OPTIMIZATION OF TIG WELDING PARAMETERS TO IMPROVE MECHANICAL PROPERTIES OF WELD JOINT BY TAGUCHI APPROACH

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Abstract: Welding is the most common operation in any industry. Focus of any industry is production of high quality product at low cost and to increase production rate. For this it is essential to focus on various parameters of welding. Hence in current situation it is necessary to focus on welding parameters such as welding current, voltage, welding speed, feed rate of electrode etc. GTAW is the versatile process used for joining of two metals with applications of heat and pressure or filler material to increase production with less time and cost. The up going study is to carried out to investigate inflame of current, voltage, welding speed, feed rate of electrode on mechanical strength of material with the tensile test, impact test, hardness test. Also it is necessary to focus on HAZ (Heat Affected Zone) of plates. Mechanical testing such as tensile test, impact test, and hardness test are carried out to find out strength and other mechanical properties of welded joints. Taguchi approach with L9 array is used to find regression equation so that we get strength and hardness for the given combination of process parameters. Signal to noise ratio used to validate the results by using Minitab17 software and from all this analysis we come to know that voltage is the most dominant factor among all these three parameters.

Index Terms: Current, voltage, feed rate of electrode, , heat affected zone, mechanical properties.

I. INTRODUCTION

Tungsten inert gas welding is widely used method for joining of ferrous and non-ferrous materials. This welding offers several advantages like joining of unlike metals, low heat affected zone, absence of slag etc compared to Metal inert gas welding. There are many applications of weld made of structural steel, pipelines, fuel tank, are subjected to various stresses such as tensile compressive and thermal stresses etc. The strength of joint is depend on various parameters such as welding parameters geometric shapes, methods implemented for welding and others. In welding accuracy and quality of welded joint largely depends on type of power supply, welding speed, type of inert gas used for shielding. There are so many researches are done on welding speed and effect of the filler material. Hence we took new parameters for analysis. This project deals with investigation of process parameters such as current, voltage, Flow rate of shielding gas, feed rate of filler material etc on tensile strength, impact strength and hardness of heat affected zone and change in the microstructure at 45° bevel angle and 2mm bevel height of welded joint. The results are optimized using Taguchi Method.

II. LITERATURE REVIEW

In the past several researches have studied the effect of various parameters of TIG welding on mechanical properties of welded joint by Taguchi's method of Design of Experiments (DOE). Narendra sura et al [1] studied and evaluate effect of varying current, voltage and number of passes on mechanical properties HAZ. The remaining welding parameters torch angle, welding speed grove angle, wire feed rate, stick out distance, shielding gas pressure etc were kept constant. Welding parameters were optimized using GMAW welding. R. R. Balasubramanyam et. al. [2] studied and compared the mechanical properties of non heat treatable aluminum alloy AA5080 and heat aluminum alloy AA7020 using TIG welding. G. Magudeeswaran et. al. [3] studied the activated TIG (ATIG) welding process mainly depends on increasing the depth of penetration and concluded that with the depth of penetration we can get better strength of weld joint. K. M. Eazhil et. al. [4] studied the taguchi method L27 was used to optimized the pulsed TIG welding process parameter of 6063 aluminum alloy weldments for maximizing the mechanical properties. Then the optimal parameters of TIG welding process are optimized and experimental results illustrate the proposed approach. Ajit Khatter et al. [5] studied the purpose of this study is to propose a method to decide near optimal setting of the welding process parameters in TIG welding. The properties of welded joints are affected by large numbers of parameters. By using Taguchi and ANOVA technique an optimal solution is find out, which provides us an optimal results of the varying condition. S. R. Patil et a. [6] studied the influence of welding parameters like welding current, welding voltage, welding speed on ultimate tensile strength (UTS) of AISI 1030 mild steel material during welding. From this study, it is observed that welding current and speed are major parameters which influence on the tensile strength of welded joints. Samer Jasim Mahmood et. al. [7] studied the investigation of effect of welding process on mechanical properties and microstructure of aluminum alloy 6061, using FSW and TIG welding. In this final results are, microstructure in FSW shows three weld zones such as fine crystalline while the TIG welding shoes dendrite structure.

III. PROBLEM STATEMENT AND OBJECTIVE

In industry there are so many joints of equipments are welded. Failure of such joints may cause undesirable accidents in the industry and other areas. Hence it is necessary that the strength of that joint should be maximum. For the maximum strength of joint, it is necessary to use proper combination of the welding parameters.

Hence primary objective of this experiments are

- To find the effect of different current, voltage and gas flow rate on tensile strength, impact strength of butt weld joint.
- To find the effect of different current, voltage and gas flow rate on heat affected zone of butt weld joint.

IV. MATERIAL

The base material used for experimental work is IS 2062-E250. This material is commonly used in industry for different applications such as power plants, refineries, industrial shades, cold storage, metro stations, aircraft hangers, commercial buildings etc. This material has good machinability and weld ability. The dimensions of base metal plates are 8x300x300 mm. The composition and mechanical properties of work material IS 2060-E250 are given in following table.1

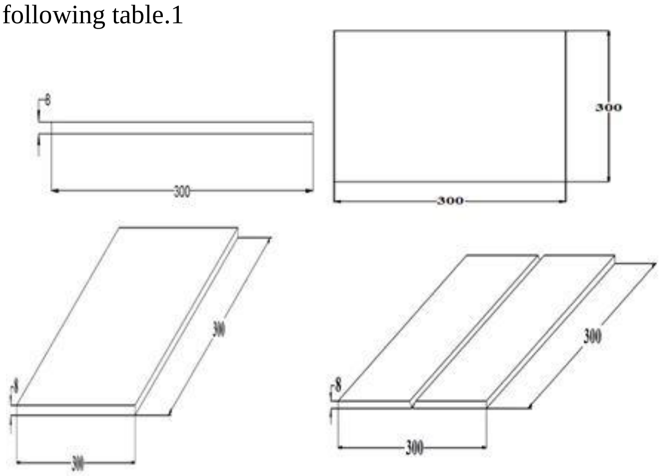

Fig 1: Plate before and after machining operation

Table 1 Chemical composition of work material

Elements	C	Mn	P	S	Si
Wt Max %	0.23	1.50	0.045	0.045	0.40

Table 2 Mechanical properties of work material

Tensile strength (MPa)	410
Yield strength (MPa)	240
Elongation (%)	23

V. METHODOLOGY

Methodology used in this work is TIG welding method. This method is commonly used in the industrial applications.

A. Experimental Procedure

In TIG welding, an arc is maintain between a tungsten electrode and the workpiece in an inert atmosphere. Depending on the weld preparation and the work piece thickness, it is possible to work with or without filler. The filler can be introduced manually or half mechanically under current. The process itself can be manual, partly mechanized, fully mechanized or automatic. The welding power source delivers direct or alternating current. The major difference between the welding of steel and the TIG welding of aluminum is the adhering oxide film on the aluminum surface which influences the welding behavior and has to be concerned. The oxide film has to removed to prevent that oxides from being entrapped between them. The oxide film can be removed by varying the current type or polarity or also through the use of inert gas. The electrode used in this case is ER70S-6 and having a diameter of 2mm. This MIDALLOY ER70S-6 welding wire is designed for welding of carbon steel materials. Gas used for the experiment is Argon.

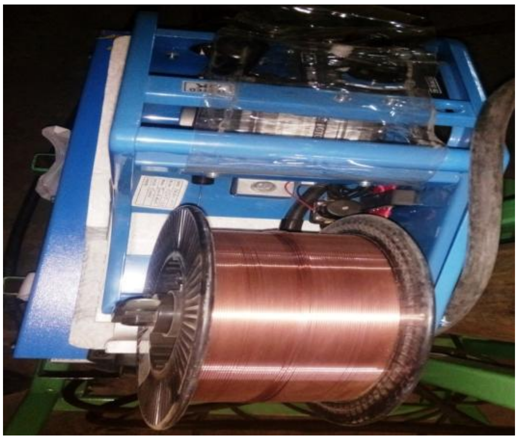

Fig 2: Welding electrode ER70-6

Table 3 Chemical composition of electrode

Elements	Weight(%)
C	0.08
Mn	1.45
Si	0.98
Cr	0.05
Mo	0.05
V	0.01
P	0.012
S	0.01
Cu	0.04

Table 4 : Mechanical properties of electrode.

Tensile strength (MPa)	586
Elongation (%)	22

B. Selection of Joint

In literature survey we were investigated that in V- groove butt weld joint the volume of filler material required is less so the cost of welding is also less. Also V-groove is easy to prepare. So in this experimentation we are going to connect two plates by using V-groove geometry with 45° groove angle, 2mm bevel height and 2mm root opening. The selected standard V- groove geometry is as per American Welding Society Handbook.

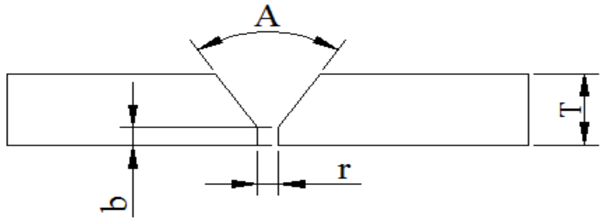

Fig 3: Geometry dimensions as per Standards of AWS

C. Sample Preparation

Samples are prepared by deciding ranges of current, volt and gas flow rate passing through the joint. These ranges are as shown in table. 5:

Table 5 Sample preparation Table

Sr. No	Sample Name	Current (A)	Voltage (V)	Gas Flow rate(Lpm)
1	D1	110	25	12
2	D2	110	27	15
3	D3	110	29	18
4	D4	120	25	12
5	D5	120	27	15
6	D6	120	29	18
7	D7	130	25	12
8	D8	130	27	15
9	D9	130	29	18

VI. TESTING

There are three types of testings conducted for this experimentation. These tests are tensile test, impact test and hardness test.

A. Tensile testing

Experiments have been conducted with above process parameters to obtain butt joint. The weld joint is completed in three pass. Specimen for tensile testing were taken at the middle of all the joints and machined to IS 1608-2005 standards. The configuration of specimen used under tensile testing is as shown in fig. And welded specimens were tested in the UTS machine and tested specimens are shown in fig 4.

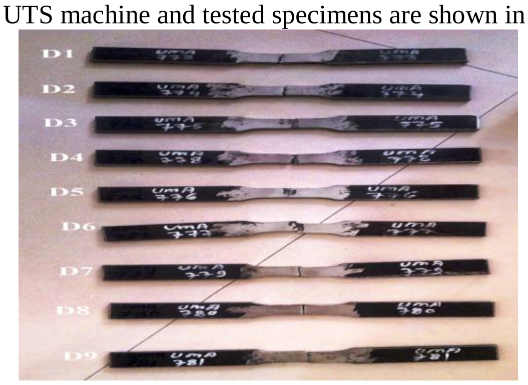

Fig. 4 Tensile test specimens

B. Impact testing

Specimens for impact testing are taken at the middle of all the joints and machined to IS 1757-1988 standards. The configuration of specimen used under impact testing is shown in fig. And welded specimen were tested in the impact machine and the tested specimens are as shown in fig.5

Fig 5: Impact test specimens

C. Hardness testing

Specimens for hardness testing were taken in the HAZ of all the joints and machined to IS 1501-2002 standards. The welded specimens were tested in the Vicker hardness Machine and the tested specimens were as shown in fig.6

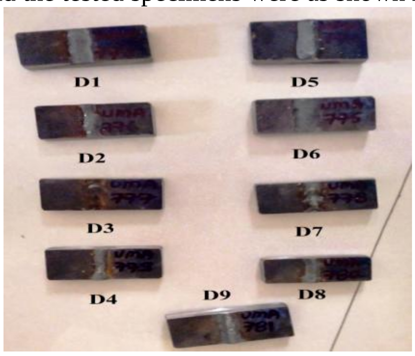

Fig : 6 Hardness test specimens

VII. TAGUCHI APPROACH

Taguchi invented a new method of conducting the design of experiments which are based on well defined guidelines. This method uses the special sets of array called orthogonal arrays. These standard arrays stipulate the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter.

In taguchi method signal to noise (S/N) ratio is used to represent the quality characteristic and the largest value of S/N ratio is required. There are three types of S/N ratio the lower the better, the higher the better and nominal the better.

As per the previous research papers and the welding manual for the plates, the welding parameters and their values are as given in table 6. These are the parameters which have higher probability of affecting on weld joint and mechanical properties of metal.

Table 6 : Working Range of Process Parameters

Process Parameters	Units	Levels		
		Lower	Middle	Higher
Current	Amps	110	120	130
Voltage	Volt	25	27	29
Gas Flow Rate	Lit/min	12	15	18

Table 7 : Design matrix selected based on Taguchi's orthogonal array (L9)

Exp. No	C	V	GFR	Ultimate Tensile Strength	Impact Tensile Strength	Hardness At HAZ (VHN)
1	1	1	1	463	16	224
2	1	2	2	484.7	24	227
3	1	3	3	518.36	26	218
4	2	1	2	421.86	8	215
5	2	2	3	522.66	30	230
6	2	3	1	485.98	28	221
7	3	1	3	387.65	22	224
8	3	2	1	511.79	26	224
9	3	3	2	384.53	16	230

VIII. RESULT AND DISCUSSION

A. Tensile testing

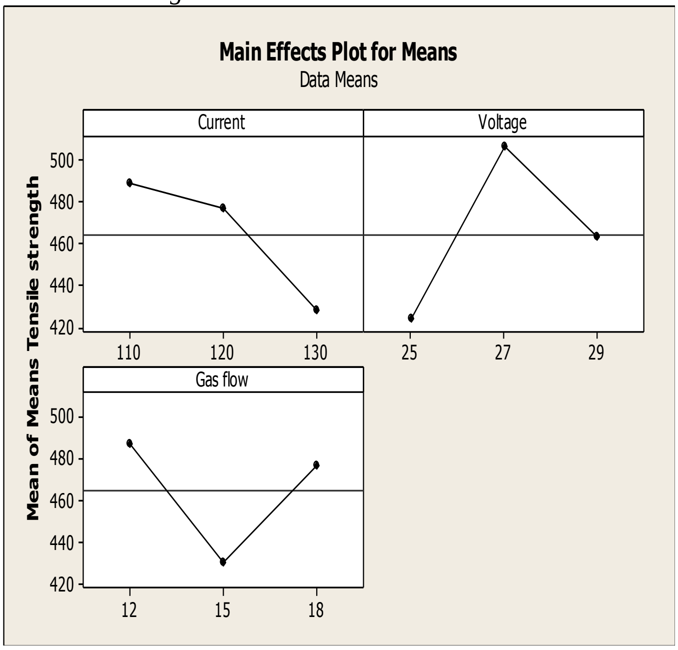

Fig 7 : Mean of Tensile strength vs main effect of plot for means of current, voltage, gas flow

Factor levels for prediction

Current	Voltage	Gas Flow
110	27	12

Value of mean = 552.987

From above graph, mean of tensile strength is maximum when current is 110A, voltage is 27 V and gas flow is 12 lit/min. When we put predictor values as 110A, 27V and 12 lit/min for current, voltage, gas flow resp., we get value of mean as 552.987

Table 8 : Response table for mean

Level	Current	Voltage	Gas Flow
1	488.7	424.2	486.9
2	476.8	506.4	430.4
3	428.0	463.0	476.2
Delta	60.7	82.2	56.6
Rank	2	1	3

From the above response table, it is cleared that voltage is main affecting factor on welding.

Regression Analysis : Tensile Strength versus Current, Voltage, Gas Flow

The regression equation is

TS = 594 – 3.03 Current + 9.7 Voltage – 1.78 Gas Flow

Table 9 : Predictor Value table

Predictor	Coef	SE Coef	T	P
Constant	593.6	427.2	1.39	0.223
Current	-3.035	2.277	-1.33	0.240
Voltage	9.700	11.39	0.85	0.433
Gas Flow	-1.783	7.591	-0.23	0.824

For S/N Ratio

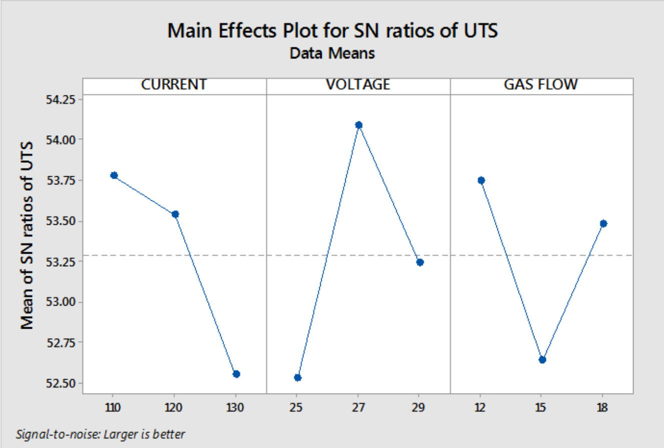

Fig 8 : Main effect Plot for S/N ratios of UTS

From this graph, it is cleared that mean of S/N ratio for tensile strength is maximum when current is 110 A, voltage is 27V and gas flow is 12 lit/min.

Table 10 : Response table for S/N Ratio

Level	Current	Voltage	Gas Flow
1	53.77	52.53	53.74
2	53.53	54.09	52.64
3	52.55	53.24	53.48
Delta	1.22	1.56	1.10
Rank	2	1	3

From the response table, it is cleared that voltage is main affecting factor in welding. After voltage current and gas flow are the responsible factors for welding respectively.

B. Impact strength

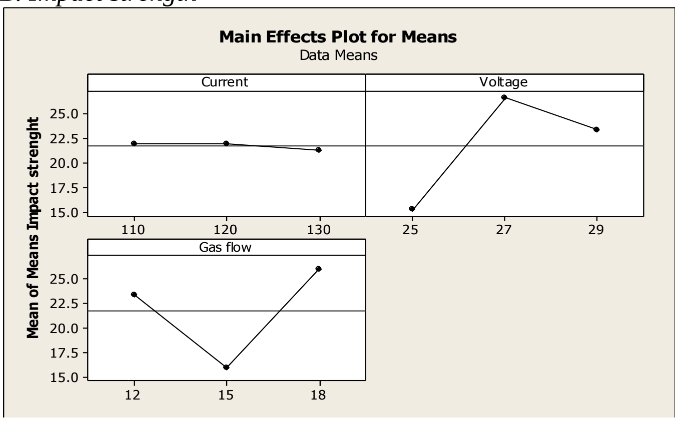

Fig. 9 Current, voltage, gas flow

Factor Levels For Prediction:-

Current	voltage	flow
110	27	18

Value of mean = 31.11
From above graph, mean of impact strength is maximum when current is 110A, 27 V and gas flow is18 lit/min. When we use factor levels for current, voltage, gas flow as 110A, 27V and 18 lit/min then we get value of mean as 31.11.

Table 11 : Response table for mean:-

Level	Current	Voltage	Gas Flow
1	22.0	15.33	23.33
2	22.0	26.67	16.0
3	21.33	23.33	26.0
Delta	0.67	11.33	10.0
Rank	3	1	2

From response table, it is cleared that voltage is most affecting parameter in this welding.

Regression Analysis : Impact Strength verses Current, Voltage, Gas Flow

The regression equation is
IS = - 34.9 - 0.033 Current + 2.00 Voltage + 0.44Gas Flow

Table 12 : Predictor value table

Predictor	Coef	SE Coef	T	P
Constant	-34.98	58.95	-0.59	0.580
Current	-0.033	0.314	-0.11	0.920
Voltage	2.000	1.571	1.27	0.259
Gas Flow	0.444	1.047	0.42	0.689

For S/N Ratio

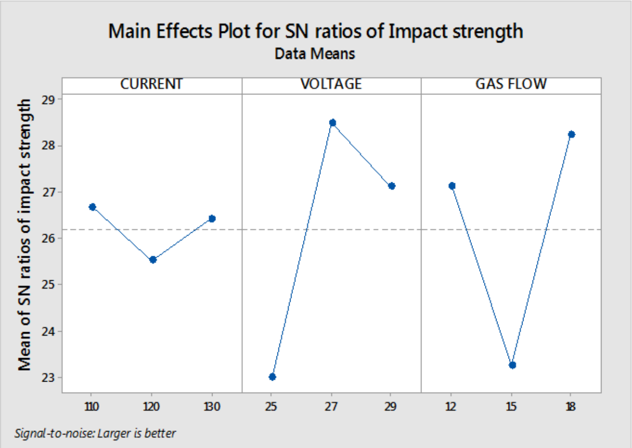

Fig 10 : Main Effects plot for S/N ratios of Impact Strength

Table 13 : Response table for S/N Ratio

Level	Current	Voltage	Gas Flow
1	26.66	23.00	27.11
2	25.52	28.48	23.25
3	26.41	27.11	28.23
Delta	1.15	5.48	4.98
Rank	3	1	2

From above graph and response table, we can say that voltage is most affecting parameter in welding for impact strength.

C. Hardness testing

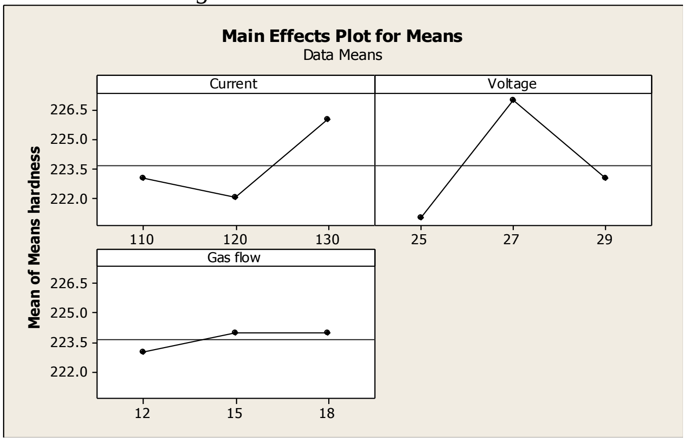

Fig 11 : Mean of hardness vs main effect for means of current, voltage and gas flow

Factor Levels for Prediction

Current	Voltage	Gas Flow
120	25	12

Value of mean : 218.667
From above graph, mean of hardness is minimum when current is 120A, voltage is 25V and gas flow is 12 lit/min. When we use factor level of current, viltage and gas flow as 120A, 25V and 12 lit/min resp., we get mean value as 218.667

Table 14 : Response table for Mean

Level	Current	Voltage	Gas Flow
1	223.0	221.0	223.0
2	222.0	227.0	223.0
3	226.0	223.0	224.0
Delta	4.0	6.0	1.0
Rank	2	1	3

From response table it is cleared that voltage is major responsible parameters in welding followed by current and gas flow.

Regression Analysis : Hardness at HAZ verses Current, Voltage, Gas Flow

Regression equation is
H = 190 + 0.150 Current + 0.50 Voltage + 0.167 Gas Flow

Table 15 : Predictor value table

Predictor	Coef	SE Coef	T	P
Constant	189.67	46.580	4.07	0.010
Current	0.1500	0.2483	0.60	0.572
Voltage	0.5000	1.2420	0.40	0.704
Gas Flow	0.1660	0.8278	0.20	0.848

For S/N Ratio :-
From the S/N ratio graph and response table shown below, its cleared that voltage is major responsible and affecting parameter in welding followed by current and gas flow.

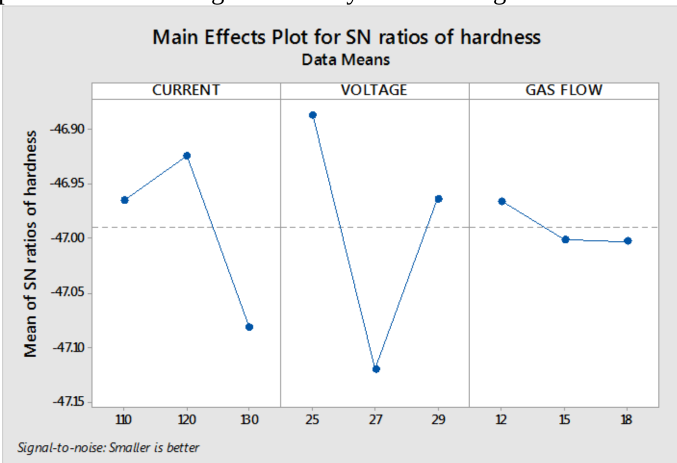

Fig 12 : Main Effects plot for S/N ratios of Hardness

Table 16 : Response table for S/N Ratio

Level	Current	Voltage	Gas Flow
1	-46.96	-46.89	-46.97
2	-46.92	-47.12	-47.00
3	-47.08	-46.96	-47.00
Delta	0.16	0.23	0.04
Rank	2	1	3

D. Composite desirability of structure

The graphs as shown in fig 13 gives information about desirability of tensile strength, impact strength and hardness w.r.t. current, voltage and gas flow. By considering regression equation from DOE as a objective function, composite desirability approach is used to find optimal setting of each factor. When all these three variables are used simultaneously, we get the plot of composite desirability and value of the desirability as shown in fig 13. This is useful when we need to evaluate the impact of multiple inputs on response of structure. The desirability of structure should be greater than or near about 0.85. Our optimized desirability is 0.85915.

Table 17 : Response optimizer table

Parameters	Goal	Lower	Target	Upper	Wt
Tensile Strength	Max	387.65	522.66	522.66	1
Impact strength	Max	8	30	30	1
Hardness	Min	215	215	230	1

The global values obtained from Minitab are 110V, 29A and 18 lit/min for current, voltage and gas flow respectively.

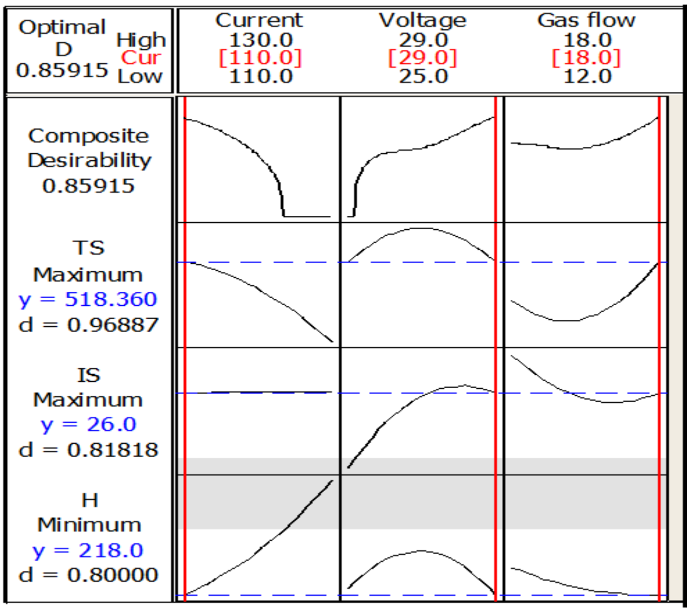

Fig 13: Composite desirability of Parameters

IX. CONCLUSION

Taguchi experimental design for determining the welding parameter was successful. Accordingly the optimal combination of welding parameters for TIG welding is studied. The current of 120A, Voltage of 25V and gas flow rate of 12 lit/min, it is recommended level of the controllable parameters of TIG welding process as the minimization of the percentage of elongation and maximization of ultimate tensile strength.
Also from this experimentation we conclude that

1. For tensile strength and hardness, voltage is main affecting factor in TIG welding followed by current and gas flow.
2. For impact strength, voltage is main affecting factor in TIG welding followed by gas flow and current.
3. Regression equation gives the better results for various values of parameters.
4. The DOE technique was successfully used to study effect of TIG welding parameters on mechanical properties of welded joints.

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REFERENCES

[1] Narender Sura, Dr Vijay Mittal, "Experimental Study on Effects of Process Parameters on HAZ of Plain Carbon Steel Using GMAW", International Journal of Latest Research in Science and Technology, Volume 4, Issue 2: Page no 167-170, March- April 2015.
[2] R. R. Balasubramaniam, P. Vijayasarathi,, "

Experimental Investigation of Microstructure and Mechanical Properties of TIG Weld Aluminum Alloy", Jornal of International Association of Advance Technology and Science, Vol 16 March 2015, ISSN-3347-4482 .
[3] G. Magudeeswaran, Sreehari R. Nair, " Optimization of Process Parameters of Activated Tungsten Inert Gas Welding for Aspect Ratio of UNS S32205 Duplex Stainless Steel Welds:, Defence Technology 10 (2014) 251-260.
[4] K. M. Eazhil, S. Mahendran, "Optimization of TIG Welding Parameters on 6063 Aluminum Alloy on Taguchi Method", Volume 1, Issue III August 2014, IJRSI, ISSN 2321-2705
[5] Ajit Khatter, Pawan Kumar, "Optimization of Process Parameters in TIG Welding Using Taguchi of Stainless Steel-304", IJRMET, Vol 4, Issue 1, Nov 13-Apr14, ISSN: 2249- 5770
[6] S. R. Patil, C. A. Waghmare, "Optimization of MIG Welding Parameters for Improving the Strength of Welded Joint", IJAERS, E-ISSN 2249-8974
[7] Sammer Jasim Mahmood, " Comparative Investigation of FSW and TIG Welding of 6061 Aluminum Alloy on Mechanical Properties and Microstructure", Eng. and Tech. Journal, Vol 31 Part A No 6, 2013
[8] S.C. Juang, Y. S. Tarang, "Process Parameter Selection for Optimizing the Weld Pool Geometry in Tungsten Inert Gas Welding of Stainless Steel" Journal of Material Processing Technology 122 (2010) 33-37
[9] BIS, Hot rolled and high tensile structural steel specifications IS 2062 : 2011 p-3

BIOGRAPHIES

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