An Experimental Study to Predict Optimum Weld Bead Geometry through Effect of Control Parameters for Gas Metal Arc Welding Process in Low Caron Mild Steel

Arka Sen[1], Dr. Sudip Mukherjee[2]

[1]*Assistant Professor, Department of Mechanical Engineering, Surendranath Institute of Engineering & Management, Siliguri ,WestBengal, India*

[2] *Professor, Department of Mechanical Engineering, Jalpaiguri Government Engineering College, Jalpaiguri, West Bengal, India,*

Abstract: *Here in this work, an attempt has been made to find the interaction between control parameters and weld bead geometry for fillet welding in mild steel specimen using Gas Metal Arc Welding process. Accordingly control parameters have been adjusted to find the optimal bead geometry. Initially the equations involving control parameters and bead geometry were developed by multiple regression analysis method. These equations are then simulated in computer to find the effects of the control parameters on weld bead geometry. Finally optimization of weld bead parameters is done by obtaining a single set of control parameters from its four different best sets through computer simulation.*

Keywords: *Bead width, GMAW process, Left leg length, Re-informent height, Right leg length.*

I. INTRODUCTION

Nowadays Gas Metal Arc welding process (GMAW) has been the most commonly used welding technique throughout the industrial world. GMAW uses a welding torch, a electric power source, shielding gas & a wire pool with wire drive control. The welding process is very simple. GMAW process can be used to weld thicker metal plates with high productivity. The shielding gas is used to protect the weld pool from oxidation. The shielding gas used is either inert gas or carbon dioxide.

GMAW process is done in butt joints as well as fillet joints. The quality of weld is determined by the weld bead geometry characteristics (also referred as physical parameters in this study); i.e the weld bead width, weld bead penetration, weld re-inforcement height, weld left leg length , weld right leg length. This weld bead geometry characteristics is a function of input variables (also referred as control parameters in this study) which are welding current, welding voltage, welding speed, wire tip distance, weld joint position, wire diameter, shielding gas composition, gas flow rate, material composition and material thickness. These control parameters affect the quality of the weld.

Previously, various studies and analysis on butt weld for prediction of bead geometry have been performed but there is very little work done on describing the effects of control parameters on fillet weld bead geometry. This study has developed mathematical models to determine the effects of each control parameters on weld bead geometry and optimization of the control parameters to get the best weld bead geometry characteristics.

II. EXPERIMENTAL WORKS

The experimental research work for predicting the relationship between process parameters of welding & the weld bead geometry is done systematically by a defined process. For the purpose of the experimental work the gas metal arc welding process (GMAW) was conducted on mild steel plates.

2.1 Determination of experimental parameters.

Before conducting the welding experiment, three most important control parameters are identified which mostly determines the weld bead profile? These parameters are welding current, welding voltage & the welding speed. The operating range of each of the parameters is taken in accordance with the normal operating range for such kind of operation. The assigned control parameters are listed in the Table. 1

Table 1: Control factors & their levels

PARAMETERS	SYMBOL	LEVEL		
		LOW	MIDDLE	HIGH
WELDING CURRENT (Amp)	I	160	220	280
WELDING VOLTAGE (Volt)	V	20	22.5	27
WELDING SPEED (mm/sec)	S	1.97	3.57	5.17

2.2 Experimental procedure

The experimental procedure to measure bead geometry using input weld data was performed. In this experimental work, the FAIR WELD MIG 400A welding machine was used. The experimental material 25mm (2.5cm) thick 1018 Mild (low carbon) steel plates cut into 150mm (15cm) length were fixed by the prepared jig. Table. 2 and Table. 3 show mechanical properties and chemical composition of base metal .Carbon-dioxide shielding gas was employed in the experiment.

Table 2: Mechanical properties of base metal

Ultimate Tensile Strength, Kpa	439885.514464
Yield Strength, Kpa	370248.465936
Elongation	15.00%
Rockwell Hardness	B71

Table 3: Chemical properties of base metal

Material	% Composition
Iron (Fe)	98.81 - 99.26%
Carbon (C)	0.18%
Manganese (Mn)	0.6 - 0.9%
Phosphorus (P)	0.04% max
Sulphur (S)	0.05% max

2.3 Conduct of the Experiment

From the Taguchi design of experiment, a conclusion is made that for three number of independent experimental parameters (i.e welding current, welding voltage & welding speed), with three different levels of each parameters (i.e. low level, mid level & high level), there has to be nine different observation sets. The physical parameters of the weld bead geometry to be measured are weld bead width, weld re-inforcement height, weld left leg length & weld right leg length.

The weld bead geometry is shown in Fig.1

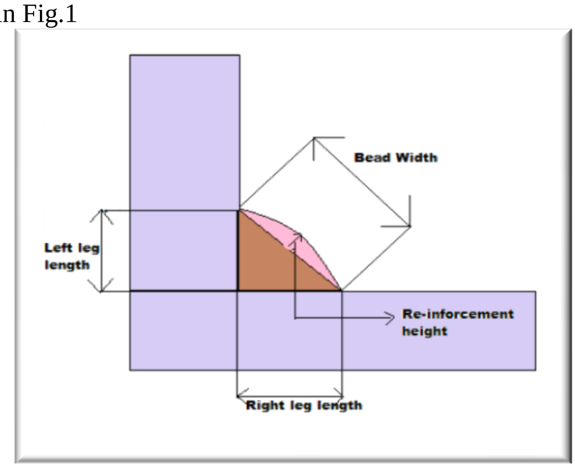

Fig.1: Weld bead geometry

Table. 4 shows the experimental results using the nine observation sets.

Table 4 : Measured experimental data

Experiment No	Welding Current (A)	Welding Voltage (V)	Welding Speed (sec/15cm)	Bead Width (mm)	Re-inforcement Height (mm)	Left Leg length (mm)	Right leg length (mm)
1	160	21	76	10.2	0.5	7.4	7.4
2	180	20	58	10.1	0.7	6.3	5.8
3	190	21	65	10.4	0.9	8.6	8.1
4	200	23	52	11.1	1.2	8.0	8.4
5	210	24	76	10.1	1.5	7.1	7.2
6	220	22	74	12.1	1.5	9.0	8.6
7	240	22	55	10.5	0.9	7.1	8.4
8	250	26	35	11.0	1.3	7.6	7.2
9	280	27	29	12.5	1.1	9.1	8.6

III. DEVELOPMENT OF MATHEMATICAL MODEL

From the experimental observations, multiple regression analysis was done to find the relationship between control parameters & physical parameters. The equations obtained are as follows:

Bead Width (BW) $= 0.0123 + 0.0095 *I + 0.35005 * V + 0.00981 * S + 0.00092764* I^2 + 0.000561 * V^2 - 3.8726 * S^2 - 0.4 *I * V + 0.01329 *I*S +0.035 *V*S$ --------------------(1)

Re-inforcement height (RH) $= -0.0035197 + 0.003848444 *I + 0.0017637334 *V +0.077151088 *S + 0.000048641* I^2 + 0.0000545898 *V^2 - 14.186 * S^2 + 0.0283 *I*V -0.000778671* I* S + 0.026906535 *V*S$ --------------------(2)

Left leg length (LLL) $= -0.044638867 + 0.281959034 * I + 2.840262884* V - 5.583572 * S + 0.00001485 * I^2 + 0.001725776 * V^2 + 527.541 * S^2 -14.07151286* I * V + 12.19315 *I*S+ 0.039817247 *V* S$ --------------------(3)

Right leg length (RLL) $= -0.0154 + 0.0900 * I + 0.8077 * V + 1.7139* S - 0.0002 * I^2 - 0.0004 * V^2 - 322.5063 * S^2 - 3.3705 * I * V + 0.0034 * I* S -0.0088 * V* S$ --------------------(4)

IV. EFFECT OF CONTROL PARAMETERS ON WELD BEAD GEOMETRY

It is observed that the control parameters have a definite effect on weld bead geometry and by the analysis of the graphs the best values of physical parameters are obtained. Keeping the two control parameters at their arithmetic means, the third control parameter is varied within its range to get the effect on physical parameters. The graph from Fig.2 to Fig. 13 illustrates the matter.

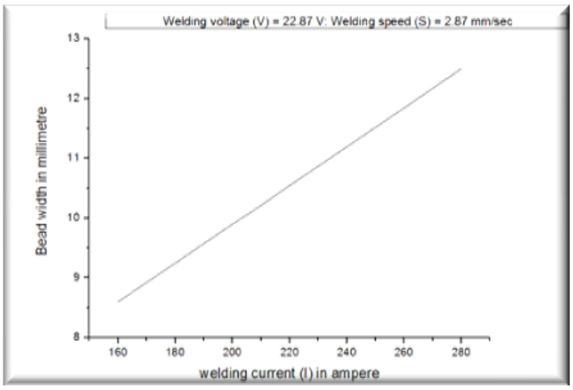

Fig.2: Variation of welding current with bead width

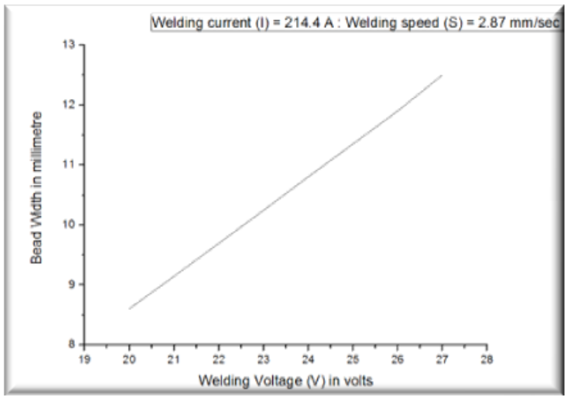

Fig.3: Variation of welding voltage with bead width

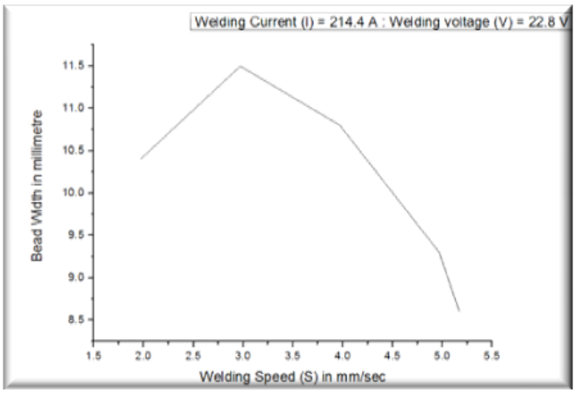

Fig.4: Variation of welding speed with bead width

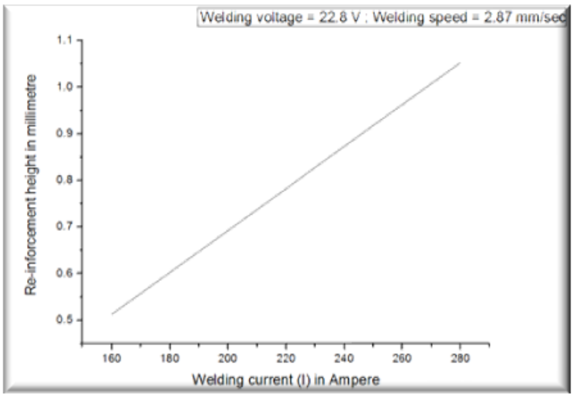

Fig.5: Variation of welding current with re-inforcement height

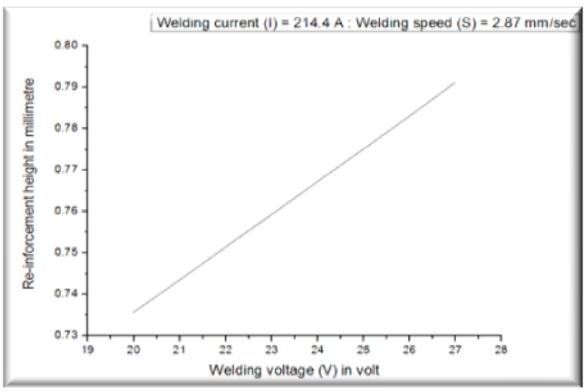

Fig.6: Variation of welding voltage with re-inforcement height

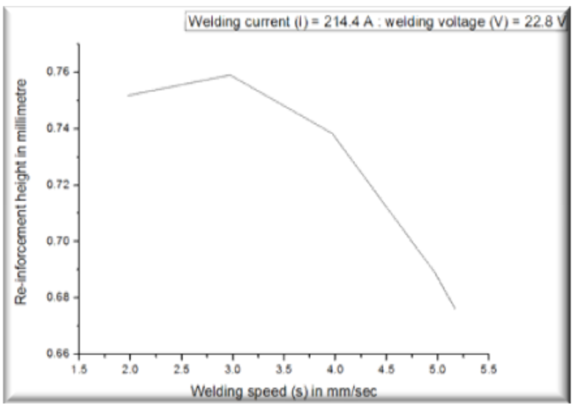

Fig.7: Variation of welding speed with re-inforcement height

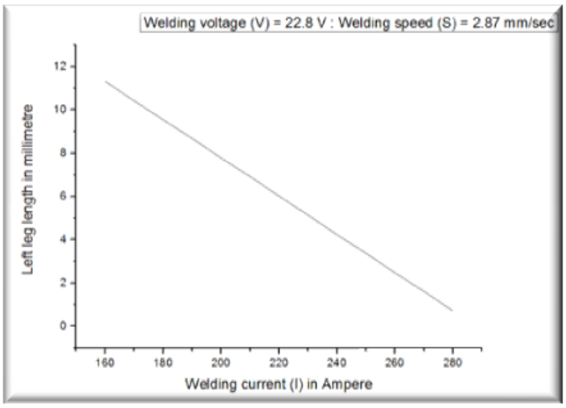

Fig.8: Variation of welding current with left leg length

Fig.9: Variation of welding voltage with left leg length

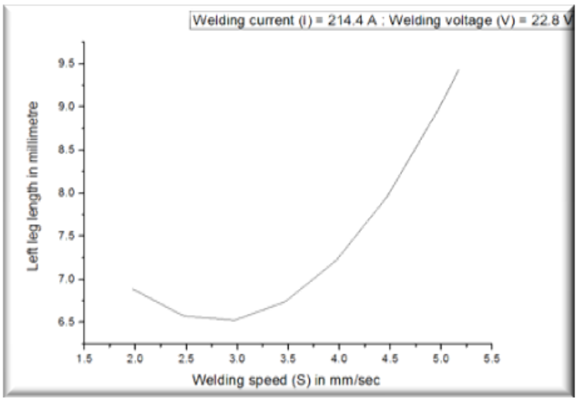

Fig.10: Variation of welding speed with left leg length

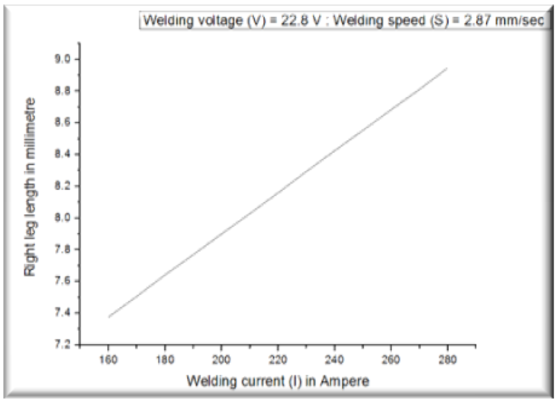

Fig.11: Variation of welding current with right leg length

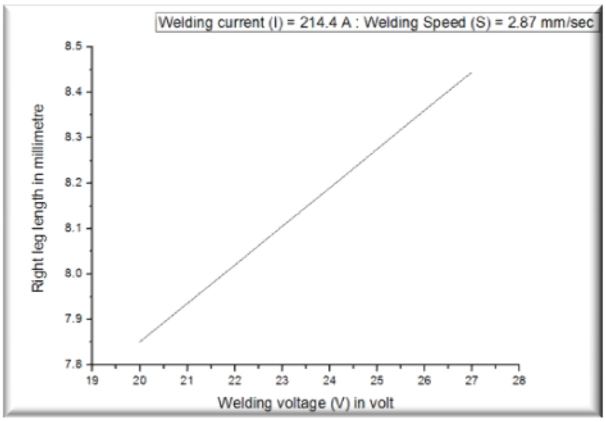

Fig.12: Variation of welding voltage with right leg length

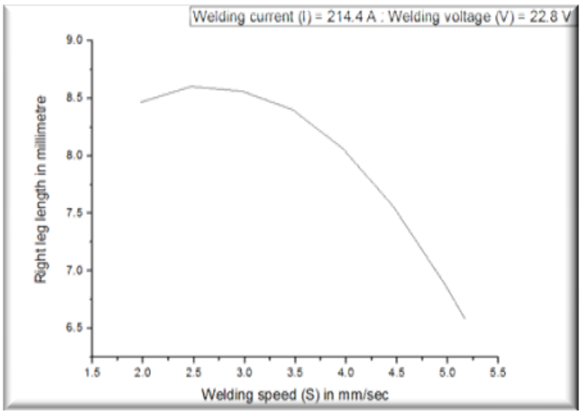

Fig.13: Variation of welding speed with right leg length

V. RESULTS & DISCUSSIONS

Based on the experimental results on gas metal arc fillet welding, regression analysis was done for predicting the weld bead geometry. From the graphs above, four different best sets of results for bead geometry profile is observed which are as follows:

a. The set of control parameters for maximum bead width are welding current (I) = 280 A, welding voltage (V) = 27 V, and welding speed (S) = 2.97 mm/sec and the corresponding bead width is 11.58 mm.
b. The set of control parameters for minimum re-inforcement height are welding current (I) = 160 A, welding voltage (V) = 20 V, and welding speed (S) = 5.17 mm/sec and the corresponding re-inforcement height is 0.408mm.
c. The set of values of control parameters for maximum left leg length are welding current (I) = 160 A, welding voltage (V) = 20 V, and welding speed (S) = 5.17 mm/sec and the corresponding left leg length is 8.05mm.
d. The set of control parameters for maximum right leg length are welding current (I) = 280 A, welding voltage (V) = 27 V, and welding speed (S) = 2.99 mm/sec and the corresponding right leg length is 8.35mm.

VI. OPTIMIZATION

In a welding process, best bead parameters are normally obtained by using different sets of control parameters as is shown in the results earlier. So practically it may not be possible to get the best bead parameters. Therefore it is necessary to develop a single set of control parameters which will provide optimum weld bead geometry.

From the four sets of control parameters providing the best bead parameters, it is seen that most of the control parameters are repeated twice. Therefore average from the four sets of control parameters are taken in a bid to find the optimum bead parameters which are:

Welding current (I) = 220 A
Welding voltage (V) = 23.5 V
Welding speed (S) = 4.075 mm/sec

These values are then varied by ±10% keeping the other two control parameters constant in order to find the optimum bead geometry which is found as follows:

Bead width = 10.08 mm
Re-inforcement height = 0.66 mm
Left leg length = 8.75 mm
Right leg length = 7.34 mm

And the corresponding control parameters are:

Welding current (I) = 198 A
Welding voltage (V) = 23.5 V
Welding speed (S) = 4.075 mm/sec

6.1 Comparison with best values:

The following Table.5 compares the best values of control parameters with their optimum values & their corresponding physical parameters. It is found that the optimum set of control parameters which gives the best values of physical parameters is very close to its corresponding best set of results.

Table 5: Comparison table of best values with optimum values

BEST VALUES			OPTIMUM VALUE		
		BEAD WIDTH			BEAD WIDTH
WELDING CURRENT	280 A				
WELDING VOLTAGE	27 V	11.58 mm			10.08 mm
WELDING SPEED	2.97 mm/sec				
		RE-INFORCEMENT HEIGHT			RE-INFORCEMENT
WELDING CURRENT	160 A				
WELDING VOLTAGE	20 V	0.408 mm	WELDING CURRENT (I)	198 A	0.66 mm
WELDING SPEED	5.17 mm/sec		WELDING VOLTAGE (V)	23.5 V	
			WELDING SPEED (S)	4.075 mm/sec	
		LEFT LEG LENGTH			LEFT LEG LENGTH
WELDING CURRENT	160 A				
WELDING VOLTAGE	20 V	8.05 mm			8.75 mm
WELDING SPEED	5.17 mm/sec				
		RIGHT LEG LENGTH			RIGHT LEG LENGTH
WELDING CURRENT	280 A				
WELDING VOLTAGE	27 V	8.35 mm			7.34 mm
WELDING SPEED	2.99 mm/sec				

VII. CONCLUSION

Hence from the experimental study, it can be concluded that a single set of control parameters can provide bead parameters which are considerably close to the best bead parameters obtained by four sets of control parameters. Therefore, it is much more practical to use a single set of control parameters which will provide optimum bead geometry.

REFERENCES

Journal papers:

[1] A New Approach for Predicting and Optimizing Weld Bead Geometry in GMAW by Farhad Kolahan, Mehdi Heidari, World Academy of Science, Engineering and Technology 2:2 2010

[2] Optimization of GMAW process parameters using Particle Swarm Optimization by Sreeraj, T Kannan, Subhashis Maji / Mechanica confab.

[3] Achieve to desired weld bead geometry for the vessel fillet joints in mobile robotic welding by M. Golestani Sehat, Kh. Farhangdoost Mechanical Engineering Department Ferdowsi University, mashhad, Iran; Published inTehran International Congress on Manufacturing Engineering (TICME2005) December 12-15, 2005, Tehran,Iran.

[4] Effect of Welding Parameters on Dilution and Weld Bead Geometry in Cladding by M.Nouri, A.Abdollah-zadehy and F.Malek Department of Materials Engineering, Tarbiat Modares University; J. Mater. Sci. Technol., Vol.23 No.6, 2007.

[5] Optimization of weld bead geometry in TIG welding process using grey relation analysis and taguchi method by Ugur Esme, Melih Bayramoglu, Yugut Kazancoglu, Sueda Ozgun: UDK 621.791.05 Original Scientific Article : ISSN 1580-2949, MTAEC9, 43(3)143(2009)