Experimental Analysis of Alternating Shielding Gas Supply in TIG Welding

C. Gurupadam
PG student, Manufacturing Engineering,
University College of Engineering (BIT Campus),
Anna University, Trichy.

G. Mahadevan
Assistant Professor
University College of Engineering (BIT Campus),
Anna University, Trichy.

Dr. T. Senthil Kumar
Associate Professor
University College of Engineering (BIT Campus),
Anna University, Trichy.

Abstarct: **Recently, unlike conventional method in supplying shielding gas, a newly method which alternately supplies different kinds of shielding gases in weld zone is developed and partly commercialized. However, literature related to the present status of the technology in the actual weld field is very scant. To give better understand on this technology, this study was performed. Compared with conventional gas supply method, the variations of weld porosity and weld shape in aluminum welding with alternate supply method of pure argon and pure helium were compared with conventional gas supply method with pure argon and argon + 67%helium mixture, respectively. As a result, compared with the welding by supplying pure argon, helium and argon + 67%helium mixture by conventional method, the welding by supplying alternately pure argon and pure helium. Also analyzing their weld porosity, deeper, broader weld penetration and weld strength.**

1. INTRODUCTION

Welding is a permanent joining process used to join different materials like metals, alloys or plastics, together at their contacting surfaces by application of heat and or pressure. During welding, the work-pieces to be joined are melted at the interface and after solidification a permanent joint can be achieved. Sometimes a filler material is added to form a weld pool of molten material which after solidification gives a strong bond between the materials. Weld ability of a material depends on different factors like the metallurgical changes that occur during welding, changes in hardness in weld zone due to rapid solidification, extent of oxidation due to reaction of materials with atmospheric oxygen and tendency of crack formation in the joint position.

2. LITERATURE REVIEW

B.Y. Kang,et.al, [1] explains about comparison with the welding by supplying pure argon and argon + 67%helium mixture by conventional method, the welding by supplying alternately pure argon and pure helium, produced lower degree of weld porosity and deeper and broader weld penetration profile. Under the same welding conditions, compared with the welding by supplying Ar and Ar + 67%He by conventional method, the welding by supplying alternately Ar and He, produced the deepest and broadest weld penetration profile.(3) Compared with Ar + 67%He, alternate supply of Ar and He gives the advantage of reducing weld porosity and improved weld shape. Prachya Peasuraa et.al [2] used Aluminum alloy AA 5083 as the test specimen. Plates of specimens 6 mm.thickness and 50x50 mm.. Experimental results showed that the argon condition provided smaller grain size, suitable size resulting in higher hardness both in weld metal and HAZ. The results can be concluded that the grain size and precipitation Mg affect the hardness of sample. I. Bitharas a, et.al, [3] conducted a study using a stationary welding torch located between the mirrors M1 and M2 with the arc struck on to a water-cooled copper plate to prevent melting of the anode surface. A 13% increase in weld penetration was observed with the alternating shielding gas method compared to the 'pre-mixed' case, suggesting that the helium is used more efficiently with the alternating shielding gas method. B.Y. Kang, Yarlagadda et.al., [4] concluded that 1. Under similar welding conditions, the alternate method with Ar and He compared with the conventional methods of Ar and Ar + 67% He produced the lowest degree of welding distortion. Sanjeev kumar et. al [5] attempted to explore the possibility for welding of higher thickness plates by TIG welding. Shear strength of weld metal (73MPa) was found less than parent metal (85 MPa). From the analysis of photomicrograph of welded specimen it has been found that, weld deposits are form co-axial dendrite micro-structure towards the fusion line and tensile fracture occur near to fusion line of weld deposit. Indira Rani et. al [6] investigated the mechanical properties of the weldments of AA6351 during the GTAW /TIG welding with non-pulsed and pulsed current at different frequencies. From the experimental results it was concluded that the tensile strength and YS of the weldments is closer to base metal. Failure location of weldments occurred at HAZ and from this we said that weldments have better weld joint strength.

2. EXPERIMENTAL DETAILS

1) 2.1. Apparatus for alternate supply of shielding gases

In the present study, the apparatus called KR301 (KR301 is a trademark of KR Precision Co. Ltd. in South Korea.) is used for alternate supply of pure argon and pure helium. As shown in Fig. 1, the equipment is largely composed of two parts. One is the electronic part, which controls the flow rate, and supplies frequency of shielding gases, and the other is the valve that operated by electromagnetic force for alternate supply of shielding gases. Fig. 2 shows a schematic diagram for sequence alternate supply of shielding gases by electromagnetic valve. Unlike the conventional method, the alternate method uses the discrete gases (gas A and gas B) with a different flow rate, and is alternately supplied by the valve with return working. The sequence of gas supply is gas (A), gas (A+ B) and gas (B) and/or conversely. The frequency of alternate supply of shielding gases is controlled from 2 to 10 Hz.

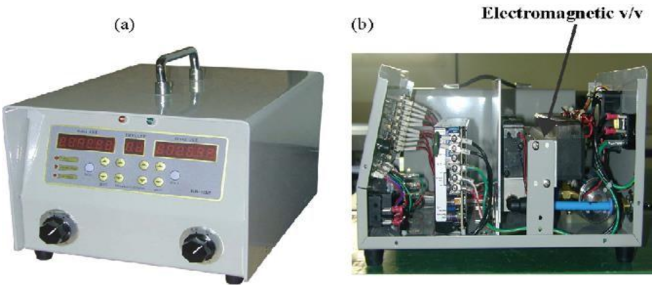


Fig. 1. The apparatus for alternate supply of shielding gases: (a) outside view and (b) inside view.

2.2. Base material: Al-Mg-Si alloy 6061

The base material used in the present investigation was Al-Mg-Si alloy 6061 which is widely used in aerospace sheet metal structures. Alloy 6061 is a heat-treatable Aluminum alloy used in structural applications; Alloy 6061 is normally used in T4 and T6 conditions. The base material is generally solution heat treated at 500°C followed by quenching and subsequent aging, either at room temperature for T4 temper, or aging at 170°C up to 18 h for T6 temper.

2.3. Welding tests

Shielding gases ware supplied to welding torch through solenoid valve orifice with 4mm diameter in welding power source. Two kinds of experiments were carried out. The first experiment is to investigate the welding voltage waveforms to confirm the alternate supply of different gases in apparatus for alternate supply of shielding gases, and the latter is the experiment to investigate the effect of alternate supply method of shielding gases on the weld porosity and weld shape in aluminum GMA welding. Welding voltage waveforms by supplying Ar and He, respectively with conventional method were compared with those by alternately supplying Ar and He by alternate method.

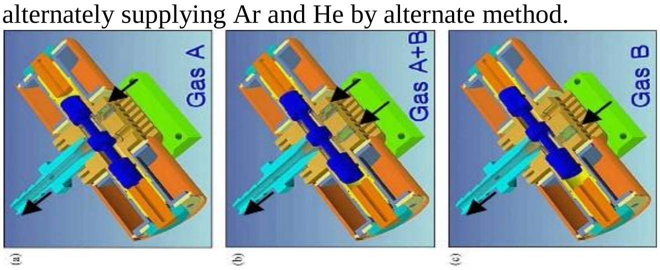


Fig. 2. Schematic diagram showing the alternate supply of shielding gases by electromagnetic valve.

Major welding conditions should define GMA welding process, which can be shown to be the best with respect to some standard and chosen combination of process parameters, which give an acceptable balance between production rate, and the extent of defects for a given situation. In the case of the former, welding was performed in welding conditions of Table 1. Three kinds of shielding gases, Ar and He, respectively for conventional method and Ar to He for alternate method were employed. The welding parameter used in the experiments were; wire feed rate of 13.4 m/min, welding voltage of 25V, welding speed of 40 cm/min, three levels of flow rate (Ar and He) with 20 l/min for conventional method and flow rate of 15 l/min Ar to 5 l/min He with frequency of 2.2 Hz for alternate method. Welding voltage waveforms were measured by arc monitoring system for 5 s at sampling rate of 10 kHz. In the case of the latter, welding was performed under welding conditions as shown in Table 2.

Table 1 Welding conditions for the measurement of welding voltage waveforms.

Gas	Wire Feed Rate (M/Min)	Welding Voltage(V)	Welding Speed(Cm/Min)	Flow Rate (I/Min)
Ar	13.5	25	35	20
He	13.5	25	35	20
Ar:He	13.5	25	35	15:5

Table 2 Welding conditions for the investigation of weld porosity and weld shape

Gas	Wire Feed Rate (M/Min)	Welding Voltage(V)	Welding Speed(Cm/Min)	Flow Rate (I/Min)
Ar	13.5	25	30	20
Ar+He	13.5	25	30	20
Ar:He	13.5	25	30	15:5

Three kinds of shielding gases, Ar and Ar + 67%He for conventional method and Ar to He for alternate method were employed. The welding parameter used in the experiments were; wire feed rate of 13.4 m/min, welding voltage of 25 V, welding speed of 25 cm/min, three levels of flow rate (Ar and Ar + 67%He) with 20 l/min for the conventional method and flow rate of 15 l/min Ar to 5 l/min He with frequency of 2.2 Hz for alternate method. All other parameters except these were fixed. Flow rate was respectively measured by flow rate gauge for Ar in Ar and Ar + 67%He, and for He in He.Welding was carried out at flat position by using the automatic GMA welding carriage. Fig. 3 shows a schematic diagram of weld joint to evaluate the weld porosity. Fig. 3(a) is a bead-on-plate weld and Fig. 3(b) is a multi-pass weld. For bead-on-plate specimen, a plate of 12mm in thickness, 100mm in width and 250mm in length as base metal and 90◦ in groove angle and 5mm in depth as weld joint design were used. For multi-pass specimen, a 100mm×200mm plate of 15mm in thickness as base metal and 60◦ in groove angle and 5mm in root gap as weld joint design is employed. To evaluate weld porosity, three specimens for each shielding gas in welding conditions as shown in Table 2 under a shielding gas atmosphere supplying Ar and Ar + 67%He by conventional method and supplying alternately Ar and He by alternate method were used. In the case of multi-pass welding, the total number of weld bead was 4. To evaluate weld shape, a

100mm×200mmspecimen of 12mm in thickness has been prepared and welded using welding conditions as shown in Table 2 under a shielding gas atmosphere supplying Ar and Ar + 67%He by conventional method and supplying alternately Ar and He by alternate method. For the observations of the cross-section of welded specimen with each shielding gas, the transverse sections of each weld were cut using a power hacksaw from the midlength position of welds, and the end faces were machined.

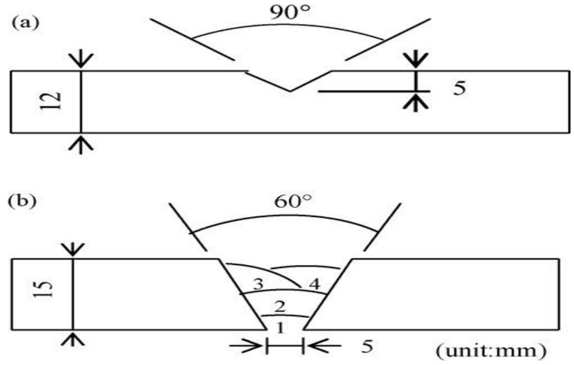
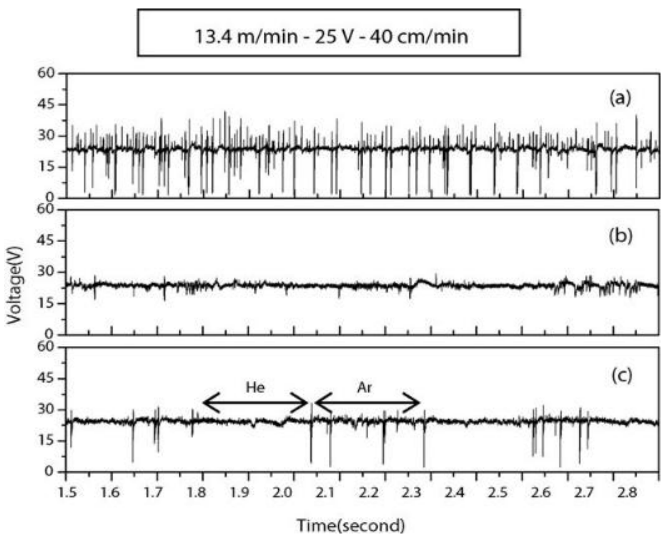


Fig. 3. Schematic diagram of weld joint: (a) bead-on-plate weld specimen and (b) multi-pass weld specimen.



Observation of porosity

For the observation of weld porosity for welded specimens, X ray radiographic test for the completed bead-on-plate welds and the nick break test by three point bending method for completed multi-pass welds were performed. In X-ray radiographic test for three specimens, all porosities on X-ray film for three specimens were investigated and then averaged regardless of size and shape. In the nick break test, porosity on fracture surface was observed by the naked eye.

3. RESULTS AND DISCUSSION

3.1. Alternate supply of shielding gases

Welding voltage waveforms by supplying Ar and He, respectively with conventional method were compared with those by alternately supplying Ar and He with alternate method. However, it is quite difficult to make sure whether Ar and He is alternately supplied with given sequence in torch side or not because the difference of density between Ar and He exists.Fig. 4 represents welding voltage wave forms produced by welding according to the different type of shielding gas and type of shielding gas supply. Fig. 4(a) and (b) is welding voltage wave forms measured under a 20 l/min flow rate of Ar and He shielding gas, respectively by conventional method, while Fig. 4(c) is those of a 15 l/min Ar and He 5 l/min flow rate of shielding gas supplying alternately by alternate method.

Experimental results showed that shielding gas affects molten metal transfer mode in welding. Fig. 4(a) represents welding voltage waveforms for a mixed type of short circuit transfer mode and instantaneous short circuit transfer mode in a gas atmosphere supplying Ar by conventional method. While in a gas atmosphere supplying He by conventional method as shown in Fig. 4(b),welding voltage waveforms show spray transfer mode. Meanwhile, a short circuit transfer mode and spray transfer mode in welding voltage waveforms in a shielding gas atmosphere supplying alternately Ar and He by alternate method periodically appear as shown in Fig. 4(c).From these results, It was confirmed that apparatus used in the present study alternately supplies Ar and He with a frequency of about 2.2 Hz. Considering that Ar and He is simultaneously supplied for a short time, the range of metal transfer mode equivalent to a mixed gas of Ar and He is expected to be shown in welding voltage waveform. However, It might be concluded that the detailed analysis of welding voltage waveforms is required, but it is beyond the scope of this study.

3.2. Effect of alternate supply of argon and helium on weld porosity

Fig. 5 shows the number of weld porosity observed from bead-on-plate specimens welded under a shielding gas supplying alternately Ar and He by alternate method and supplying Ar and Ar + 67%He by conventional method. In the case of conventional method, thenumber of porosity forAr + 67%Heproducedless porosity level than those for Ar. This result is similar to other researcher's work (Collins, 1958; Hilton and Norrish, 1988). They were found that the Ar–He shielding gas mixture for GTA and GMA welding processesin aluminum welding reduces the degree of porosity. They also explained that reduced porosity levels with the Ar–He mixture are attributed to a more efficient oxide removal mechanism as well as providing a more stable spray transfer than argon alone. Meanwhile, compared with conventional method with Ar and Ar + 67%He, the alternate method with Ar and He shows the lowest porosity level. This can be shown from the process of formation weld porosity in aluminum welds. The process of formation of is summarized as follows (Howden, 1971; Shirus, 1969; Devletian and Wood, 1983; Ramirez et al., 1994; Howden and Milner, 1963): hydrogen introduced into arc atmosphere from hydrogen sources is dissociated by arc heat and absorbed into high temperature zone just below arc. This gas is immediately distributed to the entire weld zone by various types of convective fluid flow. During solidification of molten pool, when molten metal of the weld contains more hydrogen than can be maintained in solution, gas is rejected and forms gas bubbles by heterogeneous nucleation. Gas bubbles grow and coalesce, and then in the course of escaping by buoyancy of gas bubbles, these get trapped in weld metal.

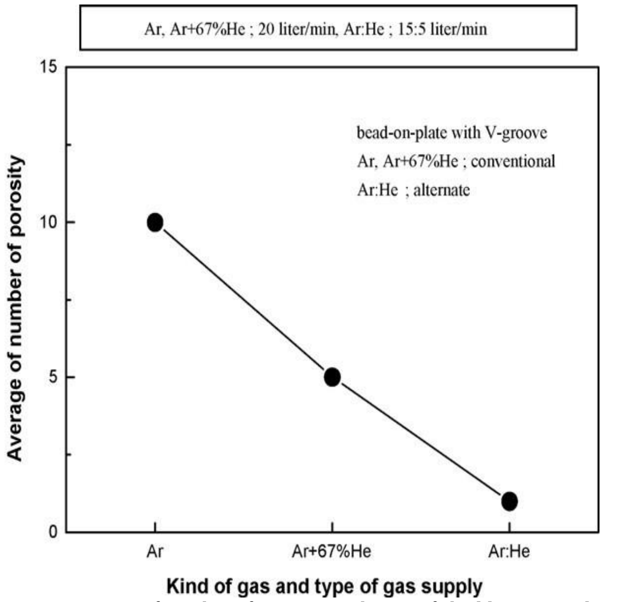


Fig. 4. Comparison of number of porosity with type of shielding gas and type of gas supply.

Porosity formed in aluminum welds is classified as two types. One is to be produced due to the difference of solubility in hydrogen in the liquid temperature region (boiling point to melting point) and the other is to be produced due to the increased concentration of hydrogen in front of solid–liquid interface in melting temperature region. However, it is known that most porosity of in aluminum welds is to be produced in the latter. Fig. 6 represents the solubility curve of hydrogen with temperature with kind of shielding gas and type of shielding gas supply. As a rule, compared with argon, helium has higher arc energy, and thus gives higher heat input in weld (Hilton and Norrish, 1988; Brosilow, 1978; Salter and Dye, 1971; Kennedy, 1970). Accordingly, the heat input is expected to increase in the following order: Ar + 67%He, alternate supply gas of Ar and He, and Ar. Therefore, as illustrated in Fig. 6, the difference of slow cooling rate produces that of solubility of hydrogen, and thus during solidification of molten pool, in liquid temperature range, amount of rejected gas is produced in the following order: Ar + 67%He, alternate supply gas of Ar to He, and Ar. As the result, Ar + 67%He produces the most amount of gas bubbles as weld porosity sources. However, in melting temperature region, the case of Ar showing the fastest cooling rate in three types of shielding gases produces the largest difference of solubility of hydrogen. Therefore, amount of rejected gas bubbles is produced in the following order: Ar, alternate supply gas of Ar to He, and Ar + 67%He. As the result, Ar + 67%He produces the lowest amount of gas bubbles as weld porosity sources. As mention above, considering that most porosity in aluminum welds is to be produced in melting temperature region, compared with alternate supply gas of Ar and He by alternate method, the case of Ar + 67%He by conventional with the lowest amount of gas bubbles as weld porosity sources and higher heat input must be show lower porosity. In flat position welding, the amount of weld metal porosity would tend to decrease at the high values of heat input (Devletian and Wood, 1983). In spite of this fact, the result of this study is not so. It is considered that this result was due to the increased fluidity of molten pool in alternate method. Fig. 7 shows the behavior of weld pool and arc pressure with type of shielding gas supply. Fig. 7(a) shows the behavior of weld pool and the variation of arc pressure because of electromagnetic force supplied by Ar + 67%Heinflowrate of 20 l/min by conventional method. Arc pressure is constant with time and works downwards so that the fluidity of weld pool moves only downwards.

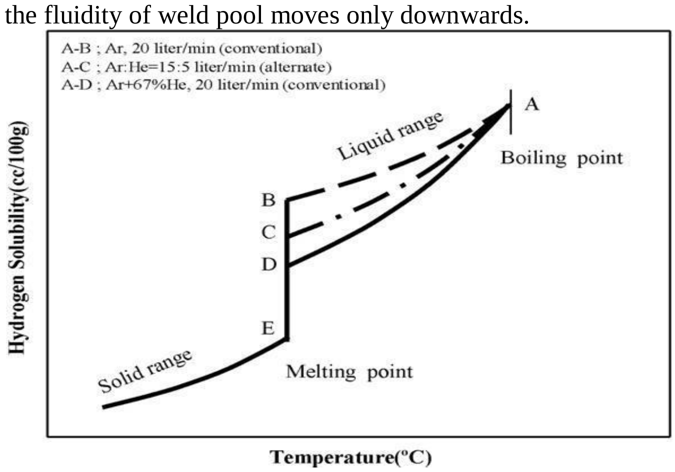


Fig. 5. Schematic diagram showing the difference of hydrogen solubility with temperature with type of gas and type of gas supply.

The behavior of weld pool and the variation of arc pressure observed on supplying alternately Ar and He in flow rate of 15 l/min and 5 l/min, respectively by alternate method is shown in Fig. 7(b). On supplying Ar, welding current increases, and thus arc pressure increases as arc pressure is changes depending upon the type of supplied gas (Kazuo et al., 1985; Adonyi et al., 1992). Alternate supply of Ar and He produces peak of arc pressures in between whenever there is a change in shielding gas from Ar to He or vice versa. As illustrated in Fig. 7(b), the variations of arc pressure gives rise to the variation in the behavior of weld pool. Supplying alternately Ar with higher arc pressure and He with lower pressure causes weld pool to move downwards and vice versa, respectively. Accordingly, when compared to supplying Ar + 67%. He with conventional method, supplying alternately Ar and He by alternate method is considered to show higher fluidity.

Consequently, it can be inferred that in the alternate method, the increase of the fluidity of weld pool helps in escaping of hydrogen gas bubbles, which is the cause of weld porosity in weld pool. Matsuda et al. (1978) reported that turbulent convective fluid flow during solidification produces a substantial reduction in porosity in 5083 and 5052 aluminum welds deposited by the GTAW process. The similar result was also observed in the multi-pass welds. Weld porosity in multi-pass welds was observed by the naked eye for fracture surface of specimen welded. To do this, the nick break test by three point bending method for completed multi-pass welds was performed. Fig. 8 shows the fracture surface produced by the nick break test of multi-pass welded specimen. On welding by supplying Ar by conventional method, a great deal of weld porosity was observed whereas in the case of supplying Ar + 67%He by conventional method and Ar and He by alternate method comparatively showed sound welds.

3.3. Effect of alternate supply of argon and helium on weld shape

Fig. 8 shows macroscopic views of the cross-section and the variation of the depth and width of weld penetration measured from specimen welded under a shielding atmosphere supplying alternately Ar and pure He with flow rate of 15 l/min and 5 l/min, respectively by alternate method and supplying Ar and Ar + 67%He with flow rate of 20 l/min by conventional method.

The shielding gas may have a pronounced effect on the weld shape in both GTA and GMA welding processes. Pure helium gas possesses higher thermal conductivity than argon and also produces arc plasma in which the arc energy is more uniformly dispersed.The argon arc plasma is characterized by a very high-energy inner core and an outer mantle of lesser heat energy (Hilton and Norrish, 1988; Brosilow, 1978; Salter andDye, 1971;Kennedy, 1970). This difference in characteristics of arc strongly affects the weld bead profile. The helium arc produces a deep and broad weld bead whereas argon arc produces a bead profile most often characterized by a papillary (nipple) type penetration pattern.

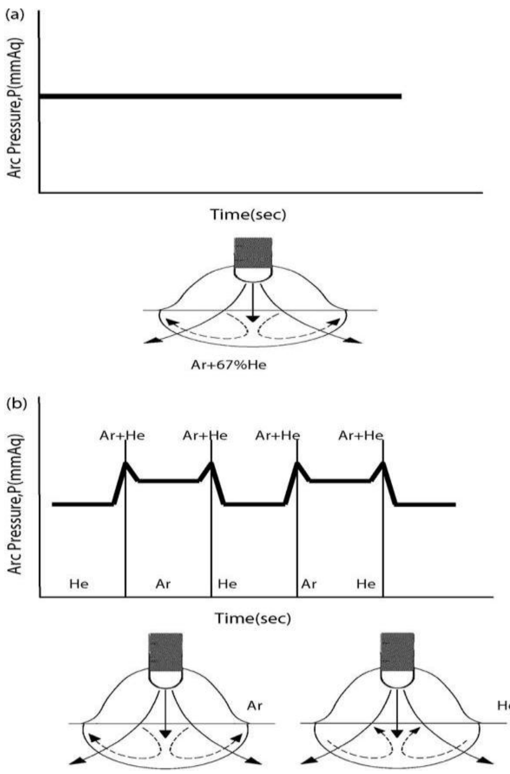


Fig. 6. Schematic diagram showing the variation of arc pressure and weld pool behavior with type of shielding gas and type of gas supply: (a) Ar + 67%He, conventional and (b) Ar to He, alternate.

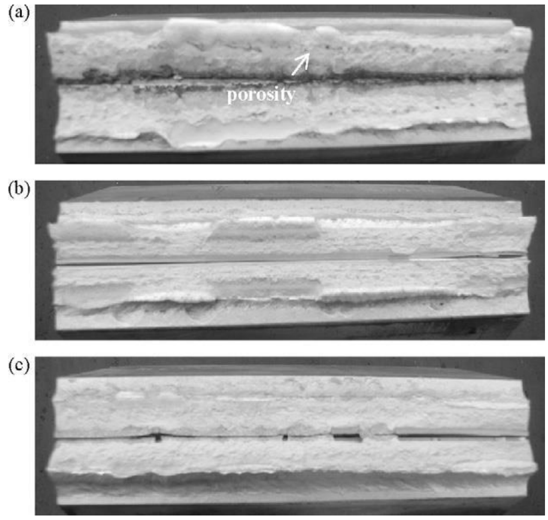


Fig. 7. Views of fracture surface of multi-pass welded specimens: (a) Ar, conventional, (b) Ar + 67%He, conventional and (c) Ar to He, alternate.

3.3. Effect of alternate supply of argon and helium on weld shape

The reason for it is as follows: although the arc plasma with arc energy in pure argon is concentrated, the heat transfer in weld pool is larger in the direction of the width of weld pool than in the direction of the depth of weld pool because of greater thermal conductivity of aluminum, and thus the lower depth of weld penetration is due to the dispersion of arc heat. Whereas arc plasma in Ar + 67%He expands and has higher arc energy and thus the arc heat contributes to the depth and width of weld penetration. Therefore, Ar + 67%He produces deeper and wider weld penetration. Meanwhile, in the case of alternate method, the deepest and Broadest weld profile was produced. It is considered that this is due to the combine effect of the characteristics of the arc concentration of Ar and the arc expansion of He under acting of arc pressure of impulse with alternate supply of shielding gas as shown in Fig. 7(b). As shown in Fig.8,macroscopic views of cross-section of specimen, respectively is shown well such results.

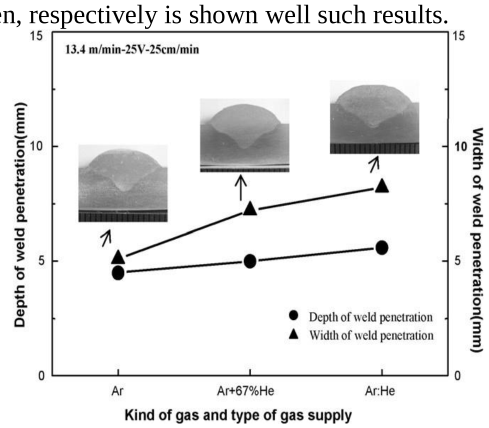


Fig. 8. Comparison of weld shape with type of gas and type of gas supply.

4. CONCLUSION

An investigation to find the effect of alternate supply of shielding gases in aluminum GMA welding was carried out. The following conclusions were made:

1. Under the same welding conditions, compared with the welding by supplying Ar and Ar + 67%He by conventional method, the welding by supplying alternately Ar and He, produced the lowest degree of weld porosity.
2. Under the same welding conditions, compared with the welding by supplying Ar and Ar + 67%He by conventional method, the welding by supplying alternately Ar and He, produced the deepest and broadest weld penetration profile.
3. Compared with Ar + 67%He, alternate supply of Ar and He gives the advantage of reducing weld porosity and improved weld shape.

5. REFERENCES

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