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Investigation on Effect of Process Parameters on GMAW Auto Tack Welding Towards Minimize the Repairs

(Examine the quality of GMAW affected by the process variables for HSLA pipes)

Kuldeepsinh Solanki[1], Nagesh Chaddarwala[2], Vishal Jain[3], Sanjay Patel[4]
[1]Research Scholar, Department of Mechanical Engineering, M.S.University, Baroda, Gujarat, India,
[2]Assistant General Manager, Welspun corp.ltd, Dahej, Gujarat, India,
[3]Senior Manager, Welspun corp.ltd, Dahej, Gujarat, India,
[4]Associate professor, Department of Mechanical Engineering, M.S.University, Baroda, Gujarat, India,

ABSTRACT: *The Gas Metal Arc Welding (GMAW) process is increasingly implemented for fabrication in many industries. Improvement in productivity of GMAW process is most sought research area in welding technology. In the manufacturing of Line pipes GMAW is used to tack the grooves after the plates are formed into pipes. The objective of this paper is to identify the optimal process parameters and reduce the defects like porosity and spatters. There were very little more work have been carried out on using 4mm diameter of electrode wire (ER70S6) at the 3.5 - 4 m/min. welding travel speed as a parameter for a line pipe industry.*

After analyzing the past data on welding defects it was decided to focus on porosity and spatter. So the experiment was carried out with Design of Experiments (DOE) technique. Design of Experiments (DOE) approach was employed in order to optimize the process parameters. Given the wide range of variables for study and ways of evaluating weld quality, a design-of-experiments (DOE) approach was used. Two factors taken for study (gas flow rate, welding travel speed) and two defects (porosity, spatter) measures, while the other parameters where unchanged. Results of these trials were analyzed using standard statistical methodology. This normalized data was used to produce "best fit" regression equations.

The results were analyzed for finding parameter that gives minimum amount of porosity and spatter. These paper helps in achieving effective weld as a serves as a failure prevention guide to the operators performing the welding operation.

Key words: *Shielding gas flow rate, Welding travel speed, Design of Experiment approach, Mini Tab 17, Porosity, Spatter, HSLA (High strength low alloy).*

I. Introduction

Gas Metal Arc Welding (GMAW) is a metal joining process in which an arc forms between welding consumable metal electrode and the work piece, and the arc and the molten weld puddle are protected from atmospheric contamination (i.e. oxygen and nitrogen) with an externally supplied gaseous shield of either an inert gas such as argon, helium or an argon-helium mixture; or some active gas such as carbon dioxide, argon-carbon dioxide mixture, which is chemically active or not inert [1]. Initially GMAW was called as MIG Welding because only inert gases were used to protect the molten weld puddle.

The application of this process was restricted to aluminum, deoxidized copper and silicon bronze. Later it was used to weld ferrite and austenitic steels, and mild steel successfully by using active gasses in place of inert gasses and hence was term MAG (Metal Active Gas) welding [2].

GMA welding is used as a semi-automatic or automatic arc welding process in many applications. If a welder controls the direction of travel and travel speed the process is considered semi-automatic [3]. The process is fully automated when a machine controls direction of travel and travel speed; such is in the case of robotics. In this project GMA welding process is fully automatic.

In GMA welding shielding gas has several applications, for example cooling of the torch, the definition of the arc properties or the protection of the melt from oxidation. High quality welds can be achieved by proper selection of consumables and process parameters such as gas flow rate and welding travel speed. The optimum flow rate of gas and welding travel speed will ensure a good quality weld. This research focuses upon modeling the effect of various gas flow rates and welding speeds, and analyzing the change in the weld quality for the different combinations of the gas flow rate and welding travel speed.

1.1 Modes of Metal Transfer in GMAW

Metal transfer in GMAW is process of transferring material of the welding consumable wire in the form of molten liquid droplets to the work-piece. It plays an important role in determining the process stability and weld quality.

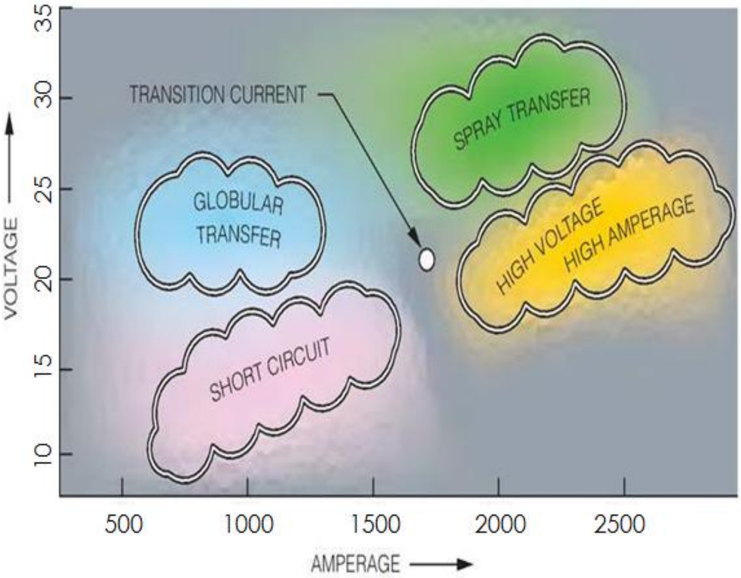


Fig.1. Schematic of modes metal transfer in GMAW

Fig.1 shows modes of metal transfer in GMA welding (Auto tack).
The mode of metal transfer in GMAW is determined by a number of parameters

1. Filler Metal Composition
2. Polarity
3. Arc Current
4. Arc Voltage/Arc Length
5. Shielding Gas Composition
6. welding variables

By changing one or more variables, the metal transfer can be changed from one mode to another. In this research, mode of metal transfer is Globular and axial with 100% CO_2 shielding, whatever may be the value of the welding current, current density and other factors. Globular mode of metal transfer gives deep penetration with flat position welding.

In Globular modes of transfer electrode forms a balled end approximately 2 times than the electrode diameter, and filler metal is deposited when gravity causes the molten droplet to detach from the electrode and fall across an open gap, causing an explosive deposit, that's why it gives deep penetration. So according to combination of amperage and voltage globular modes of transfer was selected.

1.2 Shielding Gas

Shielding gases are necessary for gas metal arc welding to protect the weld pool from atmospheric gases such as nitrogen and oxygen, which is soluble in the puddle at high temperatures and will cause porosity as it escapes during cooling of the weld bead. If the atmospheric gases come into contact with the electrode, the arc, or the welding metal it may cause fusion defects and weld metal embrittlement. Hence selection of proper gas flow rate is important for the good quality of the welding.
In this case 100% CO_2 gas is used to provide shielding for the weld pool.

II. Experimental Procedure

Based on the data of past six months the occurrence of defects in GMAW auto tack welding process of line pipes is shown in the Fig.2.

From the pie chart (fig.2) it can be observed that majority of the defects are due to the porosity and spatter. Thus it can be concluded that focusing on reducing/eliminating the above mentioned issues could help in optimizing the process parameters and simultaneously help in reducing up to 81% of defects.

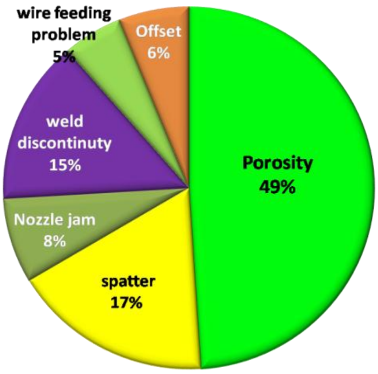


Figure 2: Schematic of average defects in GMAW auto tack welding for line pipes

The experimental setup is shown in Fig. 3.

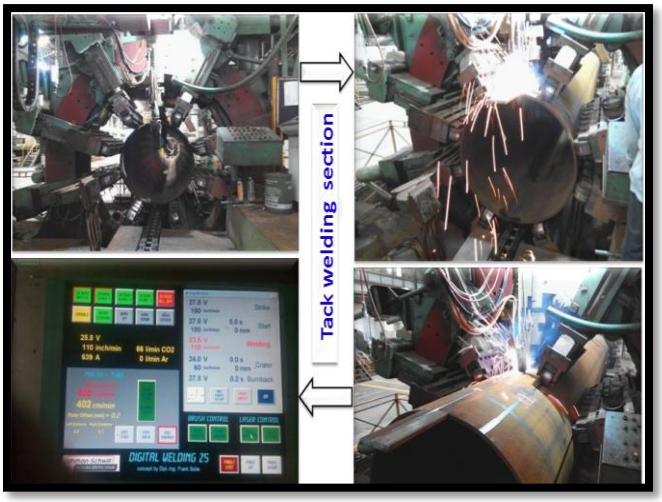


Figure 3: GMAW auto tack welding

2.1 Weld Groove Design

After forming of plate, its groove design is shown in fig 4.this paper focusing only on 1 no. of portion (4-5mm) of groove which is welded by GMA Welding, 2 and 3 no. of groove portion is welded by SAW welding.

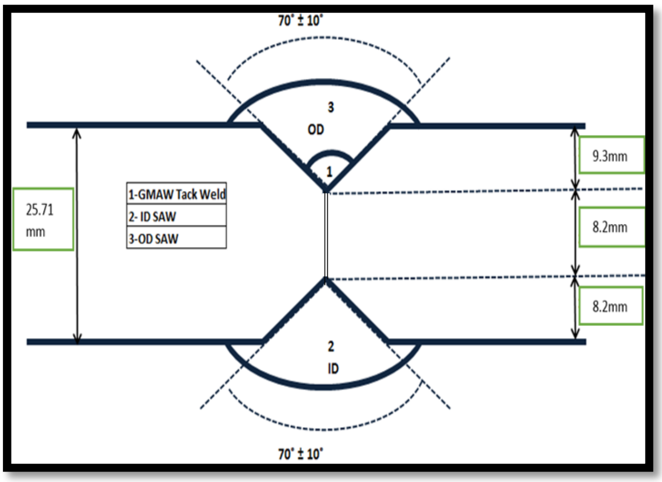


Figure 4: Schematic of Groove design for GMA welding

Table I- Experimental Details

Base metal	X-70
Base metal type	HSLA Steel
Base metal Thickness (Total) (mm)	25.71
Consumable (wire)	ER70S6
Wire Dia. (mm)	Ø 4
Shielding gas	100%CO2
Pipe diameter (Inch)	Ø 56
Type of power source	CV
Welding Electrode Polarity	DCEP
Process type	Automatic
Mode of metal transfer	Globular

Table II- Tests conducted during experimental work

Welding Parameter (Non variable)	
Welding current (A)	1000
Voltage (V)	23.2
Wire feed Rate (Inch/min)	110
Electrical stick out (mm)	19

Experimental details and the welding parameters used during the tests are illustrated in Table 1 and Table 2 respectively.

The currents research focuses upon optimizing GMA welding process parameters by varying only two variables that is **welding speed** and **gas flow rate**.

2.2 Experimental Work

2.2.1 One Factorial at a One Time

In this concept (One Factorial at a One Time), one parameter kept constant with respect to other parameter.

Table III- Experimentation

PHASE NO.	WELDING SPEED (M/min)	HEAT INPUT (KJ/mm)	TRIAL NO.	GAS FLOW RATE (LPM)	DEPTH OF PENETRATION (mm)	BEAD HEIGHT (mm)
PHASE 1	3	0.460	T1	40	2.3	4.6
			T2	50	2.5	4.5
			T3	**60**	**3.1**	**4.8**
			T4	70	3.1	5.1
			T5	80	2.8	5
PHASE 2	3.5	0.397	T6	40	2.1	3.5
			T7	50	2.2	4.5
			T8	**60**	**3.5**	**4.8**
			T9	70	2.1	5
			T10	80	2.1	4.5
PHASE 3	4	0.358	T11	40	1.1	2.5
			T12	50	1.5	2.7
			T13	**60**	**2**	**3.2**
			T14	70	1.8	3.2
			T15	80	1.5	3.3

Table 3 shows the results which was got from macrostructure testing, for achieved exact shape of curve and for further study of the values of depth of penetration and bead height experiments are done with the 50,70 Lpm gas flow rate also. In DOE it was not considered.

2.2.2 General Full Factorial Design

Given the wide range of variables for study and ways of evaluating weld quality, a design-of-experiments (DOE) approach was used. A 13-trial design was selected that covered two factors for study (including 3 level- general full factorial designs) and two defects measures.

Table IV – Factors and levels for full factorial design

Factor	Unit	Level 1	Level 2	Level 3
Gas flow rate	Lpm	40	60	80
Welding speed	m/min.	3	3.5	4

Table V – Data points of Full Factorial design of experiment

Run Order	Blocks	welding speed (M/min)	gas flow rate (Lpm)	Porosity (%)	Spatter (%)
1	1	3	40	6	8
2	1	4	40	7	4
3	1	3	80	8	6
4	1	4	80	7	8
5	1	3	60	2	2
6	1	4	60	3	5
7	1	3.5	40	4	5
8	1	3.5	80	7	7
9	1	3.5	60	1	2
10	1	3.5	60	2	0
11	1	3.5	60	0	1
12	1	3.5	60	1	1
13	1	3.5	60	2	2

After observing the quality of weld, repair length was measured, from that got the values of Porosity and Spatter in percentage which table 5 shows.

$$\textbf{Porosity}(\%) = \frac{\textbf{Length of Repair}(\textbf{porosity})}{\textbf{Total Length}} \times \textbf{100}$$

$$\textbf{Spatter}(\%) = \frac{\textbf{Area of Repair}(\textbf{spatter})}{\textbf{Total Area}} \times \textbf{100}$$

This experiment was done on pipe directly, for the study purpose samples are cut from the pipe.

III. Testing of WELDMENTS

In this research for observing the quality of bead Visual Inspection was done, for measuring the weld bead geometry Macrostructure testing was done and for subsurface defects Magnetic particle testing was done.

3.1 Macrostructure testing

The weld bead samples are cut from each pipe, the transverse faces of the specimens were further prepared for study of weld bead geometry like depth of penetration and weld bead height.

Finally the specimens were etched with mixture of CH_3OH (95%) and HNO_3 (5%). All the test specimens were washed off with water to reveal the geometry of the weld bead. Several critical parameters, such as bead penetration & bead heights were measured.

IV. Results and Analysis

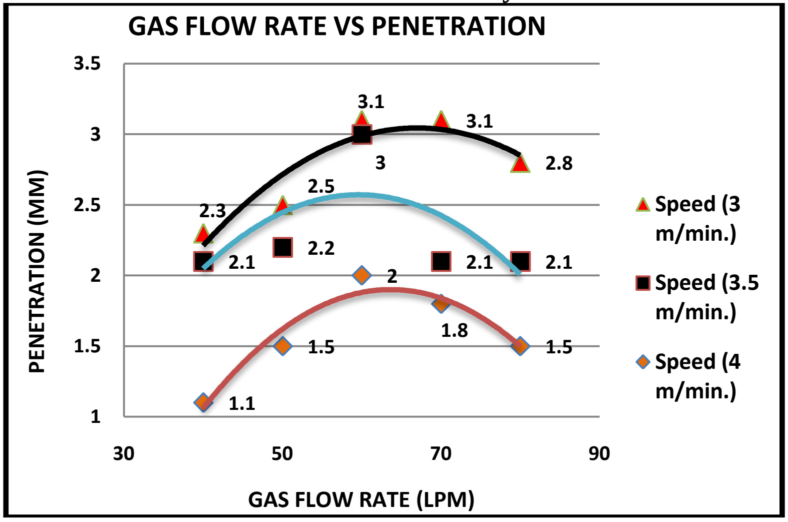


Figure 5: schematic of gas flow rate vs. penetration

Form fig. 5 it was observed that the depth of penetration increases with increasing gas flow rate up to 60 Lpm points which was the optimum value to obtain maximum penetration, because it begins to decrease after this point again linearly.

Form fig. 6 it was observed that the Bead heights decreased when welding speed is increases from 3.5M/min. to 4 M/min.

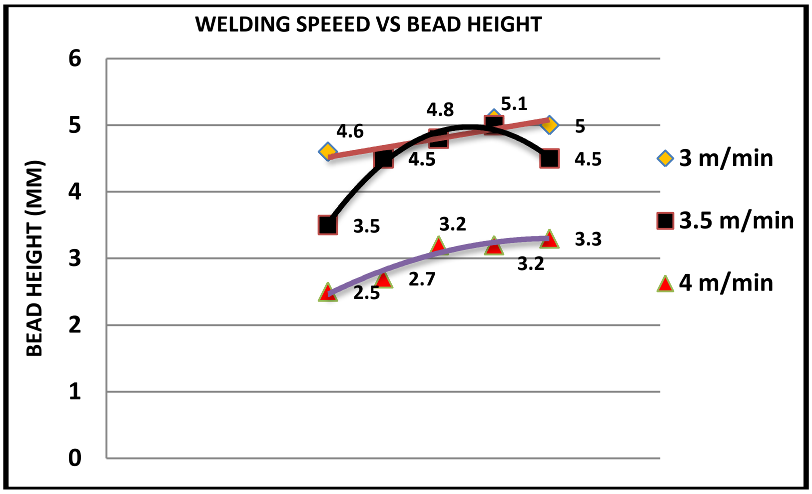


Figure 6: schematic of welding speed Vs Bead height

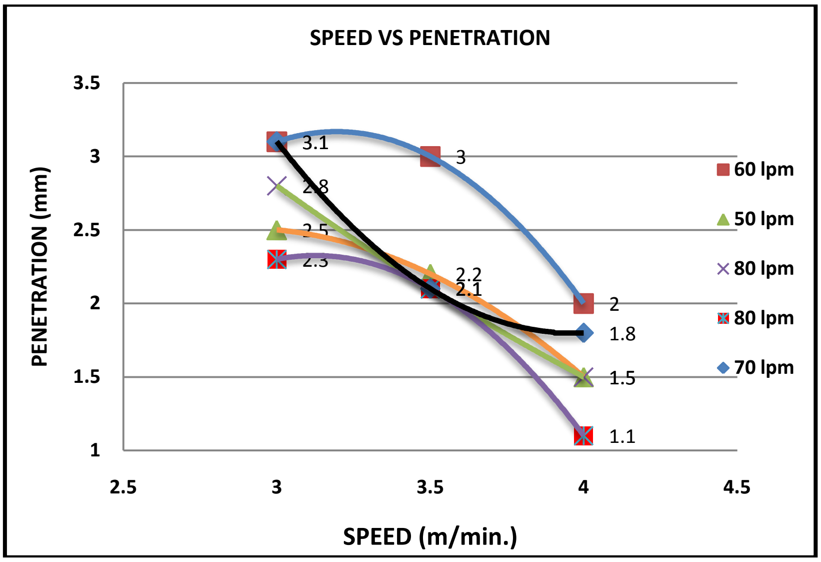
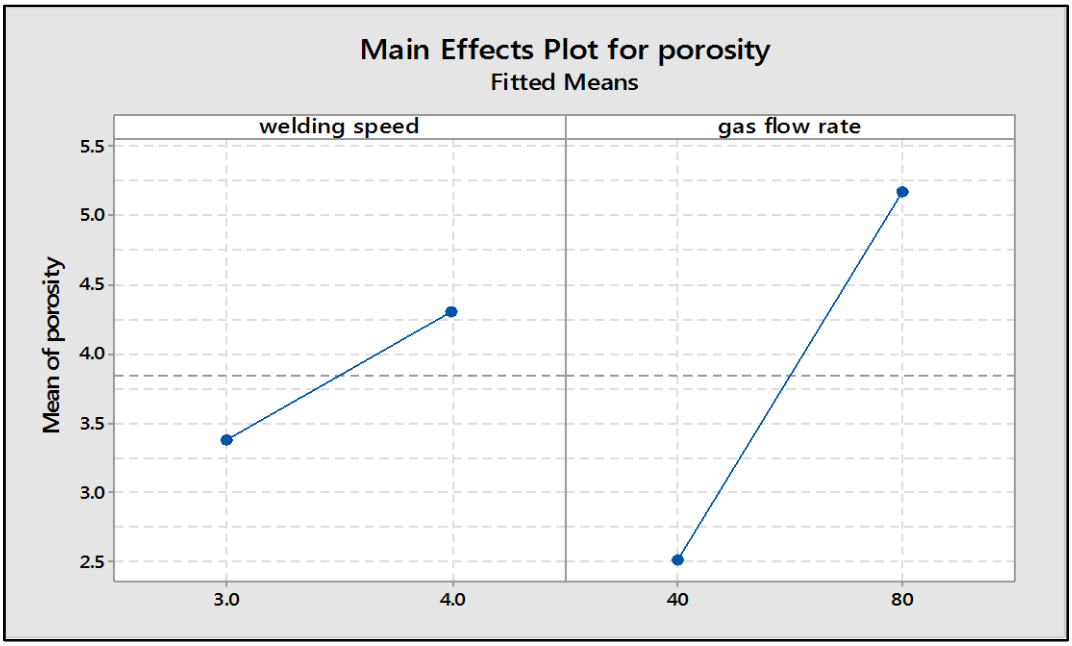
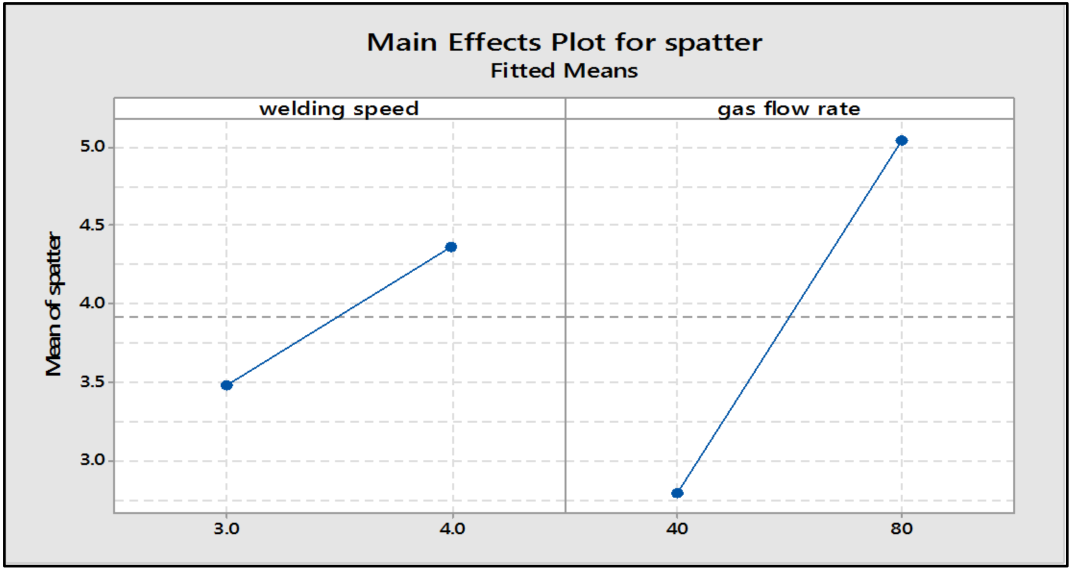


Figure 7: schematic of welding speed vs. Penetration

Form fig. 7 it was observed that the Bead height increases when gas flow rate increases from 40 Lpm to 60 Lpm. Depth of penetration decreased when welding speed is increases from 3.5M/min. to 4 M/min. for all gas flow rate.



(A)



(B)

Figure 8: Main Effects Plots (A & B)

Fig. 8 shows Main Effects Plot for porosity and spatter. It is concluded from this plots lines are not horizontal (Slop>0) so welding speed and gas flow rate significantly affect porosity and spatter. The greater the lines depart from being parallel, the greater the strength of the Main effect present.

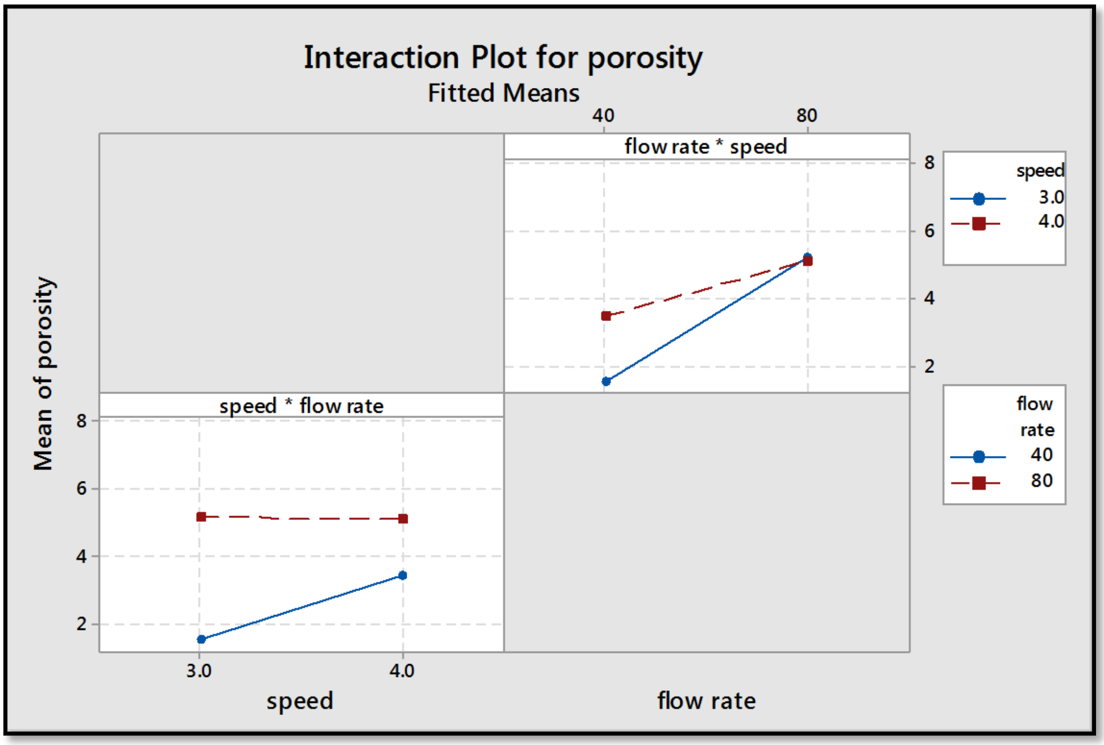


Figure 9: Interaction Plots (Porosity)

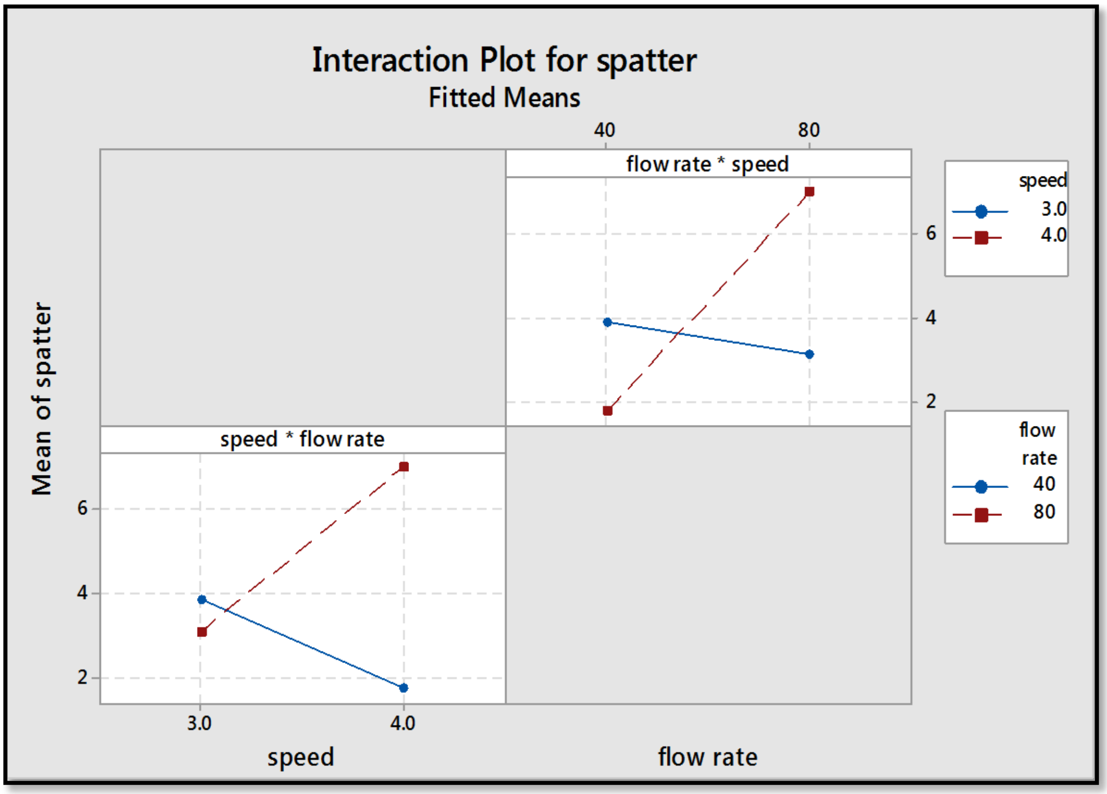
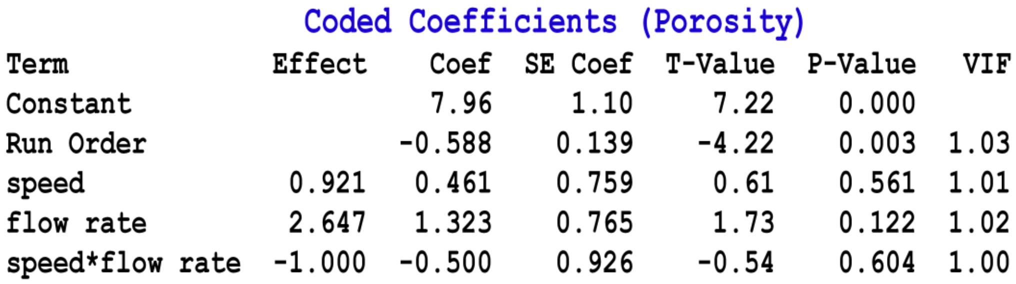


Figure 10: Interaction Plots (Spatter)

Fig. 9&10 consequently shows Interaction Plot for porosity and spatter, it shows (lines) strength of interaction for porosity and spatter. When the effect of a one factor depends on the level of the other factor interaction plot was used to visualize possible interactions. The greater the lines depart from being parallel, the greater the strength of the interaction. So Interaction of Welding speed and gas flow rate strongly affect the spatter than porosity.

4.1 statistical analysis results



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                 Coded Coefficients (Porosity)

Term              Effect     Coef  SE Coef  T-Value  P-Value   VIF
Constant                     7.96     1.10     7.22    0.000
Run Order                  -0.588    0.139    -4.22    0.003  1.03
speed              0.921    0.461    0.759     0.61    0.561  1.01
flow rate          2.647    1.323    0.765     1.73    0.122  1.02
speed*flow rate   -1.000   -0.500    0.926    -0.54    0.604  1.00
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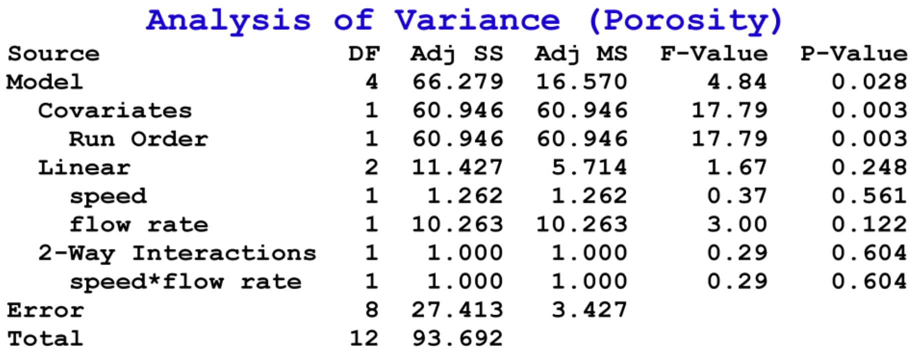
Figure 11: coded coefficients (Porosity)



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              Analysis of Variance (Porosity)
Source                    DF   Adj SS   Adj MS  F-Value  P-Value
Model                      4   66.279   16.570     4.84    0.028
  Covariates               1   60.946   60.946    17.79    0.003
    Run Order              1   60.946   60.946    17.79    0.003
  Linear                   2   11.427    5.714     1.67    0.248
    speed                  1    1.262    1.262     0.37    0.561
    flow rate              1   10.263   10.263     3.00    0.122
  2-Way Interactions       1    1.000    1.000     0.29    0.604
    speed*flow rate        1    1.000    1.000     0.29    0.604
Error                      8   27.413    3.427
Total                     12   93.692
```

Figure 12: analysis of variance (porosity)

Fig. 13&16 consequently shows residual plots for porosity& Spatter.

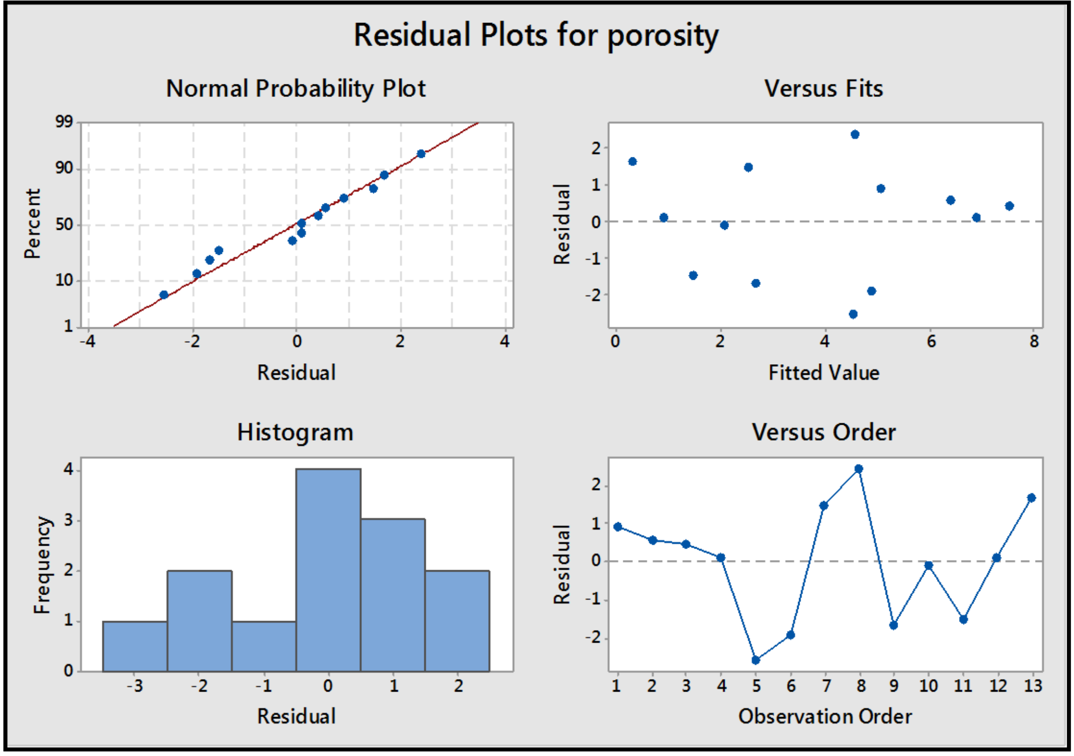


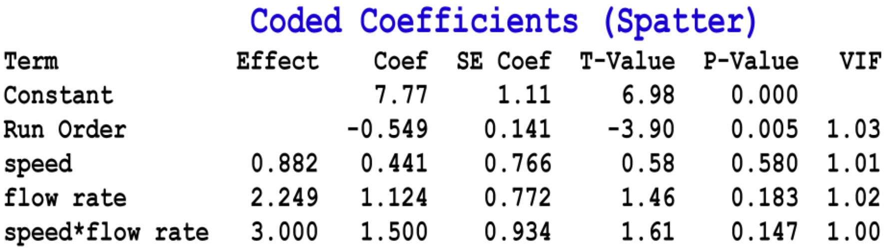
Figure 13: Residual plots (porosity)

These plots (histogram, normal probability plots, Residuals versus fitted values, and Residuals versus order of the data) were used to analyze the effects of different parameter on porosity and spatter.

Histogram was used to examine the shape and spread of sample data which indicates the data (for porosity and spatter) are skewed or there were not any outliers exists. From probability plots, it was observed that the data are normally distributed. Residual versus fitted values shows variance is constant for the porosity and spatters. From the residual versus order of the data, systematic effects in the data due to time or data collection order was observed.

Regression Equation in Un-coded Units

Porosity = -9.7 +3.92 speed + 0.241 flow rate-0.0500 speed * flow rate



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                     Coded Coefficients (Spatter)
Term              Effect     Coef  SE Coef  T-Value  P-Value   VIF
Constant                     7.77     1.11     6.98    0.000
Run Order                  -0.549    0.141    -3.90    0.005  1.03
speed              0.882    0.441    0.766     0.58    0.580  1.01
flow rate          2.249    1.124    0.772     1.46    0.183  1.02
speed*flow rate    3.000    1.500    0.934     1.61    0.147  1.00
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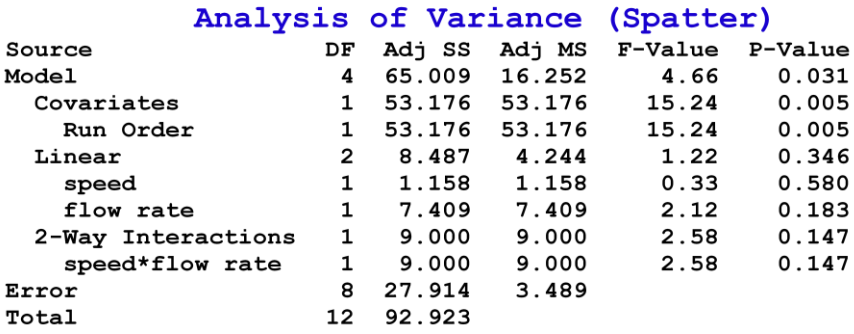
Figure 14: Coded coefficients (Spatter)



```
                     Analysis of Variance (Spatter)
Source                     DF   Adj SS   Adj MS  F-Value  P-Value
Model                       4   65.009   16.252     4.66    0.031
  Covariates                1   53.176   53.176    15.24    0.005
    Run Order               1   53.176   53.176    15.24    0.005
  Linear                    2    8.487    4.244     1.22    0.346
    speed                   1    1.158    1.158     0.33    0.580
    flow rate               1    7.409    7.409     2.12    0.183
  2-Way Interactions        1    9.000    9.000     2.58    0.147
    speed*flow rate         1    9.000    9.000     2.58    0.147
Error                       8   27.914    3.489
Total                      12   92.923
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Figure15: analysis of variance (Spatter)

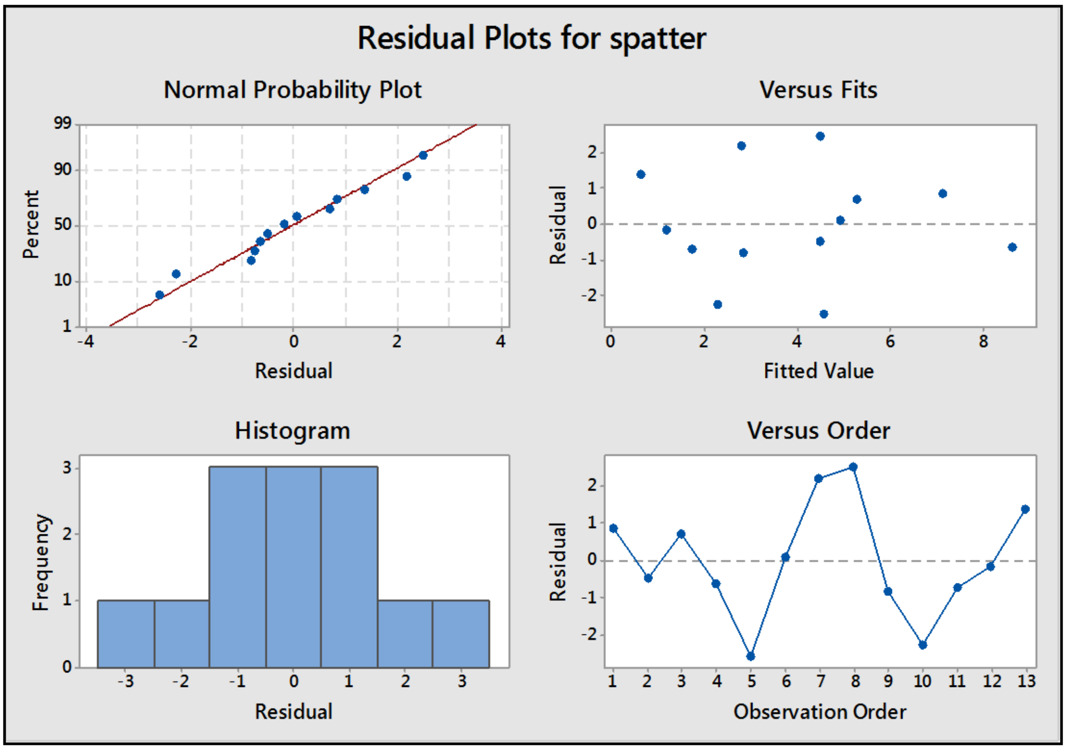

Figure 16: Residual plots (Spatter)

Regression Equation in Un-coded Units

Spatter = 32.8 -8.12 speed -0.469 flow rate + 0.1500 speed*flow rate

The resulting regression equations from statistical analysis of corrected data are presented in fig 11–15.

The P value was observed little less because of the experiment was done with single sample data but interaction plots of porosity and spatter shows interaction of both the variables (welding speed & gas flow rate) and main effect was also observed for the both variables.

V. Conclusion

When the GFR was between 50 to 60 Lpm, it was observed shielding of gas in GMAW process was very effective. Beyond certain level excess gas caused turbulence flow in weld pool which leads to the defects in welding.

In case of welding speed 3.5 M/min. is optimum speed for welding which gives better penetration for weld metal joining & also gives optimum bead height for the Good quality of welding.

The depth of penetration increases with increasing welding speed up to 3.5 M/min. point which was the optimum value to obtain maximum penetration, because it begins to decrease after this point again linearly.

The depth of penetration increases with increasing gas flow rate up to 60 Lpm points which was the optimum value to obtain maximum penetration, because it begins to decrease after this point again linearly.

Bead height increases when gas flow rate increases from certain level after that Bead heights linearly decreased when welding speed was increase.

The welding defect data was analyzed in detail got Regression equations of the defects and discussed using histogram, Control Charts and Probability Plots etc.

The analysis carried out in this project has been found effective in quantitative understanding of effect of gas flow rate and welding speed on GMA welding for HSLA pipe. It is clearly identified that the variation in GFR and speed significantly affects the quality of weld bead.

REFERENCES

[1]. E. Karadeniz, Ozsarac, U. and Yildiz, C., “The effect of process parameters on penetration in gas metal arc welding process”, Materials and Design, 2007, Vol. 28, Issue 2, pp. 649-656.

[2]. M. Suban and J. Tusek, “Methods for the determination of arc stability”, Journal of Materials Processing Technology, 2003, pp. 430-437.

[3]. J. Lancaster “The Physics of Welding”, Pergamon Press, New York, USA.

[4]. M. Weglowski, Y. Huang, Y.M. Zhang, “Effect of welding current on metal transfer in GMAW”, (International Scientific Journal, World Academy of Materials and Manufacturing Engineering)Archives Of Materials Science and Engineering, Volume 33 Issue 1, September 2008, Pages 49-56.

[5]. S. Ramasamy, J. Gould, AND D. Workman,” Design-of-Experiments Study to Examine the Effect of Polarity on Stud Welding”, supplement to the welding journal, February 2002 (Sponsored by the American Welding Society and the Welding Research Council).

[6]. M. Singla, D. Dharmpal et al., ”Parametric Optimization of Gas Metal Arc Welding Processes by Using Factorial Design Approach”, in Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.4, pp.353-363, 2010 jmmce.org

[7]. J. Peter, A. Kumar,” Fluid Flow Behavior under Different Gases and Flow Rate during Gas Metal Arc Welding“, Journal of Engineering Research and Applications Vol. 3, Issue 5, Sep-Oct 2013, pp.52-55.

[8]. R. Sharma, R. Sisodia, A. Shukla, V. Sharma “The use of Taguchi method to analyze the effect of welding parameters on weldments”, International Journal of Engineering Research and Development e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com Volume 10, Issue 6 (June 2014), PP.47-52

[9]. T.P. Quinn, C. Smith, C.N. McCowan, E. Blachowiak, R.B. Madigan, “Arc Sensing for Defects in Constant-Voltage Gas Metal Arc Weldiing”, Welding Journal, 1999, Vol. 78,pp. 322-328.

[10]. Y. S. Kim, “Metal transfer in gas metal arc welding”, PhD Thesis, 1989, MIT: USA.

[11]. F. Wang, W. K. Hou, S. J. Hu, E. Kannatey-Asibu, W. W. Schultz, P. C. Wang, “Modeling and analysis of metal transfer in gas metal arc welding”, J. Phys. D: Appl. Phys., Vol. 36, 2003, pp.1143-1152.