Vol. 2, Issue 2 (Apr. - Jun. 2016)

ISSN : 2454-4736 (Online)
ISSN : 2454-8723 (Print)

Effect of Process Parameters on Bead Geometry and Shape Relationship of Gas Metal Arc Weldments

Pankajkumar. J. Mistry

Dept. of Mechanical Engineering, Rungta Engineering College, Raipur, India

Abstract

The present trend in the industries is to use automated welding processes for obtaining high production rate and desired precision at reduced price. To automate a welding process it is essential to establish the relationship between weld bead geometry and process parameters to control and predict weld bead quality. The objective of this paper is to analyze the effect of welding arc current, voltage, welding speed, and the contact tube to work distance on weld bead geometry such as weld penetration, weld bead width, and height of reinforcement. It is essential to assess the effect of process parameters on specific bead geometry and shape relationships. The result of this study helps in improved understanding of applying control methods in forecasting the quality of Weldments during electric arc welding.

Keywords

Bead Geometry; Shape Relationship; Welding Current; Arc Voltage; Contact Tube to Work Distance; Welding Speed.

I. Introduction

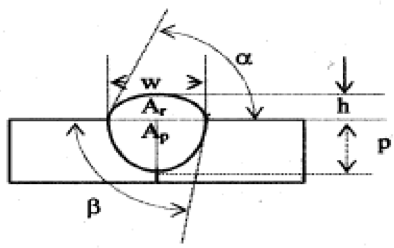
Welding is the universally accepted method of permanently joining metals and non-metals, thus playing an important role in the industrialization process globally. Welding is a complex interactive process involving many parameters, any of which may have an important effect on the quality of the Weldments.

The complexity of welding can be readily judged when one considers the intense heat source used specially in the fusion welding processes where, steep temperature gradients of thousands of degrees, over a distance of less than a centimeter, occurring on a time scale of seconds, involving multiple phases of solid, liquid, gaseous and plasma and high cooling rates are generated in the weld zone, which affect the mechanical properties of the Weldments.

II. Weld Bead Geometry And Shape Relationships

The present trend in the fabrication industries is the use of automated welding processes to obtain high production rates and high precision. In programmed applications, a stringent means of selection of the process variables and strict control over weld bead shape is essential because the mechanical strength of a weld is influenced by the composition of the metal as well as by the weld bead shape [1]. It is vital to establish a relationship between process parameters and weld bead geometry to assess and control weld bead quality [2].

The bead geometry and shape relationship (BG & SR) responses *viz.*; penetration (p), reinforcement height (h), weld bead width(w), weld penetration shape factor (WPSF) defined as the ratio of width to penetration (w/p), weld reinforcement form factor (WRFF) defined as the ratio of width to crown height (w/h) and % dilution (D) defined as the ratio of area of parent plate melted to the total bead area at a given cross section. The terminology used to describe the BG & SR is shown in Figure-1.



w = Weld bead width

p = Weld bead penetration

h = Weld reinforcement height

α = Angle of convexity

WPSF (w/p) = Weld penetration shape factor

WRFF (w/h) = Weld reinforcement form factor

Ap = Area of penetration

Ar = Area of reinforcement

A_t =Total weld bead area = $A_p + A_r$

% D = Ap /At * 100

Fig.1: Bead Geometry & Shape Relationships. [3]

The significance of the bead geometry and shape relationships is briefly discussed below.

A. Weld Penetration

Penetration is the maximum distance from the surface of the base plate to the depth of fusion. Penetration is influenced by welding current, welding speed, weld polarity, and electrode stick out . Penetration is directly proportional to the welding current and inversely proportional to the welding speed and diameter of electrode. Increase in thermal conductivity of the weld metal decreases penetration. Deepest penetration is achieved with D.C. Electrode Positive (DCEP) polarity than D.C. Electrode Positive Negative (DCEN) polarity. A stable arc increases penetration because the arc wander is minimized allowing more efficient heat transfer [4-7]

B. Bead Width

The bead width of a weld is the maximum width of the deposited weld metal. It is directly proportional to the arc current, welding voltage, the diameter of electrode and is inversely proportional to the welding speed [8, 9, 10]. The variations in Contact tube-to-Work Distance (CTWD) also affect the bead width and the height of reinforcement [11]. A proper bead width eliminates the lack of side wall fusion defect [12]. It is observed that bead width enhances with increase in arc voltage and melting rate increases with reduction in electrode diameter [13].

C. Reinforcement Height

It is the bead height above the surface of the plate. The reinforcement influences the strength of the weld and wire feed rate. Increasing the wire feed rate increases the weld reinforcement irrespective of welding current and polarity. Reinforcement is inversely proportional to welding voltage, welding speed and diameter of the electrode. A larger reinforcement is obtained with DCEN polarity than with DCEP polarity[4,8,14,15]

D. Weld Penetration Shape Factor (WPSF)

It the ratio of weld width to the penetration.The greater is WPSF, the higher is the proportion of deposited metal in the weld bead. The shape coefficients (WPSF and WRFF) are observed to be different for each welding process [11]. It is reported that WPSF enhances with increase in welding current and also with increase in arc voltage [16]. A high value of WRFF indicates minimum deposition of excess weld metal (reinforcement). The condition is reversed for repair welding as the objective is to fuse as much filler metal as possible with minimum penetration.

E. Weld Reinforcement Form Factor (WRFF)

WRFF is the ratio of weld width to reinforcement height. It is an important property as the angle between base metal and reinforcement, which affects the fatigue strength, relies upon this factor [17]. It is reported that WRFF is inversely proportional to CTWD. Higher WRFF indicates minimum deposition of excess metal and low value of WRFF has high significance in repair welding. [18]

F. Dilution

Dilution is the ratio of area of the base metal melted to the total area of the weld bead measured across its cross section. It is defined as the ratio of weight of parent metal melted to the total weight of fused metal [19, 20] expressed in %. Weldment properties such as strength, ductility, corrosion resistance, resistance to weld cracking, and heat treatability are greatly influenced by the extent of dilution.

III. Effects of Various Weld Variables

The mechanical properties of welded joint can be improved by controlling the process parameters. The main direct welding parameters which affect them are welding wire feed rate (W), arc voltage (V), contact tube to work distance (N) and welding speed (S). Many attempts have been made to show a relationship of bead geometry with the welding parameters [4, 21, and 22].

1. Welding Current

It is the most significant parameter affecting the weld bead shape. An increase in welding current enhances the weld penetration and reinforcement height. A small welding current leads to unstable arc, overlapping and low penetration. Polarity affects the amount of heat produced at the workpiece and electrode thereby affecting the weld bead geometry, metal deposition rate, and mechanical properties of the weld metal. The DCEN polarity produces higher deposition rate and reinforcement than the DCEP polarity. The level of hydrogen absorption in underwater wet welding which results in porosity can be minimized by using low current DCEP or a high current DCEN [23]. Figure-2 shows the effect of current on weld bead.

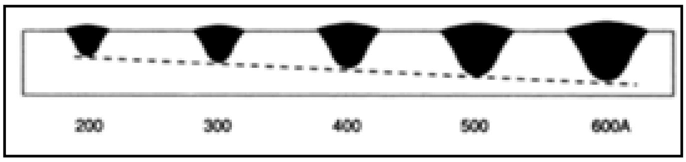


Fig. 2: Effect of Current on Weld Bead [25]

2. Welding Voltage

The voltage is a deciding factor for the shape of the weld bead cross- section. Augmenting the voltage at constant current results in a wider, flatter, and reduced penetration, leading to reduced porosity caused by rust on steels. Raising in arc voltage beyond the optimum value leads to an enhanced loss of alloying elements affecting the metallurgical and mechanical properties of the weld metal. Arc voltage beyond the optimum value produces a wide bead shape and decreased penetration that is prone to cracking and increased undercut [24]. Figure-2 shows the effect of current on weld bead.

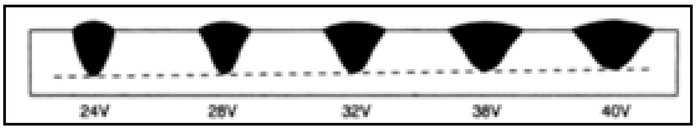


Fig. 3: Effect of Arc Voltage on Weld Bead [25]

3. Welding Speed

It is the rate at which the arc moves along the joint to be welded and influences the heat input per unit length of the weld. The welding speed is the most influencing factor on weld penetration compared to other parameters except welding current. Enhancing the welding speed diminishes the heat input and less filler metal is deposited per unit length of the weld leading to less weld reinforcement and a lesser weld width. Increased welding speed results in undercutting, arc blow, cracking, porosity and uneven bead shape.

Excessive welding speed also results in lower heat affected zone and finer grains. Slow welding speed facilitates escape of gases from the molten metal, thereby reducing porosity. The bead width is inversely proportional to the welding speed at any current. [24].

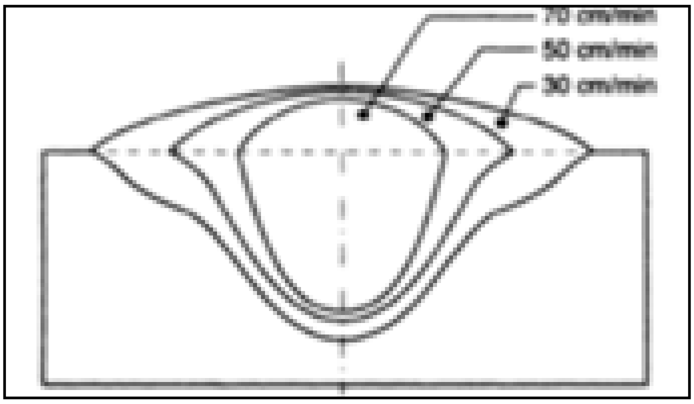


Fig. 4: Effect of Welding Speed on Weld Bead [25]

ISSN : 2454-4736 (Online)
ISSN : 2454-8723 (Print)

4. Contact tube-to-Work Distance (CTWD)

The CTWD influences the development of the weld pool by changing the arc length and welding current. The arc length is decided by the welding voltage and CTWD.

An increase in arc length due to an increase in CTWD increases the bead width because of the widened arc area at the surface of the weld. Increase in arc length reduces the reinforcement height because the same volume of filler metal is used [26].

Figure-5 shows the schematic of contact tube-to-work distance

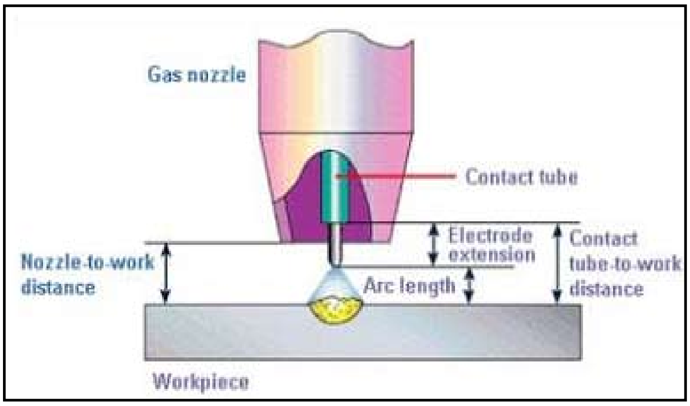


Fig. 5: Contact tube-to-work distance

IV. Conclusions

The weld bead shape of a welded joint determines the mechanical properties of the joint. Weld joint is considered to be sound and economical if it has a maximum penetration, bare minimum bead width, reinforcement and dilution.

Welding current has larger influence on penetration than on bead width and reinforcement Arc stability increases penetration because of the efficient heat transfer and reduction of arc wander.

Enhancement in voltage will increase bead width, penetration, and reinforcement. Voltage has a positive effect while welding speed has a negative effect on weld bead width.

The relationship between current, voltage, speed and contact tube-to-work distance with penetration, bead width, reinforcement height, WRFF, WPSF and dilution is explained. It is evident that a correct fine-tuning of welding process parameters yields a sound weld.

References

[1] Brien RL. Welding Handbook. vol.2, 8th edition, Miami, U.S.A: American Welding society; 1978

[2] Parmer R S. Welding Processes and Technology. New Delhi: Khanna Publishers; 1992..

[3] Pandey, S., Misra, S., Mathematical Modeling and Optimisation of GMAW Procedure for Aluminium Alloy 5083, Sixth International Conference on Aluminium Weldments (INALCO-95), The American Welding Society, Cleveland, Ohio, USA, 1995.

[4] McGlone J.C., Weld Bead Geometry Prediction- A Review, Metal construction, July 1982, pp 378-384

[5] Cary, Howard B., Modern Welding Technology, Prentice-Hall, U.S.A., 1989

[6] Houldcroft, P.T., Welding Process, Cambridge University Press, Cambridge, UK, 1977.

[7] Horsfield, A.M., Weld surfacing and hardfacing, The welding Institute, Abington Hall, 1980.

[8] Gurev H. S., Stout R.D., Solidification phenomena in inert-gas metal arc welds, Weld. J., 42 (7), 1963, pp 298s–310s.

[9] Houldcroft, P.T., and John, R., Welding and Cutting, Industrial Press Inc., New York, 1951

[10] Jefferson, T.B., The Welding Encyclopedia, 13th Edition, McGraw-Hill, New York, 1951.

[11] Cornu, J., Advanced Welding System – part 2, IFS Ltd., London, 1988.

[12] Jackson, C. E., and Shrubsall, A. E., Control of penetration and melting rate with welding technique, Welding Journal, 32: 1953, 172s -178s.

[13] Chandel, R.S., Seow, H.P., Cheong, F.L., Effect of increasing deposition rate on the bead geometry of submerged arc welds, Journal of Materials Processing Technology, 72, 1997, pp 124–128.

[14] Kearns, W.H., Welding Processes, Welding Hand Book, American Welding Society, Macmillan, Miami, 1978, pp 154-187.

[15] Renwick, B.G., and Patcheet, B.M., Operating characteristics of the submerged arc process, Welding Journal, No. 3, 1976, pp 69s - 76s.

[16] Madatov, N.M., Shape relationships for underwater welding Welding Production, 16(3), 1969, pp 18-23

[17] Mukesh Kumar, Some studies of MIG welding of Al-Zn-Mg, Ph.D Thesis, IIT, Delhi, 1989.

[18] Khaliq, A., Some studies on Pulse GMAW of Aluminium alloy, Ph.D. thesis, IIT –Delhi, 1997

[19] Klimpel, A., Dobrzanski, L. A., Janicki, D., Lisiecki, A., Abrasion resistance of GMAW metal cored wired deposits, Journal of Material Processing Technology, 2005, pp 1056-1061

[20] Lancaster, J.F., Metallurgy of Welding, Allen & Unwin, London, 1998

[21] Murray P. E. Selecting Parameters for GMAW using Dimensional Analysis Welding Journal, July 2002, pp 125 s-131 s

[22] Shultz,B.L., Jackson, C.E., Influence of weld bead area on weld metal mechanical properties, Welding journal, Jan 1963, pp 27s-37s

[23] Srivastava B. K. , Tewari S. P. & Prakash, J. "A review on effect of arc welding parameters on mechanical behaviour of ferrous metals/alloys," International Journal of Engineering Science and Technology, vol. 2, no. 5, 2010,. pp. 1425-1432

[24] Yang L. J. , Chandel R. S. & Bibby M. J. , "The Effects of Process Variables on the Weld Deposit Area of Submerged Arc Welds," WELDING RESEARCH SUPPLEMENT, 1993, pp. 11-18.

[25] Klas Weman , Welding Process Handbook, Woodhead Publishing Ltd., Cambridge, England, 2003

[26] Kim. J., & Na. S., "A Study on the Effect of Contact Tube-to-Workpiece Distance on Weld Pool Shape in Gas Metal Arc Welding," Welding Research, pp. 141-152, 1995.

Author's Profile

Dr. Pankajkumar. J. Mistry is working as Principal in Rungta Engineering College, Raipur, Chhattisgarh State, India. He has more than 25 years of Experience and has worked as Principal/Director of Engineering Colleges for than 8 years. He has authored three text books and published more than 35 papers in International/ National Journals and Conferences.