Study on effect of welding parameters on weld bead geometry of AC TIG welding in aluminium

Niramay Ghosh[1*] and Santanu Das[2]

[1*]*Mechanical Engineering Department, Asansol Engineering College, Asansol*
[2]*Department of Mechanical Engineering, Kalyani Govt. Engineering College, Kalyani*

ABSTRACT

Keywords:
Aluminium,
TIG Welding,
Visual Bead Inspection,
Penetration,
Bead Width,
Bending Test,
Micro Hardness Test.

Aluminium and aluminium alloys have large uses in different industries due to its higher strength to weight ratio. Due to controllable heat input and filler consumption Tungsten Inert Gas Welding (TIG) is widely used in aluminium welding. In this work, bead geometry of Al 6060 alloy have been studied in different AC TIG welding parameters, like welding current, welding speed etc. Butt joint was performed. From the observation, it is found out that at a current 177, 190 and 200 A with a welding speed of 110, 130 and 150 mm/min respectively, good depth of penetration can be achieved, and hence, this condition can be used for joining aluminium alloy satisfactorily.

1. Introduction

Aluminium and its alloys are used for several applications due to its various properties like good low temperature toughness, high strength to weight ratio etc., [1, 2]. Many of these applications require welding as a tool for fabrication.

Partially melted zone cracking (PMZ) in AA6061 welding was investigated by Rao et al.,[3]. They studied PMZ cracking of AA6061 alloy with fillers as GTAW AA4043 and AA5356. They varied different parameters like current, pulsed current. They used scandium, zirconium and tabor for refining grains in the above fillers. In metallurgical analysis, PMZ cracking susceptibility was found higher in AA5356 than with AA4043. It has been seen reduction in pulsed current application. Various grain refiners reduced that type of cracking.

Morphology Variation and mechanical properties of Al6061 automotive aluminium alloy in GTAW with Al4043 filler of diameter 1.6mm were investigated by optical metallography, scanning electron microscopy, micro hardness measurement, X-ray diffraction, tensile testing and fractography by Fahimpour, et al., [4].

*Corresponding author,
E-mail: niramoybiet@gmail.com (Niramay Ghosh)

The centre-line dendritic micro structure and micro hardness lessening at heat-affected zone (HAZ) were investigated in TIG welding. Weldability is reduced due to the presence of magnesium and silicon in Aluminium 6061 alloys. It was seen that microstructure of GTAW sample had coarse columnar grains. Mechanical properties like tensile and fatigue properties of such alloys minimized with pulsed current flow [4].

Pitting effect of pulsed TIG welding parameters were investigated by Kumar et al. pitting effect is nothing but the extremely localised corrosion making holes inside the weld [5]. Basically continuous current flow provides better welding efficiency and mechanical property of the welding portion. But when they investigated the pitting effect with pulsed current variation, at certain conditions they got least corrosion result. It was seen that pulsed current provided better mechanical properties in 6061 aluminium alloy. By regression analysis, they made a model a pitting corrosion at different pulsed current. They saw peak current and pulsed frequency were directly proportional to the pitting resistance. When peak current was increased, pitting resistance also increased. Similarly this resistance was found to increase with pulsed frequency. This resistance power was also observed to be dependent upon pulse on time. With the increase in pulsed on time, corrosion resistance also shown as in increasing trend [5].

Huang et al studied the porosity formations in alternating current TIG welding on aluminium alloys at two different conditions: such as use of a groove and thickness of the welding root face [6]. They have used pulsed current. They achieved an improvement in weld quality with the application of a groove. With 2 mm welding root face thickness, number of pores and pores region were reduced [6].

Huang et al studied the porosity formation on the basis of sheet gap in pulsed TIG welding of 5A06 Al alloy [7]. X-ray was used for validation of analytical outcomes. They got reduction in porosity significantly with the use of appropriate gap [7].

Inconsistency of mechanical properties in GTA welding in 2219 Al alloy was studied by Zhang et al [8]. Mechanical properties of the welded portions can be boosted up by two ways, firstly by regulating the process parameters the contours of the joints can be tuned, secondly by regulating welding heat input and speed of wire feeding, the degree of segregation in weld zone as well as partially melted zone can be decreased [8].

Depth of penetration, behaviour of molten pool and the arc shape were studied in direct current straight polarity GTA welding on aluminium alloy by chen et al.,[9]. They observed that with the helium gas streaming rate of 5 to 20 L/min, tearing of oxidation layer was decreased and due to the compression effect, penetration was increased with gas flow [9].

2. Experimental Work

2.1. Experimental Set-up

The experimental investigation was performed by a Gas Tungsten Arc Welding machine as shown in Fig. 1. Photographs of welding torch holding device, constant welding speed controlling device are shown in Fig. 2 and Fig. 3 respectively. The specification of the welding machine and its accessories, work piece, Filler, Electrode used in the investigation are given as follows:

2.1.1. Welding machine and other accessories specification

Welding was conducted by KEMPPI make tungsten inert gas (TIG) welding machine. Welding current can be controlled from 3 to 300 A, but voltage is not adjustable. Detail specifications are given in

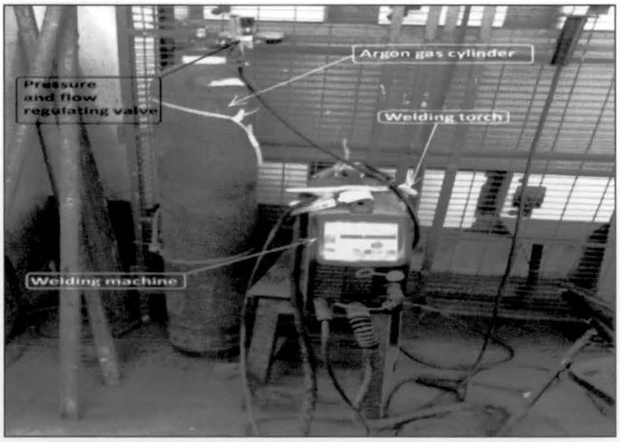

Fig. 1. Tungsten inert gas welding machine.

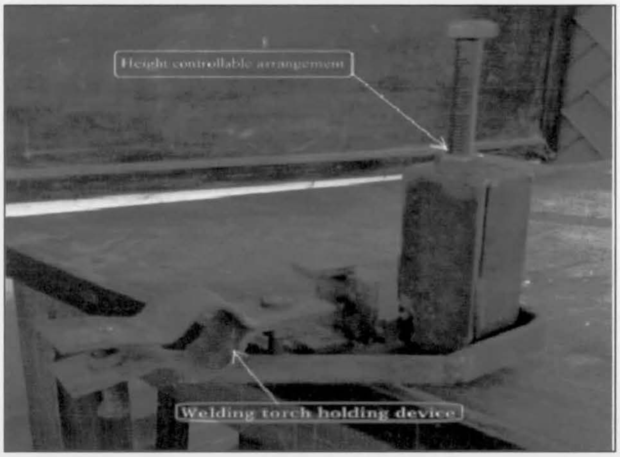

Fig. 2. Photograph of welding torch holding device with electrode work piece gap controllable arrangement.

Fig. 3. Photograph of constant welding speed controlling device.

Table 1. Welding torch holding device was made indigenously and is shown in Fig. 2. Electrode work piece gap can be controlled by the welding torch holding device with a height controllable arrangement. Welding electrode is attached by the welding torch holding device on a constant welding speed controlling device for getting a constant speed.

Table 1
Specifications of welding machine.

Welding machine &	Master TIG MLS™ 3003 ACDC, KEMPPI,
Sl. No.	2067667
Connection voltage	3~230 V -10 % ... 460 V +10 %
Rated power at maximum current	9.2 kV-A
Welding range	3 A/10 V – 300 A/22 V
Power factor at max. current	0.95
Striking voltage	Up = 10 kV

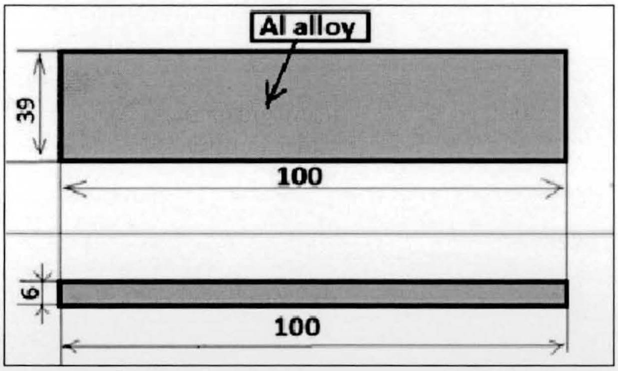

Fig. 4. Dimension of parent material (Al 6060).

2.1.2. Work piece dimension

The experimental investigation was performed on flat plates(100mm×39mm×6mm) of Al 6060 alloy with Al 4043 filler of diameter 2.2 mm, as shown in Fig. 4.

2.2. Experimental Procedure

Experiments of AC TIG welding were conducted on Al 6060 with Al 4043 filler wire without any edge preparation. Electrode work piece gap was set at 4 mm before each pass. Experiment was done at five different welding currents and at three different welding speeds. Table 2. shows details of parameters of experiment.

2.2.1. Heat input

In this experiment heat input has been calculated by using the following relation [10,11].

$$Q = \{(V \times I \times 60)/(S \times 1000)\} \times \text{Efficiency}$$

Where,

Q = Heat input (kJ/mm)
V = Voltage (V)
I = Current (A)
S = Welding speed (mm/min)
Efficiency = For TIG welding process efficiency is 0.75[12].

Table 2
Details of parameters of experiment.

Current type	AC square wave
Balance	-25%
Frequency	60 Hz
Used gas	100 % Argon
Gas flow rate	15 lit/min
Gas pressure	1 kg/cm^2
Electrode- work-piece gap	4mm
Welding torch angle	90°
Electrode type	Thoriated tungsten
Electrode diameter	2.4 mm
Filler diameter	3.2 mm
Root gap	1 mm
Weld current	152, 165, 177, 190, 200 A
Welding speed	110, 130, 150 mm/min
Parent material	Al 6060 (Si 0.353%, Mg 0.099%, Fe 0.128%, Cu 0.07%, V 0.01%)
Hardness of parent material	66.89 HV
Filler material	Al 4043 (Si3.55%, Mg 0.401%, Fe 0.12%)

3. Result and Discussion

3.1. Details of Experiment on Butt Joint of Al 6060 with 4043 Filler Material and Discussion on Results Obtained

3.1.1. Conditions for experiment

AC TIG welding was conducted on Al-6060 alloy using Al-4043 filler wire of diameter 3.2mm alloy at the frequency of 60 Hz with wave balance -25% in 100% argon shielding. Welding was carried out at three different welding speeds without any edge preparation and in each speed, five different levels of current 152, 165, 177, 190 and 200 A were taken. Gas flow rate and pressure were maintained at 15 lit/min and 10kg/cm2. Table 2 shows details of conditions of experiment. Reinforcement, penetration and bead-width were measured over those particular welding conditions by cutting and polishing the weld bead section at 15 mm from welding starting position. Bead quality was observed by visual inspection and dye penetration test. The results are shown in Table 3. Using the tabulated values, graphs have been plotted and presented. It indicates variation on reinforcement, penetration, bead-width with current, under varying welding speed.

3.1.2. Experimental results for experiment

Visual observation of weld-bead at different parameters

After completing the welding, visual observation was made done over the weld beads of different parameters. Fig. 5, Fig. 6, Fig. 7 shows that weld bead widths are increasing with increase of current at three constant welding speeds. Arrow head indicates direction of weld torch movement. Detail observations by visual and dye penetration test of all specimens are given in table 3.

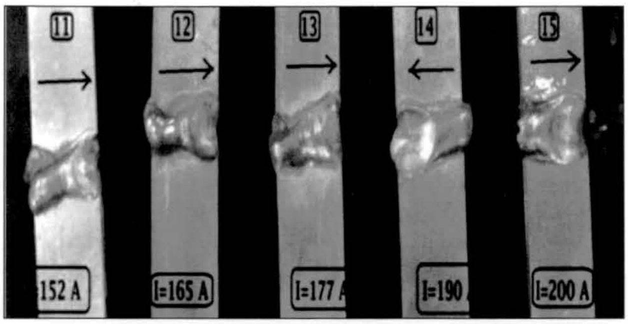

Fig. 5. Weld beads at welding speed 110 mm/min.

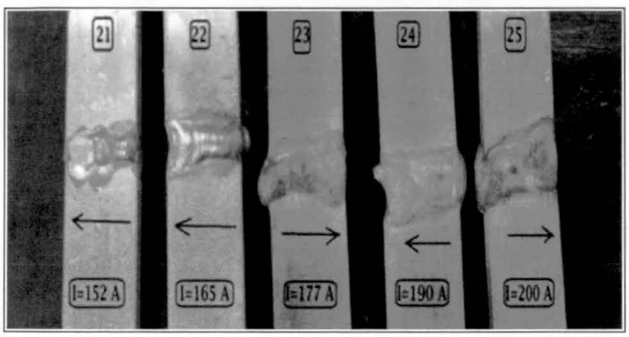

Fig. 6. Weld beads at welding speed 130 mm/min.

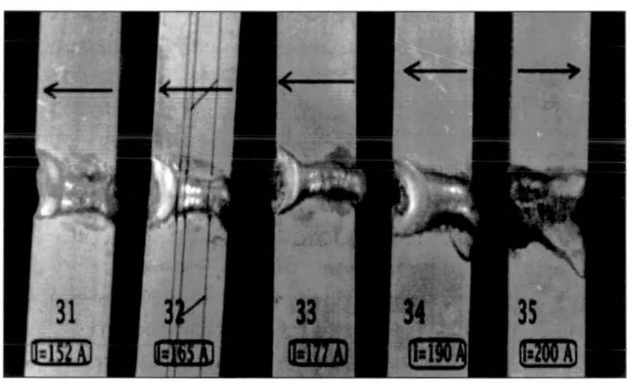

Fig. 7. Weld beads at welding speed 150 mm/min.

Observation of reinforcement, penetration and width of weld bead

Each weld bead was cut at a distance of 10-12 mm from the start position. Then bead section was polished using a belt grinder/ polisher. Reinforcement and penetration was observed on the polished specimens. Reinforcement and penetration were evaluated by tool maker's microscope. It is found that these are gradually changing with current. Bead width measured by a plain steel rule. Evaluated bead geometry of all specimens is shown in table 4.

Variation of penetration with weld current

Plot of variation of penetration depth with current during front side welding is shown in Fig. 8 at three different welding speeds. These plots show on the whole increasing trend in penetration with

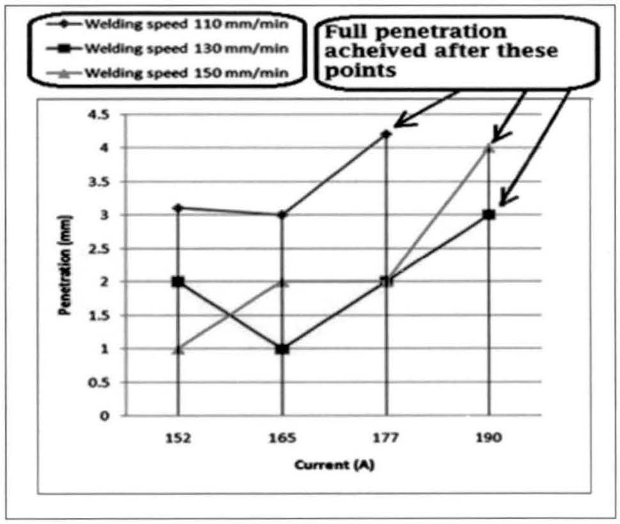

Fig. 8. Penetration at three different welding speeds.

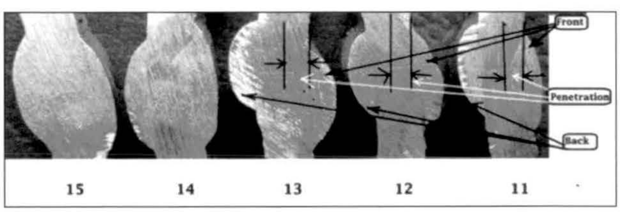

Fig. 9. Penetration of weld-bead at welding speed 110 mm/min.

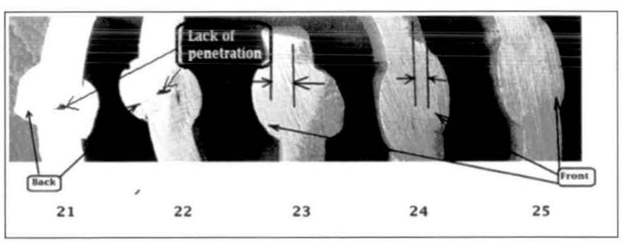

Fig. 10. Penetration of weld-bead at welding speed 130 mm/min.

Table 3

Heat input and weld-bead quality at various levels of current and welding speed.

Sl. No.	Weld Speed (mm/min)	Avg Current (A)	Avg. Voltage (V)	Heat Input (kJ/mm)	Visual Observation and Dye Penetration Test of Weld Bead	
					Front Side	Back Side
1	110	152	21.25	1.321	Good weld bead was achieved. Wettability was not up-to the mark, Initially filler was not melting properly and did not sticking over work piece. Weld bead was porous at the starting portion (Observed by dye penetration).	Good weld bead was achieved. Wettability was not good, Initially filler was not melting properly and did not sticking over work piece. Weld bead was porous at the starting portion (Observed by dye penetration).
2		165	21.75	1.46 8	Better weld bead and wettability was achieved without any porosity. Weldbead was smooth (Observed by dye penetration).	Good weld bead and Better wettability was achieved. No porosity was found and weldbead was smooth (Observed by dye penetration).
3		177	20.85	1.518	Better weld bead and wettability was achieved. No porosity was found and weldbead was smooth. (Observed by dye penetration).	Better weld bead and better wettability. No porosity was found and weldbead was smooth. (Observed by dye penetration).
4		190	22.8	1.772	Better weld bead but little-bit spreaded and very high Wettability. No porosity was found and weldbead was smooth.	Better weld bead and better Wettability. No porosity was found and weldbead was smooth. (Observed by dye penetration).
5	110	200	24	1.993	Highly spreaded weld bead and very high wettability was found. Smooth weldbead without any porosity was found. (Observed by dye penetration).	Spreaded weld bead and very high Wettability was found. Small amount of porosity was observed.(Observed by dye penetration).
6	130	152	22.1	1.158	Wettability was very bad, Initially filler was not melting properly and did not sticking over work piece. Bad weld bead. No porosity was found (Observed by dye penetration).	Wettability was very bad, less than the front side, Initially filler was not melting properly and did not sticking over work piece. Bad weld bead. Weld bead was little bit porous at the starting portion (Observed by dye penetration).
7		165	19.4	1.111	Good weld bead was found. Wettability was better but not upto the mark, Initially filler was not melting properly and did not sticking over work piece. No porosity was observed (Observed by dye penetration).	Wettability was better, Initially filler was not melting properly and did not sticking over work piece. Good weld bead was acheived but not like the front side, that was far better.No porosity was observed. (by dye penetration).
8		177	20.2	1.237	Very good wettability and weld bead was found without any porosity (Observed by dye penetration).	Very good Wettability and weld bead but narrower than the front side with very small amount of porosity was found.
9		190	22.1	1.459	Very good Wettability and weld bead without any porosity was found. (Observed by dye penetration).	Good weld bead and very good Wettability was found but less than the front side. No porosity was observed. (dye penetration).
10		200	22.45	1.569	Very good Wettability with highly spreaded weld bead was present. No porosity was observed.(by dye penetration).	Very good wettability with highly spreaded weld bead without any porosity was found. (by dye penetration).

11	150	152	21.2	0.966	Weld bead was bad. Wettability was very bad, Initially filler was not melting properly and did not sticking over work piece. Very small amount of porosity at the starting portion of weld bead and bead edge, improper filling (Observed by dye penetration).	Weld bead was bad. Wettability was very bad, Initially filler was not melting properly and did not sticking over work piece. Very small amount of porosity at the ending edge of weld bead and bead edge (Observed by dye penetration).
12		165	22.85	1.124	Good weld bead but wettability was very bad, Initially filler was not melting properly and did not sticking over work piece. Very small amount of porosity at the starting portion of weld bead was observed. (by dye penetration).	Weld bead and wettability was very bad, Initially filler was not melting properly and did not sticking over work piece. No porosity was observed. (by dye penetration).
13		177	21.2	1.125	Wettability was very bad, Initially filler was not melting properly and did not sticking over work piece but this sticking is better than the previous condition. Better weld bead without any porosity (Observed by dye penetration).	Bad weld bead. Wettability was bad, Initially filler was not melting properly and did not sticking over work piece but this sticking is far better than the previous condition. Very small amount of porosity at the weld bead, 1-2 small blow holes (Observed by dye penetration).
14	150	190	22.5	1.128	Very good Wettability and weld bead. Filler was properly sticking with work piece. No porosity (Observed by dye penetration).	Very good Wettability and weld bead. Filler was properly sticking with work piece even better than the front side. Very small blow holes (Observed by dye penetration).
15		200	24.8	1.488	Very good Wettability and good but spreaded weld bead. Filler was properly sticking with work piece. Small porosity (Observed by DP test).	Very good Wettability and good but spreaded weld bead. Filler was properly sticking with work piece. Very small blow holes (Observed by DP test).

current. This may be due to the increase of heat input, as heat input increases with current. But at one point with 165 A welding current with a welding speed of 110 mm/min, some deviation from this trend is seen. This may be due to decrease of voltage with the increase of electrode work piece gap as sharp electrode edge gets balling up quickly after first 1 or 2 passes. These changes the constant gap set before the pass. Another reason may be due to the problem relating to manual feeding of filler wire, as more decomposition of filler wire absorbs more amount of heat, it restricts penetration. After 2 or 3 passes, when electrode tip gets balled up to some extent, further balling may be stopped, leading to almost uniform electrode work piece gap. At weld speeds of 110 mm/min, 130 mm/ min and 150mm/min after 178 A, 190 A and 190 A weld current, weld beads show fully penetration. Fig. 9, Fig. 10 and Fig. 11 show penetration at weld-bead cross-section at five different weld currents and three different welding speeds. These photographs of weld joints were taken after bending test.

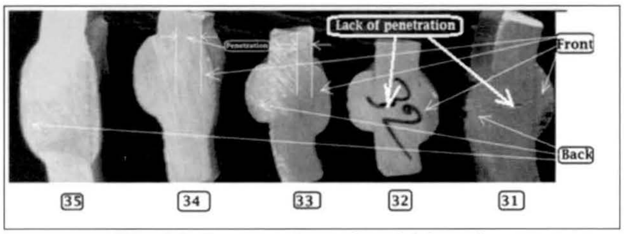

Fig. 11. Penetration of weld-bead at welding speed 150 mm/min.

Variation of bead width with current

Plot of bead width with current at three different welding speeds of front side welding is shown in Fig. 12. These plots show on the whole increasing bead width with current. This trend of increasing bead width is achieved due to increase of heat input with increase of current, at a constant welding speed. When heat input increases, parent metal and filler both liquefy properly, which increases spread ability of the filler metal, thus width of bead increases. Fig. 12 shows only two points that are deviated from this trend. This may have occurred due to manual feeding of filler. Fig. 13, Fig. 14,

Table 4

Evaluation reinforcement, penetration and bead width of weld bead.

Sl. No.	Welding Speed (mm/ min)	Average Current (A)	Heat Input (KJ/ mm)	Reinforcement (mm)		Penetration (mm)		Weld bead width (mm)		Penetration Remark
				Front	Back	Front	Back	Front	Back	
1		152	1.321	1.7	3.1	3.1	0.5	14.5	12.0	Very less
2		165	1.468	2.7	2.2	3.0	0.5	15.0	11.0	Better
3	110	177	1.518	2.8	3.0	4.2	1.5	15.0	11.0	Good penetration, both sides almost touch each other.
4		190	1.772	1.6	2.8	Full	Full	17.0	14.0	Penetration depth at each Individual side was not measurable, as it was fully penetrated
5	110	200	1.993	1.5	2.4	Full	Full	16.0	15.0	Penetration depth at each Individual side was not measurable, as it was fully penetrated
6		152	1.158	2.4	3.3	2.0	1.0	11.0	11.0	Lack of penetration.
7		165	1.111	2.3	3.6	1.0	0.5	11.0	14.0	Lack of penetration.
8		177	1.237	2.6	3.9	2.0	1.0	13.5	15.0	Small penetration
9	130	190	1.453	2.0	2.5	3.0	2.7	14.0	12.0	Very good penetration.
10		200	1.569	2.0	2.4	Full	Full	16.0	11.0	Penetration depth at each Individual side was not measurable, as it was fully penetrated
11		152	0.966	3.0	4.0	1.0	0	11.0	10.0	Lack of penetration.
12		165	1.124	2.9	3.9	2.0	0.5	10.0	9.0	Lack of penetration.
13	150	177	1.125	2.6	3.5	2.0	0	10.5	8.5	Lack of penetration.
14		190	1.282	1.5	3.2	4.0	1.0	14.0	12.5	Good at front side
15		200	1.488	1.0	3.0	Full	Full	18.0	17	Penetration depth at each Individual side was not measurable, as it was fully penetrated

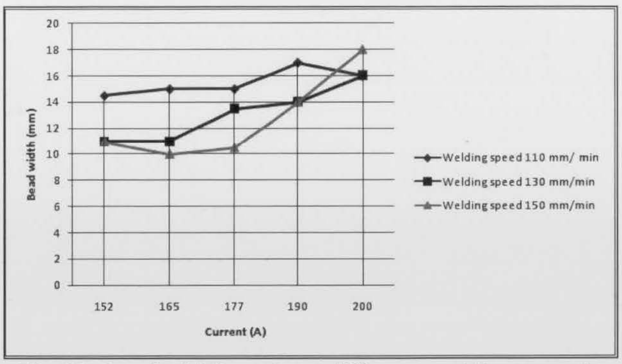

Fig. 12. Bead width at three different welding speeds.

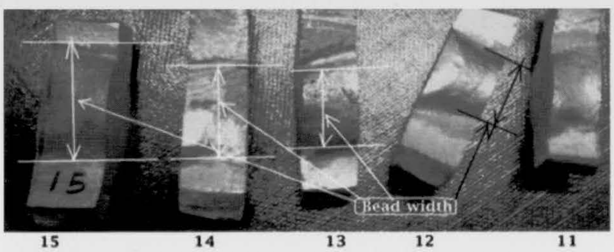

Fig. 13. Bead width at welding speed of 110 mm/min.

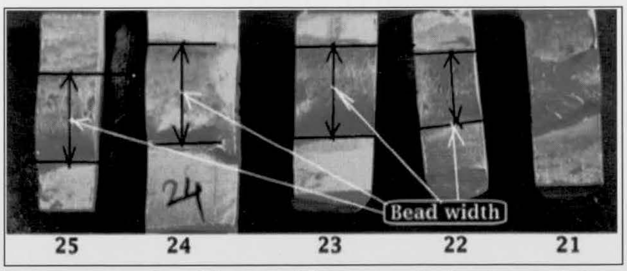

Fig. 14. Bead width at welding speed of 130 mm/min.

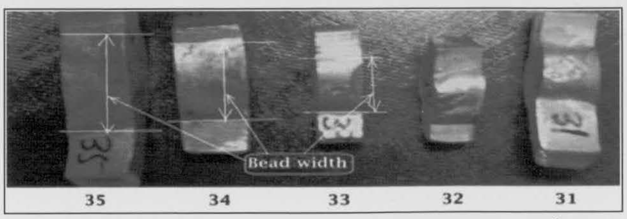

Fig. 15. Bead width at welding speed of 150 mm/min.

Fig. 15, show width of weld-bead at different values of current and welding speeds. These photographs of weld joints were taken after bending test. It is also seen that for a specific

Table 5
Bending test at universal testing machine.

Sl. No.	Welding Speed (mm/min)	Average Current (A)	Heat Input (kJ/mm)	Load at 15° (kN/mm)	Load at 30° (kN/mm)	Load at 45° (kN/mm)	Load at 60° (kN/mm)	Remarks
1	110	152	1.321	0.125	0.148	0.160	0.160	No cracks
2		165	1.468	0.124	0.151	0.168	0.168	No cracks
3		178	1.518	0.125	0.15	0.16	0.16	No cracks
4		190	1.772	0.124	0.146	0.146	0.160	No cracks
5		202	1.993	0.112	0.128	0.14	0.14	No cracks
6	130	151	1.158	0.08	0.088	0.092	0.1	No cracks
7		165	1.111	0.088	0.097	0.097	0.102	No cracks
8		177	1.237	0.066	0.093	0.1	0.1	No cracks
9	130	190	1.453	0.074	0.088	0.091	0.097	No cracks
10		202	1.569	0.093	0.097	0.12	0.128	No cracks
11	150	152	0.966	0.093	0.097	0.106	0.106	No cracks
12		164	1.124	0.125	0.142	0.16	0.165	No cracks
13		177	1.125	0.12	0.142	0.154	0.160	No cracks
14		190	1.282	0.112	0.116	0.116	0.12	No cracks
15		200	1.488	0.112	0.12	0.124	0.132	No cracks

Table 6
Micro hardness test results of fully penetrated specimen.

SL. No.	Welding Speed (mm/min)	Average Current (A)	Heat Input (KJ/mm)	Micro Hardness Vickers Hardness No (HV)			
				Test 1	Test 2	Test 3	Average
1	110	190	1.772	46.9	60.2	55	55.03
2	110	202	1.993	60.4	68.4	62.2	63.66
3	130	202	1.569	63	75	76	71.33
4	150	200	1.488	64	58.5	59.4	60.63

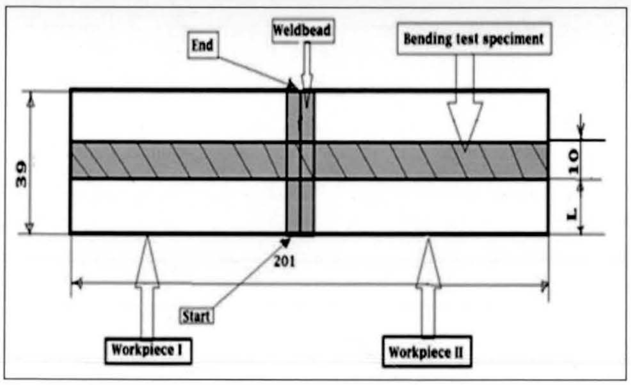

Fig. 16. Location of bending test specimen to cut from a work piece (L is from 10-12 mm).

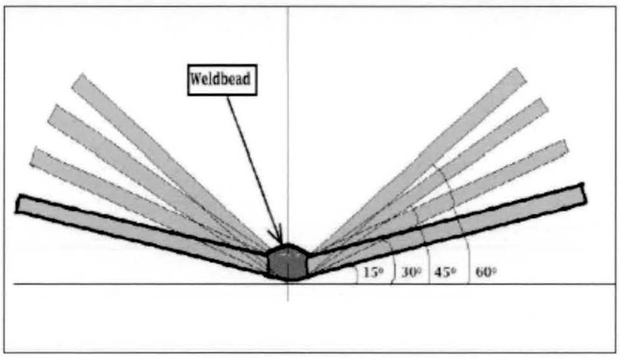

Fig. 17. Bending with the application of load.

welding current, bead width is, in general high at a low welding speed.

Results of bending test

Table 5 shows load was applied up to a bend angle of 600. There was no any crack produced up to this bend angle. Welded specimen was cut cross sectionally to the weld bead at the distance of L(10-12 mm) from welding start position as shown in Fig. 16. Bending test specimen of width around 10 mm was taken for testing purpose at Universal Testing Machine. With increasing load, specimens were started to bend as shown in Fig. 17. Load was noted down at different angles (15°, 30°, 45°, 60°). Table 5 shows observations of different load per unit width at different angles of all specimens.

Results of micro-hardness test

Weld beads were cut and polished to conduct micro hardness (Vickers Hardness) testing over it. The applied load was 200 gm. Micro hardness testing was done three times at the mid position fo each specimen (fully penetrated). Table 6 shows average micro hardness testing results of all fully penetrated specimens.

Conclusion

From the above experiment it can be concluded that welding with a higher current provides better penetration but wider bead width. Specifically in experiment set-I, at a welding speed of 110, 130 and 150 mm/min with a current 177, 190 and 200 A, provided good penetration depth. This may be due to the increase of heat input, as heat input increases with current.

References

1. ASM Metals Handbook, vol. 2, 10th Ed., ASM International, USA, 1993.
2. AWS Welding Handbook, vol. 3, 8th Ed., Chapter on Welding Aluminum, American Welding Society, USA.
3. Rao, KP; Ramanaiah, N; Viswanathan, N: Partially melted zone cracking in AA6061 welds, 'A Journal Of Materials & Design', vol. 29, 2008, 179-186.
4. Fahimpour, V; Sadrnezhaad, SK; Karimzadeh, F: Microstructure and Mechanical Property Change During FSW and GTAW of Al6061 Alloy, 'A Journal of The Minerals, Metals & Materials Society', vol. 44A, 2013, 2187–2195.
5. Kumar, TS; Balasuvramanian, V; Sanavullah, M, Y; Babu, S: Effect of Pulsed Current TIG Welding Parameters on Pitting Corrosion Behaviour of AA6061 Aluminium Alloy, 'A Journal of Material Science & Technology', vol. 23, 2006, 223–229.
6. Haung, Y; Wu, D; Lv, N; Chen, H; Chen, S: Investigation of Porosity in Pulsed GTAW of Aluminum Alloys Based on Spectral and X-Ray Image Analyses, 'Journal of Materials Processing Technology', vol. 243, 2017, 365-373,
7. Haung, Y; Zhao, D; Chen, H; Yang, L; Chen, S: Porosity Detection in Pulsed GTA Welding of 5A06 Al Alloy Through Spectral Analysis, 'Journal of Materials Processing Technology', vol. 259, 2018,332-340.
8. Zhang, D; Wang, G; Wu, A; Zhao, Y; Li, Q; Liu, X; Meng, D; Song, J; Zhang, Z: Study on the Inconsistency in Mechanical Properties of 2219 Aluminium Alloy TIG-Welded Joints, 'J of Alloys and Compounds', vol. 777, 2019, 1044-1053.
9. Chen, C; Wei, X; Zhao, Y; Yan, K; Jia, Z; He, Y: Effects of Helium Gas Flow Rate on Arc Shape, Molten Pool Behaviour and Penetration in Aluminum Alloy DCEN TIG Welding, 'J of Materials Processing Technology', vol. 255, 2018, 696-702.
10. Funderburk, R, S: Key Concept in Welding Engineering, 'Welding Innovation', vol. 16, 1999, 1-4.
11. http//ssabox.com, Welding of Weldox and Hardox, 'SSAB oxelosund, 2007, 1-16.
12. Balasubramanian, V; Ravisankar, V; Reddy, GM: Effect of Pulsed Current Welding on Fatigue Behaviour of High Strength Aluminium Alloy Joints, 'Journal of Materials & Design', vol. 29, 2008, 492-500 ◘

Niramay Ghosh is working currently as Asst Prof, Dept of Mechanical Engg, Asansol Engineering College, Asansol, West Bengal, India. He graduated in 2012. He obtained his post graduation in 2014 from Kalyani Govt. Engineering College, Kalyani, West Bengal, India. He has 5 years of teaching experience. He presented a seminar paper in National welding seminar. His area of interest is production.

Dr. S Das is, at present, Prof. & Head of Mech. Engg. Dept. of Kalyani Govt. Engg. College, Kalyani, West Bengal, India. He was awarded Doctor of Philosophy in Engineering by IIT Kharagpur in 1997. He guided five Ph.D's, 123 MTech and 97 BTech projects in the area of machining, grinding, coating, weld cladding, inventory management, etc. At present, he is guiding seven Ph.D. research scholars. He has 140 publications in Journals, and 80 in International and 135 in National Conferences. He was awarded 'Shiksha Ratna' on September 05 2018 by the Dept. of Education, Govt. of West Bengal as an Outstanding Teacher. He delivered 17th Hem Chandra Dasgupta Memorial Lecture in 2016 and Engineer Soumitra Kumar De Memorial Lecture in 2019 as invited by the West Bengal State Centre of The Institution of Engineers (India) and Kolkata Branch of The Indian Institute of Welding respectively.