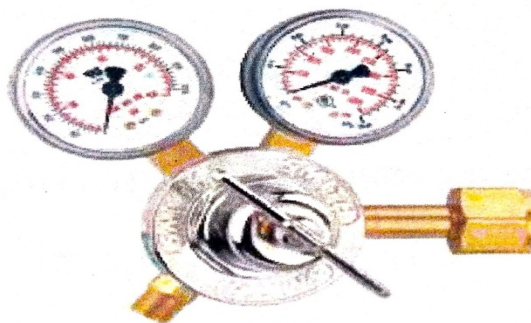


Fig 6 Regulator

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TIG ARC

In D.C TIG welding, the tungsten electrode is usually connected to the negative polarity and the work piece to the positive polarity. According to the theory of electrons, the negatively charged electrons and the positively charged ions will migrate, when the arc is ignited.

The negative pole and approximately 70% to the work piece is connected to the positive pole.

Shielding Gas

As with other welding processes such as gas metal arc welding to protect the welding area from the atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embrittlement if they come in contact with 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. The selection of a shielding gas depends on several factors, including the type of material being welded, joint design, and desired final weld appearance. Argon is the most commonly used shielding gas for GTAW. Shielding gas mixture, argon hydrogen, is used in the mechanized welding of light gauge stainless steel, because hydrogen can cause polarity, its uses are limited. Similarly nitrogen can sometimes be added to argon helping to stabilize the austenite stainless steels and increase penetration when welding copper.

Electrode

An electrode in an electrochemical cell is referred to as either an anode or a cathode. The anode is now defined as the electrode at which electrons leave the cell and oxidation occurs, and the cathode as the electrode at which electrons enter the cell and reduction occurs. Each electrode may become either the anode.

III. LITERATURE REVIEW

Tsann-Shyi Chern, Kuang-Hung Tseng and Hsien-Lung Tsai (2010)

investigated the effects of the specific fluxes used in the tungsten inert gas (TIG) process on surface appearance, weld morphology, angular distortion, mechanical properties, and microstructures when welding 6mm thick duplex stainless steel. The applied flux increases the heat input therefore, there is an increase in the peak temperature of the weld metal and a reduction in the cooling rate. TIG weld metal produced using SiO_2 flux possessed microstructures consisting of equal proportions of ferrite (52.3%) and austenite (47.7%) at room temperature. In this study, grade 2205 stainless steel TIG welding with SiO_2 flux produced a full joint penetration and the greatest weld depth-to-width ratio. As a result, the angular distortion value was almost zero.

G. Ru'ckert, B. Huneau, S. Marya (2006)

the performance of silica coating on tig welding of AISI304L stainless steel by investigating the effect of coating geometry and thickness on weld penetrations. Two coating design technique were used, one is 20 mm wide continuous coating across the weld zone and second design technique is two parallel coatings 2mm apart around the joint. Activating flux mixing water and acetone or alcohol decides the particle size of the powder. Coating thickness will increase the penetration capability at their current level. This study investigates the design of fluxcoating. The optimized thickness in ATIG is observed to vary between 40 and 70 μm depending on the welding current.

S.C. Juang, Y.S Tarang (2002)

about the selection of process parameters for obtaining an optimal weld pool geometry in the TIG welding of S304 stainless steel plates with thickness of 1.5mm. Modified Taguchi method is adopted to analyze the effect of each welding process parameter on the weld pool geometry (front height, back height, front width, and back width). 3D-hommelewerk profilometer used to measure quality characteristic as lower the better adopted. Process parameter of arc gap, flow rate, welding current and welding speed are affecting the multiple quality characteristics.

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Kuang-Huang Tseng, Nai-Shein Wang (2013) evaluated the potential of using gas tungsten arc welding assisted by FeS/FeF₂ mixtures to improve joint penetration and weld quality in joining 316L stainless steel plates. The differences in surface appearance, geometric shape, and out of plane deformation of the elements made by using conventional and activated gas tungsten arc welding processes have been compared. The present study used mixtures of iron (ii), sulfide (FeS) and iron (ii) fluoride (FeF₂) to systematically investigate the influence of specific components on the surface appearance, geometric shape, and out of plane deformation of the activated gas tungsten arc weldment. Author explored the application of GTA welding assisted by mixed compounds not only to increase joint penetration but also to improve the weld quality of stainless steel.

M.. Yousefieh, M. Shanmanian, A. Saatchi (2010)

It investigated corrosion resistance of super duplex stainless steel using pulsed current gas tungsten arc welding. Taguchi method was adopted to optimize the parameters of pulsed current gas tungsten arc welding. Among the parameters pulsed current was the most affecting parameter on corrosion resistance. Taguchi design experiment details and procedure are reviewed in this study.

V. Muthupandi , P. Bala Srinivasan, S.K. Seshadri, S. Sundaresan (2003) discussed the excellent combination of strength and corrosion resistance in duplex stainless steels. This is due to their strict composition control and micro structural balance. To achieve the desired ferrite/austenite balance and hence properties, either the weld metal composition and the heat input is controlled. TEM studies, vicker hardness, charpy impact test were performed in this study. Nickel is very effective in controlling the ferrite/austenite ratio than the cooling rate for the range of composition studied.

IV. EXISTING MODEL IN KUNDAN PIPES

EXPERIMENTAL WORK

The rectangular specimens with length 250 mm, width 100 mm and thickness 6mm of duplex stainless steels are joined using TIG welding machine. TIG welding electrode was made by tungsten. The experiment was conducted only for a single experiment of TIG. Complete penetration has obtained at current (250 A), welding speed (100 mm/min) and gas flow rate (15 l/min). Fig 3.2 shows the welding process

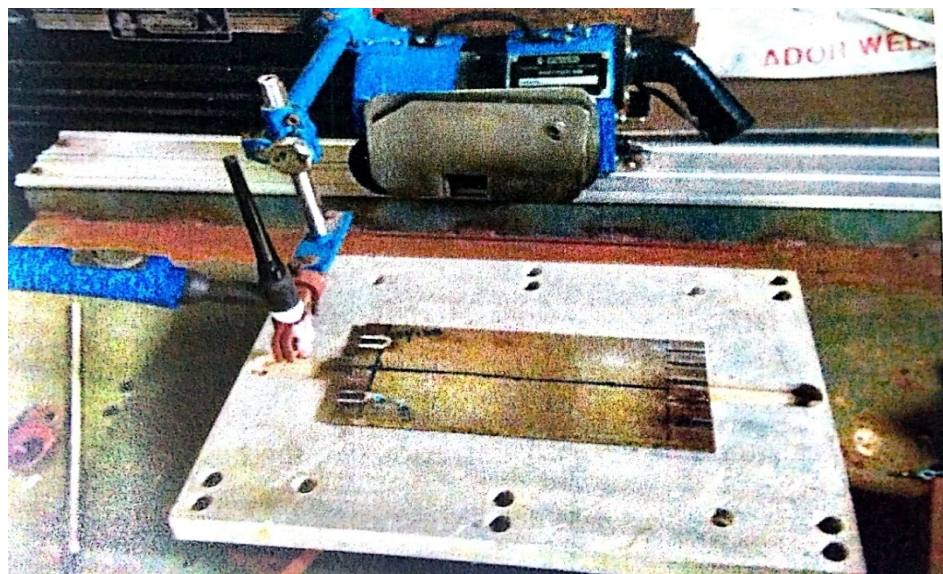


Fig12 Welding Process

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DESIGN OF EXPERIMENT

The investigation of this study is to find the effect of TIG welding on tensile strength. The material selected is duplex stainless steel. By designing the experiment with the help of traditional or classical approach a lot of experiments have to be performed and it is a tedious process which leads to wastage of time and money, taguchi design is adopted. Taguchi method is systematic approach to design and analyze experiments for improving the quality characteristics.

- The parameter design based on the taguchi method can optimize the quality characteristics through the settings of the process parameter values.
- Taguchi uses a special design of orthogonal array to study the entire parameter space with a small number of experiments.
- The experimental results are then transformed into s/n ratio. The s/n ratio can be used to measure the quality characteristics deviating from the desired values.
- And there are usually 3 characteristics higher the better; nominal the best lower the better for the static problem. For the dynamic problem. Slope and linearity are involved.
- Finally a statistically level of ANNOVA is performed to see which process parameters are statically significant and based on the above analysis a confirmation experiment is made to verify the optimal process parameters, obtained from the parameter design.

The major steps required for the experimental design using taguchi method are

- Establishment of objective function,
- Identification of the factors and their levels,
- Selection of an appropriate orthogonal array,
- Experimentation,
- Analysis of the data and determination of the optimal levels,

V. RESULTS AND DISCUSSION REGARDING TIG WELDING BY USING TAGUCHI METHOD

STEP-1

IDENTIFICATION OF FACTORS AND THEIR LEVELS

Table- 5.1

SI.NO	FACTORS	UNIT	LEVEL1	LEVEL2	LEVEL3	LEVEL4
1	Current	A	220	230	240	250
2	Welding speed	Mm/min	100	110	120	130
3	Gas flow rate	l/min	10	12	14	16
4	Arc gap	mm	1.8	2.0	2.2	2.4

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MECHANICAL PROPERTIES OF TIG WELDING

STEP 2 (Table5.3) SELECTION OF L16 ORTHOGONAL ARRAY

	Tensile strength Mpa	% Elongation	Hardness value
Base metal	746	35	272
Without flux	730	31	265

CURRENT	WELDING SPEED	GAS FLOW RATE	ARC GAP	DEPTH OF PENETRATION
220	100	10	1.8	4.94
220	110	12	2.0	3.98
220	120	14	2.2	3.08
220	130	16	2.4	3.02
230	100	12	2.2	4.88
230	110	10	2.4	5.04
230	120	16	1.8	3.92
230	130	14	2.0	3.04
240	100	14	2.4	6.12
240	110	16	2.2	4.04
240	120	10	2.0	3.94
240	130	12	1.8	3.40
250	100	16	2.0	6.04
250	110	14	1.8	6.02
250	120	12	2.4	5.14
250	130	10	2.2	4.56

STEP 3

ANALYSIS AND CALCULATION OF S/N RATIO, AND GRAPH DISCUSSIONS

All the parametric design parameter and their values are converted to statistical data that is signal to noise ratio.

It is to analyze which parameters are significant and which would affect the depth of penetration and ferrite content and which influence the welding processes.

This is the use of calculating s/n ratio. The analysis and calculation of s/n ratio is briefly discussed in the following table which are listed as follows

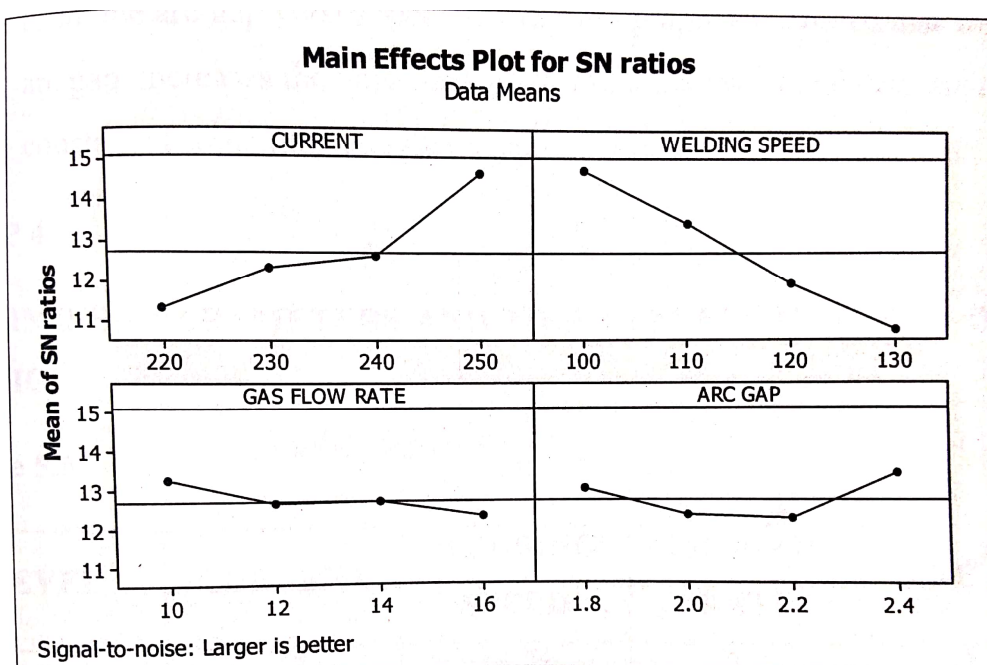
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EXPERIMENT	CURRENT	WELDING SPEED	GAS FLOW RATE	ARC GAP	DEPTH OF PENETRATION	S/N RATIO
1	220	100	10	1.8	4.94	13.8745
2	220	110	12	2.0	3.98	11.9977
3	220	120	14	2.2	3.08	9.7710
4	220	130	16	2.4	3.02	9.6001
5	230	100	12	2.2	4.88	13.7684
6	230	110	10	2.4	5.04	14.0486
7	230	120	16	1.8	3.92	11.8657
8	230	130	14	2.0	3.04	9.6575
9	240	100	14	2.4	6.12	15.7350
10	240	110	16	2.2	4.04	12.1276
11	240	120	10	2.0	3.94	11.9099
12	240	130	12	1.8	3.40	10.6296
13	250	100	16	2.0	6.04	15.6207
14	250	110	14	1.8	6.02	15.5919
15	250	120	12	2.4	5.14	14.2193
16	250	130	10	2.2	4.56	13.1793



The above graph is plotted based on the calculation of s/n ratio and their appropriate parameters. Our assumption should be taken as the larger the better value.

From the current versus mean of s/n ratio graph it is proved that when the current increases the value of s/n ratio also gradually increases.

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1. From the welding speed versus mean of s/n ratio graph it is proved that when the welding speed increases the value of S/N ratio gradually decreases.
2. From the gas flow rate versus mean of s/n ratio graph it is proved that when the gas flow rate increases the value of s/n ratio first decreases and then maintained constant at sometime and then decreases.
3. From the arc gap versus mean of s/n ratio graph it is proved that when the arc gap increases the value of s/n ratio first decreases and then maintained constant at some time and then again increase.

STEP 4

OPTIMISED PARAMETERS AND THEIR LEVELS IN TERMS OF S/N RATIO

Table 5.6

LEVEL	CURRENT	WELDING SPEED	GAS FLOW RATE	ARC GAP
1	11.31	14.75	13.25	12.99
2	12.34	13.44	12.65	12.30
3	12.60	11.94	12.69	12.21
4	14.65	10.77	12.30	13.40

CALCULATION OF OPTIMIZED PARAMETER IN TERMS OF S/N RATIO

The optimized parameters and their levels in terms of s/n ratio are tabulated. It is calculated based on the previous table.

By calculating the average value at each parameter at each level the optimized parameters are listed. By our assumption the larger value should be taken as the better value.

So the larger one is considered as the standard optimized one. So the optimized parameter level is

1. Current-250 amps
2. Welding speed-100mm/min
3. Gas flow rate- 10l/min
4. Arc gap- 2.4mm.

STEP5

ANOVA TABLE PERFORMANCE

Table 5.7

SOURCE	ADJ MEAN SQUARE VALUE	PERCENTAGE CONTRIBUTION OF
CURRENT	6.0865	35.833%
WELDING SPEED	9.0893	53.512%
GAS FLOW RATE	0.3605	2.122%
ARC GAP	1.1795	6.944%
ERROR	0.2697	1.587%
TOTAL	16.9855	100%

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CALCULATION OF PERCENTAGE OF CONTRIBUTION

1. CURRENT=(ADJ MS/TOTAL)*100=35.833%
2. WELDING SPEED=(ADJ MS /TOTAL)*100=53.512%
3. GAS FLOW RATE=(ADJ MS/TOTAL)*100=2.122%
4. ARC GAP=(ADJ MS/TOTAL)*100=6.944%
5. ERROR=(ADJ MS/ TOTAL)*100=1.587%

STEP 6

REGRESSION ANALYSIS BY PREDICTIVE METHOD

Regression analysis is a technique for finding the depth of penetration theoretically.

Before finding the depth of penetration experimentally by using video measuring system we can find the depth of penetration theoretical value must almost near or equal to the experimental value. By this way can check whether our experiment goes in a right path. The generational regression equation is explained as follows.

$$Y=b_0+b_1x_1+b_2x_2+b_3x_3+b_{12}x_1x_2+b_{13}x_1x_3+b_{23}x_2x_3+b_{11}x_1^2+b_{22}x_2^2+b_{33}x_3^2$$

Where b_0 =constant coefficient

b_1 = clamping pressure

b_2 =amplitude of vibration

b_3 =weld time

Where x_1, x_2, x_3 are the regression coefficients.

The coefficients of the regression equation are determined using Minitab 15.0 software.

The regression equation is depth of penetration = $-0.20 + 0.0521$

CURRENT -0.0672 WELDINGSPEED -0.0440 GASFLOW RATE $+0.335$ ARCGAP.

The table is listed as follows

Table 5.8

PREDICTOR VALUE	COEFFICIENT
CONSTANT	-0.199
CURRENT	0.05210
WELDING SPEED	-0.06720
GAS FLOW RATE	-0.04400
ARC GAP	0.3350

EXPERIMENT	CURRENT	WELDING SPEED	GASFLOW RATE	ARC GAP	DEPTH OF PENETRATION
1	220	100	10	1.8	4.705
2	220	110	12	2.0	4.012
3	220	120	14	2.2	3.319
4	220	130	16	2.4	2.626
5	230	100	12	2.2	5.272
6	230	110	10	2.4	4.755
7	230	120	16	1.8	3.618
8	230	130	14	2.0	3.101
9	240	100	14	2.4	5.772

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10	240	110	16	2.2	4.945
11	240	120	10	2.0	4.47
12	240	130	12	1.8	3.643
13	250	100	16	2.0	6.071
14	250	110	14	1.8	5.42
15	250	120	12	2.4	5.037
16	250	130	10	2.2	4.386

VI. CONCLUSION

In this present work, DUPLEX STAINLESS STEELS 2205 are taken as the base materials for joining to occur through TIG welding process. The TIG welding resulted in inferior mechanical properties of the welds. Hence the present work, a design of experiment technique, the taguchi method has been used to optimize the TIG welding parameters (current, welding speed, gas flow rate) for the tensile strength of duplex stainless steel. Microstructure studies have been carried out on welded specimen. The following conclusions are drawn from this work.

- In this study 6mm thick DUPLEX STAINLESS STEELS 2205 PLATES were successfully welded using TIG welding using TIG welding machine.
- TIG welding of DUPLEX STAINLESS STEEL 2205 was investigated with different process parameters and also developed the design matrix to optimize process parameters. Microstructure study was carried to reveal that ferrite phase of the welded duplex stainless steel 2205 higher than base material due to recrystallization

Microstructure study was carried to reveal that ferrite phase of the welded duplex stainless steel 2205 higher than base material due to re crystallization.

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