Investigations on the Effect of Alternating Shielding Gases on Bead Profile Characteristics of AA6061 Aluminium Alloy using GTA Welding

Leo Joseph Besky. A [A]*, Mahadevan. G [A], Senthilkumar. T[a]
[a] Department of Mechanical Engineering
University college of Engineering, Anna university,
Tiruchirappalli, 620 024, Tamil Nadu, India

***Abstract*:- The present investigation is aimed to study the effect of alternate supply of the shielding gas in different alternating frequencies in comparison with the conventional method of GTA welding with pure argon gas. In this investigation, a gas alternator is used to control and supply the argon and helium shielding gases cyclically to the weld pool for a particular period of time. There are three types of alternating frequencies 1s (Ar) : 0 s (He), 0.5 s (Ar): 0.5 s (He) and 0.75 s (Ar): 0.25 s (He) are used in the supply of alternating shielding gases. Bead on plate welding is performed on AA6061 aluminium alloy plate at different combinations of input parameters like welding current (I) and alternating frequencies of shielding gases (T) at constant welding speed. From the bead on plate welding experiments, the influence of alternating shielding gases on the bead profile characteristics like depth of penetration, area of penetration, width of weld, reinforcement height, wetting angle and percentage of dilution have been studied. Influence of alternating shielding gases on micro hardness and micro structural characteristics of beads also been investigated. The alternate supply of the shielding gas produced better bead profile characteristics with improved mechanical properties as compared with the conventional method of pure argon.**

***Keywords:* Alternate gas supply, GTAW, AA6061, Bead Geometry**

1. INTRODUCTION

AA6061 alloys play a vital role in automobile, aerospace, marine and structural industries due to their light weight and higher strength to weight ratio, because many industries are moving towards lighter and stronger materials to reduce the overall weight of the structure to improve the efficiency. Gas metal arc welding (GMAW) and Gas Tungsten arc welding (GTAW) are playing a vital role in joining of aluminium alloys due to their flexibility and economy [1]. GTA welding is a high-quality and stable welding process which has of low weld spatter and good weld bead appearance characteristics. But there are few problems like low welding speed, partial penetration and lack of the deposited metal occurred during this process.

Shielding gases are critical part of gas tungsten arc welding process. They play a vital role on strength and porosity of joint made by GTA welding. Gases possessing unique properties like ionization potential and thermal conductivity, creates unique arc characteristics are used as shielding gases [2]. For the majority cases argon gas is used for the shielding purpose. Also gases like helium, oxygen, CO_2, nitrogen and mixture of these gases are used for the shielding purpose. Type of material to be welded influences the selection of shielding gases. Shielding gas can also have a positive influence on the speed of welding [3].

In order to utilize the advantage of the favorable properties of each gas, shielding gases are often used as premixed combinations of two or more gases [4]. Helium gases are possessing higher ionization potential than that of argon, which indicates that argon gas quickly ionized at lower temperatures than that of helium. As compared to argon, helium gas possessing higher arc power density which produces a smaller cathode spot and potentially deeper penetration [5]. Shielding gases influences on joint properties can also be studied by the additions of nitrogen and helium to conventional argon [6]. Addition of helium to argon increased heat input to the work piece with reduced arc pressure [7]. Huang [8] reported that the addition of nitrogen to argon resulted in the increase of penetration and cross sectional area of the bead made by TIG welding. Rao et al. [9] reported that argon helium gas mixture resulted in improved bead profile characteristics.

Compared with supply of premixed shielding gases, the alternative supply of shielding gas is more economical and reduces heat transfer to the work piece for an equivalent weld penetration. In order to utilize the beneficial effects of helium, it is supplied alternately along with argon gas. Initially, Novikov et al., [10] recommended for an advanced technology which connected with alternate supply of shielding gases in gas shielded arc welding processes. They found that the pressure of the welding arc is cyclically increased while supplying argon and helium gases alternately. These results in structure refinement of weld metal and the fusion zone and increase in mechanical properties of the joints. Kang et al. [11] reported that the alternate supply of the shielding gas on GMA welding reduced the porosity of 1420 and 1460 aluminium joints, compared with the conventional supply of argon gas and premixed argon with helium. Investigation made by Campbell [12] et al. reveals that the alternate supply of shielding gases in the metal inert gas welding results in reduced porosity and increased productivity compared with premixed argon with 10% helium while welding of AA6082 components. Due to low heat input and high welding speed, implementation of alternating shielding gases resulted in reduced distortion of welded joints of thin plate DH36 steel [13].

In practical, it is difficult to understand this technology of supplying shielding gases alternately unlike conventional gas supply. Since the quality of welded joint is

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

mainly characterized by the bead geometry [14], in this investigation an effort is made to study the effect of various alternating shielding gas frequencies on weld bead geometry, microstructure and micro hardness of GTA welded AA6061 aluminum alloy.

2. EXPERIMENTAL WORK

In this experiment, supply of shielding gases is regulated by gas alternator. Gas alternator is an apparatus used in alternate supply of shielding gases to the welding torch, which ensures delivery of the shielding gas alternately and directly to the GTAW torch to avoid mixing of the gas before entering the torch. The schematic layout of experimental setup consisting of welding machine (GTAW), gas alternator and gas cylinders are shown in Fig. 1. Adjusting the timer control varies the shielding gas alternating frequency. The pulsed alternate supply of shielding gas causes a dynamic action on the molten weld pool, which results in improved weld quality both in terms of fusion characteristics and bead appearance.

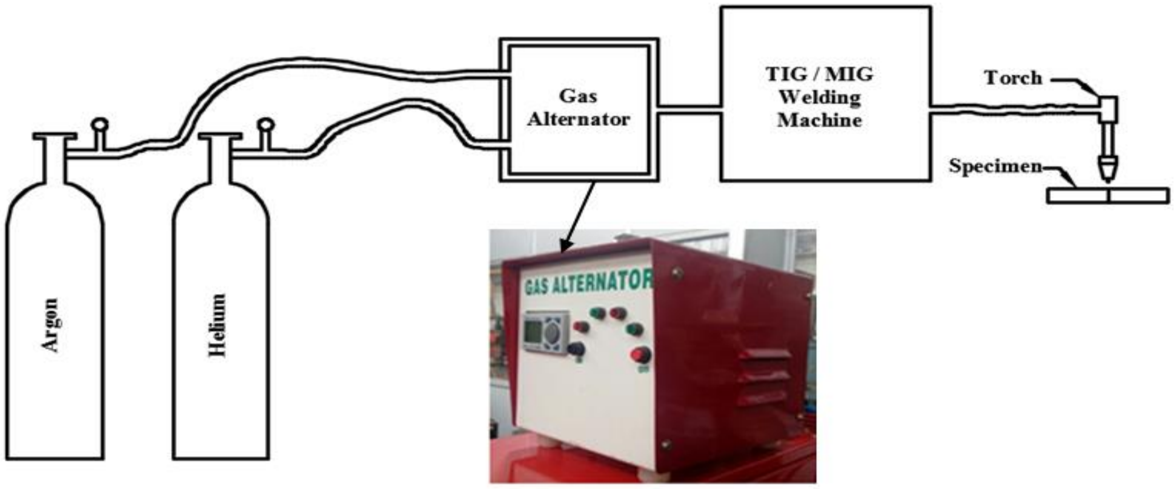


Fig.1. Schematic layout of experimental setup with gas alternator

The three types of alternating frequencies are used in the supply of alternating shielding gases. In the first type of frequency (0.5 s (Ar): 0.5 s (He)), alternator supply argon gas to the weld pool for a duration of 0.5 second, then it supply helium gas to the weld pool for a time period of 0.5 second. This cycle was repeated for entire length of welding. Similarly, it supply argon gas to the weld pool for a duration of 0.75 second, then it supply helium gas to the weld pool for a time period of 0.25 second in the second type of frequency (0.75 s (Ar): 0.25 s (He)) . In the third type (1s (Ar) : 0 s (He)) alternator only supply argon gas to the weld pool for a duration of 1second, it would not supply helium gas while using this type of alternating frequency. Hence this type of frequency would be called as pure argon or 100% argon throughout this investigation.

Table 1 Chemical composition (wt. %) of 6061 aluminum alloy

Material	Mg	Si	Fe	Cu	Cr	Mn	Zn	Ti	Al
AA6061	0.93	0.57	0.35	0.28	0.16	0.07	0.02	0.02	Balance

Fig.2. Experimental setup with gas alternator

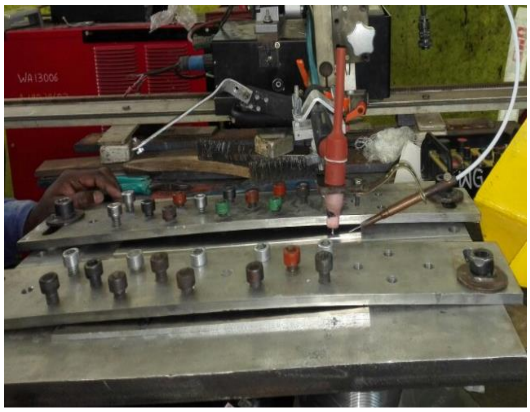


Fig.3. Automated welding arrangement

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

The plates of dimensions 300 mm × 150 mm x 5 mm were machined from the rolled plates AA6061. The chemical compositions of base metal are shown in Table 1. Single pass, autogenously welding procedure was applied to perform bead-on-plate experiments on plates of AA6061. Extensive literature survey and the basic experiments showed the way in choosing the predominant factors for GTA welding as given in Table 2. The experimental setup with gas alternator and automated welding arrangement are shown in Fig.2 and Fig.3 respectively. Weld bead made with different shielding gases and current using GTA welding are shown in Fig.4.

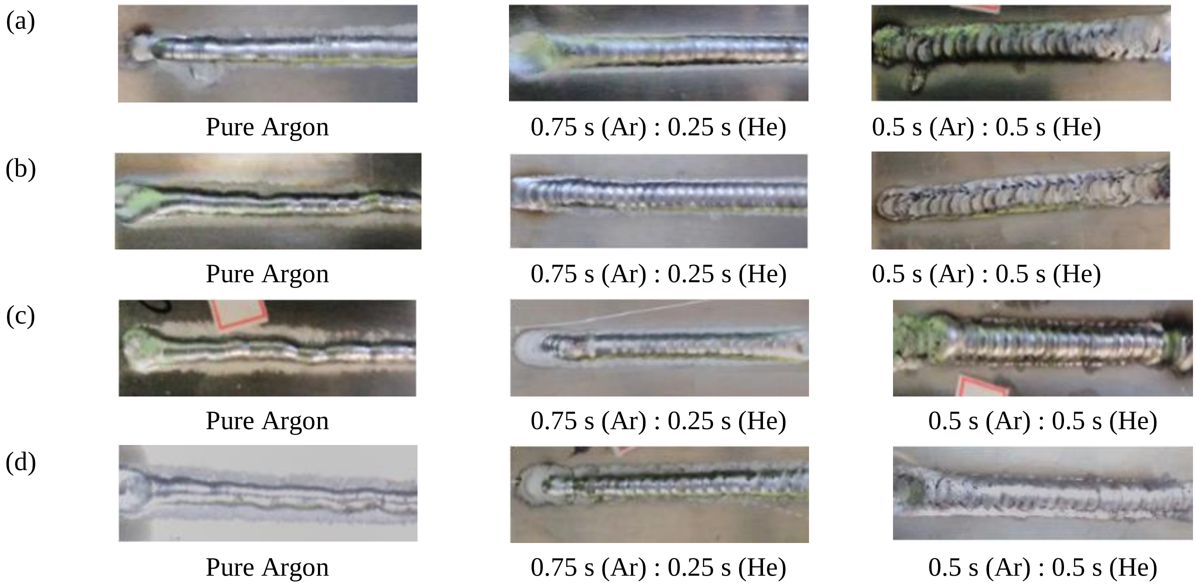


Fig.4. Bead on plate welded specimen (a) 130 A (b) 140 A (c) 150 A (d) 160 A

Transverse sections of each weld bead was processed to get a clear view of different section of weldment, the samples were etched with Keller' s solution .To get the dimensions of the bead geometry all the samples were microscopically scanned for 10X magnification. The magnified scanned images were converted into drawing files to measure the weld dimensions such as bead penetration depth, bead penetration area; bead width and reinforcement were measured. From the measured values of area of penetration and reinforcement, % dilution is calculated for all beads. The magnified macro images of weld bead are shown in Fig.5. The micro hardness values were examined moving from the base material across the weld bead toward its opposite side.

Table 2 Process parameter for bead on plate trials (GTAW)

Power Source	Lincoln Electric square wave AC/DC TIG - 355
Welding Current	130A, 140A, 150A and 160A
Welding Voltage	12-14 V
Welding Speed	180 mm/min (Automated)
Filler feed rate	2.5 m/min
Electrode type	Tungsten (2% Zirconiated)
Electrode diameter	2.4 mm
Arc gap	2 - 3 mm
Shielding gas	Argon (99.999% purity)
	Helium ((99.999% purity)
Gas flow rate	10– 12 lpm
Alternating shielding gas frequency	1 sec. (Ar) and 0 sec. (He) - Pure Argon
	0.75 sec. (Ar) and 0.25 sec. (He)
	0.5 sec. (Ar) and 0.5 sec. (He)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

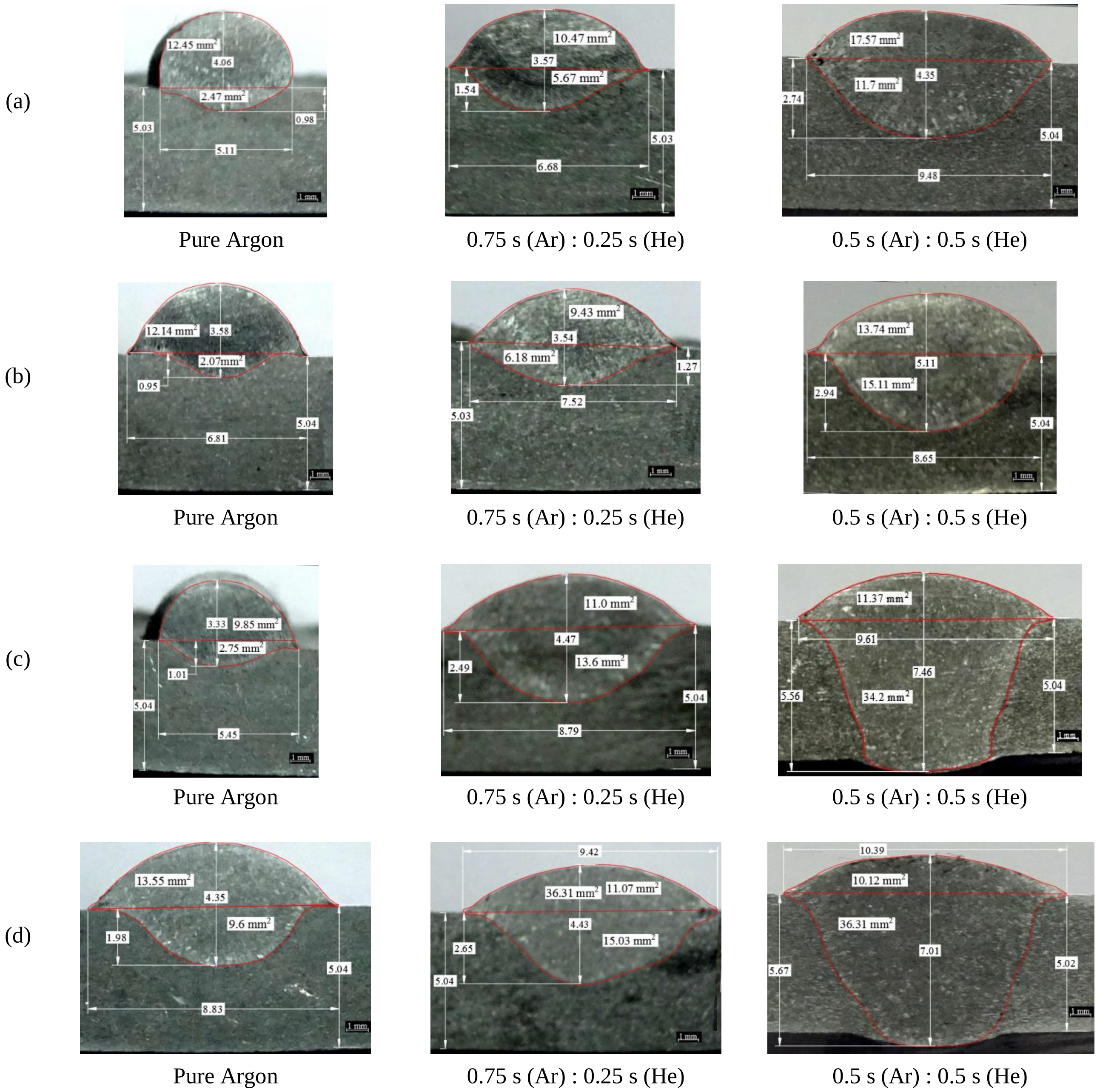


Fig.5. Macro images of bead geometry (a) 130 A (b) 140 A (c) 150 A (d) 160 A

3. RESULTS AND DISCUSSION

The influences of welding current and different shielding gases on the bead profile characteristics and microstructure were investigated. Processed macro images of weld bead made by single pass welds were displayed in Fig.5.

It was observed that, for the all types of shielding gases, increase in welding current resulted in increase of bead profile characteristics such as bead penetration depth, total bead area, bead width and dilution. But reinforcement height and wetting angle of bead were decreased in response to increase in welding current. Increase in welding current increases the rate of heat input leading to better weld bead dimensions. For similar welding currents, as compared to the supply of pure argon, introduction of alternating shielding gases 0.5s (Ar): 0.5s (He) increased the bead penetration depth by 64 - 80 % (Fig.6), bead width by 15 - 46 % (Fig.7), dilution percentage by 47 - 71 (Fig.9).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

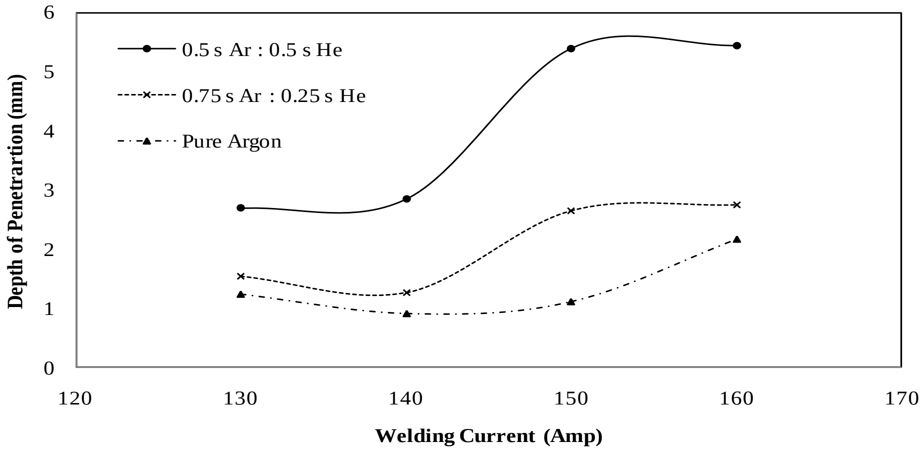


Fig.6. Effect of alternating shielding gases on depth of penetration

Supply of alternating shielding gases 0.5s (Ar): 0.5s (He) also resulted in decrease of the reinforcement height and wetting angle by 17 - 48% (Fig.8) and by 28 - 49% (Fig.9) respectively as compared to pure argon. Supply of the alternating shielding gases 0.75s (Ar): 0.25s (He) increased the bead penetration depth by 25-59 % (Fig.6), bead penetration width by 6-38 % (Fig.7), dilution percentage by 25-60% (Fig.10) as compared to pure argon. This type of supply also resulted in decrease of the reinforcement height and wetting angle by 14-34% (Fig.8) and by 9-30% (Fig.9) respectively as compared to pure argon.

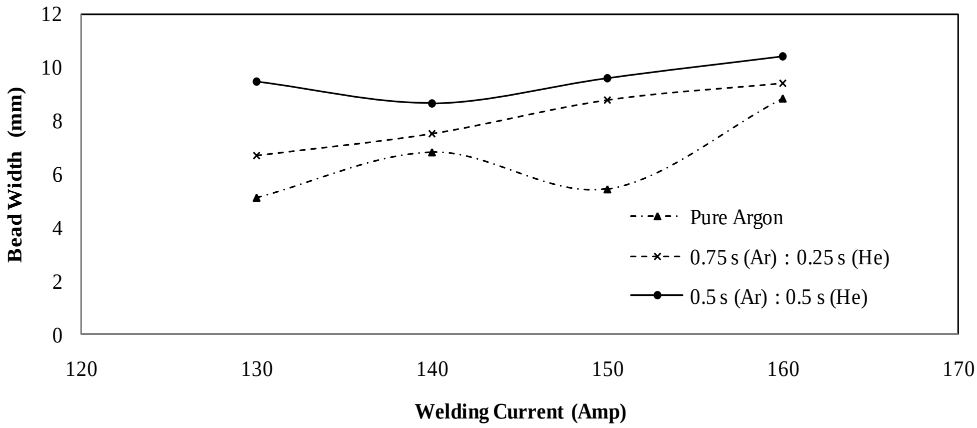


Fig.7. Effect of alternating shielding gases on bead width

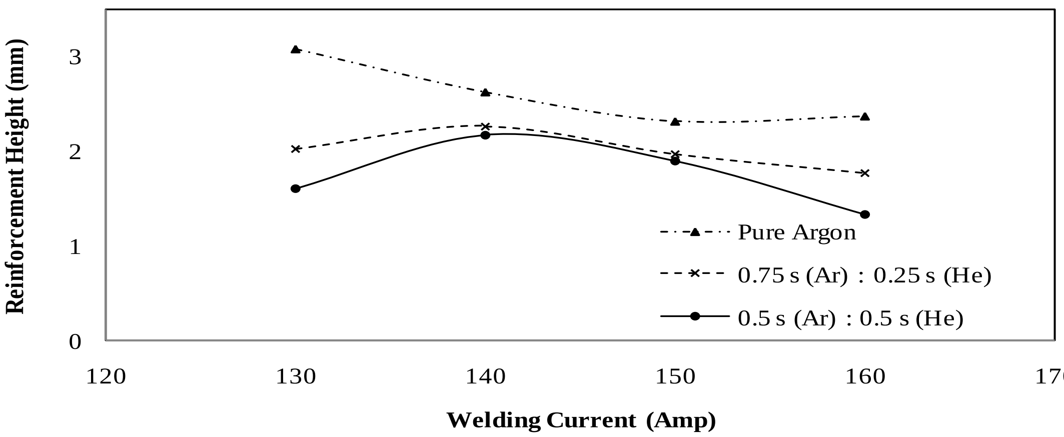


Fig.8. Effect of alternating shielding gases on reinforcement height

It was observed that conventional supply of pure argon usually produced poor fusion when compared with the supply of alternating shielding gases. Since alternate supply of shielding gases brought about variety in arc pressure and weld pool fluidity, each supplementing the other to make the stir action in the weld pool in order to give the better fusion characteristics [15]. Alternate supply of helium along with argon produces deeper penetration than conventional supply of argon owing to its higher ionization potential producing a smaller cathode spot.

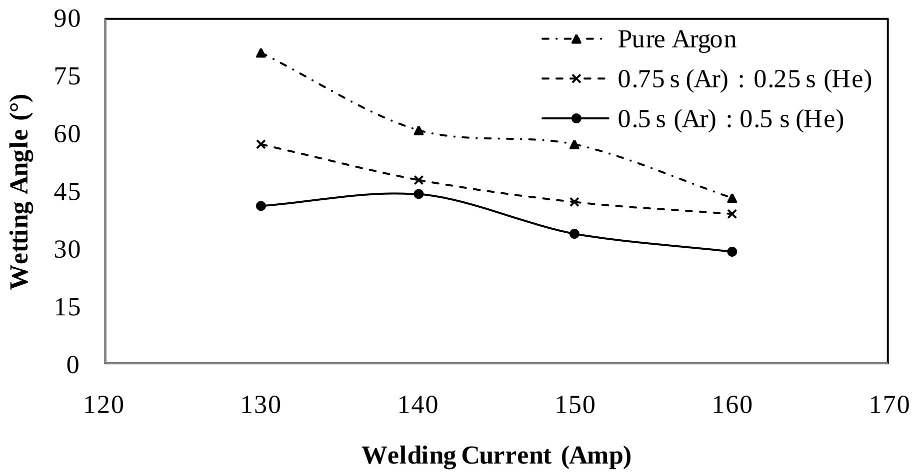


Fig.9. Effect of alternating shielding gases on wetting angle

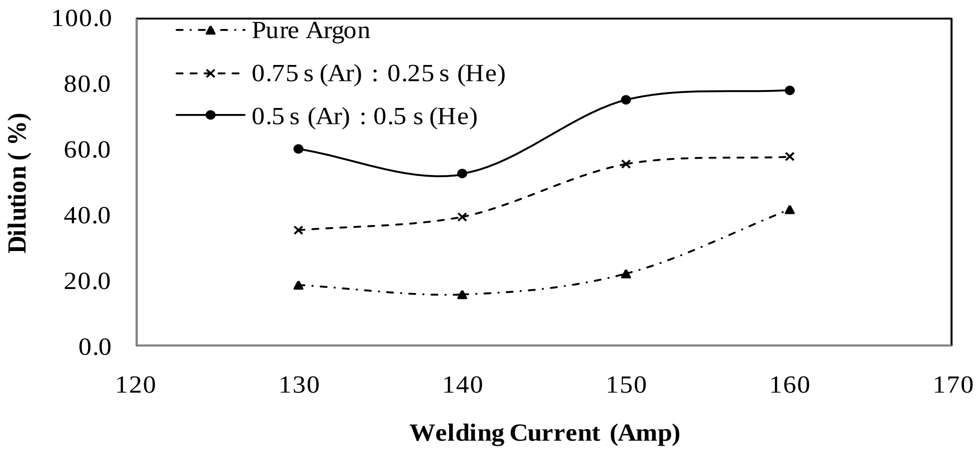


Fig.10. Effect of alternating shielding gases on dilution percentage

The effect of shielding gases on weld metal hardness was studied using three different alternating shielding gases 0.75 s (Ar): 0.25 s (He) , 0.5 s (Ar) : 0.5 s (He) and pure argon. Fig.11. shows the effect of three different alternating shielding gases on micro hardness of the weld metal, HAZ and base metal for welding current 150A and 160A. In all cases HAZ is relatively harder due to the transformation of micro structure caused by heat treatment during welding. Whereas at weldment area, the hardness is moderately low due to overheat treatment received inside the fusion area. Weld bead made by alternating shielding gas 0.5 s (Ar) : 0.5 s (He) with welding current 150A and 160A resulted in hardness increment in the weld zone, which is induced by precipitation hardening effects, microstructure refinement due to the rapid cooling of the weld pool.

Due to the higher ionization potential of helium, supplying of alternating shielding gases resulted in increase of thermal frequency. Hardness of the weld joint was enhanced with the increase of thermal frequency because of decreased porosity rate and increased Mg_2Si precipitate [16].

For all welding currents, microstructure of heat affected zone of weld bead shown enough fusion of filler to base material with no evidence of residual stresses (Fig.12). It also displays eutectic dendritic particles of Al-Mn-Si in a matrix of aluminium solid solution in all types of shielding gases. Microstructure of weld metal shows network of fine dendritic particles of Al-Mn-Si in a matrix of aluminium solid solution in all types of shielding gases for all welding currents.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

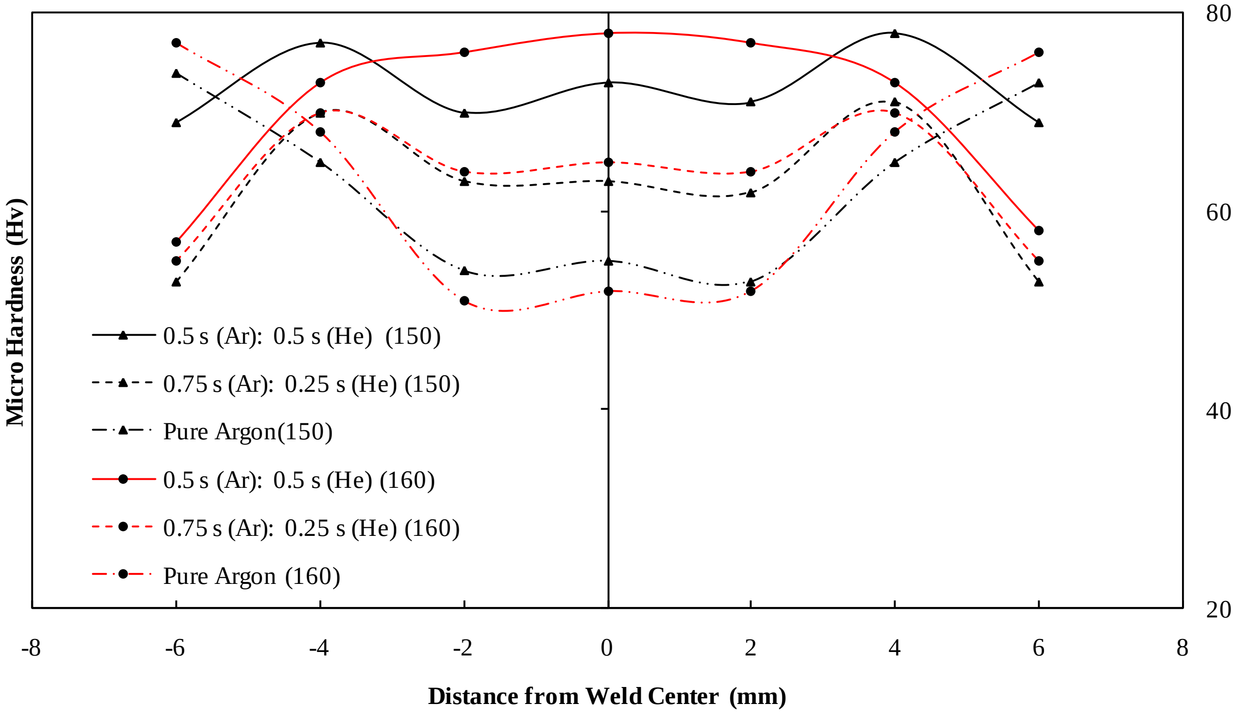
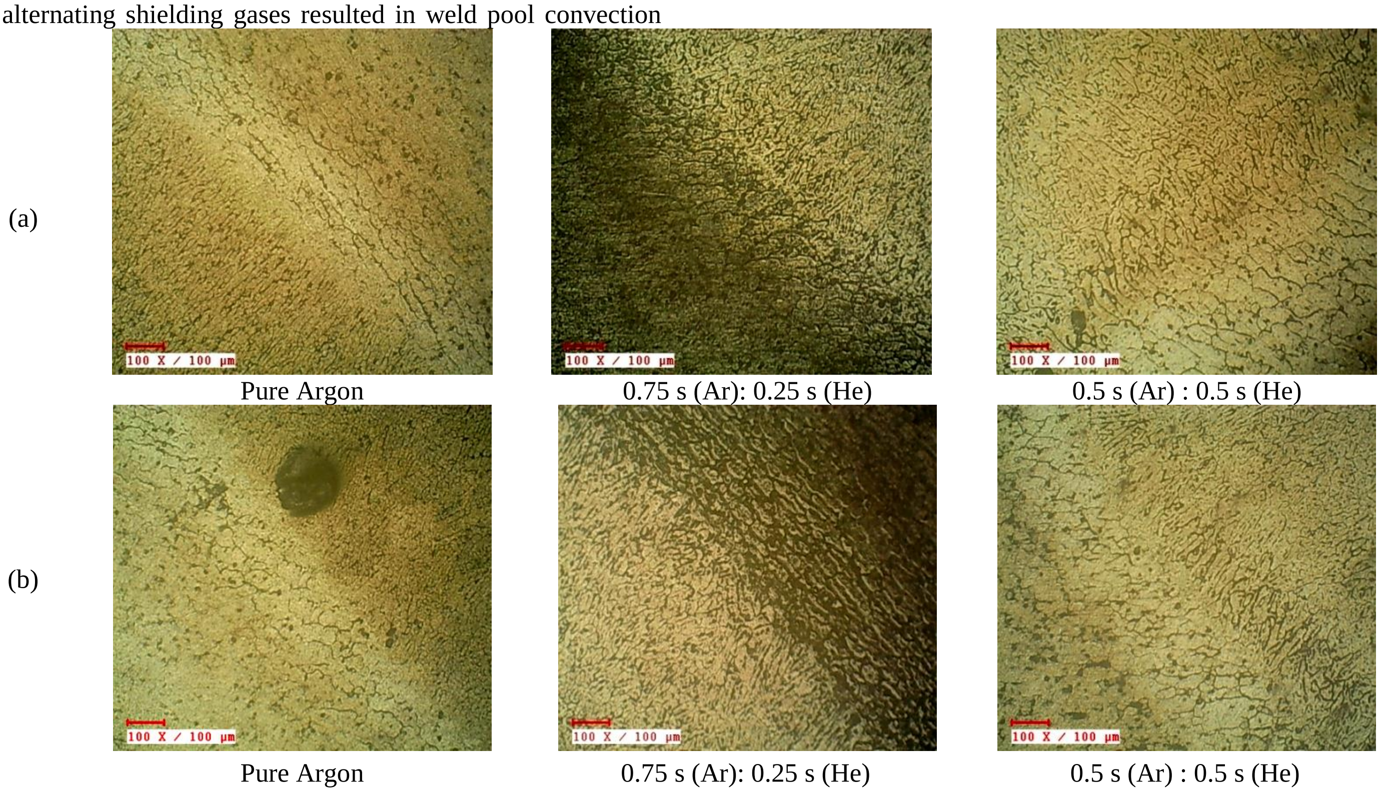


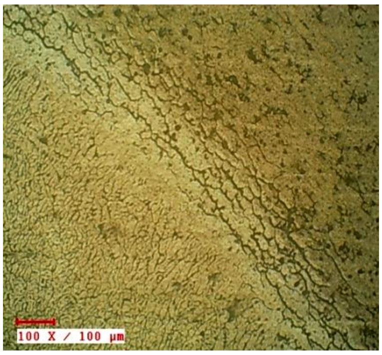
Fig.11. Effect of alternating shielding gases on micro hardness

Presence of porosities were observed in the micro structure of weld metal made using alternating shielding gas 0.5 s (Ar): 0.5 s (He) for all welding currents (Fig.13). These porosities could be eliminated by doing multi pass welding during joint fabrication. During multi pass weld, use of alternating shielding gases resulted in weld pool convection [17] which causes, the molten metal to move forward and back in the weld pool. Due to this effect, solidification process is affected, grain growth is hindered, and the broken grains become the nucleation sites for new grains.

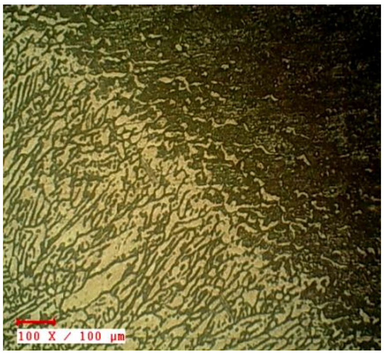


International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

(c)



Pure Argon

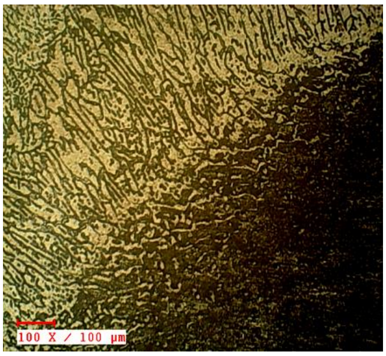


0.75 s (Ar): 0.25 s (He)

0.5 s (Ar) : 0.5 s (He)

(d)

Pure Argon

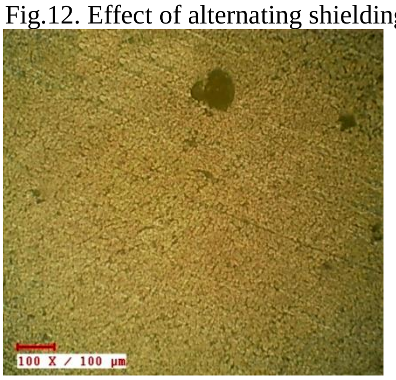


0.75 s (Ar): 0.25 s (He)

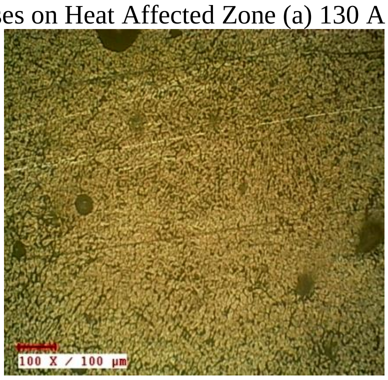
0.5 s (Ar) : 0.5 s (He)

Fig.12. Effect of alternating shielding gases on Heat Affected Zone (a) 130 A (b) 140 A (c) 150 A (d) 160 A

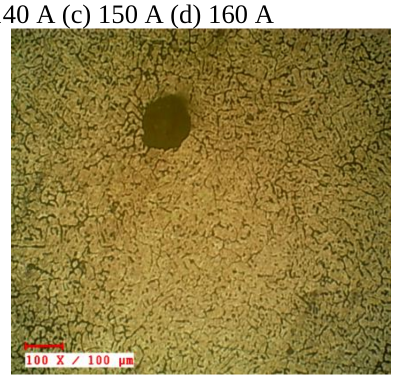
(a)



Pure Argon



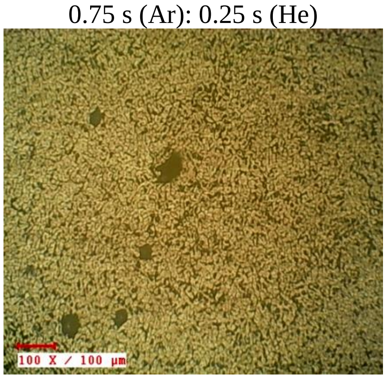
0.75 s (Ar): 0.25 s (He)



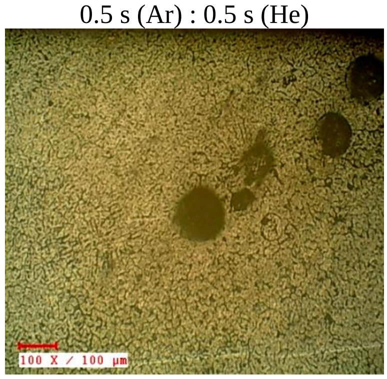
0.5 s (Ar) : 0.5 s (He)

(b)

Pure Argon



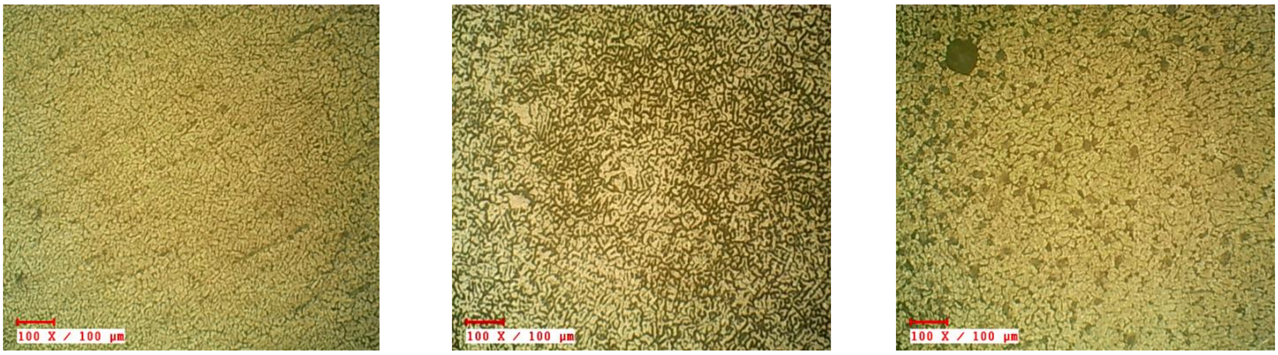
0.75 s (Ar): 0.25 s (He)



0.5 s (Ar) : 0.5 s (He)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

(c)



Pure Argon | 0.75 s (Ar): 0.25 s (He) | 0.5 s (Ar) : 0.5 s (He)

(d)

Pure Argon | 0.75 s (Ar): 0.25 s (He) | 0.5 s (Ar) : 0.5 s (He)

Fig.13. Effect of alternating shielding gases on weld metal (a) 130 A (b) 140 A (c) 150 A (d)160 A

4. CONCLUSIONS

The present investigation was carried out to study the effect of alternate supply of the shielding gas in different alternating frequencies in comparison with the conventional method of GTA welding with pure argon gas.

- In GTA welding introduction of alternating shielding gases 0.5s (Ar): 0.5s (He) increased the bead penetration depth, bead penetration width, dilution as compared to pure argon. It also resulted in decrease of the reinforcement height and wetting angle as compared to alternating shielding gases 0.75s (Ar): 0.25s (He) and pure argon.
- Hardness of the weld metal was enhanced with the increase of thermal frequency because of increased Mg_2Si precipitate of the weld joint.
- Use of alternating shielding gases 0.5 s (Ar): 0.5 s (He) resulted in grain coarsening of microstructure in all zones of weld bead and resulted in porosity which could be eliminated during multi pass welding, no significant difference in the width of the HAZ has been observed.

5. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the Welding Research Institute (WRI), Bharath Heavy Electricals Limited (BHEL), Tiruchirappalli for supported this work.

6. REFERENCES

[1] *Madhusudhan Reddy, G., Gokhale, A.A., and Prasad Rao, K.*, Optimization of pulse frequency in pulsed current gas tungsten arc welding of aluminium - lithium, *J. Mater. Sci. Tech.*, 1998, vol. 14, pp. 61- 66.

[2] *Marya, M., Edwards, G. R., and Liu, S.,* An investigation on the effects of gases in GTA welding of a wrought AZ80 magnesium alloy, *Weld. J.*, 2004, vol. 83, no. 7, pp. 203-212.

[3] *Gillies, A., Galloway, A.M., and McPherson, N.A.*, Helium additions to MIG shielding gas - an economic option? *Welding and Cutting*, 2011, vol. 10, no. 2, pp. 118-121.

[4] *Welding and brazing*, ASM metals handbook, 1993, 8th ed., vol. 6, pp. 85.

[5] *Jonsson, P.G., Eagar,T.W., and Szekely, J.*, Heat and metal transfer in gas metal arc welding using argon and helium, *Metall. Mater. Trans.B, Process Metall. Mater. Process. Sci*., 1995, vol. 26, pp. 383-395.

[6] *Galloway, A.M., McPherson, N.A., and Baker, T.N.*, An evaluation of weld metal nitrogen retention and properties in 316LN austenitic stainless steel, *J. Mat. Desi. Applic.*, 2011, vol. 225, no. 2, pp. 61-69.

[7] *Zahr, J., Fussel, U., Hertel, M., Lohse, M., Sende, M., and Schnick, M.,* Numerical and experimental studies of the influence of process gases in TIG welding, *Weld. World.*, 2012, vol. 56, pp. 85-92.

[8] *Huang H.Y.,* 2008. Effects of shielding gas composition and activating flux on GTAW weldments, *Mater. Des.*, 2008, vol. 30, pp. 2404-2409.

[9] *Rao, Z.H., Liao, S.M., and Tsai. H.L.*, Effects of shielding gas compositions on arc plasma and metal transfer in gas metal arc welding, *J. Appl. Phys.*, 2010, vol. 107, pp. 044902-1-11.

[10] *Novikov, O.M., Persidskii, A.S., and Rad'Ko, E.P.*, Effect of changes in the composition of the gas shielding medium on the properties of arc welded joints in aluminium alloys, *J. Welding International*, 2013, vol. 27, no. 3, pp. 222-225.

[11] *Kang, B.Y., Prasad, Y.K.D.V., Kang, M.J., Kim, H.J., and Kim, I.S.,* Characteristics of alternate supply of shielding gases in aluminium GMA welding, *J. Mater. Process. Technol.,* 2009, vol. 209, pp. 4716-4721,

[12] *Campbell, S.W., Galloway, A.M., McPherson, N.A., and Gillies, A.,* Evaluation of gas metal arc welding with alternating shielding gases for use on AA6082T6, *Proc. IMechE, J. Eng. Manuf.,* 2012, vol. 226, no. 6, pp. 992 -1000

[13] *Campbell, S.W., Galloway, A.M., and McPherson, N.A.,* Techno-economic evaluation on the effects of alternating shielding gases for advanced joining processes, *Proc. IMechE, Part B: J Engineering Manufacture*, 2011, vol. 225, pp. 1863– 1872.

[14] *Nagesh, D.S., and Datta, G.L.,* Prediction of weld bead geometry and penetration in shielded metal-arc welding using artificial neural networks, *J. Mater. Proces. Tech.,* 2002, vol. 123, pp. 303-312.

[15] *Chang, Y.H.,* Improve GMAW and GTAW with Alternating Shield Gases, *Welding Journal*, 2006, vol. 85, no. 2, pp. 41-43.

[16] *Wang, L., Jin, L., Huang, W., Xu, M., and Xue, J.,* Effect of Thermal Frequency on AA6061 Aluminum Alloy Double Pulsed Gas Metal Arc Welding, *J. Mater. Manuf. Proces.,* 2016, vol.31, no.16, pp. 2152- 2157.

[17] *Becker, D.W., and Jr, C.M.A.,* The role of pulsed GTA welding variables in solidification and grain refinement, *Welding Journal,* 1979, vol. 58 no. 5, pp. 143-152.