Experimental Study on Activated Tungsten Inert Gas Welding

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Abstract— Tungsten Inert Gas Welding (TIG) is welding process which is used in those applications requiring a high degree of quality and accuracy. However, this welding process has disadvantage of less productivity. To overcome this disadvantage Activated Tungsten Inert Gas Welding is found. Experiments were performed on 304L stainless steel plates using A-TIG welding process. TIG welding fixture was designed and developed for getting fixed arc length and different welding speed. Different kinds of fluxes, TiO_2, SiO_2, CaO, MnO_2 and Al_2O_3 were used to investigate the effect of A-TIG welding process on weld geometric characteristic and distortion of weldments. A-TIG welding was carried out with different process parameters are used like welding current (60-140 A), speed (100-150 mm/min), arc gap (2 mm), gas flow rate (10 L/min), tip angle (75 degree), electro diameter (4 mm). Inverted Optical microscope with image analyzer was used to capture microstructure of weldment. A-TIG welding process parameters optimization was performed by multi objective optimization technique named as Gray Principal Component Analysis (G-PCA). The optimum process parameters were found to be 140 A current, 100 mm/min speed and mixture of SiO_2 and TiO_2 flux.

Key words: TIG and A-TIG welding, TIG welding fixture, G-PCA

I. INTRODUCTION

The Tungsten Inert Gas (TIG) welding process (or GTAW) is used when a good weld appearance and a high quality of the weld are required. An electric arc is formed between a tungsten electrode and the base metal in this process.

It was also found that flux formulation for activated TIG welding was rare. Higher thickness of plates can be welded by single pass in A-TIG welding without filler metal. The penetration depth was got higher at lower cost. Tensile and impact toughness tests were carried out on weld metal. It indicated that the value of mechanical properties was obtained high in A-TIG welding process. The heat of the arc melted and vaporizes part of this flux during welding process. The penetration of the weld bead was increased greatly

II. CONSTRUCTION, WORKING AND PROCESS OF A-TIG WELDING

TIG welding makes use of a shielding gas like argon or helium to protect the welding area from atmospheric gases such as oxygen and nitrogen, otherwise which may cause fusion defects and porosity in the weld metal.

TIG equipment consists of a welding torch in which a non-consumable tungsten alloy electrode is held rigidly in the collet.

Pressure regulator and flow meters are used to regulate the pressure and flow of gas from the cylinder. The work pieces to be joined are cleaned to remove dirt, grease and other oxides chemically or mechanically to obtain a sound weld. This will avoid atmospheric contamination of the solidifying metal thereby increasing the strength of the joint.

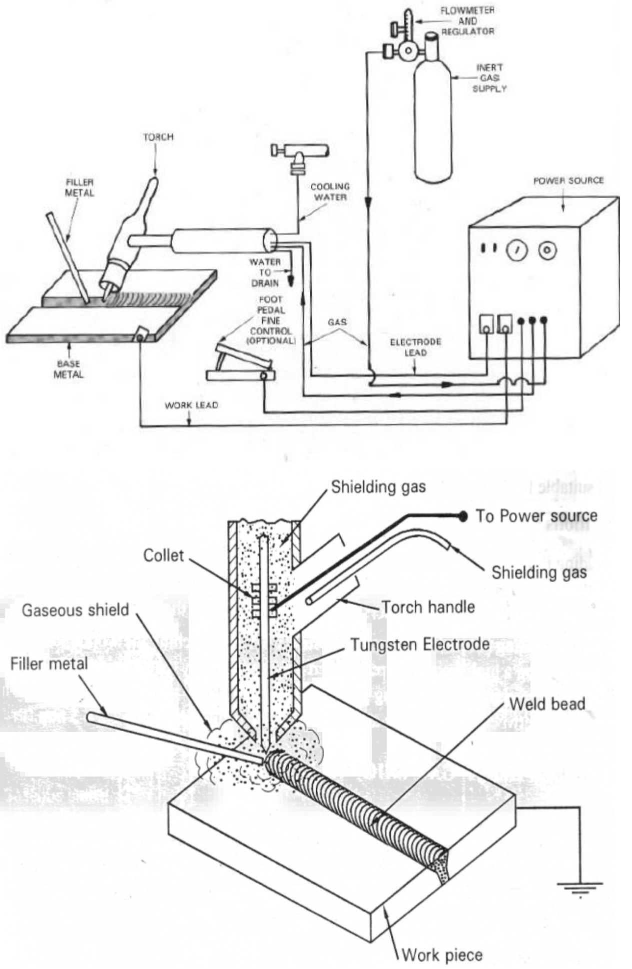


Fig. 1: Construction, Working and Process of A-TIG Welding

III. PROBLEM DEFINITION

Major Problems Caused in TIG welding as follow:

1) TIG is the most difficult process compared to all the other welding processes. The welder must maintain short arc length, avoid contact between electrode and the work piece and manually feed the filler metal with one hand while manipulating the torch with the other hand.
2) Tungsten material when gets transferred into the molten metal contaminates the same leading to a hard and brittle joint.
3) Process is slower so result in low productivity
4) Its relatively shallow penetration capability in single passes welding operations. Not suitable for thick metals.
5) The high sensibility of the weld bead shapes to variations of the chemical composition of the base metal

IV. EXPERIMENTAL PROCEDURE OF A-TIG WELDING

A. Experimental Set-Up

Fixture design and development which is used to secure weld plate in position during welding.

B. Experimental Investigation

Activated TIG welding process is used for Stainless steel 304L with 6 mm thickness as a base metal.

Various kinds of fluxes and combination of input parameters are used in A-TIG and TIG welding process.

After welding the surface morphology and cross section of weld bead is etched by etching solution.

Tool Maker Microscope is used to measure penetration depth and width of weld.

Inverted Optical Microscope with image analyzer is used to examine the microstructure of TIG and A-TIG weldments.

C. Process Parameter Optimization

By using selection of different process variables like Arc Voltage, Arc Current, Travel Speed, Activated Flux and Optimization of process parameters for penetration depth, width and angular distortion in A-TIG welding process using optimization technique

D. Optimize Process Parameter by Trial Experiments

Trial experiments are carried out to determine the working range of the process parameters and good quality of weld joints. Feasible limits of the parameters are chosen in such way that the A-TIG welded joints should be good quality. A-TIG welding of stainless steel plate with 6 mm thickness has been carried out on TIG welding fixture prepared with TIG welding machine.

Process parameter		Value	
Welding Speed (mm/min)	160		80
Welding Current (A)	140		60

Table 1: Process Parameter by Trial Experiments of A-TIG

Fig. 2: Appearance of a weld made on Stainless Steel 304L

E. Selection of Work-Piece Parameter

Stainless steels are engineering materials with good corrosion-resistance, strength and fabrication characteristics. They can readily meet a wide range of design criteria, including load, service life and low maintenance.

Selecting the proper stainless steel grades involves four qualities in the following order of importance:

a) Corrosion or heat resistance
b) Mechanical properties
c) Fabrication operation
d) Cost

Type 304L is an extra low-carbon variation of Type 304 with a 0.03% maximum carbon content that eliminates carbide precipitation due to welding. As a result, this alloy can be used in the "as welded" condition, even in severe corrosive conditions.

F. Measurement of Angular Distortion

The five positions on either side of the welds are marked, and the distance from each point to the horizontal surface is then recorded. Measurements are taken before and after welding.

Conclusively the five positions on either side of the welds are averaged, then added together to get the mean angular distortion value.

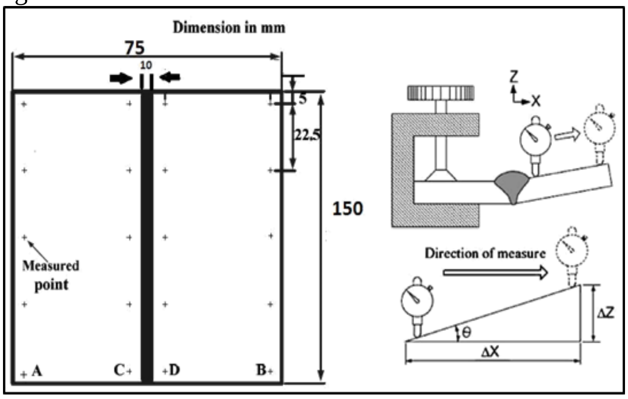


Fig. 3: Schematic Diagram of Weld Distortion Measurement

G. Measurement of Penetration Depth

Fig.4 show the effect of flux on depth of penetration and weld bead width for type 304L stainless steel. The A-TIG weld was made in single pass while the multi pass weld was made with 11 passes. The A-TIG welds produced in the present work were sound and passed radiographic examination and bend tests without any indications. There was residual fused flux layer produced on the face of the A-TIG welds that had to remove using wire brush.

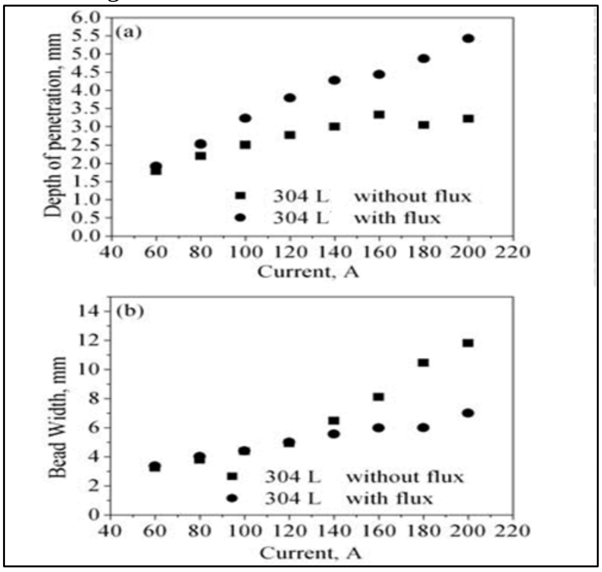


Fig. 4: Effect of activated flux on depth of penetration and weld bead width for 304L stainless steel

V. ANALYSIS METHOD

A. Grey Principal Component Analysis (G-PCA)

In G-PCA, experimental results are first normalized and then the grey relational coefficient is calculated from the normalized experimental data to see the relationship between the desired and actual experimental results.

Trial	Penetration	Width	Distortion
1	0.367	0.527	0.768
2	0.398	0.790	0.722
3	0.389	0.561	0.429
4	0.380	0.414	0.428
5	0.400	0.615	0.405
6	0.528	0.592	0.397
7	0.809	0.642	1
8	0.724	0.607	0.650
9	0.553	0.333	0.594
10	0.509	1	0.751
11	0.333	0.985	0.500
12	0.404	0.595	0.453
13	0.373	0.971	0.558
14	0.517	0.651	0.541
15	0.391	0.389	0.333
16	0.730	0.675	0.670
17	0.608	0.607	0.576
18	1	0.559	0.603

Table 1: Deviation sequence

B. Principal Component Analysis (PCA)

Principal Component Analysis (PCA) explains the structure of variance covariance by the linear combinations of each quality characteristics.

These data used to assess the correlation coefficient matrix and determine the Eigen values is shown in Table 2. The Eigen vector corresponding to each Eigen value is listed in Table 3 and its square is represented the contribution of the corresponding quality characteristic to the principal component.

Principal component	Eigen value	Explained variation (%)
First	1.643	54.775
Second	0.97	32.34
Third	0.385	12.885

Table 2: Eigen values and explained for principal component

Quality characteristics	First	Second	Third
Penetration Depth	0.528	-0.672	-0.52
Width	0.483	0.741	-0.467
Distortion	0.699	-0.005	0.715

Table 3: Eigen vector for principal component

C. Result of ANOVA

From the results of ANOVA, current appearances to be most important processing parameter with the highest percentage contribution of 47.81% which increases penetration depth and reduces weld width as well as distortion of the A-TIG welding.

ANOVA analysis is carried out using Minitab software. ANOVA was used to determine which parameter was significantly affected the quality characteristics. The results of ANOVA for the grey relational grades are listed in Table 4.

It shows that the two parameters current and flux are found to be the major factors with the selected multiple quality characteristics by determined by the percentage contribution.

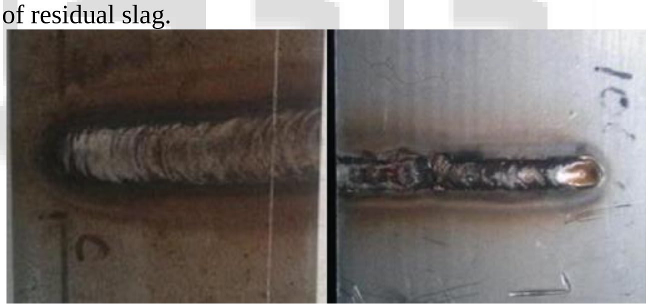
Symbol	Process Parameter	DOF	SS	MS	F-value	Contribution (%)
A	Current	2	0.1311	0.0656	14.23	47.81
V	Speed	2	0.0359	0.0179	3.89	13.09
F	Flux	2	0.0565	0.0283	6.13	20.61
Error		11	0.0507	0.0046		18.49
Total		17	0.2742			

Fig. 6: Microstructure of 304L stainless steel base metal

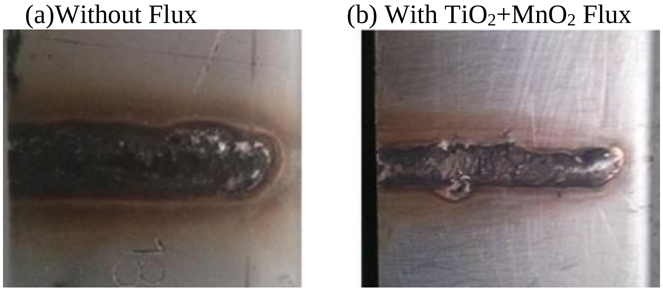
VI. PARAMETRIC EFFECT ON A-TIG WELD

A. Surface Appearance

These results were clearly indicated that on 304L stainless steel, SiO_2+TiO_2 powder was produced TIG welds with a satisfactory surface appearance but while using other two combination fluxes were produced to the formation of slag and spatters. It was happened because oxide compounds have substantially higher melting point, boiling point and thermal decomposition temperature than fluoride and sulfide compounds. Oxide powders were not easily melted by the arc heat source of TIG welding. It was indicated that TIG weld was produced with oxide fluxes contributed to the formation of residual slag.



(a)Without Flux (b) With TiO_2+MnO_2 Flux



(a)Without Flux (b)With Al_2O_3+CaO Flux

Fig. 5: Effect of oxide flux on surface appearance

B. Microstructure

Microstructure examination of any material is depended on its chemical composition and various process parameters used by the welding. The experiments used type 304L stainless steel plates as a base metal. The microstructure examination was carried out using Inverted Optical Microscope with image analyzer. The cross section of samples were fine polished and etched by etching solution of 10g CuSO4 with 100 ml HCl to examine the microstructure of FZ, HAZ and fusion boundary. Fig 6 shows the microstructure of 304L stainless steel base metal consists of tempered martensite and the grain size is smaller compared to that of the grain size in the fusion zone of weld joint. Fig 7 shows the microstructure of 304L stainless steel weld metal at fusion zone and HAZ were produced with and without flux.

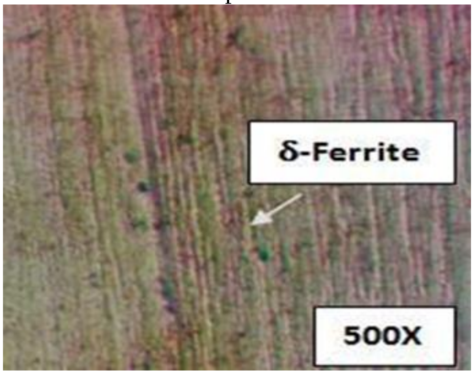
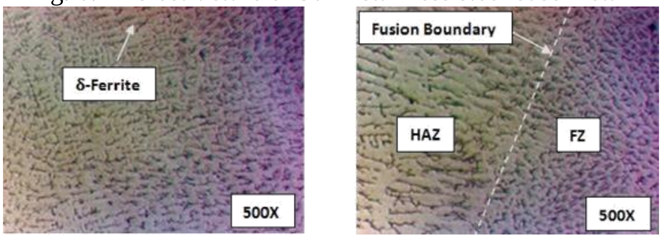
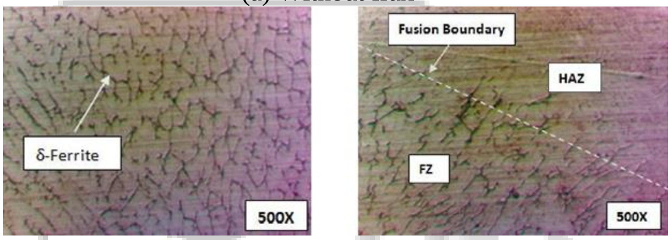


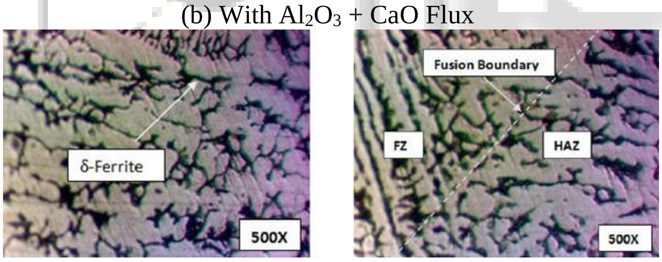
Fig. 6: Microstructure of 304L stainless steel base metal



(a) Without flux



(b) With Al_2O_3 + CaO Flux



(c) With TiO_2 + MnO_2 Flux

Fig. 7: Effect of activated flux on microstructure

C. *Weld Morphology*

In the experiments, SiO_2+TiO_2 powder was facilitated complete penetration in 304L stainless steel TIG welds. Al_2O_3+CaO and TiO_2+MnO_2 can capable of increasing penetration depth of TIG welds. A weld with high penetration depth was indicated that energy density of the heat source was increased in welding which was produced high concentration of heat energy during welding. The energy density of heat source was increased the overall heat required per unit length of the weld was decreased. It was indicated that A-TIG welding was also achieved higher melting efficiency. A-TIG welding was significant reduce the amount of heat required for the welds with large cross section area and high weld depth.

Fig. 8: Effect of TIG welds with various flux powders on weld morphology

D. *Angular Distortion*

The angular distortion of TIG welding was made with and without different combination of oxide compound. A-TIG welding was increased penetration joint and decreased angular distortion. It was characteristic of high degree of energy concentration during welding and reduced the quality of supplied heat. It was prevented to overheat of the base metal and reduced the incidence of thermal strains and incompatible strain was caused by shrinkage in thickness.

VII. CONCLUSION

TIG welding with mixture of SiO2 and TiO_2 fluxes achieves increase in weld depth and decrease in weld width as well as angular distortion.

The results indicate that TIG welds produced without flux the surface appearances clean and smooth but with flux formed residual slag, spatters and small amount of fume is reported. Hardness value of the weld zone change with the distance from weld centre due to change of microstructure.

The G-PCA method is supplemented by the ANOVA which is revealed that current, speed and flux are controllable factors significantly the multiple quality characteristics with desire contribution of 47.81%, 13.09% and 20.61% respectively.

The optimal combination of the process parameters was obtained from the proposed method was set with values of current, speed and flux 140 A, 100 mm/min and mixture of SiO2 and TiO2 flux respectively. The corresponding responses are penetration depth, weld width and distortion of 3.64mm, 3.76mm, and 0.76 respectively.

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