International Journal For Technological Research In Engineering
Volume 5, Issue 3, November-2017 ISSN (Online): 2347 - 4718

EXPERIMENTAL INVESTIGATION OF PROCESS PARAMETERS ON WELD BEAD GEOMETRY FOR SS-304 USING TIG WELDING

Ananya H. Prajapati
Student in Mechanical Engineering, VICT, Gandhinagar, India

Abstract: TIG welding also known as GTAW is one of widely used techniques for joining ferrous and non-ferrous metals. TIG welding offers several advantages like joining of dissimilar metals, low heat affected zone, absence of slag, etc. It uses a non-consumable electrode to produce welds. Weld pool is easily controlled such that arc is stable at very low welding currents enabling thin components to be welded and the process produces very good quality weld metal, although highly skilled welders are required for the best results.TIG weld quality is strongly characterized by the weld pool geometry. It is very important to select welding process parameters for obtaining optimal weld pool geometry. In this work, the selection of process parameters for obtaining optimal weld pool geometry in the TIG welding of SS 304 will be presented. Experiments will carry out as per Taguchi design will determine input–output relationships of the process and Genetic Algorithm will be used for optimization.
Keywords: TIG Welding, Stainless Steel-304, Taguchi Approach, MINITAB-16, Genetic Algorithm.

I. INTRODUCTION

Welding is the process of joining two pieces of metal by creating a strong metallurgical bond between them by heating or pressure or both. A welded joint is obtained when two clean surfaces are brought into contact with each other and either pressure or heat, or both are applied to obtain a bond. The tendency of atoms to bond is the fundamental basis of welding. As the demand for welding new materials and larger thickness components increase, mere gas flame welding, which was first known to the welding engineer, is no longer satisfactory and improved such as metal inert gas welding, tungsten inert gas welding, electron and laser beam welding have been developed [1]. We know that there is various welding process are present, among the various welding process, Tungsten inert gas (TIG) welding plays a major role in the welding of mild steel or thin sections of non-ferrous metals such as copper alloys, aluminum alloys, magnesium and stainless steel. Tungsten inert gas (TIG) welding is also known as Gas tungsten arc welding (GTAW). It is one of the most widely used methods in many manufacture industries. The basic equipment for TIG welding comprises a power source, a welding torch, a supply of an inert shield gas, a supply of filler wire and perhaps a water cooling system. Tungsten inert gas (TIG) welding is an inert-gas shielding arc-welding process using non-consumable electrode. The electrodes may also contain 1 to 2% thoria (thorium oxide) mixed along with the core tungsten or tungsten with 0.15 to 0.40% zirconia (zirconium oxide). As pure tungsten electrode are less expensive but it will carry less current. The thoriated tungsten electrodes carry high currents and are more desirable because they can strike and maintain a stable arc with relative ease. The zirconia added tungsten electrode is better than pure tungsten but inferior to thoriated tungsten electrodes. We know that TIG welding has several advantage like joining of dissimilar metals, the absence of slag, low heat affected zone and etc. Since input parameters play a major role in determining the quality of a welded sample. So, welding parameters those are affecting the arc should be calculated and their variable conditions during the process must be known before, in order to get good or optimum results, in order to get a perfect arc, we have achieved stable parameters. We also know that the properties of the welded sample are affected by a greater number of welding Parameters [2]. Properties are Hardness, Impact force, Tensile strength, Ductility, Toughness, Hardness etc. Now, in order to overcome from this problem, there are various optimization methods are there to get desired output. Now in this experiment, we are using SS-304. The mild steel is more flexible than other steel. The present experiment mainly focused on the weldability of SS-304 with the process of TIG welding. The work details of process parameters (welding speed, welding current and gas flow rate) influence on the response (bead penetration, bead height and bead width) by using analysis of variance (ANOVA) with the help of Taguchi array [L9] and Genetic Algorithm.

II. WORK PIECE MATERIAL

SS 304 is perhaps the most widely used because of its extrudability AISI 304 Stainless Steel is widely used because of its good weldability, resistance against corrosion & chemicals, good machinability, and good heat resistance. Stainless steel-304 has lower carbon to minimize carbide precipitation. Used in high-temperature applications. It’s wide application in Chemical Equipments, Cooking Equipments, Cooling coil, Evaporators, Food Processing Equipments, Hospital Equipments, Refrigerator Equipments, Paper & Rubber Industry.

Material	C	Cr	Fe	Mn	Ni	P	S	Si	N
AISI 304 Wt.%	Max 0.08	18-20	66.345-74	Max 2	8-10.5	Max 0.045	Max 0.03	0.75	0.1

Table 1: Chemical composition of Stainless Steel-304

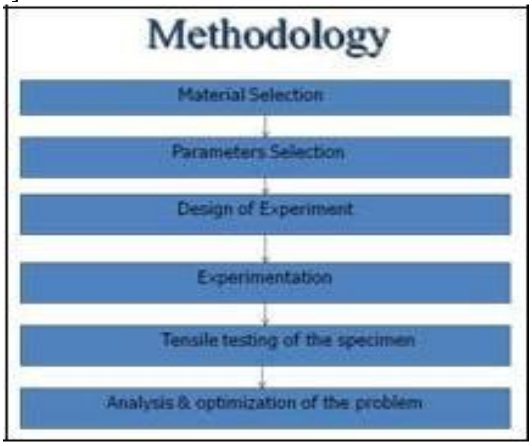
Melting Point	Density	Compression strength	Tensile strength	Modulus of Elasticity	Electrical Resistivity	Thermal Conductivity
1400-1450° C	8.00 g/cm^2	210 Mpa	520Mpa	193Gpa	0.00000072 Ωm	16.2 W/m °C

Table 2: Mechanical properties of Stainless Steel-304

International Journal For Technological Research In Engineering
Volume 5, Issue 3, November-2017 ISSN (Online): 2347 - 4718

III. TAGUCHI METHOD

A Japanese scientist i.e. Genichi Taguchi, develop a technique on an orthogonal array. This method is widely used in manufacturing industries. The main objective of this method is to provide a high-quality product at very low cost to the producer (manufacturer). Taguchi developed an array for predict how different parameters affect the mean and variance of the process parameters. He made the method in such a way that each factor have equally weighted because each factor is evaluated independently of other factors, so that's why the effect of one factor does not affect the value of other factors [3] or we can it is statistically technique that allows us to improve the consistency of production. Taguchi method recognizes that not all factors that cause variability can be controlled. These uncontrollable factors are called noise. Taguchi designs try to identify controllable factors to evaluate variability that occurs and then determines optimal factor setting that minimize the process variability. A process designed with this goal will produce more consistent output and performance regardless of the environment in which it is used [4].



Methodology of Experiment

List of Equipment:-
A. TIG welding machine
B. Power Source
C. Filler Wire Feeders
D. Torch Traversing Mechanism
E. Shielding Gas Regulators
F. Welding torch
G. H.F. (High Frequency Unit) for Arc initiation
H. Servo controlled drive mechanisms
I. DCIS (Digital Communication Interface system)

A. TIG Welding Machine

The experiments have been conducted using a Unitor UWI 400Power Source and an Automated Welding Set up. In this welding machine automated Tungsten Inert Gas torch as well as automatic feeler wire feeding unit are provided. For experimentation, servo motors are used for maintaining welding speed during actual welding. This would be rather different with hand held manual torch. While using automated TIG torch welding speed can be set to specific value directly on this machine as it is a controlled automation.

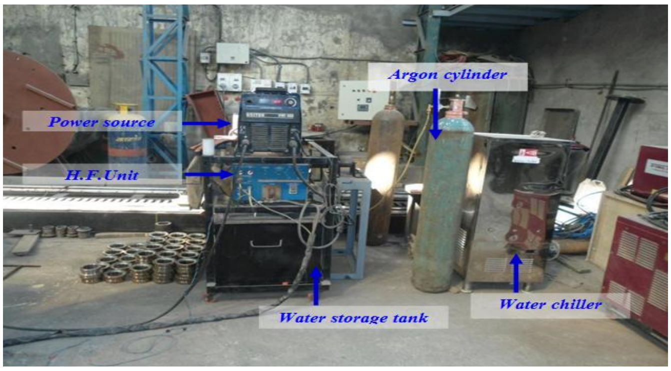


Fig.1 : TIG welding machine

B. Power Source

Power sources for GTAW are generally of the constant current type with drooping volt-ampere static curves. Light weight transistorized direct current power sources are currently used, being more stable and versatile than the old thyristor-controlled units. In rectifier-inverter power sources the incoming AC current is rectified and then converted into AC current at a higher frequency than that of the mains supply, in the inverter. Afterwards high voltage AC current is transformed into low voltage AC current suitable for welding, in the transformer, and then rectified. The aim to increase the current frequency is to reduce the weight of the transformer and other components of the source such as inductors and capacitors.

Fig.2 Power source

C. Filler Wire Feeders

Wire feeders are referred to as cold or hot, depending on whether the filler wire they feed mechanically into the arc is at room temperature or preheated by electric resistance method. There are two systems: cold wire and hot wire feeding system.


Fig.3 Automatic filler wire feeding

D. Torch Traversing Mechanism

They are designed to move the electrode torch or the welding head with respect to the joint or vice versa. They maintain the position of the electrode with respect to the joint within close limits and travel smoothly at a set speed without much vibration. The sketch below shows the experimental set up for automatic torch travel for welding.

Fig.4 Automated torch travel

E. Shielding Gas Regulators

The regulator is a device that reduces source gas pressure to a constant working pressure, independently of source pressure variations. Pressure reduction can be made in two stages. Regulators in two stages give in general a more stable output flow.

Fig.5 Shielding gas regulator

F. Welding torch

The welding torch holds the non-consumable electrode, assures transfer of current to the electrode and flow of shielding gas to the weld pool. Torches with welding regimes up to 200A are generally gas cooled and those with continuous operation with 200 to 500A are water cooled.

G. H.F. (High Frequency Unit) for Arc initiation

The welding torch holds the non-consumable electrode, assures transfer of current to the electrode and flow of shielding gas to the weld pool. Torches with welding regimes up to 200A are generally gas cooled and those with continuous operation with 200 to 500A are water cooled.

Fig.6 H.F. Unit

H. Servo controlled drive mechanisms

There are two servo controlled motors for controlling movements along three axes. One servo motor controls the X-Y movements and the other servo motor controls the movement along the Z-axis.

I. DCIS(Digital Communication Interface system)

The digital communication interface system allows the connection of the system with a laptop. This enables us to input the values of process variables and carry out a control over the fully automatic welding cycle.

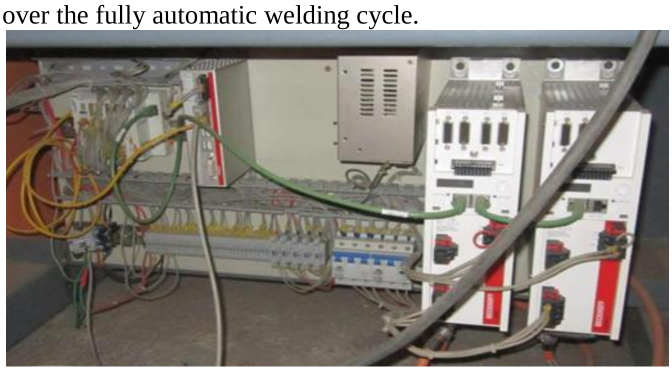


Fig.7 Servo controls and DCIS system

Selection of Orthogonal Array OA:-

The choice and the selection of the parameter were decided by considering the objective of present study. Before selecting a particular OA to be used as a matrix for conducting the experiments:

1. The number of parameters and interactions of interest.
2. The numbers of levels of the parameter of interest [5].

Each three level parameter has 2 degree of freedom (DOF) (Number of level – 1), the total DOF required for three parameters each at three levels is 8[=4x (3-1)]. As per Taguchi's method the total DOF of the OA must be greater than or equal to the total DOF required for the experimentation. So an L_9 OA (a standard 3- level OA) having 8 degree of freedom was selected for the present analysis. The standardized Taguchi-based experimental design used in this study was an L_9 orthogonal array, as described shown in Table 3.

Run	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 3: The Basic Taguchi L_9 Orthogonal Array

This basic design uses up to three control factors, each with three levels. A total of nine runs must be carried out, using the combination of levels for each control factor [6].

Experiment Procedure:-

After the orthogonal array has been selected, the second step in Taguchi parameter design is running the experiment. The 304 stainless steel grade was used in mostly industry, homes, agriculture. The dimension of work sample is length 50 mm, width 152 mm, thickness 5 mm. Now the setup has been ready and was prepared for doing TIG welding on given sample. Fig.8 shows the welded sample of SS-304 by using TIG welding.

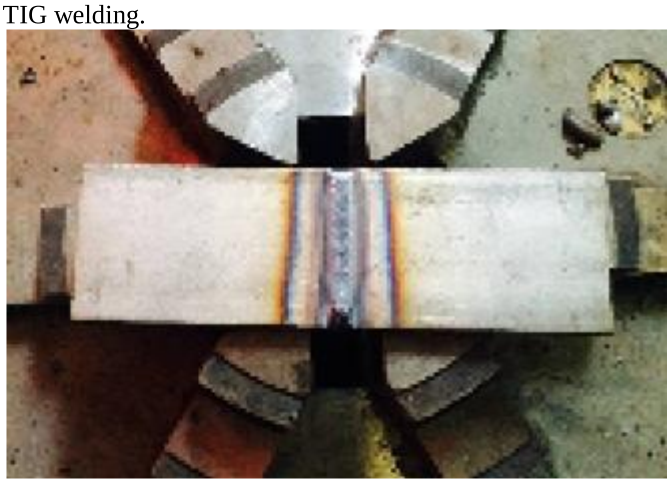


Fig.8 Welded Sample of SS-304

In this experimental work, the sample is welded at three different levels of welding input parameters i.e. welding speed, welding current and gas flow rate as shown in table.

Factors	Notation	Range	Levels		
Welding speed (Unit : cm/min)	S	20-25	20	22.5	25
Welding current (Unit : Amps)	I	120-150	120	130	140
Gas flow rate (Unit : lits. Per min)	L	15-20	15	16	17

Table 4: Welding parameter and their levels

Total nine experiments were performed based on L9 orthogonal array as shown in Table 5. The effect of different input parameters on output parameters (i.e. bead height, bead penetration and bead width) were analyzed and measured.

Welding speed	**Welding current**	**Gas flow rate**	**Bead height (mm)**	**Bead penetration (mm)**	**Bead width(mm)**
20	120	15	0.68	7.20	8.72
20	130	16	0.72	7.25	8.76
20	140	17	0.75	7.28	8.79
22.5	120	16	0.83	7.42	8.91
22.5	130	17	0.86	7.45	8.93
22.5	140	15	0.89	7.36	8.98
25	120	17	0.96	7.98	9.12
25	130	15	0.98	7.88	9.16
25	140	16	0.99	7.98	9.20

Table 5: L_9 Orthogonal Array Design Matrix

Data Analysis:-

We know that Analysis of variance (ANOVA) is a statistical tool used to analyse the S/N ratio. Here the term "signal" represents the desirable mean value and the "noise"-undesirable value. Hence, we can say that S/N ratio show the amount of variation, which is represented in the performance characteristics. ANOVA most commonly applied to the results of the experiment to determine the present contribution of each factors. Study of ANOVA table for a given analysis helps to determine which of the factors need control and which do not. Once the optimum condition is determined, it is usually good practice to run a confirmation experiment. The analysis of the partial experiment must include an analysis of confidence that can be placed in the results. So analysis of variance is used to provide a measure of confidence. Analysis provides the variance of controllable and noise factors. By understanding the source and magnitude of variance, robust operating conditions can be predicted. Analysis of the experimental data obtained from Taguchi design runs is done on MINITAB-16 software linear response surface model.

ANOVA and Normality testing for Bead Penetration (BP):-

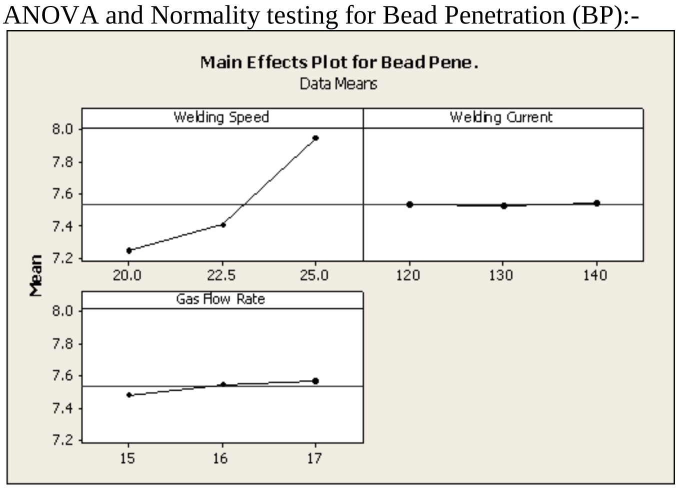


Fig.9 Main effect of process parameters on bead penetration

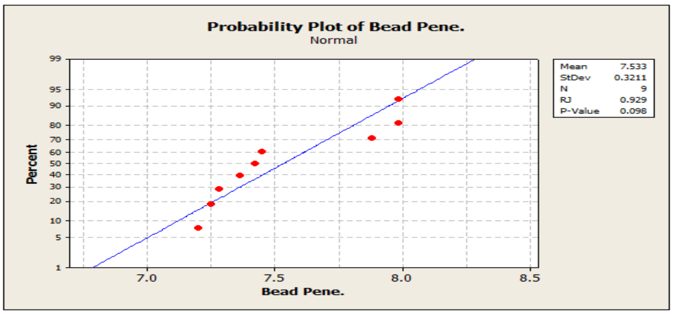


Fig.10 Probability graph for bead penetration (Normal)

From the figure, it can be seen that:-
Effect of welding speed: Bead penetration increase with the increase in welding speed
Effect of current: Bead penetration is almost constant with the increase in current
Effect of gas flow rate: There is an increase in bead penetration with the increase in gas flow rate.

ANOVA and Normality testing for Bead Height (BH):-

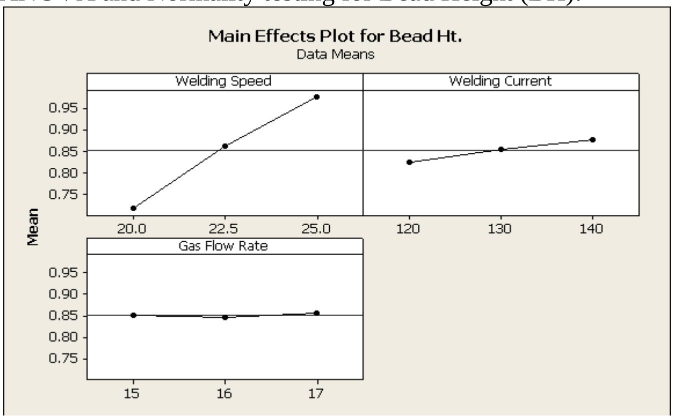


Fig.11 Main effect of process parameters on bead Height

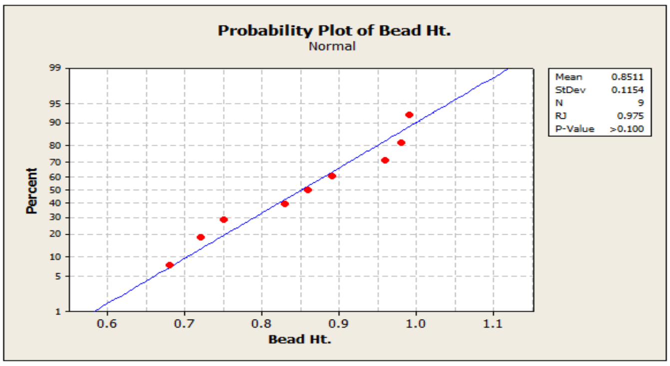


Fig.12 Probability graph for bead Height (Normal)

From the figure, it can be seen that:-
Effect of welding speed: Bead height decreases with the increase in welding speed
Effect of current: Bead height increases with the increase in current
Effect of gas flow rate: There is a slight increase in bead height with the increase in gas flow rate.

ANOVA and Normality testing for Bead Width (BW):-

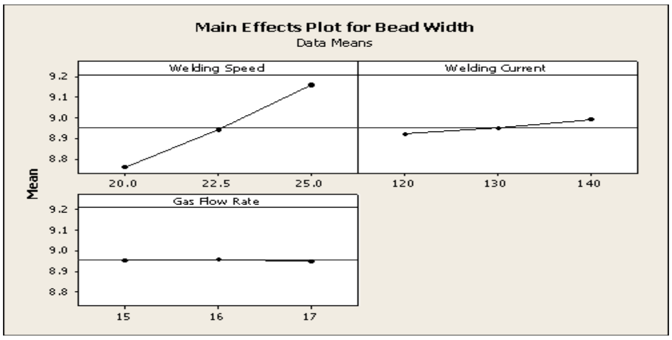


Fig.13 Main effect of process parameters on bead Width

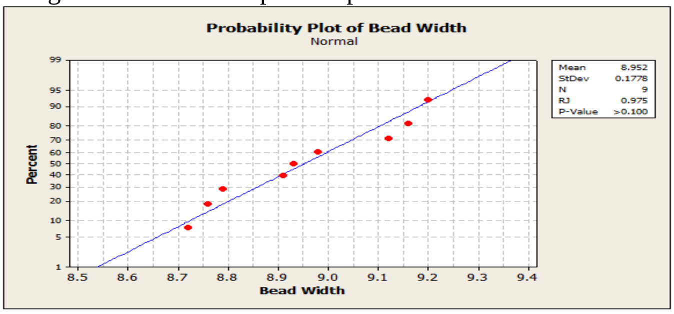


Fig.14 Probability graph for bead Width (Normal)

From the figure, it can be seen that:-
Effect of welding speed: Bead width increase with the increase in welding speed.
Effect of current: Bead width increase with the increase in current.
Effect of gas flow rate: Bead width is almost constant with change in gas flow rate.
Interaction Plots:-
Figures below show the interaction effect plots of process parameters on output parameters at different parameters like welding speed, current and gas flow rate.

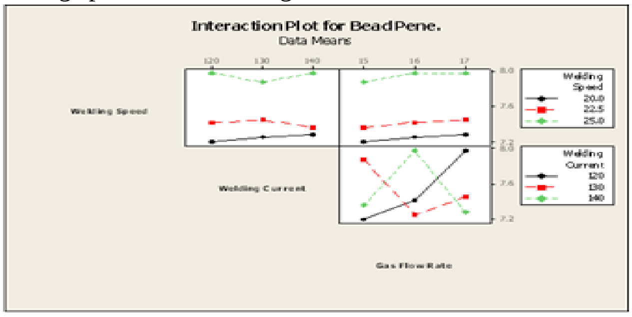


Fig.15 Interaction effect of process parameters on bead penetration

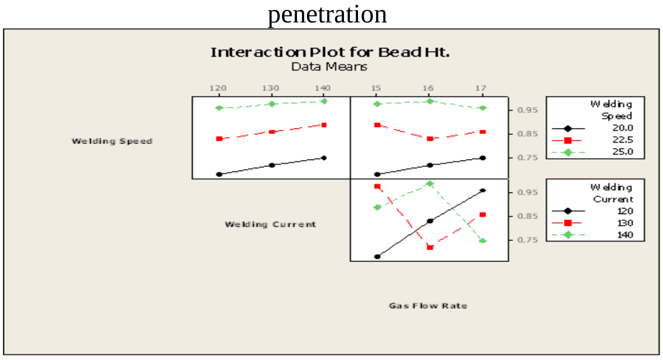


Fig.16 Interaction effect of process parameters on bead height

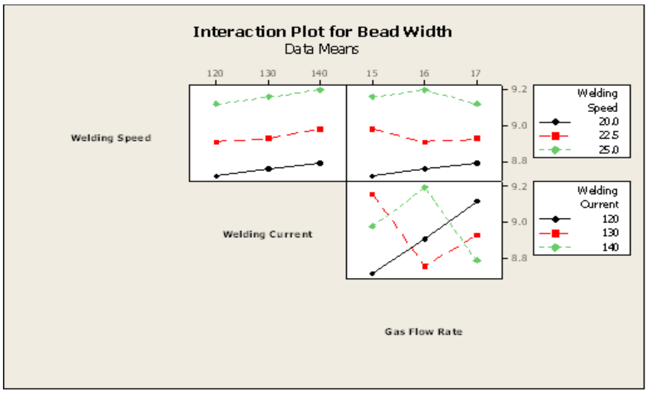


Fig.17 Interaction effect of process parameters on bead width

The interaction plots in Figures suggest interactions. As the lines are not parallel; meaning the change in any one parameter will have effect on other parameters.

Mathematical Regression Model:-
Multiple linear regression equations are developing a relation between the process variables and response. The regression equation developed for the Bead Height (BH), Bead Penetration (BP) and Bead Width (BW) from software is as follows:

BP = 3.60 + 0.141 S+ 0.00033 I+ 0.0450 L
BH = -0.719 + 0.0520 S + 0.00267 I + 0.00333 L
BW = 6.71 + 0.0807 S + 0.00367 I - 0.00333 L

Optimization Problem Formulation:-
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. The weldment area can be obtained in terms of bead height, width and penetration (refer to Fig.18) based on the assumption that it follows the parabolic curves.

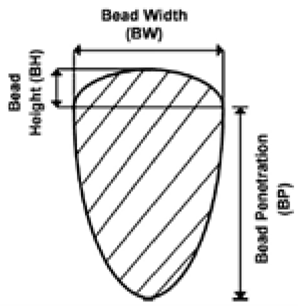


Fig.18 Important weld bead parameters

The above constrained optimization problem can be mathematically stated as follows:
Minimize:

$$f = \frac{2}{3}(BH + BP)BW$$

subject to the condition that BP takes the maximum value and
$S_{min} \leq S \leq S_{max}$, $I_{min} \leq I \leq I_{max}$, $L_{min} \leq L \leq L_{max}$
i.e. 20cm/min $\leq S \leq$ 25cm/min, 120A $\leq I \leq$ 140A, 15lit/min $\leq L \leq$ 17lit/min

Optimization using MATLAB Tool box:-
The objective optimization function GA from the GENETIC OPTIMIZATION and DIRECT SEARCH tool box of MATLAB is used for defining and solving the problem. Fig.19 shows the single objective optimization problem definition screen.

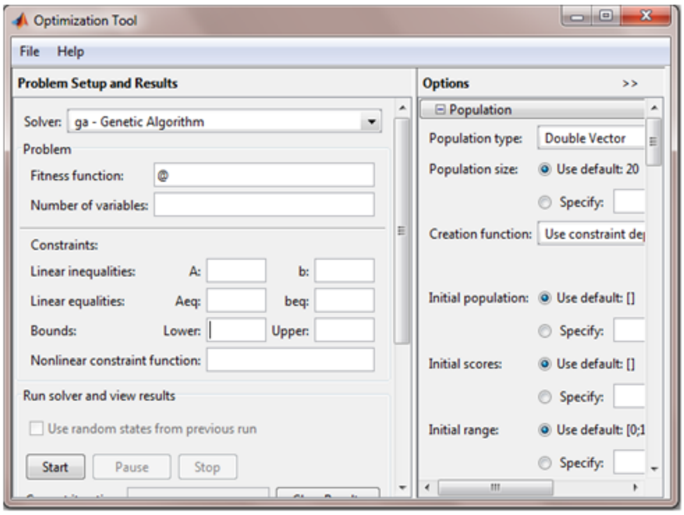


Fig.19 view of Genetic algorithm toolbox of MATLAB

Results of optimization:-
Regression model formulae for BH, BW and BP are
function BP = DOE_BP(x)
BP = 3.60 + 0.141 * x(1) + 0.00033 * x(2) + 0.0450 * x(3);

function BH = DOE_BH(x)
BH = -0.719 + 0.0520 * x(1) + 0.00267 * x(2) + 0.00333 * x(3);

function BW = DOE_BW(x)
BW = 6.71 + 0.0807 * x(1) + 0.00367 * x(2) - 0.00333 * x(3);

Using above mentioned equations Plots of best fitness and best individual for GA are created.

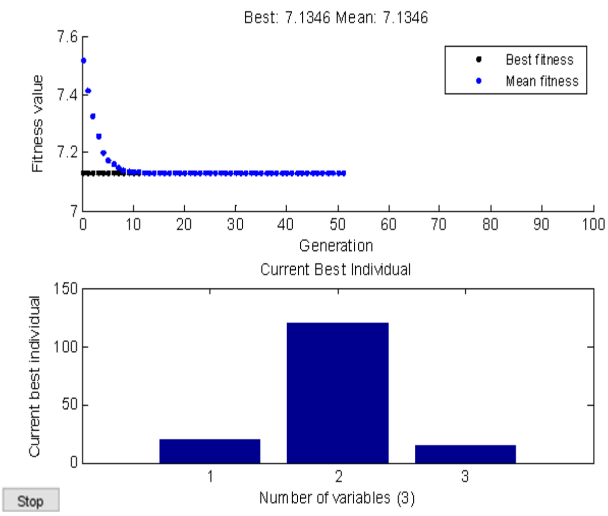


Fig.20 Optimization By GA for Bead Penetration

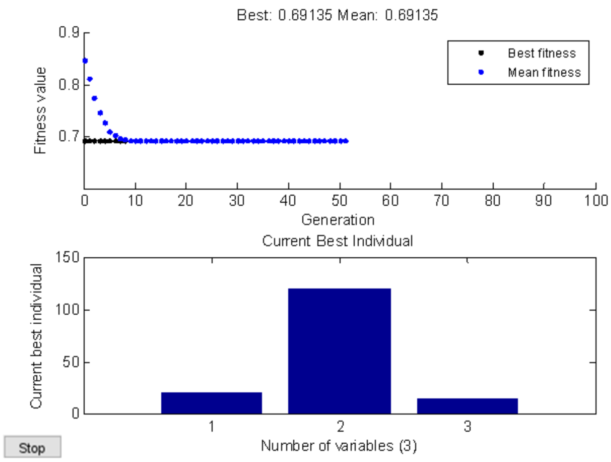


Fig.21 Optimization By GA for Bead Height

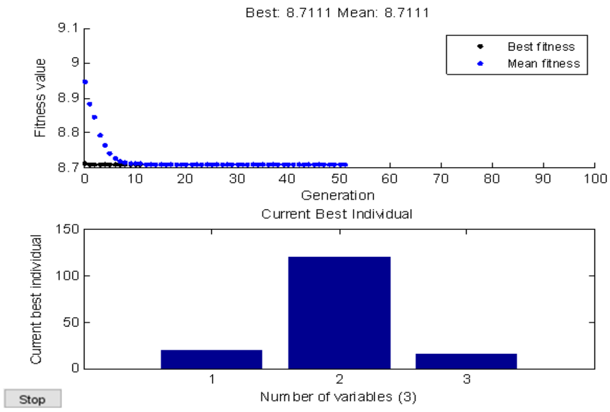


Fig.22 Optimization By GA for Bead Width

Validation through practical experiment:-
The results obtained through optimization had to be validated. This was done through practical performance of the experiment in the same manner as the practical performed earlier as per DOE. The results are tabulated as under:

Input Parameters	Value*	Optimized value of Bead Ht.	Experimental value of Bead Ht.	% Error
Welding Speed	20	0.69	0.68	-1.47
Welding Current	120			
Gas Flow Rate	15			

Table 6: Validation through practical experiment for bead height

Input Parameters	Value*	Optimized value of Bead Pene.	Experimental value of Bead Pene.	% Error
Welding Speed	20	7.13	7.20	0.97
Welding Current	120			
Gas Flow Rate	15			

Table 7: Validation through practical experiment for bead penetration

Input Parameters	Value*	Optimized value of Bead Width.	Experimental value of Bead Width.	% Error
Welding Speed	20	8.71	8.72	0.11
Welding Current	120			
Gas Flow Rate	16			

Table 8: Validation through practical experiment for bead width

IV. CONCLUSION

In this study, weld runs were performed using an automatic GTAW setup. Experiments were carried out as per Taguchi design and regression analysis was conducted to determine input-output relationships of the process.

A constrained optimization problem was formulated to minimize weldment area after ensuring the condition of maximum bead penetration. Genetic Algorithm was used to solve the said problem. Following are the important conclusions of the work.
Effect of process parameters on bead height was concluded as under :

- Effect of welding speed: Bead height decreases with the increase in welding speed
- Effect of current: Bead height increases with the increase in current
- Effect of gas flow rate: There is a slight increase in bead height with the increase in gas flow rate.

Effect of process parameters on bead penetration was concluded as under :

- Effect of welding speed: Bead penetration increase with the increase in welding speed
- Effect of current: Bead penetration is almost constant with the increase in current
- Effect of gas flow rate: There is a increase in bead penetration with the increase in gas flow rate.

Effect of process parameters on bead width was concluded as under :

- Effect of welding speed: Bead width increase with the increase in welding speed
- Effect of current: Bead width increase with the increase in current
- Effect of gas flow rate: Bead width is almost

constant with change in gas flow rate.

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

Genetic Algorithm was able to reach the optimal solution, after satisfying the constraints. This was validated in present work practically, after performing a confirmatory experiment as per process parameters optimized by GA. Maximum error of 5% was found between the predicted weld geometry parameters and the actually measured weld geometry parameters.

REFERENCES

[1] Radhakrishnan V.M., “WELDING TECHNOLOGY AND DESIGN”, Mcgraw Hill, New York, 2006.

[2] Abhishek Prakash , Raj Kumar Bag , 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, Vol. 5, Issue 3, March 2016, ISSN (Online) : 2319-8753, ISSN (Print) : 2347-6710

[3] Nirmalendhu Choudhury, Ramesh Rudrapati and Asish Bandyopadhyay, “Design Optimization of Process Parameters for TIG Welding Based on Taguchi Method”, International Journal of Current Engineering and Technology, Special Issue-2, February 2014.

[4] Bipinkumar Srivastava, S.P. Tewari, Jyoti Prakash, "A Review on effect of arc welding parameters on mechanical behaviour of ferrous metals/alloys", 2010.

[5] Ross P. J,“Taguchi Techniques for quality engineering”, McGraw Hill, New York, 1996.

[6] Ajit khatter, Pawan Kumar, Manish Kumar “Optimization of Process Parameter in TIG Welding Using Taguchi of Stainless Steel-304”, International Journal of Research in Mechanical Engineering and Technology, Vol.4, Issue1, Nov 2013 - April 2014, ISSN : 2249-5762 (Online), ISSN : 2249-5770 (Print)

