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Mathematical Investigation of Process Parameters affecting in Cladding when Performed using FCAW

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Abstract: The paper describes a theoretical study conducted to investigate effect of the process parameters in the cladding work performed using a kind of fusion welding process i.e. flux cored arc welding (FCAW). It involves a statistical empirical model developed on the basis of regression analysis to predict the weld bead geometry for the given set of process parameters, in the form of mathematical correlations. The formulation is made with an inclusion of significance/weightage analysis for the parameters like penetration, reinforcement, weld bead width and percentage dilution to limit the mathematical labour for the second-order polynomial equation. Also, effect of each variable is traced separately to know the corresponding influence on the behaviour of rest of the process parameters thereby on the weld bead geometry.
Keywords: FCAW, cladding, mathematical model, regression analysis, effect on process parameters

I. INTRODUCTION

Components used in engineering applications are often subjected to wear and corrosion due to the prevailing load, relative motion and the temperature conditions; thus, requires frequent maintenance to sustain its reliability. The full replacement cost associated with those components are hard to bear thereby extension of its service life by its reconditioning is the best option to save against the cost [1]. Cladding used for reconditioning of the engineering components is a process of depositing a layer of filler material on a base metal, generally employed for carbon or low alloy steels. Weld cladding is a popular method used in repair of worn-out parts or for the deposition of a corrosion resistant surface [2]. Amongst the fusion welding processes, flux cored arc welding (FCAW) having a flux filled inside the hollow electrode has been widely accepted in the cladding work due to its high productivity and ease of adaptability to automation. In the process of FCA welding the weld bead shape and dilution being governed by the bead geometry plays a vital role in computing the mechanical properties of the welded specimens. For the attainment of the desired quality of welds, it is important to have complete control over the process parameters to obtain the required bead geometry, upon which the quality and the integrity of a weldment relies [4]. For that, it is very important to properly select and control the process parameters in order to achieve optimal bead geometry [5]. Mathematical models which are derived from the experimental analysis based on the observational computations can be used to correlate the welding process parameters and the bead shapes, for the prediction of the weld bead geometry variables [6]. It has also been suggested by various research scholars that efficient use of statistical design of experimental methods facilitates the formulation of an empirical methodology, to use a statistical approach in the welding procedure [7-10]. Thus, in the prescription of this paper, design of experiment technique is used to perform the experiments for investigating the dependency of the process parameters. The study is carried-out in two steps. In the first step, regression models is developed using empirical relations of the weld bead geometry parameters for the prediction of area of penetration and dilution. In the second step, for the each of the process variables separate graphs are plotted to illustrate significance of each variable, with the increase or decrease in the rest of the variables.

II. THEORETICAL STEPS FOR EXPERIMENTATION

The study needs to be performed in the following sequence of steps:

A. Listing The Important Control Variables And Identifying Their Upper And Lower Control Limits

The controllable process parameters are identified as welding current (I), welding speed (S) and nozzle to plate distance (N). The trial runs are to be carried-out with the bead laid on plates while varying any one of the process parameters and keeping the others at constant values, to identify the range of the process parameters after inspecting the bead for smooth texture and absence of any visible surface defects.

Also it is found that the feed rate of wire is directly proportional to the welding current, which can be written as:

$$W_f = -6.92 + 0.0860*I$$

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Where, I is the welding current in ampere,
Wf is the wire feed rate in m/min.
The upper & lower control limit of the stated factor is considered as +1.682 & −1.682, respectively. While the values of the intermediate level is to be calculated from the relationship:

$$X_i = 1.682^* [2X - (X_{max} + X_{min})] / (X_{max} - X_{min})$$

Where, X_i is the required value of a variable is any value of the from X_{min} to X_{max},
X_{min} is the lower level of the variable,
X_{max} is the upper level of the variable.

B. Forming The Design Matrix And Performing The Experiments As Per The Design Matrix

For the formation of the design matrix firstly the structural plates are to be cut of a standard section for 20 mm thickness using an oxy-acetylene flame. The top surface of the test plate which is to be cladded needs to cleaned with the help of emery paper or wire brush to remove the unwanted dust.
Further, the experiments are to be conducted by laying a single bead on structural steel plates with the stainless steel flux cored wire of a standard diameter, under the constant shield of 95% air and 5% CO2 mixture; direct current electrode positive (DCEP) is to be used with preferably 90° weld work angle.

C. Recording the Responses like Penetration (P), bead width (W), Reinforcement (R) and % Dilution (D)

Plenty of experimental runs are to be conducted at random intervals to avoid any systematic/trend error coming into the system. Thereafter the surface plates are to be cross-sectioned at the midpoints to obtain test specimens of 25 mm in width. These specimens are to be ground, polished and etched with suitable etchant, to trace the bead dimensions like width (W), penetration (P) and reinforcement (R) with the use of profile projector.

D. Developing The Mathematical Model, And Determining The Co-Efficient Of The Regression Model

The response function representing the weld bead dimensions can be written as

$$Y = f(I, S, N) \qquad \ldots(1)$$

Where, Y is the response e.g. penetration, bead width etc.,
I is welding current in ampere,
S is welding speed in cm/min,
N is nozzle-to-plate distance in mm.
The second-order polynomial equation for the development of the regression model for the K number of factors could be expressed as:

$$Y = b_0 + \sum_{i=k}^{k} b_i X_i + \sum_{i,j=1}^{k} b_{ij} X_i X_j + \sum_{i=1}^{k} b_{ii} X_i^2 \qquad \ldots(2)$$

Where, b_o is the free term of the regression equation,
Coefficients b_1, b_2 , …b_k are linear terms,
Coefficients b_{11}, b_{22}, …b_{kk} are the quadratic terms,
Coefficients b12, b_{13}, …b_{k+1k} are the interaction terms.
For three factors, the given polynomial could be expressed as given below:

$$Y = b_0 + b_1I + b_2S + b_3N + b_{12}IS + b_{13}IN + b_{23}SN + b_{11}I^2 + b_{22}S^2 + b_{33}N^2 \ldots (3)$$

E. Assessing The Model Developed

The coefficients expressed as above are to be used to develop the model for the response parameter. Then the adequacy of the prescribed model is to tested using the analysis of variance technique. From the technique ratio of the F is to be calculated at the 95% confidence level, to check whether the developed model is adequate or not.

1) *Testing the Coefficients for Their Significance:* The values obtained from the regression coefficients provide a base about to what extent the factors affect the responses, the coefficients which are relatively less significant can be omitted without sacrificing much of the accuracy, to avoid cumbersome calculations and reduce the mathematical labour. To separate the significant and the insignificant coefficients the T-test and F tests are to be used. In these tests basically in the backward steps a variable is removed from the model and during forward steps a variable is added to the model. After determination of the significant coefficients, the final model is to be constructed by using only those coefficients.

III. DEVELOPMENT OF THE FINAL MATHEMATICAL MODEL

The final mathematical model with parameters in coded form, obtained by the abovementioned procedure are presented as below:

$$P = 0.971 + 0.093 *I - 0.062 *S - 0{:}016 *N - 0.047 *I * I + 0.02 *S * S - 0.039 *N * N - 0.03 *I * S - 0.042 *I * N - 0.042 * S * N \quad \ldots (4)$$

$$R = 4.417 + 0.143 * I - 0.253 *S * 0.038 * N + 0.067 * S * S \quad \ldots (5)$$

$$W = 10.531 + 1.539 * I - 0.46 * S + 0.069 * N + 0.3 * N * N - 0.357 * I * N \quad \ldots (6)$$

$$D = 7.533 + 0.039 * I + 0.001 * S + 0.266 * N - 0.275 * S * S - 0.237 * N * N - 1.22 * I * N - 0.375 * I * S - 1.512 * S * N \quad \ldots (7)$$

Where, P = depth of penetration in mm

R = height of reinforcement in mm

W = weld width in mm

D = dilution, %

A. Confirmation to Experiments

In order to verify the weather the conducted experiments satisfies the validity criteria laid by the developed regression models, a tool called scatter diagram is to be used for the pictorial indication of the prevailing variance. Further, the scatter diagram is to be plotted for various parameters and if the line adjoining the points of observed values obtained from the experiment and values predicted by the mathematical model comes to be parallel then the experiment can said to be nearly optimal.

IV. EFFECTS OF WELDING PROCESS VARIABLES ON THE BEAD GEOMETRY

A. Effects of Process Variables on the Depth of Penetration (P)

Referring to the Fig.1, when the voltage (V) and the current (C) is increased it leads to slight increase in the penetration (P) in the initial part, and with the further increase in the voltage & current the penetration tends to decrease.

There exhibits increase in the penetration with the increase in the speed of welding, as at the higher welding speeds the pool of weld metal becomes smaller thereby gives lesser cushioning effect and provides deeper penetration. Also, because of the flux shield on the weld bead requires more time for the heat to liberate into the surrounding in turns to nominal increase in the penetration.

The increase in nozzle to plate distance (N) gives hike to the penetration by a small amount initially, while the further increase in the nozzle to plate distance the penetration decreases due to the decrease in welding current.

B. Effects of Process Variables on Reinforcement (R)

Referring to the Fig. 2, as can be observed that reinforcement increases with the increase in the current due to the corresponding increase in the convexity of the bead and the increase in the melting rate. Whereas the reinforcement decreases with the increase in the welding speed. As evident from the Fig.2 initially when the voltage is increased it leads to increase in the reinforcement, and decreases with the further increase in the voltage, due to the widespread of the arc of cone.

If the fusion rate of the electrode is kept constant for all values of the welding speeds, then at lower speeds the bead comes to be large in size whereas at higher speeds it is relatively smaller.

C. Effects of Process Variables on Bead width (W)

Referring to the Fig. 3 shows the trade-off between the current and the speed, as can be observed that the bead width increases with the corresponding increase in welding current, as the higher current facilitates higher metal deposition rate. Conversely, with the increase in the speed it decreases the bead width as at the higher speed volume of metal deposited per unit length decreases, and the heat input per unit length also reduces which results into narrower bead. The bead width increases when voltage increases due to the increase in the arc length and the spreads the arc cone. Further, when the speed of welding is increased then initially it shows the decrease in the bead width and with further increase in the speed it tends to increase the width, due to the sudden drop and pick in the welding current.

D. Effects of Process Variables on % Dilution (D)

Referring to the Fig.4, which illustrates the percentage dilution decreases with the increase in the electrode angle and the speed of weld, as the increase in the melting rate of electrode and diffusing energy of the arc when it strikes on the base metal with increased speed.

The dilution initially decreases with the increase in voltage but increases after the further increase in the voltage, due to increase in the heat input and the decrement in the reinforcement.

It can be observed that the dilution of the base metal in the weld pool increases with the increase in the welding speed because of the fact that the weight of the deposited metal per unit length decreases with the increase in the welding speed whereas the cross section of the weld bead decreases by a nominal amount.

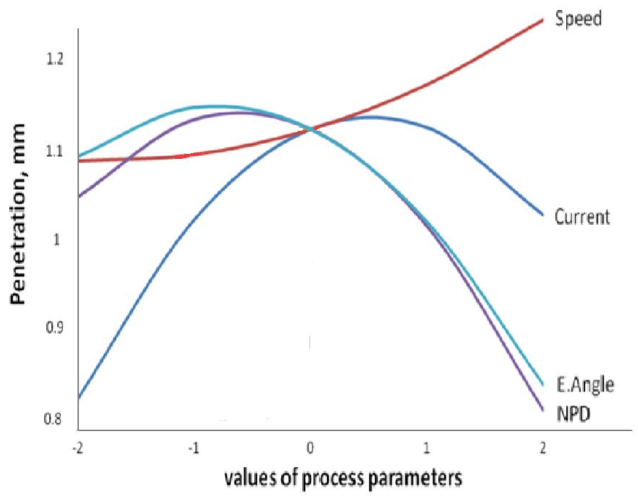

Fig.1 Effect of variables on penetration

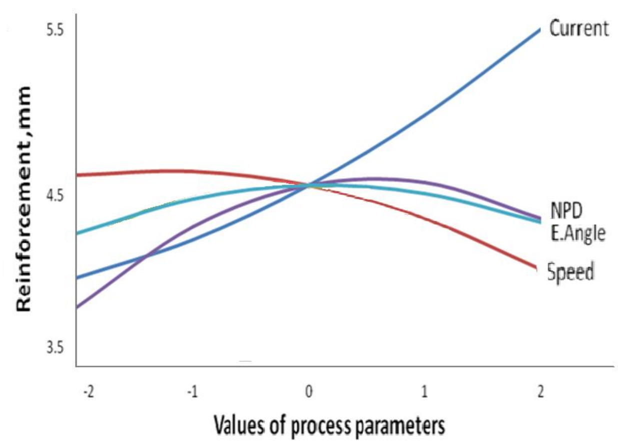

Fig.2 effect of variables on reinforcement

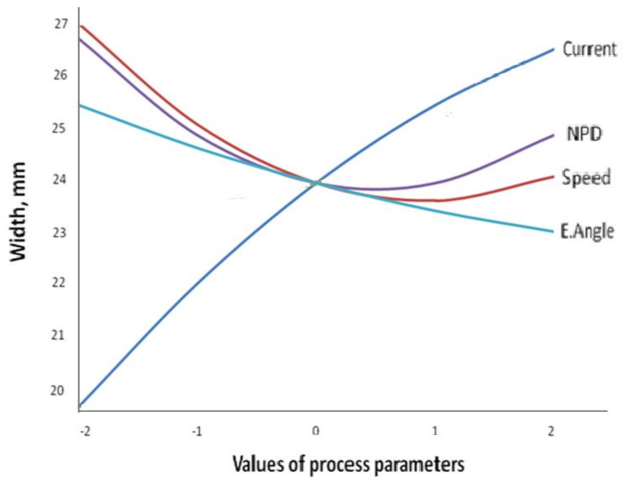

Fig.3 effect of variables on width

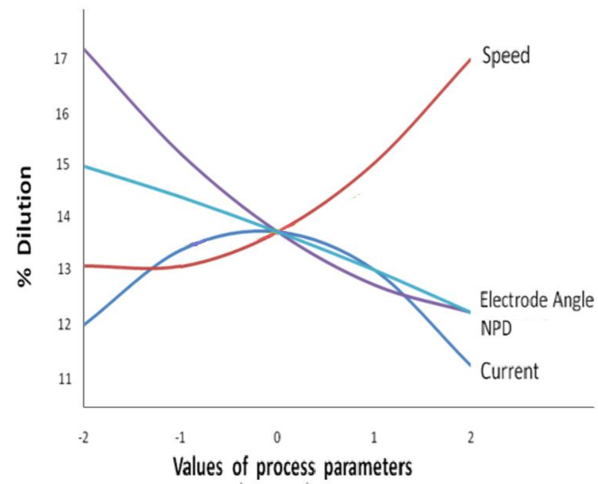

Fig.4 effect of variables on % dilution

V. CONCLUSION

After referring to this paper it can be concluded that, after performing the significance/weightage analysis the obtained equation no. 4, 5, 6 & 7 can be used to directly compute the ideal values of the penetration (P), reinforcement (R), weld bead width (W) and percentage dilution (D) parameters of the weld bead geometry. Whereas for the conformance to the performed experiments and for the attainment of the optimal values of process parameters the graph is to be plotted involving the values of P, R, W & D computed from the equation 4, 5, 6 & 7 with that of recorded from the experiments, and the identical slope of both the lines/curves is the indication to the optimal output.

VI. ACKNOWLEDGMENT

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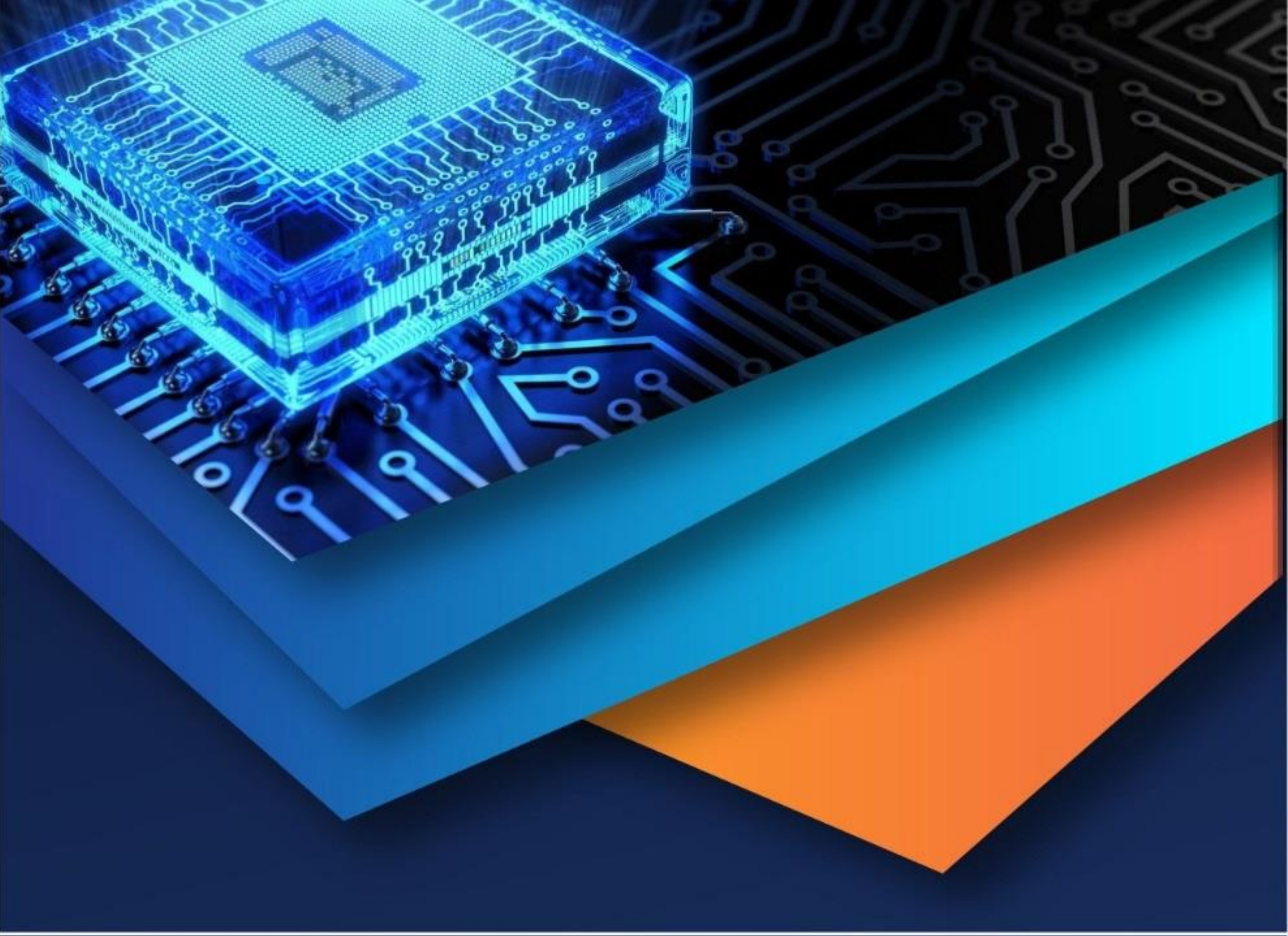
REFERENCES

[1] Alam N, Jarvis L, Harris D, Solta A (2002) Laser cladding for repair of engineering components. Aust Weld J 47:38–47
[2] Missori S, Murdolo F, Sili A (2004) Single-pass laser beam welding of clad steel plate. Weld J 83(2):65s–71s
[3] Kim I-S, Son J-S, Jeung Y-J (2001) Control and optimization of bead width for multi-pass welding in robotic arc welding processes. Aust Weld J 46:43–46
[4] Kang MJ, Kim YS, Ahn, Rhee S (2003) Spatter rate estimation in the short circuit transfer region of GMAW. Weld J 82 (9):238s–247s
[5] Juang SC, Tarng (2002) Process parameter selection for optimizing the weld pool geometry in the tungsten inert gas welding of stainless steel. J Mater Process Technology 122:33–37
[6] Kim IS, Son KJ, Yang YS, Yaragada PKDV (2003) Sensitivity analysis for process parameters in GMA welding process using factorial design method. Int. Jf Mach Tools Manufacturing 43:763–769
[7] Subramaniam S, White DR, Jones JE, Lyons DW (1999) Experimental approach to selection of pulsing parameters in pulsed GMAW, AWS. Weld J 78(5):166-s–172-s
[8] Allen TT, Richardson RW, Tagliabue DP, Maul GP (2002) Statistical process design for robotic GMA welding of sheet metal. Weld J 81(5):69s–76s
[9] Murugan N, Parmer RS (1997) Stainless steel cladding deposited by automatic gas metal arc welding. Weld J 76 (10):391-s-402-s 11. Montgomery DC [1] Edward G. Hoffman, jig and fixture design, Delmar Cengage Learning publication, 5th edition, 2004



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