Effect of using a Rotating Electrode in Gas Metal Arc Welding on Weld Bead Characteristics of Aluminium Alloy 6061-T6 Weldments

D. LINGA RAJU, G. NARASA RAJU

Abstract— **The arc rotation can be used to obtain the flat and broad weld bead due to the centrifugal force of the rotating arc during Gas Metal Arc Welding (GMAW). In this experimental investigation, traditional gas metal arc welding process is modified to change the fluid flow in the molten pool by the rotary motion of filler metal accompanied by downward feeding process. The electrode wire is continuously fed and made to rotate and translate along Aluminium 6061-T6 Alloy butt joint. To study the specific effect of Electrode rotation on weld bead geometry, a joint spacing of 0.50 mm is maintained. Joints are prepared using Standard GMAW and Pulsed GMAW by varying the voltage settings. Mechanical testing is carried out to determine the Tensile Strength and hardness of the resulting weldments. Micro structural study is carried out on all the test specimens. The results of Micro structural study are correlated with mechanical properties for both standard and pulsed GMAW joints. Grain refinement of Al-Si eutectic is observed in the inter-dendritic Primary Aluminium matrix, as a result the mechanical properties are found to be improved.**

Index Terms—**Arc Welding; Aluminium Alloy 6061; Rotation Arc Welding, Weldments, Micro Structural Study.**

1.INTRODUCTION

GMAW is a common type of welding method in the weld industry. During the welding process, the molten droplets at the tip of the welding wire are transferred into the weld pool with the interaction of acting forces, such as gravity, surface tension, electromagnetic force, viscous drag force and arc pressure. The quality of the weld joint depends on the weld bead shape and bead geometry such as bead width, height and penetration. In recent times, the motion of the wire in GMAW welding processing was improved not only to feed downward but also to rotate along its central axis. In arc rotation mechanism system, the arc is rotated continuously with certain speed during welding which results in flat and broad weld bead because of the centrifugal force of the rotating arc and penetration profile also can be improved.

The authors are with Department of Mechanical Engineering, University College of Engineering, JNTUK, Kakinada, Andhra Pradesh, India. +91-9247793403, dlraju@gmail.com.

Some researchers have attempted arc rotation, arc oscillation and wire bending method for improving the weld bead characteristics. Refining weld metal microstructure is found to be a useful way to improve joint mechanical properties, such as ductility, toughness and fatigue [1]. Different techniques used by various researchers for grain refinement of the weld metal have been discussed in the literature for different material welds. It was found that Electromagnets can be employed to oscillate the arc and by varying the electromagnetic fields with respect to the arc in a narrow groove gas metal arc welding, an improved weld penetration can be achieved [2].

Hongtao Zhang et al have introduced a Novel Rotating wire GMAW Process to change fusion zone shape and subsequent microstructure of mild steel joints. In this paper, traditional gas metal arc welding process was modified to change the fluid flow in the molten pool by the rotary motion of filler metal (wire) accompanied by downward feeding process. The rotating fluid flow of the weld pool decreased the penetration of the weld and refined the weld microstructure and subsequent increase in tensile strength was noticed [3].

Iwata Shinji et al, have investigated the effect of high speed rotating arc and submerged arc welding with a square-shaped narrow gap groove on the quality of steel corner joints and found that the rotation of the arc is effective in achieving better weld quality [4].

Sanjay Kumar et al, have investigated the Effects of eccentricity and Arc rotational speed on Weld Bead Geometry in Pulsed GMAW of 5083 Aluminum Alloy [5]. In this work an eccentric module was fixed to the GMAW torch and rotation of the electrode was achieved. The effect of input process parameters like wire feed rate, arc rotational speed, eccentricity and ratio of wire feed rate to travel speed and their variation on weld bead geometry was studied.

Ning Guo et al have studied the Effects of Welding parameters on Metal Transfer Process in Rotating Arc Narrow Gap Horizontal GMAW [6]. Using a high frame rate digital camera, the metal transfer process in Gas Metal Arc welding was studied with a rotating arc and a horizontal narrow gap. The effect of welding parameters

ISBN: 978-988-14048-0-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

like arc voltage and wire feed rate on the metal transfer process was studied.

2.EXPERIMENTAL PROCEDURE

A 5-axis CNC controlled GMAW machine unit with cold metal transfer capability is used to provide rotation to the electrode (*Courtesy: Centre for Laser Processing of Materials, ARCI, Hyderabad).* This unit consists of a digitally controlled wire feeder (Fronius VR-7000 CMT), Power Source (Transpuls Synergic 3200 CMT), 4-axis CNC Milling system (Hust CNC H4CL-M System), Remote Control Unit (RCU 5000i), a two-piece rectangular Chucks to fix the work-pieces along the travel bed and a 26 blade feeler gauge to measure the gap between the plates.

The material used in the experiment is Aluminum Alloy 6061- T6, due to its superior weldability, compatibility with electrode wires and least amount of post weld requirements along with typical applications in aerospace industry. The Welding parameters used for fabricating the open square butt joint with 0.5 mm gap in the first stage of experimentation are: Current – 131A, Voltage – 15.8 V, wire feed speed – 6 m/min and

Travel Speed – 0.8 m/min. The second set of experimentation for closed square butt joint is carried out using pulsed GMAW process. The CNC code for rotation is executed. The welding parameters for this set of experimentation are: Current – 111A, Voltage – 19.5 V, Wire feed speed – 5.0 m/min and travel Speed – 0.8 m/min. It was observed from the literature that the rotation would decrease penetration due to centrifugal force caused by high rpm rotations or due to the wider area of deposition. Hence the third set of experimentation is carried out using pulsed GMAW mode with the same welding parameters and a gap of 0.5 mm. To investigate the effect of Voltage settings on weld bead characteristics and microstructure of the weld metal, the next set of experimentation with standard GMAW is carried out by changing the input current and voltage as 89 A and 12.8 V respectively. Similarly the last stage of experimentation with 0.5 mm gap is carried out using pulsed GMAW with 96 A and 12.6 V. The photographs of the welded joints fabricated using standard GMAW and Pulsed GMAW are shown in Fig. 1 and Fig. 2 respectively.

The test samples for carrying out Tensile and hardness tests are prepared as per ASTM Standards using Wire cut Electric Discharge Machining process to ensure a uniform cut. This process also had the advantage of reducing subsequent polishing work required for microstructure study and also the forces exerted on the piece would not distort the microstructure. Initially, the pieces were allowed to cool for a period of 2 days at room temperature wrapped in Kraft paper. This is done in order to retain the tempered properties of the work pieces before welding. The Photographs of tensile samples is shown on Fig. 3. Tensile and hardness tests are conducted for all test specimens. To correlate the mechanical properties with microstructure, metallographic examination is carried out for all test samples using Optical Microscope. The microstructure consists of coarse particles of FeSiAl and Mg2Si in the Base Metal of the matrix of Aluminum. In the Heat Affected Zone the microstructure consists of fine particles of AlSiMg eutectic in the matrix of Aluminum. In the Weld Zone the Microstructure consists of Inter Dendritic Network of AlSi Eutectic in the matrix of Aluminum. Fig. 4 and Fig. 5 shows the micrographs of base metal and heat effected zone in standard GMAW process.

Fig. 1. Specimen fabricated using standard GMAW

Fig. 2. Specimen fabricated using Pulsed GMAW

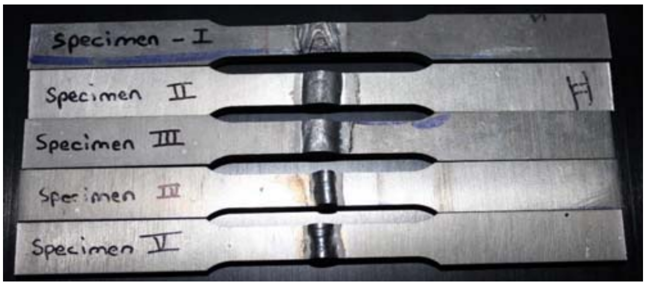

Fig. 3(a). Tensile test samples

Fig. 3(b). Tensile test samples after Grinding to uniform thickness

ISBN: 978-988-14048-0-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

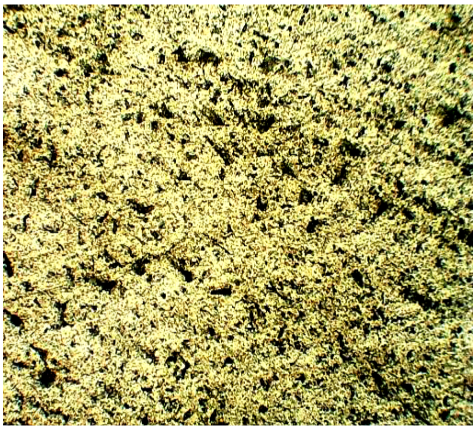

Fig. 4. Micrograph of base metal of a sample fabricated using standard GMAW

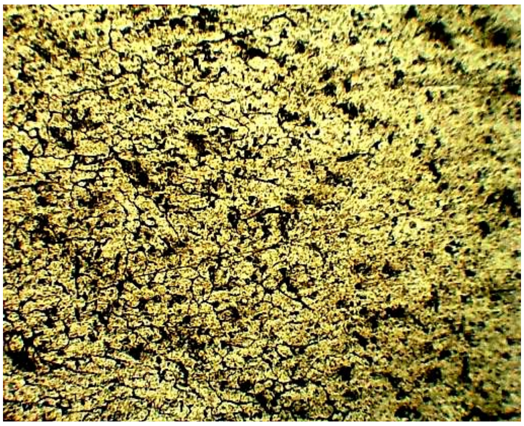

Fig. 5. Micrograph of Heat Effected Zone of a sample fabricated using standard GMAW

3.RESULTS AND DISCUSSION

3.1 EFFECT OF ARC ROTATION

The rotation caused a high specific heat input and melted the weld pool and holes formed on the joint. The reason is found to be the bell shaped arc which is assumed to be a point. When this circular arc is rotated the material at the center of rotation is exposed to more heat than the material at the periphery of the rotation and caused the melt and irregular penetration weld. However, there is a visual improvement in penetration observed with arc rotation and a gap of 0.5 mm between the plates even though the deformation due to heat was more. Micrographs of samples at weld zone produced by standard GMAW and Pulsed GMAW with rotation is shown in Fig. 4 and Fig. 5 respectively. The Microstructure in both the cases consists of Inter Dendritic Network of Al-Si eutectic in the matrix of Primary Aluminum. Due to marginal refinement of Al-Si eutectic in primary Aluminium in case of Pulsed GMAW with rotation, the tensile strength and hardness are found to be improved (187.22 MPa. and 69.87 HV respectively) compared with that of standard GMAW weldments (185.99 MPa. and 67.50 HV respectively).

Fig. 6. Micrograph of sample at weld zone fabricated using standard GMAW

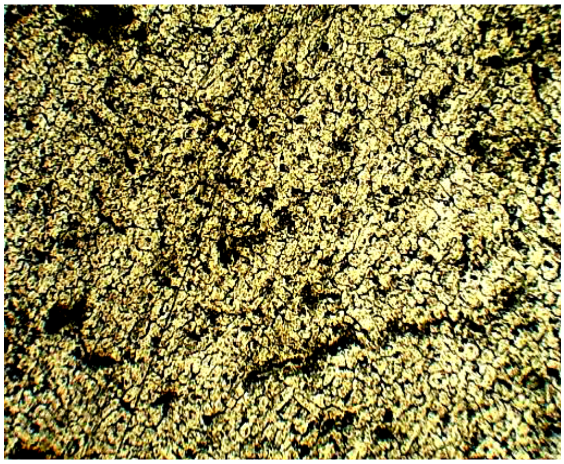

Fig. 7. Micrograph of sample at weld zone using Pulsed GMAW with arc rotation

3.2 EFFECT OF VOLTAGE SETTINGS

The experimental results obtained for different specimens fabricated using pulsed GMAW with rotation by varying voltage indicates that the increase in voltage and current leads to better weld penetration and subsequent improvement in tensile strength and hardness. The tensile strength and hardness obtained with 96 A and 12.6 V settings are 174.42 MPa. and 66.5 HV respectively. When the Voltage and current settings are increased to 111 A and 19.5 V, the tensile strength and hardness are found to be improved (187.22 MPa. and 69.87 HV respectively). This is also evident from the Microstructural investigation done for the samples with the above voltage and current settings. Fig. 6 shows the micrograph of sample fabricated with 111 A and 19.5 V and Fig. 7 shows the micrograph of sample fabricated with 96 A and 12.6 V respectively.

ISBN: 978-988-14048-0-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Fig. 8. Micrograph of sample at weld zone fabricated using Pulsed GMAW with arc rotation at 111 A and 19.5 V

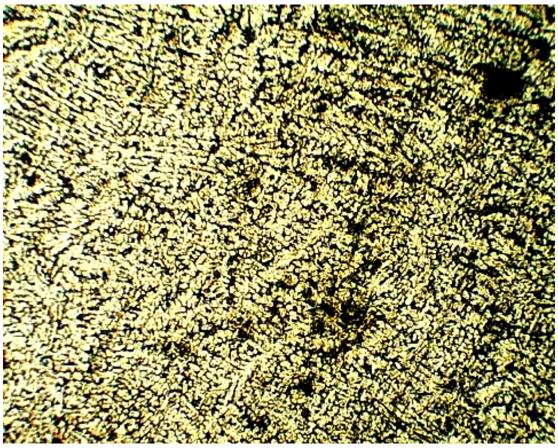

Fig. 9. Micrograph of sample at weld zone fabricated using Pulsed GMAW with arc rotation at 96 A and 12.6 V

3.3 EFFECT OF GAP BETWEEN WELD PLATES

The effect of gap between weld plates is studied for both Standard GMAW and Pulsed GMAW. In Standard GMAW process with a gap of 0.5 mm, better penetration is observed compared to that of specimen without gap.

From literature it is observed that the rotation would decrease penetration. To test if it is a result of only centrifugal force due to high rpm rotations or due to the wider area of deposition. A specimen is welded using pulsed GMAW mode with a gap of 0.5 mm. From the results it is concluded that with gap between the plates, the weld penetration is found to be effective.

4 CONCLUSIONS

(1) The arc rotation in pulsed GMAW is found to improve the weld bead characteristics and there by resulting in better mechanical properties.
(2) With increase in Voltage and Current settings in Pulsed GMAW, the deposition rate of weld metal is observed to be effective, which has lead to enhanced mechanical properties.
(3) By providing a gap between weld plates, the weld penetration is found to be marginally improved due to wide area of deposition
(4) Using pulsed Gas metal arc welding better penetration is achieved however, the high velocity spatter might disrupt the effect of the forces caused on the weld droplet.

Acknowledgement

Financial support from Science and Engineering Research Board under young scientist scheme (SB/FTP/ETA- 284/2012) is gratefully acknowledged

REFERENCES

[1] Hongtao Zhang, Qing Chang, Jihou Liu, Hao Lu, Hui Wu, Jicai Feng, (2014), "A Novel Rotating wire GMAW Process to change fusion zone shape and microstructure of mild steel", Materials Letters, Volume 123, 101 to 1033
[2] Y. H. Kang, S. J. Na, (2003), "Characteristics of Welding and Arc signal in narrow groove Gas Metal Arc Welding using Electromagnetic Arc Oscillation", Welding Journal, May, 93-S to 99-S.
[3] Iwata Shinji, Murayama Masatoshi, Kojima Yuji, (2009), "Application of Narrow Gap Welding Process with High Speed Rotating Arc to Box Column Joints of Heavy Thick Plates", JFE Technical Report No. 14, December, 16 to 21.
[4] Sanjay Kumar, P. Srinivasa Rao, A. Ramakrishna, (2011), "Effects of eccentricity and Arc rotational speed on Weld Bead Geometry in Pulsed GMAW of 5083 Aluminum Alloy", Journal of Mechanical Engineering Research, Volume 3, 186 to 196.
[5] Ning Guo, Jing Zhang, Yanfei Han, Linlin Zhang, Xin Yuan, (2011), "Effects of Welding parameters on Metal Transfer Process in Rotating Arc Narrow Gap Horizontal GMAW", Transactions of JWRI, 5 to 7.
[6] 6. P. Srinivasa Rao, O. P. Gupta, S. S. N. Murthy, A. B. Koteswara Rao, (2009), "Effect of Process Parameters and Mathematical Model for the prediction of bead geometry in Pulsed GMAW", International Journal on Advances in Manufacturing Technology, Volume 45, 496 to 505
[7] I. S. Kim, K. J. Son, Y. S. Yang, P. K. D. V. Yaragada, (2003), "Sensitivity Analysis for Process Parameters in GMAW Processes using a Factorial Design Method", International Journal of Machine tools and Manufacture, Volume 43, 763 to 769
[8] Chandan Kaushal, Lochan Sharma, (2014), "To find effects of GMAW parameters on Mechanical Properties of Aluminum Alloys", International Journal of Engineering Research and Applications, Volume 4, Issue 11, 88 to 92.
[9] 9. R. J. Brungraber, F. G. Nelson, (1973), "Effect of welding variables on Aluminum Alloy Weldments", The Welding Journal, Volume March, 97-s to 103-s.
[10] 10. D. S. Nagesh, G. L. Dutta, (2008), "Modeling of fillet welded joint of GMAW process: Integrated Approach using DOE, ANN and GA", Int J Interact Des Manuf, Volume 2, 127 to 136.
[11] 11. P. K. Palani, N. Murugan, (2006), "Development of mathematical models for prediction of weld bead geometry in cladding by flux cored arc welding", Int J Adv Manuf Technol., Volume 30, 669 to 676.
[12] 12. K. Manikya Kanti, P. Srinivasa Rao, (2008), "Prediction of bead geometry in Pulsed GMAW Using Back propagation Neural Network", Journal of Materials processing technology, Volume 200, 300 to 305.
[13] 13. U. Reisgen, M. Purrio, G. Buchholz, K. Willms, (2014), "Machine Vision System for Online Weld Pool observation of GMAW Process", Weld World, May.
[14] 14. Sang-Kwun Jeong, Gun-You Lee, Won-Ki lee, Sang-Bong Kim, (2001), "Development of High Speed Rotating Arc Sensor and Seam tracking controller for welding Robots", ISIE, 845 to 850.