PARAMETRIC OPTIMIZATION OF MIG WELDING PROCESS PARAMETERS USING ACTIVATED FLUX ($MgCO_3$, Cr_2O_3 AND Fe_2O_3) FOR SS316 MATERIAL

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Abstract: Metal inert gas welding has wide application in many industries due to its advantages such as high reliability, all position welding capability, low cost, easy operation and high productivity etc. To increase the productivity and decrease the cost advanced techniques must be used in welding. Activating flux is a concept, which used in different welding process like EBW, LBW, and PAW. The flux ingredient, which is inorganic compound (which can be used to produce deep penetration and arc constriction) are available in variety of range and compositions. In the present work, an attempt has been made to use of activated flux for improving depth-to-width ratio as well strength of welding joint. In present years heavier thicker job require so obviously need for reduce angular distortion, higher depth of penetration and as well as number of passes so decrease in cost is direct effect on productivity enhancement. Adding some various types of Shielding gas mixture to get optimum result. The properties of weld metal deposited were evaluated & compared. It was found that the weld metal obtained using activated flux showed very few changes in terms of physical Appearance, Stability, Weld Bead Geometry Mechanical Destructive Testing like Tension Testing of Welding was passed. Brinell Hardness Test was Tested Passed Finally Non Destructive Testing of Radiography results of Welding without any defect. The experimental results showed that activating flux aided MIG increased the weld area, hardness and depth of penetration and also to reduce the angular distortion of the weldment. The flux are used to may MgCO3, Cr2O3, Fe2O3, FS12 ,MnO2 and Cdcl2 further used different kind of combination of fluxes to producedthe most noticeable effect. Furthermore, the welded joint to improve better mechanical properties like tensile strength and hardness etc.

Keywords- Deep Penetration, Depth-to-width ratio, Hardness, Different flux material, welding.

I. INTRODUCTION

Gas Metal Arc Welding (GMAW) is an arc welding process that joins metals together by heating them with an electric arc that is established between a consumable electrode (wire) and the work piece. In the GMAW process an arc is established between a continuously fed electrode of filler metal and the work piece. After the operator makes proper settings, the arc length is maintained at the set value, despite the reasonable changes that would be expected in the gun-to work distance during normal operation. This automatic arc regulation is achieved in one of two ways. The most common method is to utilize a constant-speed (but adjustable) electrode feed unit with a variable-current (constant-voltage) power source. As the gun-to-work relationship changes which instantaneously alters the arc length, the power source delivers either more current (if the arc length is decreased) or less current (if the arc length is increased).The second method of arc regulation utilizes a constant-current power source and a variable- speed, voltage-sensing electrode feeder. In this case, as the arc length changes, there is a corresponding change in the voltage across the arc. As this voltage change is detected, the speed of the electrode feed unit will change to provide either more or less electrode per unit of time. This method of regulation is usually limited to larger electrodes with lower feed speeds.

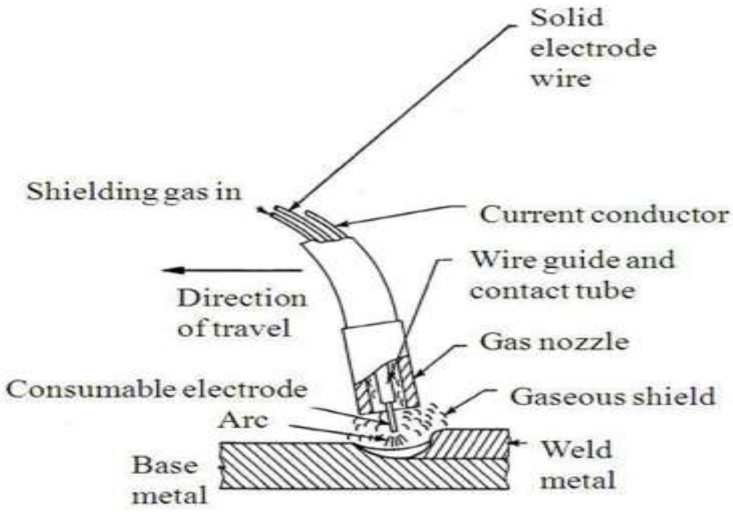

Figure 1: Schematic of GMAW process

GMAW Process Description

The study was concerned with the activating flux gas metal arc welding. The flux ingredient, which is inorganic compound (which can be used to produce deep penetration and arc constriction) are available in variety of range and compositions. Some of fluxes have been reported effective for particular materials. Activating fluxes contain oxides and halides (chlorides and fluorides). Oxide coating consists of iron, chromium, silicon, titanium, manganese, nickel, cobalt, molybdenum and calcium are reported to improve weld ability and increase the welding speed. The halogens, calcium fluoride and AlF2, have claim to constrict the arc and increase weld depth of penetration Activated flux is a mixture of inorganic material suspended in volatile medium (acetone, ethanol etc.). Inactivated flux GMAW process, a thin layer of the fine flux is applied on the surface of the base metal with brush before welding. Flux mixed with acetone to make it in a paste form as shown in the Fig.1.7. During activated flux, welding a part or all the fluxes is molten and vaporized. There is different types of fluxes (oxides) used in welding like Fe2O3, SiO2, MgCO3, Al2O3 etc. As a result, the penetration of the weld bead is significantly increased.

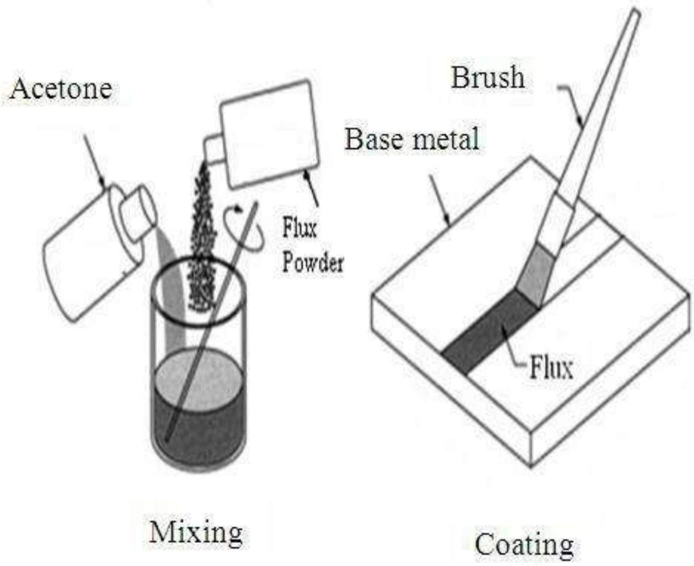

Figure 2: Method of applying flux

At the present, no theory of the mechanisms by which the activating flux leads to an increased penetration of the weld bead is generally agreed. Available literatures show that some of the mechanisms, which play major role in increase depth of penetration, are given below.

Chaudhari PG, Patel PB, Patel JD et al.investigate theEvaluation of MIG Welding Process Parameter using Activated Flux on SS316L by AHP-MOORA method. The workpiece material is used SS316. Sio2 and Cr2O3 flux gives best multi- performance features at various process parameters of MIG welding process also for without flux gives best multi- performance features achived for hardness and penetration in Mig Welding process.Tsann-ShyiChern et al.investigated the effects of the specific fluxes used inthe tungsten inert gas (TIG) process on surface appearance, weld morphology, angular distortion, mechanical properties, and microstructures when welding 6 mm thick duplex stainless steel. This study applies novel variant of the autogenously TIG welding, using oxide powders (TiO2, MnO2, SiO2, MoO3, 35and Cr2O3), to grade 2205 stainless steel through a thin layer of the flux to produce a bead-on-plate joint.Her-Yueh Hung et al.studied the application activated flux and Effects ofshielding gas composition under GTAW process and compared the process with normal process. In this study, AISI 304 stainless steel (thickness = 5mm) A-TIG welds produced with various flux compositions of MnO2 and ZnO, in which 80% MnO2 20% ZnO mixture was mixed with acetone to form a paste. The shielding gas was argon with nitrogen content ranging from 2.5 to 10 vol. %. At different nitrogen concentrations in the argon shielding gas significant variation in the penetration and bead width of the weld was achieved. Nitrogen additions to an argon base gas will increase the heat input, this cause more heat to be transferred into specimens by the arc and consequently produced deep penetration.

II. EXPERIMENTAL WORK

In many industries of manufacturing the parameters setting is made based on skill and experiment of the machinist or based on hand book.

(a) Base material and fluxes:

The Material selected for the experiment is SS316L. A 6mm thick plate is used. Three different fluxes $MgCo_3$, Fe_2O_3 and Cr_2O_3 were used to bead on plate welding. The fluxes are in the powder form.

(b) Application of fluxes:

The flux available in powdered form is not possible to apply evenly on the weld surface. For the same, the powder is converted to paste form by mixing it with acetone. Acetone has a tendency to vaporise quickly leaving the evenly distributed oxide flux on the surface. Base material plate of 6 mm thick was cut in 300*150(mm) for weld experiment. And flux paste was applied on at the center of strip throughout the length.

(c) Work piece specimen:

We have selected the material for experiment runs SS 316L as a base metal having size 300*150*6 (mm).

Figure 3: Work Piece Specimen

(d) Experiment result:

The Welding experiment was conducted with L9 orthogonal experimental sheet. A Same Nine set of parameter used for the With flux $MgCo_3$, Fe_2O_3 and Cr_2O_3 and Cr_2O_3. Total 9 experiments had done at work, that result are shown in Table 3 and Table 4

Table 1: Experimental Results of Mig Welding with Flux

	Welding speed (mm/min)	**Arc Voltage (Volt)**	**Flux**	**Weld Penetration (mm)**	**Hardness (HRBW)**
1	130	24	Cr_2O_3	2.0535	79.5
2	150	26	Fe_2O_3	3.5900	80
3	170	28	$MgCO_3$	2.7860	79.5
4	130	24	Fe_2O_3	2.5365	80
5	150	26	$MgCO_3$	1.9115	80.50
6	170	28	Cr_2O_3	1.8575	80
7	130	24	$MgCO_3$	2.0185	80.5
8	150	26	Cr_2O_3	2.0895	81
9	170	28	Fe_2O_3	4.1975	80.5

Flux (Cr_2O_3)

Flux (Fe_2O_3)

Flux ($MgCO_3$)

Figure 4: Penetration Bead on Welding plate

Figure 5: Bead on Plate With Cr_2O_3, Fe_2O_3 and $MgCO_3$ Activated Flux

(e) Weld penetration

surface cleaning & smoothing by Grinding of all welded Specimen, then I was used chemical etching by using etchant HNO3(Nitric Acid) &HCL (Hydrochloric Acid) and measure Depth of penetration by Triaxial Microscope which is shown below.

(f) Hardness

Hardness is measured to using Rockwell hardness tester.

III. PROBLEM DEFINITION

Weld penetration and hardness are maximization in MIG Welding machine process parameter such as Welding speed, Arc voltage and Activated flux are to be used for this work.

Table 2: Specifications of GMAW Machine

GMAW Description	Rated Value
Frequency Range	3 to 50-60Hz
Arc Voltage	15-39 volt
Welding Current	64-350 Amp
Travel speed	280 Mm/Min
Wire diameter	1.2 mm
Shielding gas	Ar
Types of cooling	Forced Air
Weight	127 kg

Table 3: Parameters Levels and Values

NO.	FACTOR	LEVEL 1	LEVEL 2	LEVEL 3	UNIT
1	Arc Voltage	24	26	28	Voltage
2	Welding speed	130	150	170	mm/min
3	Active Flux	Cr_2O_3	Fe_2O_3	$MgCO_3$	–

IV. SOLUTION METHODOLOGY

TLBO algorithm is a teaching–learning based optimization. There are mainly two phases.

Teacher phase:

It is included as the first segment of TLBO, where learners gain knowledge from the teacher. In this phase, the teacher attempts to increase the mean value of the class room from any value mean1 to his or her echelon IA. But sensibly it is not promising and a teacher can move the mean of the class room mean1 to any other value mean2 which is healthier than mean1 depending on his or her competence. Considered may be the mean and Ii be the teacher at any iteration i. Now, teacher Ii will try to improve the existing mean toward it so the new mean will be Ii designated as mean new, and the difference between the existing mean and new mean is given as,

$$\textbf{diverged\_ mean}_i = \textbf{ri}\ (\textbf{mean}_{new} - T_F * \textbf{mean}_j)\ \ldots\ldots.(1)$$

where TF is the teaching factor that fixes the value of mean to be changed, and ri is the random number in the range [0, 1], that is used to support the teaching factor. Value of TF can either 1 or 2 which is an interrogative step, which is determined randomly with equivalent probability as:

$$\textbf{TF} = \textbf{round}[1 + \textbf{rand}\ (0,1)\ \{2 - 1\}]\ \ldots\ldots.(2)$$

The teaching factor is produced arbitrarily in TLBO within the scope of 1–2, in which 1 compares to no increase in the learning level and 2 relates to inclusive exchange of knowledge, and intermediate values indicate the exchange of knowledge. The shifting level of knowledge can be any depending on the learner competence.

Based on diverged_mean, the existing solution is updated according to the following expression:

$$\alpha_{new,i} = \alpha_{old,i} + \textbf{diverged\_mean}_i \ldots\ldots\ldots(3)$$

Learner phase:

It is included as the second segment of the algorithm, where learners improve their knowledge by communication among themselves. A learner adapts new things if the other learner has more knowledge than him. Precisely, the learning trend of this phase is articulated as follows:

At any iteration i, consider two distinct learners α_i and α_j where $i \neq j$.

$$\alpha_{new,i} = \alpha_{old,i} + ri(\alpha_i - \alpha_j) \text{ if } f(\alpha_i) < f(\alpha_j) \ldots\ldots..(4)$$

$$\alpha_{new,i} = \alpha_{old,i} + ri(\alpha_i - \alpha_j) \text{ if } f(\alpha_j) < f(\alpha_i) \ldots\ldots..(5)$$

TLBO Procedure Steps:

<u>Step 1: Initialization Stage</u>

Initialize the population (learners), design variables (numbers of subjects offered to the learners) with random generation, threshold values, and termination criterion.

<u>Step 2: Elitist Teaching Phase</u>

Select the best learners of each subject as a teacher for that subject and calculate mean result of learners in each subject.

(a) Keep the elite solution

(b) Calculate the mean of each design variable

(c) Select the best solution

(d) Calculate the diverged_mean and modify the solutions based on best solution.

Step 3: Elitist Teaching Phase

Update procedure amid with duplicate limination Evaluate the difference between current mean result and best mean result according to Eq. (1) by utilizing the teaching factor TF

(a) If the new solution is better than the existing solution, then accept or else keep the previous solution

(b) Select the solutions randomly and modify them by comparing with each other

(c) Modify duplicate solution via mutation on randomly selected dimensions of duplicate solutions before executing the next generation

Step 4: Elitist Learners Phase

Update the learner’s knowledge with the help of teacher’s knowledge according to Eq. (3)

(a) If the new solution is better than the existing solution, then accept or else keep the previous solution

(b) Replace worst solution with elite solution

Step 5: Elitist Learners Phase

Update procedure amid with duplicate elimination Update the learner’s knowledge by utilizing the knowledge of some other learners according to Eq. (4) and (5).

(a) Modify duplicate solution via mutation on randomly selected dimensions of duplicate solutions before executing the next generation

Step 6: Stoppage Criterion

Repeat the procedure from Step 2 to Step 5 till the termination criterion is met.

(a) If termination criterion is fulfilled, then we get the final value of the solution or else repeat from Step 2 to Step 5.

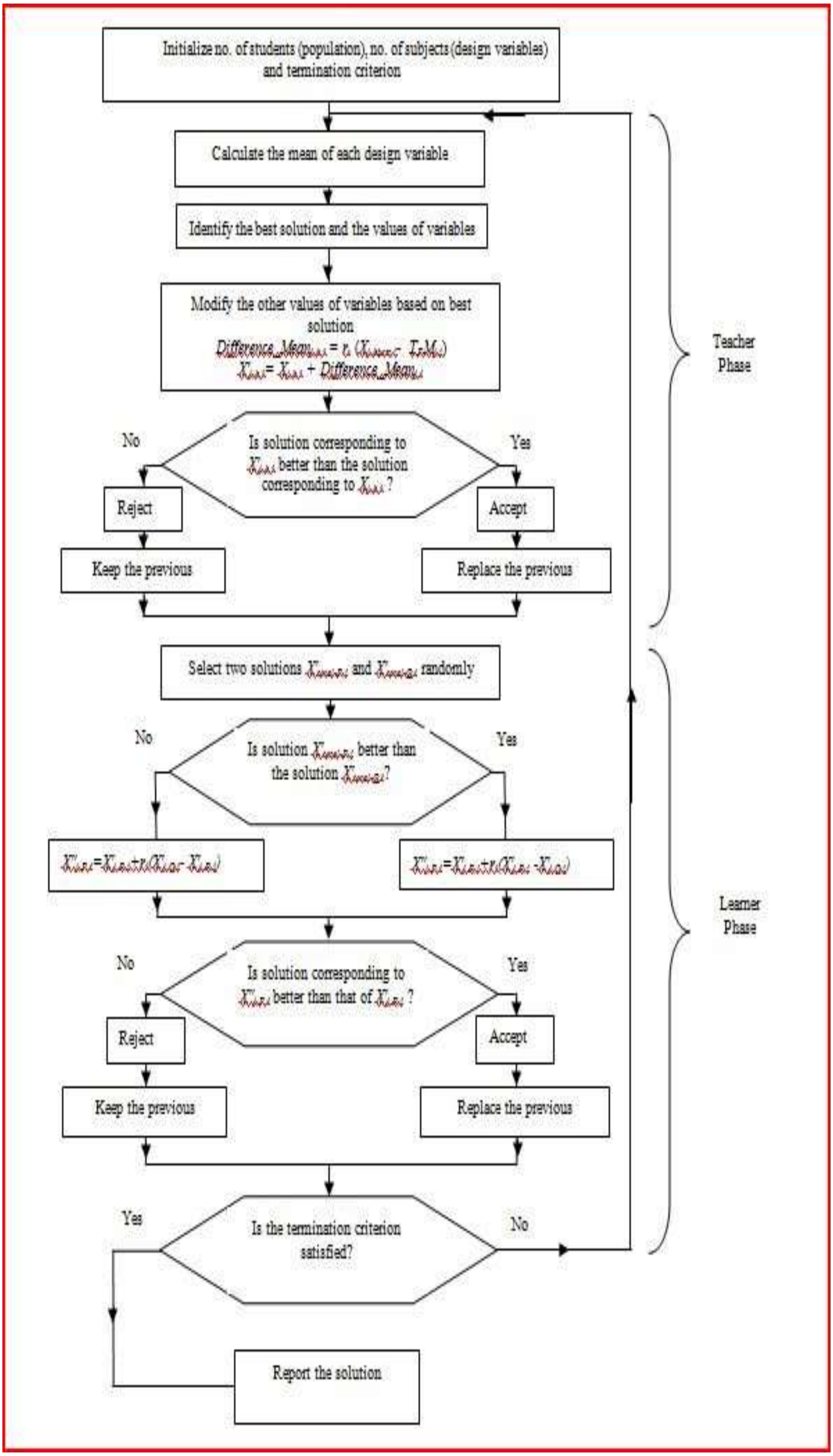

Figure 6: Flowchart of TLBO Algorithm

Function preparation:

Function prepared for multi objective optimization problem by normalizing and combining the function. Function is normalized by weighted average normalizing method. There are two objective functions Penetration (mm) and Hardness (HRBW). This objective is also conflict each other because penetration and hardness is maximizing function. So this penetration and hardness is normalized and combined as per weighted average normalizing method as per below,

Normalized function Z= W_1 PENETRET/MIN. PENETRET +

W_2 HARDNESS/MIN.HARDNESS

Where Weight (W1+W2) = 1

Here W1=W2=1/2

Normalized function Z is maximizing problem for MATLAB it must be converted to minimization problem. For convert maximization problem to minimization problem the function is inverted.

Objective function z $=\frac{1}{Normalized\ function\ z}$

Function for penetration and hardness is generated by General Regression in MINITAB 16.

V. RESULT AND DISCUSSION

In design of experiment the results are analyzed due to one or more of the following three objectives.

- To establish the best or the optimum condition for a product or a process.
- To estimate the contribution of individual factors.
- To estimate the response under the optimum condition.

The optimum condition is identified by studying the main effects of each of the factors. The main effects indicate the general trends of the influence of the factors. Knowing the characteristics, i.e. whether a higher or lower value produces the preferred results, the level of the factors which are expected to produce the best results can be predicted. The knowledge of the contribution of individual factors is a key to deciding the nature of control to be established on a production process.

Regression:

Regression in MINITAB 16 carried out for mathematical modeling of experimental data.

Objective function for Cr_2O_3,

ZZ=1./((0.5).*((-0.790458+(0.0186042.*x1)(0.02.*x2)./1)+(0.5).*(80.1667./(-0.790458 +(0.0186042.*x1)+(0.02.*x2);

Objective function for Fe_2O_3,

ZZ=1./((0.5).*((-0.650708+(0.0186042.*x1)(0.02.*x2)./1)+(0.5).*(80.1667./(-0.790458 +(0.0186042.*x1)+(0.02.*x2);

Objective function for $MgCO_3$,

ZZ=1./((0.5).*((-0.551958+(0.0186042.*x1)(0.02.*x2)./1)+(0.5).*(80.1667./(-0.551958 +(0.0186042.*x1)+(0.02.*x2);

SN ratio analysis

S/N Ratio is tool by which the influence input parameter for the output parameter can be known. S/N ratio analysis possible in MINITAB 18 with taguchi tool. Analysis gives the rank of the parameter in order of most effective parameter to list effective parameter for the specific output.

SN Ratio Analysis for SS316 material

The Taguchi method aims to find an optimal combination of parameters that have the smallest variance in performance. The signal-to-noise (S/N) ratio measures how the response varies relative to the nominal or target value under different noise conditions. Minitab 18 software help to calculate S/N Ratio based on required response and provide Analysis of variance table and response plot for deciding significant parameter and to find (%) percentage contribution of each parameter.

Smaller is better for minimize the response

$$S/N_{sb} = -10\log_{10}\left(\frac{1}{r}\sum_{i=1}^{n} y_i^2\right)$$

Larger is better for maximize the response

$$S/N_{lb} = -10\log_{10}\left(\frac{1}{r}\sum_{i=1}^{n} \frac{1}{y_i^2}\right)$$

Table 4: S/N ratio of SS316 Material

Experiment	Output		S/ N Ratio	
No	Weld Penetration (mm)	Hardness(HRBW)	Weld Penetration (mm)	Hardness(HRBW)
1	2.0535	79.5	2.7856	81.06
2	3.59	80	3.066	81.436
3	2.786	79.5	3.013	80.44
4	2.5365	80	2.756	81.543
5	1.9115	80.5	1.878	81.35
6	1.8575	80	1.5756	80.645
7	2.0185	80.5	2.6654	81.756
8	2.0895	81	3.785	82.6645
9	4.1975	80.5	4.536	81.66

The main effect plots of SN ratio of Penetration and Hardness shown in Table 3.From the main effect plot SN ratio indicates that Welding speed 170 mm/min , Arc voltage 26 Volt and Fe_2O_3 flux are the best value of Penetration and Hardness.

VI. CONCLUSION

- The work presented in this Paper has focused on optimization of process parameter of a GMAW process with most emphasis on finding optimal welding parameter for Penetration using Activated Flux. One of the aim of this research was to find out the Penetration of the weld joint, and also the find out which parameter is most effective on tensile hardness of the weld joint using Activated flux.
- By regression analysis conclude that our optimum set parameters Arc Voltage, Welding Speed and Activated Flux for

  - 25 Volt And 147mm/min with Cr_2O_3 Activated Flux gives the best multi-performance features of the MIG process.
  - 25 Volt And 148mm/min with Fe_2O_3 Activated Flux gives the best multi-performance features of the MIG process.
  - 26 Volt And 147mm/min with $MgCO_3$ Activated Flux gives the best multi-performance features of the MIG process.

Appendix- A **MT Lab Code for TLBO**

Cr_2O_3

ZZ=1./((0.5).*((-0.790458+(0.0186042.*x1)(0.02.*x2)./1)+(0.5).*(80.1667./(-0.790458 +(0.0186042.*x1)+(0.02.*x2);

Fe_2O_3

ZZ=1./((0.5).*((-0.650708+(0.0186042.*x1)(0.02.*x2)./1)+(0.5).*(80.1667./(-0.790458 +(0.0186042.*x1)+(0.02.*x2);

$MgCO_3$

ZZ=1./((0.5).*((-0.551958+(0.0186042.*x1)(0.02.*x2)./1)+(0.5).*(80.1667./(-0.551958 +(0.0186042.*x1)+(0.02.*x2);

References

(1) Chaudhari PG, Patel PB, Patel JD, "Evaluation of MIG Welding Process Parameter using Activated Flux on SS316L by AHP-MOORA method", Material Today Processing, 5(2018)5208–5220.

(2) Paulo J. Modenesi, Eustaquio R. Apolinario, Iaci M. Pereira,"TIG welding with single component fluxes" Journal of Materials Processing Technology 99 (2000) 260-265

(3) L. I. Qing-Ming, W. Xin-Hing, Z. Zeng-Da, W.U. Jun, "Effect of activating flux on arc shape and arc voltage in tungsten inert gas welding" Transactions of Non- ferrous Metal Society of China, pp 486 – 490, Feb. 2007.

(4) H.Y. Huang, S.W. Shyu, K.H. Tseng and C.P. Chou, "Evaluation of TIG flux welding on the characteristics of stainless steel", Science and Technology of Welding and Joining – Vol. 10,pp 566 – 573, 2005

(5) Y. Ruan, X.M. Qiu, W.B. Gong, D.Q. Sun, Y.P. Li, "Mechanical properties and microstructures of 6082-T6 joint welded by twin wire metal inert gas arc welding with the SiO2 flux" Materials and Design 35 (2012)2024

(6) Tsann-ShyiChern, Kuang-Hung Tseng, Hsien-Lung Tsai, "Study of the characteristics of duplex stainless steel activated tungsten inert Gas welds" Materials and Design 32 (2011) 255–263.

(7) Her-YuehHuang , "Effects of shielding gas composition and activating flux on GTAW weldments" Materials and Design 30 (2009) 2404–2409.

(8) Her-Yueh Huang, "Argon-hydrogen shielding gas mixtures for activating flux-assisted gas tungsten arc welding" The Minerals, Metals & Materials Society and ASM International 2010.

(9) Cheng HsienKuo , Kiang Tseng and Chang pin Chou, “Effect of activating TIG flux on performance of dissimilar welds between mild steel and stainless steel”, key Engineering materials vol. 479 (2011) pp 74-80.

(10) Zhang Ruihua, Fan Ding, Katayama Seiji, “Electron beam welding with activating flux”Transactions of JWRI, Vol.35 (2006),No.2.

(12) H. Sun, G. Song and L. F. Zhang, “Effects of oxide activating flux on laser welding of magnesium alloy” Science and Technology of Welding and Joining 2008 Vol. 13 No. 4.

(13) Chunli Yang, Sanbao Lin, Fengyao Liu, Lin WU and Qingtao Zhang, “Research on the mechanism of penetration increase by flux in A-TIG” J. Material. Sci. Technogy, Vole.19 Suppl.1,2003.

(14)L.-M. Liu et. al. (2007) “Gas tungsten arc welding of magnesium alloy using activatedflux-coated wire.”

(15) Chunli Yang, Sanbao Lin, Fengyao Liu, Lin WU and Qingtao Zhang, “Research on the mechanism of penetration increase by flux in A-TIG” J. Mater. Sci. Technololgy, Vole.19 Suppl.1,2003

(16) Kuang-Hung Tseng, Chih-Yu Hsu, “Performance of activated TIG process in austenitic stainless steel welds” Journal of Materials Processing Technology 211 (2011) 503–512.