DOI: 10.7763/IPEDR. 2014. V75. 16

Statistical Analysis of TIG Arc Weldment Characteristics

H. K. Narang[1 +] and M. M. Mahapatra[2]

[1]*Assistant professor*, Mechanical Engineering Department, National Institute of technology Raipur, India
[2]*Assistant professor*, Mechanical Engineering Department Indian Institute of technology Roorkee, India

Abstract. The structural steel having lower carbon percentage applied mostly used in open arc welding such as tungsten arc welding (TIG). A highly accurate and widely applicable tracking control system which guides a welding torch along a joint line is described. The present work deals the effects of process parameters on weld pool geometries such as bead width, depth of penetration and arc spread of TIG weld. It is very difficult to see an arc images by naked eyes and by using ordinary photograph because it may damage the charged coupled device. The input process variables for TIG welding of structural steel plate were modeled for achieving acceptable welds. The process variables were also studied for the interaction effects on weld width, weld penetration and arc spread. The statistical analysis multiples regression equations were developed for qualitative prediction of future outcomes of process parameters. To validate the developed mathematical model were tested for a range of test cases which has found within the acceptable range.

Keywords: TIG welding; weld width; weld penetration; Arc image magnifying system, multiple regression analysis and interaction plots.

1. Introduction

Arc welding, which is most versatile heat-type arc welding process, the most important manufacturing operations for the joining of structural elements for a wide range of applications (Guide way for trains, ships, bridges, building structures, automobiles, and nuclear reactors). It requires a continuous supply of either direct or alternating electric current, which create an electric arc to generate enough heat to melt the metal and form a weld.

To get the desired weld quality in TIG welding process, it is essential to know interrelationships between process parameters and bead geometry as a welding quality. Many efforts have been done to develop the analytical and numerical models to study these relationships, but it was not an easy task because there were some unknown, nonlinear process parameters [1]. For this reason, it is good for solving this problem by the experimental models. One of the experimental models was a multiple regression technique that was utilized to establish the empirical models for various arc welding processes [2, 3]. Datta et al. developed three empirical models for predicting bead volume of submerged arc butt welding [4]. Gunaraj et al. proposed empirical models for prediction and optimization of weld bead for the SAW process. Furthermore, Gunaraj et al. highlighted the use of RSM by designing a central composite rotatable design matrix to develop empirical models for predicting weld bead quality in SAW for pipelines [5-6]. Kim et al. developed an intelligent system for GMA welding process based on factorial experimental [7].

In this study, experimental design based full factorial were used to achieve the most reliable results. Then, an experimental data based on full factorial were used to develop the mathematical relation between the inputs process parameters (welding speed, welding voltage & welding current) and outputs parameters (arc spread, weld width and depth of penetration) of the weld pool geometry. A mathematical model of the process has also been tested for the test experiments to prove the adequacy of the developed model.

2. Experimental Details

[+] Corresponding author.
E-mail address: *narangiitr@gmail.com*.

A TIG welding machine with direct current straight polarity (DCSP) integrated with arc image magnifying system was used in experiments (Figure 1). A linear variable differential transformer LVDT and the arc magnifying system were used to set the arc length. Arc images of arc magnifying system were shown in Fig. 2. The trial experiment runs were conducted to select the range of the inputs process parameters given in Table 1, such that no observable defects like undercutting and porosity occurred. The 27 test experiments of full factorial design were conducted to obtain the test data TIG weld pool characteristics. The dimension of test specimen is; length, width and thickness of mild steel plates used in the experiments were 180, 65, and 8 mm respectively. Three input parameters, current, arc length and traverse speed were varied at three levels as shown in the Table 1. The structural steel plates before and after the weld is shown in Fig. 3. Weld samples were cut from the test pieces and polished by silicon carbide paper with different grades and etched by nital solution. The different macrostructure zones of TIG weld pool geometries are shown in Fig. 4.

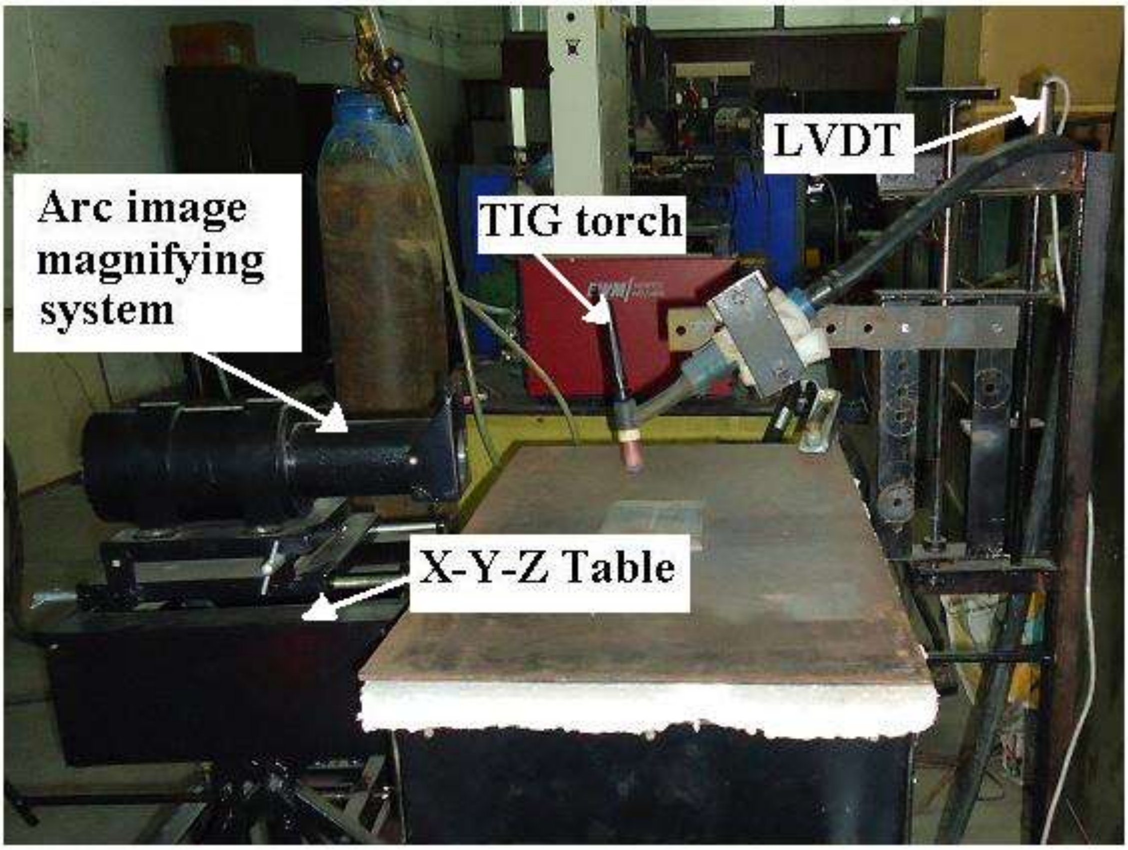

Fig.1 Experimental set-up of TIG welding with arc image magnifying system

Fig.2 Arc images of TIG welding

Table: 1 Input process parameters levels for the experiments

Sl.No	Parameter	Units	High	Medium	Low
1	Current (I)	A	95	75	55
2	Travelling speed (S)	mm/min	45	30	15
3	Arc length (AL)	mm	3.0	2.5	2

Fig. 3 Structural steel plates before and after the weld

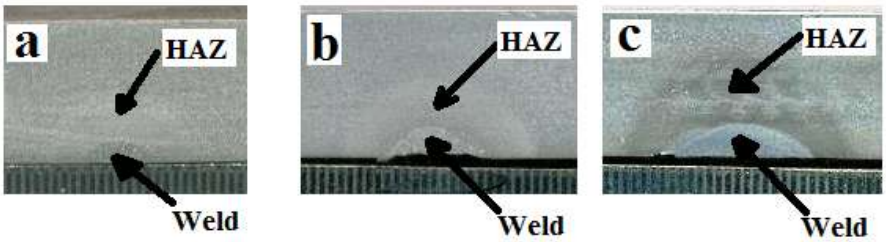

Fig. 4 Macrostructure zones of TIG weld pool geometries

3. Mathematical modeling of TIG weldment

The designs of statistical model based of full factorial analysis were used for the mathematical modelling of the TIG process. The regression analysis has been done to obtain the relationship between the inputs and outputs of the TIG weldment characteristics [8]. The experimental data obtained from the three level three factor were also used for interaction plot.

3.1. Multiple linear regression analysis

The effects of process parameters on bead characteristics have been studied and regression analysis was carried out to model the process. The multiple regression model and analysis of variance (ANOVA) was further used for studying the interaction effects of input process variables and responses. The experimental and predicted value for bead width of TIG weldment characteristics is presented in Fig.5. From the Figure 5 it observed that the experimental and predicted values are closely matched, which revel the accuracy of the developed model. The multiple regression equation based on the full factorial design experimental data is given from equation i to iii.

$$\text{(Weld width) } BW = 3.86 + 0.0256 * I + 0.607 * A*L - 0.0583*S \quad \text{i}$$

$$\text{(Penetration depth) } P1 = 1.16 + 0.00831 * I + 0.241 * A*L - 0.0261 * S \quad \text{ii}$$

$$\text{(Arc spread) } AS = 1.04 + 0.0124 * I + 0.204 * A*L - 0.0167 * S \quad \text{iii}$$

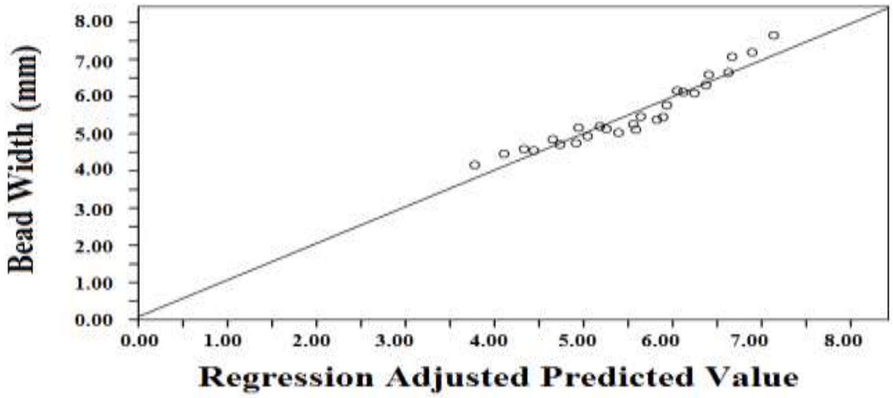

Fig.5. Experimental and predicted values of TIG weld pool for bead width

To check the adequacy of the developed mathematical model several test experiments has been done within the range of full factorial design. The variation between the experimental and predicted data by the developed mathematical in percentages is shown in Table 2. The maximum percentages of deviation were observed for test case 4 (Table 2) for the bead width because it's very difficult to get stable arcs between the electrode a work piece during the experiment.

Table: 2 Test cases of bead width of TIG weldment

S.N.	Current (A)	Arc length (mm)	Speed (mm/min)	Experimental Bead Width	Predicted Bead Width	% error
1	60	1.5	15	5.17	5.44	5.12
2	65	2.3	23	6.21	5.58	-10.13
3	95	1.8	27	6.41	5.82	-9.19
4	95	3.2	35	7.06	6.20	-12.21
5	110	2.3	42	6.33	5.63	-11.03

3.2 Interaction Plots of Data

An arc welding process is very complicated system, it is very difficult to predict the weldment characteristics by considering the effects of single processes parameters of inputs. An interaction plots on bead width were shown in Fig. 6. The combined effects of the inputs process parameters were clearly presented (Fig. 6). From the Fig. 6, as increasing the welding current the bead width of the weldment being increases not that much significantly. An arc length is directly proportional to arc voltage with increasing the arc length arc spread will increases which consequently affect the bead width of the weldment as shown in interaction plots. As increasing the welding current the width of the weldment going to decreases more significantly as shown in Fig.6. With increasing the welding speed the amount of heat required to melt get reduces, consequently the bead width of the weldment going to decrease with high welding speed [9-11].

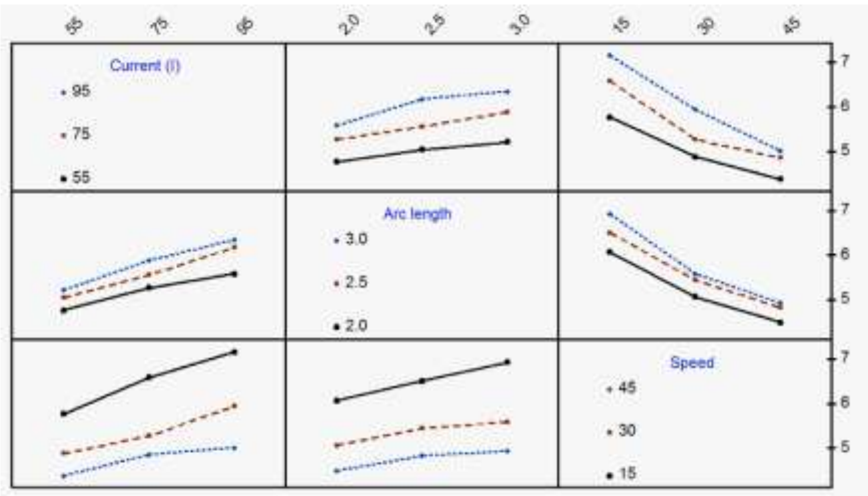

Fig. 6 Interaction plots means for bead width (BW)

Conclusions

- An arc image magnifying system was developed to observe an arc spread between the electrode and the work piece having low cost.
- The mathematical models were developed to predict the future outcomes of the weldment characteristics within the accuracy limit 13 % which is considerable.
- Interaction effects of process parameters were plots for data means of bead width which revel the combined effects on outputs of the TIG weldment joint characteristics.
- Arc spread has revel more positive effects on bead width as compared to welding current and welding speed.
- The developed mathematical model can be used to predict the weldment characteristics of TIG weld pool geometries.

References

[1] D. Kim, M. Kang, and S. Rhee. Determination of optimal welding conditions with a controlled random search procedure. *Welding J*, 2002, 84, 125-130.

[2] J. Raveendra, and R. S. Parmar. Mathematical models to predict weld bead geometry for flux cored arc welding. *Metal Construction*, 1987, **19**(2), 31R-35R.

[3] L.J. Yang, R.S. Chandel, and M.J. Bibby. The effects of process variables on the weld deposit area of submerged arc welds. *Welding. J*, 1993, **72**(1), 11-18.

[4] S. Datta, M. Sunder, A. Bandyopadhyay, P., K, Roy., S, C., and Nandi, G., Statistical modeling for predicting bead volume of submerged arc butt welds. *Australasian Welding J*, 2006, 51, Second Quarter.

[5] V. Gunaraj, and N. Murugan. Prediction and optimization of weld bead volume for the submerged arc process - Part 1. *Welding J*, 2000, 286-294.

[6] V. Gunaraj, and N. Murugan. Application of response surface methodology for predicting weld bead quality in submerged arc welding of pipes. *Journal of Materials Processing Technology*, 1999, **88**(1-3), 266-275.

[7] I.S. Kim, J.S. Son, C.E. Park, I.J. Kim., and H. Kim. An investigation into an intelligent system for predicting bead geometry in GMA welding process. *Journal of Materials Processing Technology*, 2005, **159**(1), 113-118.

[8] Li, P., M. T. C. Fang, and J. Lucas. Modeling of submerged arc welding bead using self-adaptive offset neural network. *Journal of Materials Processing Technology*, 1997, 71, 288-298.

[9] Y. S. Tarng, H. L. Tsai, and S. S. Yeh. Modelling, optimization and classification of weld quality in tungsten inert gas welding. *International Journal of Machine Tools and Manufacture*, 1999 39, 1427-1438.

[10] J. I. Lee, and K. W. Um. A prediction of welding process parameters by prediction of back-bead geometry. *Journal of Materials Processing Technology*, 2000, **108**(1), 106-113.

[11] D. S. Nagesh, and G. L. Datta. Prediction of weld bead geometry and penetration in shielded metal-arc welding using artificial neural networks. *Journal of Materials Processing Technology*, 2002, **123**(2), 303-312.