Parametric Comparison and Optimization of Process Parameters In Tig Welding With And Without Use Of Flux For SS 316

Urvish Patel[1], Divyesh Patel[2], Priyesh Santoki[3]

[1] Research scholar, Mechanical Engg. Dept., Venus International College of Technology-Gandhinagar, Gujarat, India

[2] Asst.Prof. Divyesh Patel, Mechanical Engg. Dept., Venus International College of Technology-Gandhinagar, Gujarat, India

[3] Asst.Prof.Priyesh santoki, Mechanical Engg. Dept., Venus International College of Technology-Gandhinagar, Gujarat, India

ABSTRACT

The purpose of this study is to investigate the effect of the specific fluxes used in tungsten inert gas process. Tungsten Inert Gas Welding (TIG) is welding process which is used in those applications requiring a high degree of quality and accuracy. Effect of current, voltage, and gas flow rate on weld penetration on 6 mm thick stainless steel 316 plate.Cr_2O_3 *and* TiO_2 *oxide powder were used to investigate the effect of activating flux on TIG weld penetration depth of 316 stainless steel. A-TIG welding was carried out with different process parameters are used like welding current (160-200A), voltage (10-14V), gas flow rate (5-15L/min).*

Keyword: *TIG welding, Taguchi method, 316 stainless steel, Weld penetration, Activated flux TIG welding*

1. INTRODUCTION

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding which uses an arc between a non-consumable tungsten electrode and the workpiece to be welded under a shielding gas is an extremely important arc welding process**.** The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium) and a filler metal is normally used through some welds, known as autogenous weld**.** Electrode is used only to create the arc in tungsten inert gas welding and it is not consumed in the weld [2]

Welding is used for permanent joints of metal. TIG welding is a part of welding process and it can be widely used in manufacturing industries, automobile industries, aerospace industries etc. TIG welding is used in morden industries for joining either similar or dissimilar materials. [14]

Gas tungsten arc welding process welding set utilized suitable power source, a cylinder of argon gas, welding torch having connection of cable for current supply, tube for shielding gas supply and tube water for cooling torch.[15]

1.1 CONSTRUCTION, WORKING AND PROCESS OF 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.

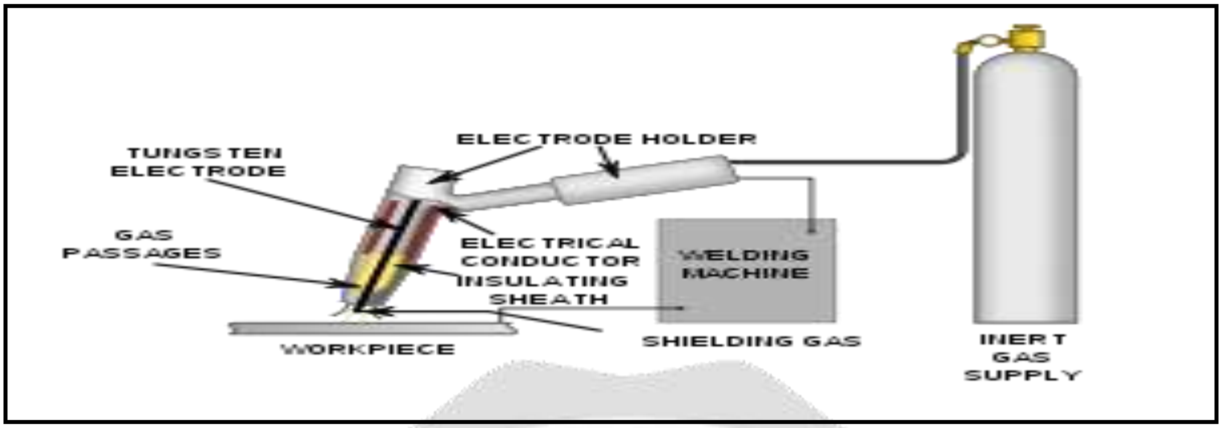


Fig.1 Schematic Diagram of TIG Welding Process [14]

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.

2. LITERATURE REVIEW

Kuang-Hung Tseng et al [1] present the characteristics of duplex stainless steel in activated TIG welding. Duplex 2205 stainless steel plate was used as base metal.in A TIG welding process. Powder form of TiO_2,MnO_2, SiO_2, MoO_3 and Cr_2O_3 were used as a activated flux. It was mixed with acetone and applied on the surface of base metal as plate form using paint brush. Duplex stainless steel 2205 of 6 mm thick plate was used as base metal. The experiments were carried out with and without activated fluxes at electrode diameter of 3.2mm.Tt was conclude that using activated flux in TIG welding increased both the join penetration and the weld depth-to-width ratio. It was also conclude the Sio_2 flux produced a full joint penetration and the greatest weld depth-to-width ratio and using. Sio_2, MoO_3 and Cr_2O_3 improved mechanical strength of grade SS2205 compared with conventional TIG weld.

Sanjay Nayee et al.[2] present investigation is to study the “Effect of Activating Fluxes on Mechanical and Metallurgical Properties of Dissimilar Activated Flux Tungsten Inert Gas Welds”.SA516Gr70 carbon steel and 304 austenitic stainless steel of 6 mm plate was used as a base metal. The mixture of Tio_2, Zno.and Mno_2 were used as a activated fluxes. It was concluded that highest D/W ratio achieve by Tio_2, Zno fluxes. It was also observed that lowest angular distortion under Tio_2 compared to normal tungsten inert gas welds.

Dinesh Kumar et al. [3] present the parametric optimization in butt joint of 304L in TIG welding. Austenitic stainless steel sheet of 1.6 mm thin sheet was used as base metal. The most important parameters affecting the responses have been found as current and speed. The optimum parameters were found to be speed 125mm/min, current 125A, standoff 2mm, frequency 3 Hz (constant),gas flow 10 lit/min(constant).Optimized process parameter would be solve the problem of corrosion and fatigue faced by the material, by improving the weld quality. At the same time, it increases the strength of the weld time with minimum heat affected zone. Good quality weld is obtained from face to root while using

Bhawandeep Singh et al. [4] presented the effect of active flux on mild steel in ATIG welding .Mild steel plate of 8mm thickness was used as base metal. To increase the penetration oxide powder Cr_2O3, MgCO3 and 1:1 mixture of both these powder, Al_2O3, MgO, and CaO also was used as activated flux. It was found that the Cr_2O3 flux increased the penetration double time as compared with conventional tig welding. It was also found that the quality of weld increased by applying the flux. It was conclude that using CaO and Cr_2O3flux increase the depth to width ratio, therefore susceptibility to get crack also reduced.

Ahmadi et al. **[5]** presented the effect of activated flux in TIG welding.316L stainless steel of 8 mm thick plate was used as base material.Sio_2 and TiO_2 oxide powders were used as activated fluxes. It was concluded that penetration depth was increased while using both fluxes and decreases the weld width. Activating fluxes improve the joint mechanical properties.

Abhishek Prakash et al. [6] presented the optimization of process parameters in activated TIG welding. Low carbon steel (ASTM A29) of 8 mm thick plate was used as base metal. It was observed that the welding current has the greatest influence on tensile and hardness in the welded sample of ASTM A29 followed by welding voltage and wire speed.

Ramkumar Devendranath et al. [7] studied on structure-property relationship and corrosion behavior of the activated flux TIG welding**.** Super duplex stainless steel (UNS S32750) of 5 mm thick plate was used as a base metal in TIG welding process. NiO, MoO3and SiO_2fluxes were mixed with acetone and applied on the surface of base metal using paint brush. It was observed that better penetration and depth to width ratio was achieved by A-TIG welding process using NiO, $MoO_3$and SiO_2fluxes.it was observed that impact toughness and corrosion resistance to be greater for NiO flux owing to the lesser quantity of oxide inclusions.

Jun Shen et al [8] reported the effect of welding current on properties of magnesium alloy joints in tungsten inert gas welding process.6mm thick plate was used as a base metal. It was observed that better penetration and depth to width ratio was achieved by A-TIG welding process using TiO_2 flux. It was also conclude that too high welding current decreased the D/W ratio

Ahmadi .E et al [9] conducted the experimental study for development and application of oxide based flux powder in ATIG welding process. Powder form of SiO2, TiO2, Cr2O3, and CaO were used as activated flux. Austenitic 316L Stainless Steel was used as base metal of 6mm thickness. It was concluded that the weld penetration and D/W ratio increased while the weld metal width decreased. It was also found A-TIG welding can increase ultimate tensile strength of weldment

Navid Moslemi, et al. [10] presented the Effect of Current on Characteristic for 316 Stainless Steel Welded Joint. 316 stainless steel pipe with diameter of 73mm and 7.0mm thickness was used as base metal. It was concluded that Arc current of 100A has also been identified as the most suitable arc current used to weld the two and half inches 316 stainless steel pipe. The optimum TIG welding parameter (100A) has been identified which may contribute to improve the productivity and cost effective process

Yung-Chang Chen, et al. [11] reported the Cr2O3 Flux Assisted TIG Welding of Type 316L Stainless Steel Plates. Powder form of Cr2O3 Flux were used as activated flux. Stainless steel 316L of 5 mm thick plate was used as base metal. It was concluded that Cr2O3 flux produces a substantial increase in depth-to-width ratio of type 316L stainless steel welds. It was also concluded that the activated TIG welding can reduce the amount of heat input per unit length in a weld, and the residual stress of stainless steel 316L weldment can therefore be reduced.

Chih-Yu Hsu et al. [12] presented the Performance of activated TIG process in austenitic stainless steel welds. 316L Stainless Steel plate of 6 mm thickness was used as base plate. Powder form of MnO_2, TiO_2, MoO_3, SiO_2, and Al_2O_3 Flux were used as activated flux. Fluxes were mixed with acetone and applied on the surface of base metal using paint brush. It was concluded that ATIG welding with SiO_2 and MoO_3 fluxes achieves an increase in weld depth and a decrease in bead width, respectively. It was also concluded The SiO_2 flux can facilitate root pass joint penetration, but the Al_2O_3 flux led to a deterioration in the penetration compared to the conventional TIG process for Type 316L stainless steel welds.

Devendranath Ramkumar et al. [13] studied on Effect of autogeneous GTA welding with and without flux addition on the microstructure and mechanical properties of AISI 904L joints. Super-austenitic stainless steel, AISI 904L plate of 5 mm thickness was used as base plate. . The use of compound flux containing 85% SiO2–15% TiO2 acquainted for better depth of penetration compared to autogeneous welding. It was concluded that Bead on trial studies showed that the use of compound flux SiO2–TiO2 had considerably increased the depth of penetration, almost thrice than that of without flux ones in the same condition.

3. METHODOLOGY

Design of experiment has become important methodology that maximize the knowledge gained from experimental data by using a smart positioning of points in engineering. This methodology provides a strong tool to design and analyze the experiments. It eliminate redundant observation and reduce the time and resources to make experiments. To meet the objective, experimental set up was searched first of all. The experimental setup consists of semi-automatic welding machine with control over welding parameters such as welding current, arc voltage, gas flow rate, etc. The experiment will be done by establishing the range of process parameters based on trial experiments. The DOE (Design of Experiment) method applied for the experiments is Response Surface method (RSM) with Central Composite Design (CCD). The DOE will be prepared using MINITAB16 software. The experimental readings was taken on weld penetration. Optimization of process parameters will be been carried out using the genetic algorithm approach. This will be done using the soft computing tool MATLAB.

3.1. MATERIAL SELECTION AND EXPERIMENTAL PROCEDURE

I had selected material for Experiment runs Stainless steel (SS316) as a base metal having size is 115×35×6 mm.

Fig. 2. Test Specimen

Table 1. Chemical Composition of SS 316

ASTM	C%	Si%	Mn%	Cr%	Ni%	Mo%	P%	S%
316	0.019	0.490	1.440	16.740	11.280	2.160	0.024	0.002

- Input parameters: Welding current, Arc Voltage, Gas Flow Rate, Activated Flux.
- Output parameters: Penetration

Table 2: Specific Range of Process Parameters

Parameters	Welding Current (Amp)	Voltage (V)	Gas Flow Rate (L/Min)	Fluxes
Value	160-180-200	10-12-14	5 -10-15	$Cr_2O_3TiO_2$

- In this research Experiment is run as 3 Phases and each Phase have 20 reading so total 60 Reading has been taken
- Welding is done on SS316 plate at 3 different phase and we get penetration on plate.
- Phase 1: Without using activated flux.
- Phase 2: with using TiO_2 as activated flux.
- Phase 3: with using Cr_2O_3 as activated flux.

Response surface method is the one of the design of experiment gives design matrix for with and without using activated flux given below.

4. RESULT AND ANALYSIS

After performing analysis of different part of welding joint with various parameters such as welding current, arc voltage and Gas flow rate with and without activated flux in response surface method and finding out best way to improve penetration of welding joint.

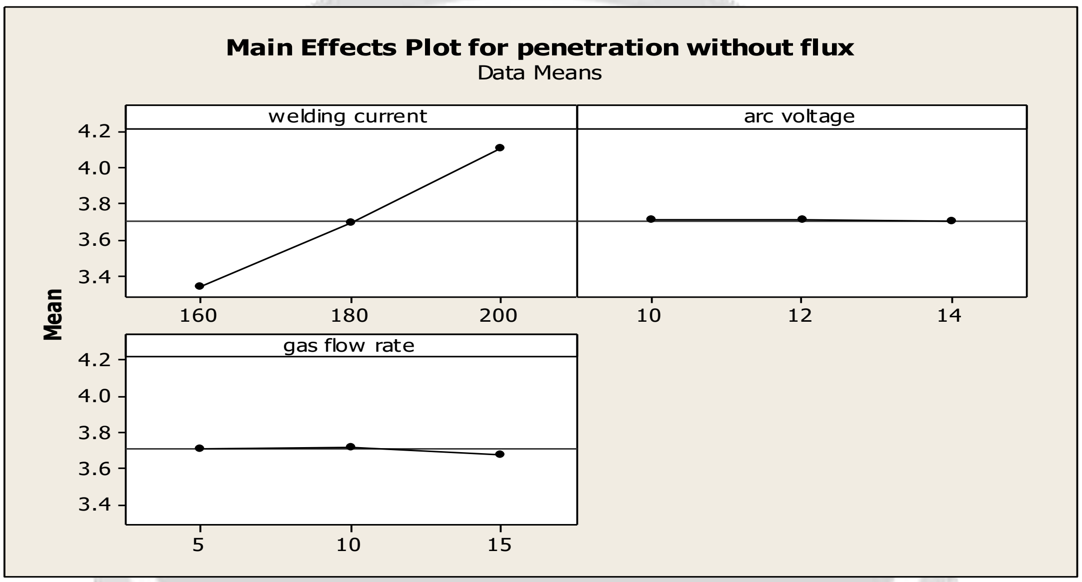
Table 3 RSM Experimental design matrix for with and without activated Flux

Std Order	Run Order	Welding current(Amp)	Arc voltage(Volt)	Gas flow rate(L/Min)	Penetration without using flux	Penetration withTiO_2 using flux	Penetration without Cr_2O_3 using flux
13	1	180	12	15	3.60	3.80	4.10
3	2	180	12	5	3.70	3.89	4.18
8	3	180	10	10	3.65	3.86	4.15
15	4	180	12	10	3.68	3.85	4.18
2	5	200	14	15	4.00	4.18	4.50
1	6	200	10	15	4.18	4.30	4.59
5	7	160	12	10	3.40	3.58	3.88
12	8	160	10	15	3.35	3.50	3.82
20	9	160	14	5	3.32	3.52	3.81
18	10	180	12	10	3.67	3.87	4.19
4	11	200	14	5	4.10	4.28	4.60
10	12	160	14	15	3.32	3.55	3.88
7	13	180	12	10	3.71	3.91	4.21
11	14	180	12	10	3.72	3.95	4.25

6	15	180	14	10	3.75	3.96	4.26
9	16	180	12	10	3.74	3.92	4.31
17	17	180	12	10	3.70	3.89	4.29
14	18	160	10	5	3.28	3.50	3.82
16	19	200	10	5	4.15	4.40	4.74
19	20	200	12	10	4.16	4.36	4.65

4.1 EFFECT OF PROCESS PARAMETERS ON PENETRATION

4.1.1 AN EFFECT OF PROCESS PARAMETERS ON PENETRATION WITHOUT USE OF FLUX



Graph 1: Main effect of process parameters on penetration without using flux

Graph 1 shows the main effect plot of process parameters on penetration at different parameters like welding current, arc voltage and gas flow rate in GTAW process of for welding SS 316. From the figure, it can be seen that :-

- **Effect of welding current:** penetration increase with the increase in welding current
- **Effect of gas flow rate:** There is a slight increase in bead penetration with the increase in gas flow rate.

The Regression equation for penetration without flux = - (0.300 + 0.0193 * I- 0.00300 * V + 0.00320 * G)

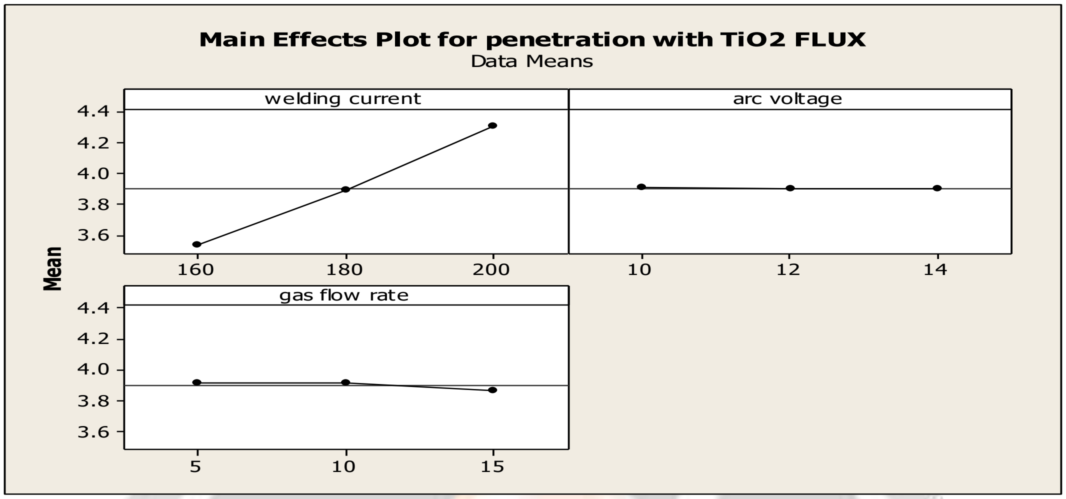
Where

I= Welding Current (Amp)

V= Voltage (Volts)

G= Gas flow rate (Lit/min)

4.1.2. AN EFFECT OF PROCESS PARAMETERS ON PENETRATION WITH USING TIO_2 ACTIVATED FLUX

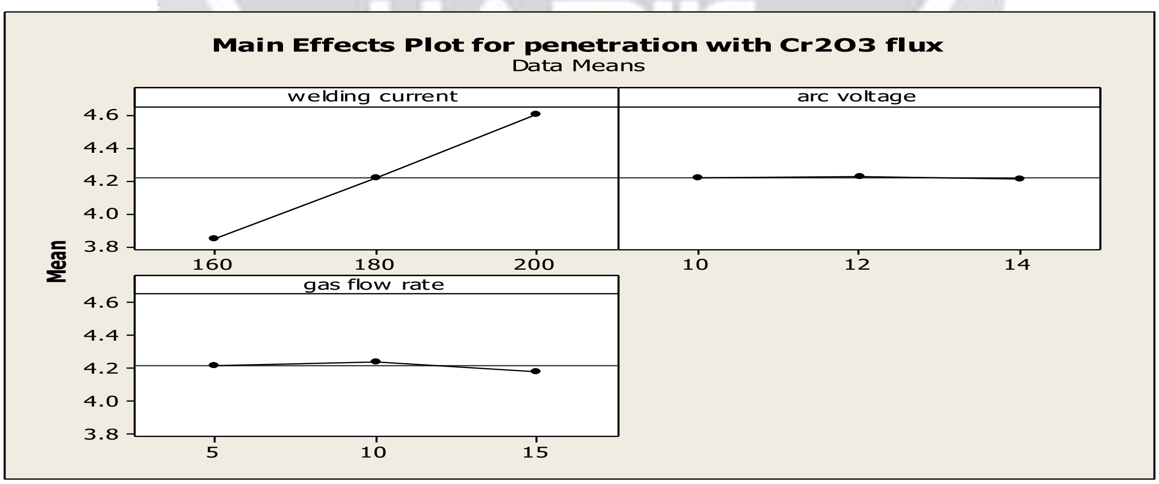


Graph 2: Main effect of process parameters on penetration with using TiO_2 flux

Graph 2 shows the increase penetration with using TiO_2 activated flux. It also show that penetration increase when increase the welding current and gas flow rate slight increase the welding penetration**.**

The Regression equation for penetration with TiO_2 flux = - (0.515 + 0.0193 * I - 0.00250 * V - 0.00480 * G)

4.1.3. AN EFFECT OF PROCESS PARAMETERS ON PENETRATION WITH USING CR_2O_3 FLUX



Graph 3: Main effect of process parameters on penetration with using Cr_2O_3 flux

Graph 3 shows the increase penetration with using Cr_2O_3 activated flux. It also show that penetration increase when increase the welding current.

The regression equation for penetration with Cr_2O_3 flux = - (0.834 + 0.0191 * I - 0.00050 * V - 0.00400 *G)

5. OPTIMIZATION

The aim of present study was to determine the set of optimal parameters of GTAW process to ensure minimum weldment area after satisfying the condition of maximum penetration.

5.1 CONSTRAINTS

Subject to the condition that penetration takes the maximum value;

$I_{min} \leq I \leq I_{max}$, i.e. 160A ≤ I ≤ 180A,

$V_{min} \leq V \leq V_{max}$, i.e. 10V ≤ V ≤ 14V.

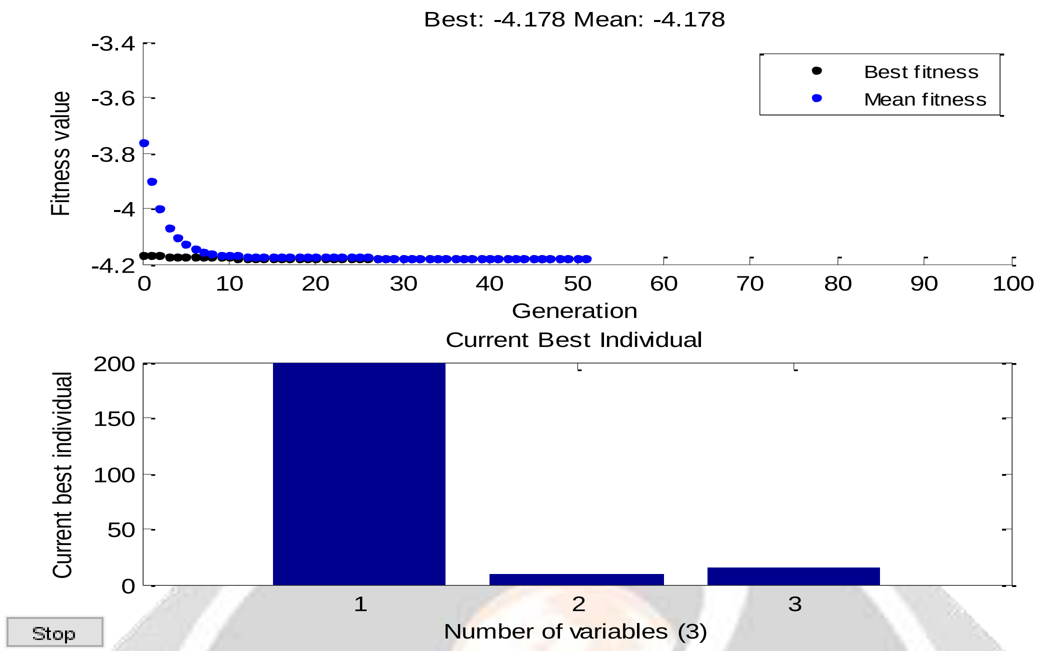
$G_{min} \leq G \leq G_{max}$ i.e. 5lit/min ≤ G ≤ 15lit/min,

5.2 OPTIMIZATION USING MATLAB TOOLBOX

The objective optimization function GA from the GENETIC OPTIMIZATION tool box of MATLAB is used for defining and solving the problem.

Table 4: Results of optimization using GA [Without use of flux]

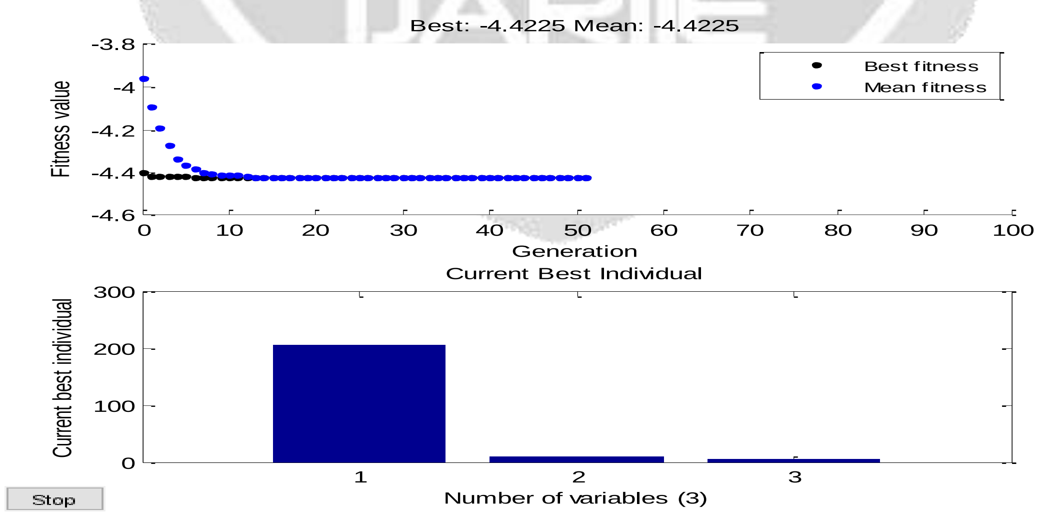
Experiment No	**Process Variable**			**Response**
	Welding current(Amp)	**Arc voltage(V)**	**Gas flow rate(Lit/min)**	**penetration**
1	200	10	15	4.17



Graph 4: Plots of best fitness and best individual for GA using regression equations for without using flux

Table 5: Results of optimization using GA [With use of TiO_2 flux]

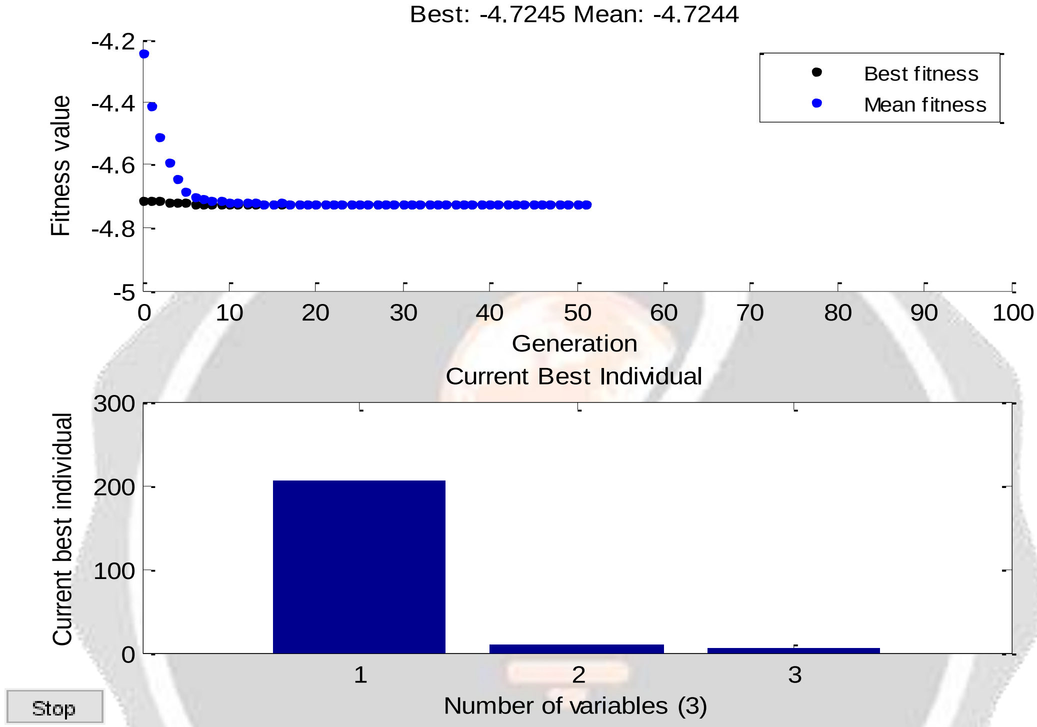
Experiment No	Process Variable			Response
	Welding current(Amp)	Arc voltage(V)	Gas flow rate(Lit/min)	penetration
1	200	10	5	4.42



Graph 5: Plots of best fitness and best individual for GA using regression equations for with using TiO_2 flux

Table6: Results of optimization using GA [With use of Cr_2O_3 flux]

Experiment No	Process Variable			Response
	Welding current(Amp)	Arc voltage(V)	Gas flow rate(Lit/min)	penetration
1	200	10	5	4.72



Graph 6: Plots of best fitness and best individual for GA using regression equations for with using Cr_2O_3 flux

2 CONCLUSIONS

From the experiment, it concluded that the:

- The experiment was carried out by with(TiO_2, Cr_2O_3), without activated flux and three processing parameter and that the welding current, arc voltage and gas flow rate the study presented that the welding current, arc voltage and gas flow rate this three parameter are affecting the penetration of the weld joint of tungsten inert gas welding process.
- From experiment result and analysis it shows clearly that Cr_2O_3 flux gives higher penetration compare to without flux and TiO_2 activated flux.

The Genetic Algorithm was used for optimization. Following was concluded:

- Both the regression and empirical models were subjected to optimization process and both have given near about same optimal values.
- Genetic Algorithm was able to reach the optimal solution, after satisfying the constraints.

REFERENCES

[1] Kuang-Hung Tseng, Tsann-Shyi Chern and Hsien-Lung Tsai"Study of the characteristics of duplex stainless steel activated tungsten inert gas welds" Materials and Design, Elsevier(2011) 255-263

[2] Sanjay G. Nayee and Vishvesh J.Badheka" Effect of oxide-based fluxes on mechanical and metallurgical properties of dissimilar activating flux assisted-tungsten inert gas welds" Journal Of Manufacturing Processes Elsevier (2014) 137-143

[3] Dinesh Kumar, Elangovan.S, Siva Shanmugam.N" Parametric optimization of pulsed-TIG welding process in butt joining of 304L austenitic stainless steel" International Journal Of Research In Engineering And Technology(2014) 213-219

[4] Er Bhawandeep Singh and Er Avtar Singh "Performance of activated TIG process in mild steel welds" Mechanical Engineering (2015) 1-5

[5] Ahmadi. E and Ebrahimi A.R. "The effect of activating fluxes on 316L stainless steel weld joint characteristic in TIG welding using the Taguchi method" Journal of Advanced Materials and Processing (2013) 55-62

[6] Abhishek Prakash, Raj Kumar Bag and Siva sankar Raju"Parametric optimization of tungsten inert gas (tig) welding by using taguchi approach " International Journal of Innovative Research in Science, Engineering and Technology(2016) 3630-3638

[7] Devendranath Ramkumar. Siva Goutham, Sai Radhakrishna, Ambuj Tiwari and , Anirudh "Studies on the structure–property relationships and corrosion behavior of the activated flux TIG welding of UNS S32750" Journal of Manufacturing Processes Elsevier (2016) 1-11

[8] Jun shen, Da-Jun ZHAI, Kai LIU and Zhong-ming CAO "Effects of welding current on properties of A-TIG welded AZ31magnesium alloy joints with TiO2 coating " Transation of Nonferrous Metals. Soc. China Elsevier. (2014) 2507-2515

[9] Ahmadi, Ebrahimi A.R., "Welding of 316l austenitic stainless steel with activated tungsten inert gas process" Journal Of Materials Engineering And Performance(2015) 1065-1071

[10] Navid Moslemi, Norizah Redzuan,Norhayati Ahmad, Tang Nan Hor Effect of current on characteristic for 316 stainless steel welded joint including microstructure and mechanical properties". 12th Global Conference on Sustainable Manufacturing (2015) 560-564

[11] Kuang-Hung Tseng, Yung-Chang Chen, and Kuan-Lung Chen"Cr_2O_3 flux assisted tig welding of type 316l stainless steel plates". Journal of Applied Mechanics and Materials (2012) 2592-2596

[12] Kuang-Hung Tseng, Chih-Yu Hsu "Performance of activated TIG process in austenitic stainless steel welds" Journal of Materials Processing Technology(2011) 503–512

[13] Devendranath Ramkumar, Jelli Lakshmi Narasimha Varma, Gangineni Chaitanya, Ayush Chaudhary, N. Arivazhagan, S. Narayanan "Effect of autogeneous GTA welding with and without flux addition on the microstructure and mechanical properties of AISI 904L joints". Journal of Applied Materials Science & Engineering(2015) 1-9

[14] Prasant Kumar Singh, Raj Kumar, Baljeet Singh, Rahul Kumar Singh. A review on TIG welding for optimizing process parameters on dissimilar joints. Journal Of Engineering Research And Applications (2015).125-128

[15] Imran Shaikh, Veerabhadra Rao"A Review on optimizing process parameters for TIG welding using taguchi method & grey relational analysis". International journal of Science and Research(2013)2449-2452