Characterization Of Butt-Welded Aluminum Alloy with Magnesium Alloy by Tig Welding

Monil Kachhadiya

Abstract— The arc is produced between a pointed tungsten electrode and the workpiece in an inert environment of argon or helium during the TIG welding process. Multiple variety alloying approach is used to combine dissimilar metal alloys. Based on an investigation of the characteristics of the Aluminium alloy and Magnesium alloy, a Zinc-based filler wire is used in TIG welding of the Magnesium (AZ31B) - Aluminium (6061) joint to decrease the formation of intermetallics, which is the weakest part of the joint. By changing welding parameters such as Welding Current and Welding Speed while maintaining one of them constant at a time. Various tests, including as the Tensile Strength Test, Face Bend Test, Root Bend Test, Micro Examination, Macro Examination, and Vickers Hardness Test, were used to determine the best welding parameters. The impact of changing welding parameters on ultimate tensile strength, ultimate bending load, macrostructure, microstructure, and hardness is investigated. The formation of brittle intermetallic compound of Aluminium and Magnesium is reduced and a good quality weld is obtained with the aid of zinc filler wire.

Keywords— TIG Welding; Aluminium Alloy (6061); Magnesium Alloy (AZ31B); Ultimate Tensile Strength; Ultimate Bending Load; Welding Current; Welding Speed; Intermetallic; Vickers Hardness; Macro Examination; Micro Examination.

1 Introduction

Use of energy-saving and environmental-protective potential, lightweight materials have piqued the curiosity of scientists in the automotive and aviation production sectors. Aluminium and Magnesium are common lightweight metals used in these applications, and welding these different elements together is advantageous. The use of Magnesium alloys in combination with Aluminium alloys increases flexibility of design along with decreasing weight of structural components. Joining Magnesium alloy with Aluminium alloy is challenging using today's joining techniques. Because the area where intermetallics are generated is the weakest part of the joint, Aluminium–Magnesium intermetallics is most important and sensitive criteria for joining Aluminium alloy and Magnesium alloy. In other welding techniques utilized in the Aluminium and Magnesium joining process to regulate the thickness of intermetallics include magnetic pulse welding, friction stir welding and diffusion bonding. In the Aluminium and Magnesium welding process, the formation of Aluminium–Magnesium intermetallics is nearly inevitable. Formation of intermetallics can be controlled by varying welding parameters in TIG welding process and can be reduced significantly by welding at optimum parameters. In an Aluminium alloy, some amount of zinc is already present. Magnesium interacts with Zinc quicker than Magnesium interacts with Aluminium to create Magnesium– Zinc intermetallics. As a result, the Zinc filler wire is viable for joining Magnesium and Aluminium together. Multiple variety alloying approach is used in this work to combine dissimilar metal alloys.

2 Experimental Setup

Selection of appropriate Aluminium alloy and Magnesium alloy which is best suitable for TIG welding. Al 6061 and Mg AZ31B are selected and are cut in dimension of 75mm x 45mm x 2mm. Chemical composition and mechanical properties of Al 6061 and Mg AZ31B are shown in table 2.1 and table 2.2. Plates are cleaned as shown in figure 2.1 since there is deposition of oxide layer on its surface which is not suitable for welding and V Groove is made to make a butt joint by TIG welding process.

Table 2.1: -Chemical Composition and Mechanical Properties of Al Alloy (6061 T6)

Weight %	Mn	Si	Cr	Cu	Fe	Zn	Mg	Ti	Other Each/Total	Al
Aluminium 6061 T6	0.15	0.4-0.8	0.15-0.35	0.15-0.4	0.7	0.25	0.8-1.2	0.15	0.005/0.15	Balance

Mechanical Properties	Value
Tensile Strength	310 MPa
Yield Strength	276 MPa
Shear Strength	207 MPa
Vickers Hardness	105 HV/10
Density	2.7 g/cm^3
Elongation	12-17%

Table 2.2: -Chemical Composition and Mechanical Properties of Mg Alloy (AZ31B)

Weight %	Al	Zn	Mn	Si	Cu	Ca	Fe	Ni	Others	Mg
Magnesium AZ31B	2.5-3.5	0.7-1.3	0.2 min	0.05 max	0.05 max	0.04 max	0.005 max	0.005 max	0.30 max total	Balance

International Journal of Scientific & Engineering Research, Volume 12, Issue 7, July-2021
ISSN 2229-5518

Mechanical Properties	Value
Tensile Strength	260 Mpa
Yield Strength	200 MPa
Shear Strength	130MPa
Vickers Hardness	83 HV/10
Density	1.77 g/cm^3
Elongation	15%

Figure 2.1: - Al 6061 and Mg AZ31B

Selection of appropriate zinc-based filler wire for butt welding of Al 6061/Mg AZ31B by TIG welding process. Zinc based filler wire AL822 (Zn78Al22) i.e., wire composition having 78% zinc and 22% aluminium of 3 mm diameter is selected. TIG welding is done using "AC/DC Rajlaxmi TIG 300 Inverter Welding Machine" and its specifications are shown in table 2.3. TIG Welding Machine and TIG Welding Setup are shown in the figure 2.2. Aragon is use as inert gas to prevent oxidation during welding with 15 L/min flow rate.

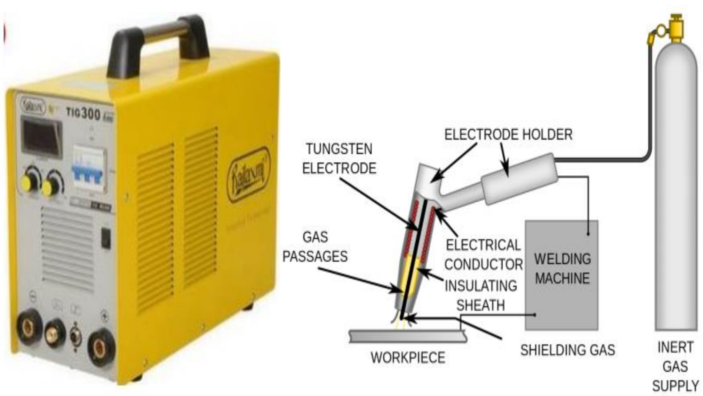

Figure 2.2: - TIG Welding Machine and TIG Welding Setup

Table 2.3: -Tig Welding Machine Specifications

Welding Type	TIG Welding
Output Current Range	5-300A
No-Load Voltage	54 W
Frequency	50/60 Hz
Input Voltage	3 Ph AC 380V +/-15%
Efficiency	85%
Rated Input Current	MMA 12.1A, TIG 12.6A
Duty Cycle	60%
No Load Loss	60 W
Power Factor	0.93

TIG welding is done with Zn based filler wire by varying the welding parameter like welding current and welding speed keeping one of the welding parameter constant at a time. Various butt-welded Mg/Al alloy samples of dimensions 90mm x 75mm x 2mm are obtained by varying welding parameters. Tensile Strength Testing Machine, Digital Vernier Caliper, Bend Testing Machine and Compound Microscope are required for various testing purpose. These welded samples are now tested by visual testing method like bead width, depth of penetration and microstructure. Then these welded samples are cut into strips of dimensions 90mm x 25mm x 2mm and are tested in lab by destructive testing method like hardness test, root bend test, face bend test and tensile strength test.

3 Results And Discussion

3.1 Varying Parameter: Welding Current

Various butt-welded samples of Al-Mg are made by varying welding current (AC) keeping welding speed and voltage constant as shown in figure 3.1. Visual observations were taken and destructive tests were conducted.

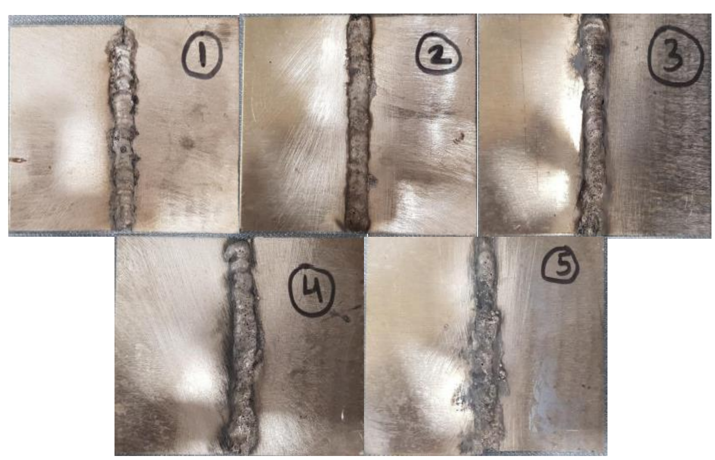

Figure 3.1: - Sample 1-5 In Increasing Order of Welding Current Keeping Welding Speed and Voltage Constant

International Journal of Scientific & Engineering Research, Volume 12, Issue 7, July-2021
ISSN 2229-5518

Table 3.1: -Butt Welded Samples of Mg-Al by Varying Welding Current Keeping Welding Speed and Voltage Constant

Sample	Welding Current (A)	Welding Speed (mm/min)	Welding Voltage (V)	Heat Input (J/mm)
1	110	440	15	225
2	120	440	15	245.45
3	130	440	15	265.9
4	140	440	15	286.36
5	150	440	15	306.81

Welding current is influencing parameter in joining process which affects depth of fusion and depth of penetration with respect to base metal. Amount of heat developed during welding depends upon the current used for given size filler wire. It is therefore essential that a correct current is used to produce good quality of weld and reduce the distortion problems on the job. The value of welding current used in TIG welding has the greatest effect on the deposition rate, the weld bead size, shape and penetration. Keeping all the other welding parameters constant, increasing the welding current will increase the depth of weld penetration and the size of the weld bead. Bead size increases from sample 1-5 (1<2<3<4<5).

With increase in welding current the heat input increases, hence results in better weld penetration but too much high current can also cause convex bead shape, resulting in rough bead, slag inclusions and burn through of the weld plate. While on decreasing weld current heat input decreases which results in improper or less weld penetration which may result in various welding defects. Depth of penetration increases from sample 1-5 (1<2<3<4<5).

Table 3.2: -Tensile Test: Test Method: IS 3600-1997

Sample	Width (mm)	Thickness (mm)	C/S Area (mm^2)	Ultimate Load (kN)	Ult. Tensile Strength (N/mm^2)
1	25	2	50	4.8	96
2	25	2	50	5.7	114
3	25	2	50	6.15	123
4	25	2	50	5.6	112
5	25	2	50	4.9	98

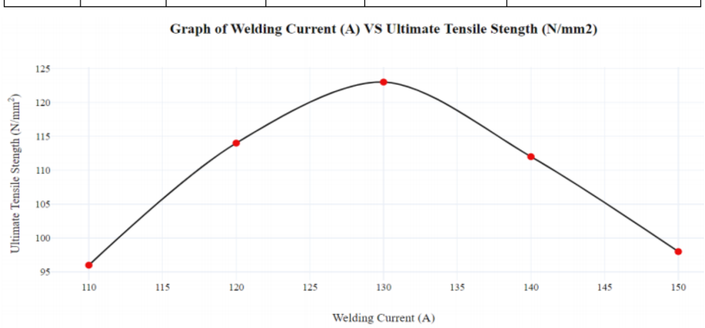

Figure 3.2: -Effect of Welding Current on Ultimate Tensile Strength

Tensile strength test in which tensile (pulling) force is applied to specimen and measures the specimen's response to the stress. It was conducted at room temperature with elongation speed of 2 mm/min of all five samples which are welded by changing welding current keeping welding speed constant. According, data from table 3.2 and figure 3.2, It is observed that on increasing value of welding current from 110A to 130A, value of ultimate tensile strength increases till a point where ultimate tensile strength is maximum i.e., 123 N/mm^2 at 130A welding current.
Then on further increasing the value of welding current above 130A value of ultimate tensile strength decreases.

Table 3.3: -Root Bend Test: Test Method: IS 3600-1997

Sample	Width (mm)	Thickness (mm)	C/S Area (mm^2)	Ultimate Bending Load (kN)	Bend Angle (Degree)
1	25	2	50	3.9	20
2	25	2	50	4.1	31
3	25	2	50	5.2	43
4	25	2	50	4.6	33
5	25	2	50	3.7	24

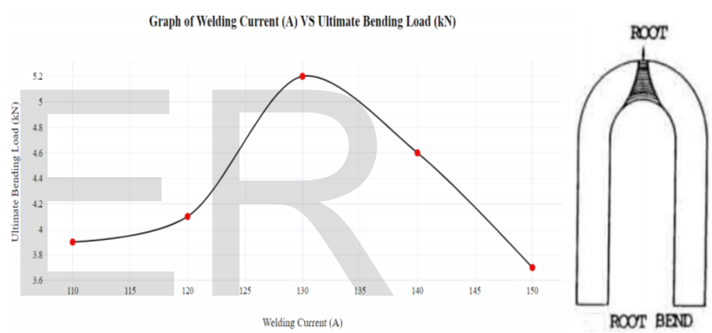

Figure 3.3: -Effect of Welding Current on Ultimate Bending Load for Root Bend Test

Root bend test in which weld root is in tension and weld face is in compression. It was conducted by slowly increasing bending load till weld specimen cracks or breaks. Different bend angles and ultimate bending load were observed for all five samples which were welded by varying welding current keeping welding speed constant.
According, data from table 3.3 and figure 3.3, It is observed that on increasing value of welding current from 110A to 130A value of ultimate bending load increases and angle at which specimen cracks or breaks also increases till a point where it becomes maximum i.e., 5.2 kN and 43 degrees at 130A welding current.
Then on further increasing value of welding current above 130A value of ultimate bending load and angle at which specimen cracks decreases.

International Journal of Scientific & Engineering Research, Volume 12, Issue 7, July-2021
ISSN 2229-5518

Table 3.4: -Face Bend Test: Test Method: IS 3600-1997

Sample	Width (mm)	Thickness (mm)	C/S Area (mm^2)	Ultimate Bending Load (kN)	Bend Angle (Degree)
1	25	2	50	4.3	15
2	25	2	50	4.5	25
3	25	2	50	5.8	37
4	25	2	50	4.7	26
5	25	2	50	4.1	16

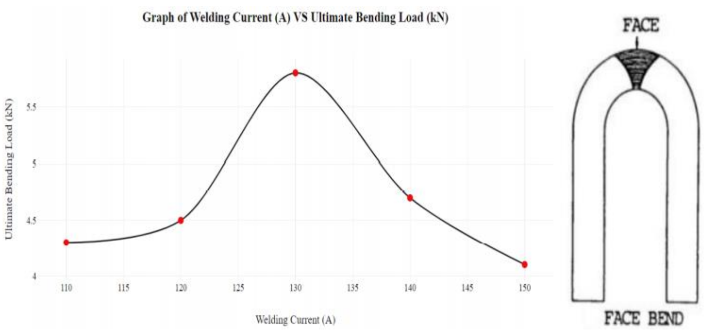

Figure 3.4: -Effect of Welding Current on Ultimate Bending Load For Face Bend Test

Face bend test in which weld face is in tension and weld root is in compression. It was conducted by slowly increasing bending load till weld specimen cracks or breaks. Different bend angles and ultimate bending load were observed for all five samples which were welded by varying welding current keeping welding speed constant.

According, data from table 3.4 and figure 3.4, It is observed that on increasing value of welding current from 110A to 130A value of ultimate bending load increases and angle at which specimen cracks or breaks also increases till a point where it becomes maximum i.e., 5.8 kN and 37 degrees at 130A welding current.

Then on further increasing value of welding current above 130A value of ultimate bending load and angle at which specimen cracks decreases.

Table 3.5: -Macro Examination: Test Method: IS 3600-1997

Parameter Observed	Sample: 1	Sample: 2	Sample: 3	Sample: 4	Sample: 5
Cracks	Observed	Not Observed	Not Observed	Observed	Observed
Undercut	Not Observed	Not Observed	Not Observed	Observed	Observed
Discontinuity	Observed	Not Observed	Not Observed	Not Observed	Not Observed
Burning	Not Observed	Not Observed	Not Observed	Not Observed	Observed
Lack of Fusion	Observed	Observed	Not Observed	Not Observed	Not Observed
Weld Penetration w.r.t. Base Metal	1.1mm	1.6mm	2mm	2mm	2mm
Bead Size	5mm	5.5mm	6.7mm	7.2mm	8mm

Macro Examination was done of all five samples welded by varying welding current. In this examination all samples were categorised based on defects like cracks, undercut, discontinuity, burning and lack of fusion.

At low welding current i.e., below 130A defects like lack of fusion, discontinuity and cracks were observed and at high welding current i.e., above 130A defects like undercut, burning and cracks were observed.

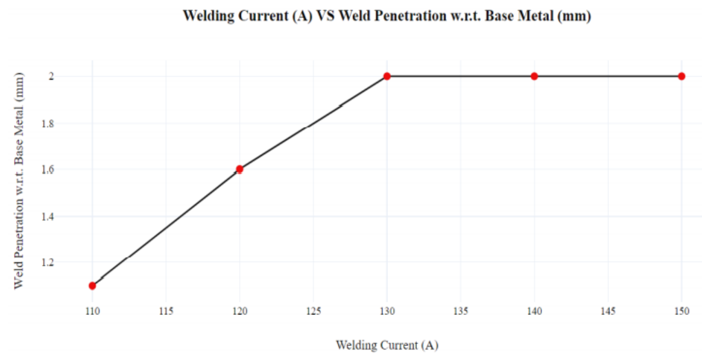

Figure 3.5: -Effect of Welding Current on Weld Penetration w.r.t. Base Metal

Figure 3.6: -Effect of Welding Current on Bead Size

From, above figure 3.5 and figure 3.6, It is observed that weld penetration increases as value of welding current increases, since base metal is of 2mm thickness so after a point on further increasing the value of welding current above 130A weld penetration will remain constant. Weld bead size increases on increasing the value of welding current.

Table 3.6: -Micro Examination: Test Method: IS 3600-1997

Observed	Sample: 1	Sample: 2	Sample: 3	Sample: 4	Sample: 5
At 100X Magnification	Lack of Fusion, Porosity and Cracks	Lack of Fusion, Porosity and Cracks	No Defects Observed	Cracks, Porosity Not Visible	Cracks, Porosity Not visible

Microscopic examination was also done at 100x magnification of all five samples welded by varying welding current.

In sample 1 and 2 which were welded at low welding current i.e., at 110A and 120A lack of fusion, porosity and cracks were observed in microstructure of weld. In sample 2 which is welded at 120A current cracks were not visible in macro exam-

International Journal of Scientific & Engineering Research, Volume 12, Issue 7, July-2021
ISSN 2229-5518

ination test but in microscopic examination cracks were visible.
In sample 4 and 5 which were welded at high welding current i.e., at 140A and 150A cracks were found but porosity was not visible.
In sample 3 which was welded at 130A current no defects were observed at 100x magnification.

Table 3.7: -Vickers Hardness Test: Test Method: IS 1501-2002

Sample Side	Sample: 1 Vickers Hardness (HV-10)	Sample: 2 Vickers Hardness (HV-10)	Sample: 3 Vickers Hardness (HV-10)	Sample: 4 Vickers Hardness (HV-10)	Sample: 5 Vickers Hardness (HV-10)
Base Metals (Al/Mg)	105/83	105/83	105/83	105/83	105/83
Weld	131	137	141	148	152
Heat Affected Zone	106	108	114	119	122

Figure 3.7: -Effect of Heat Input on Vickers Hardness at Base Metal, Weld and Heat Affected Zone

Vickers hardness test was performed on all five samples welded by varying welding current. Since the base metal were unaffected by heat its hardness remained same for all five samples i.e., for Al its 105 HV and for Mg its 83 HV.
According to the data from table 3.7 and figure 3.7, It is observed that on increasing the value of welding current, heat input increases so hardness of weld and heat affected zone increases. High hardness value in sample 5 causes brittle fracture and cracks at weld.
For any particular welded sample, it is observed that hardness value at heat affected zone is less then hardness value at weld.

3.2 Varying Parameter: Welding Speed

Various butt-welded samples of Al-Mg are made by varying welding speed keeping welding current (AC) and voltage constant as shown in figure 3.8. Visual observations were taken and destructive tests were conducted.

Figure 3.8: - Sample 1-5 In Decreasing Order of Welding Speed Keeping Welding Current and Voltage Constant

Table 3.8: -Butt Welded Samples of Mg-Al by Varying Welding Speed Keeping Welding Current and Voltage Constant

Sample	Welding Speed (mm/min)	Welding Current (A)	Welding Voltage (V)	Heat Input (J/mm)
1	540	130	15	216.67
2	440	130	15	265.9
3	360	130	15	325
4	300	130	15	390
5	270	130	15	433.33

Welding speed is defined as the rate of travel of the electrode along the seam or the rate of the travel of the work under the electrode along the seam. Some general statements can be made regarding speed of travel. Increasing the speed of travel while keeping the arc voltage and current constant will decrease the width of the bead and increase penetration until an ideal speed is obtained at which penetration is highest. Increasing the speed beyond this optimum will result in decreased weld penetration with respect to base metal. With a decrease in welding speed, the amount of heat input rises. It was discovered that connections welded at a high welding speed had smaller weld beads than junctions welded at medium and low welding rates. Bead size increases from sample 1-5 (1<2<3<4<5).

How fast the electrode travels down the joint affects how much time the arc energy has to transfer into the base plate at any particular point along the joint. As travel speed increases, the amount of time that the arc is over a particular point along the joint is less and the resulting level of penetration decreases. As travel speed decreases, the amount of time that the arc is over a particular point along the joint is greater and the resulting level of penetration increase. Depth of penetration increases from sample 1-5 (1<2<3<4<5).

International Journal of Scientific & Engineering Research, Volume 12, Issue 7, July-2021
ISSN 2229-5518

Table 3.9: -Tensile Test: Test Method: IS 3600-1997

Sample	Width (mm)	Thickness (mm)	C/S Area (mm^2)	Ultimate Load (kN)	Ult. Tensile Strength (N/mm^2)
1	25	2	50	5.8	116
2	25	2	50	6.0	120
3	25	2	50	5.85	117
4	25	2	50	5.65	113
5	25	2	50	5.2	104

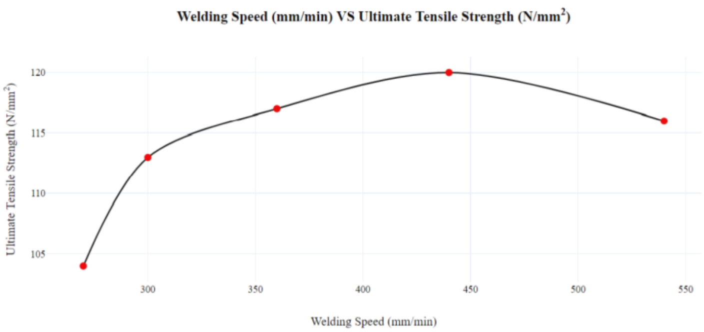

Figure 3.9: -Effect of Welding Speed on Ultimate Tensile Strength

Tensile strength test in which tensile (pulling) force is applied to specimen and measures the specimen's response to the stress. It was conducted at room temperature with elongation speed of 2 mm/min of all five samples which are welded by varying welding speed keeping welding current constant.

According to data from table 3.9 and figure 3.9, It is observed that on increasing value of welding speed from 270 mm/min to 440 mm/min, value of ultimate tensile strength increases till a point where ultimate tensile strength is maximum i.e., 120 N/mm^2 at 440 mm/min welding speed.

Then on further increasing the value of welding speed above 440 mm/min value of ultimate tensile strength decreases.

Table 3.10: -Root Bend Test: Test Method: IS 3600-1997

Sample	Width (mm)	Thickness (mm)	C/S Area (mm^2)	Ultimate Bending Load (kN)	Bend Angle (Degree)
1	25	2	50	4.9	37
2	25	2	50	5.1	42
3	25	2	50	5.0	38
4	25	2	50	4.7	31
5	25	2	50	4.5	23

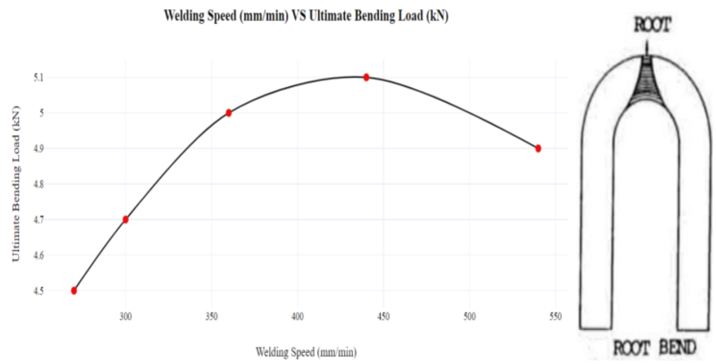

Figure 3.10: -Effect of Welding Speed on Ultimate Bending Load for Root Bend Test

Root bend test in which weld root is in tension and weld face is in compression. It was conducted by slowly increasing bending load till weld specimen cracks or breaks. Different bend angles and ultimate bending load were observed for all five samples which were welded by varying welding speed keeping welding current constant.

According to data from table 3.10 and figure 3.10, It is observed that on increasing value of welding speed from 270 mm/min to 440 mm/min value of ultimate bending load increases and angle at which specimen cracks or breaks also increases till a point where it becomes maximum i.e., 5.2 kN and 42 degrees at 440 mm/min welding speed.

Then on further increasing value of welding current above 440 mm/min value of ultimate bending load and angle at which specimen cracks decreases.

Table 3.11: -Face Bend Test: Test Method: IS 3600-1997

Sample	Width (mm)	Thickness (mm)	C/S Area (mm^2)	Ultimate Bending Load (kN)	Bend Angle (Degree)
1	25	2	50	5.4	31
2	25	2	50	5.6	35
3	25	2	50	5.5	32
4	25	2	50	5.1	26
5	25	2	50	4.9	21

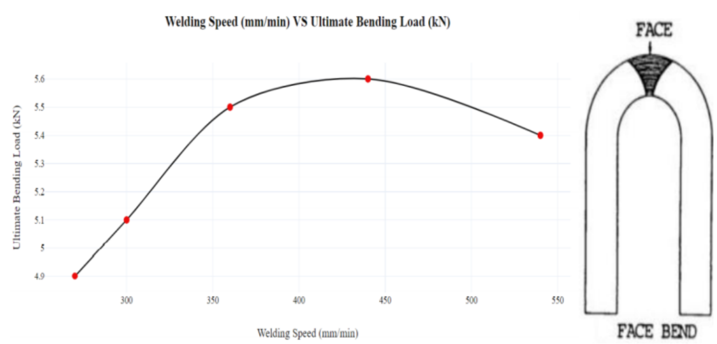

Figure 3.11: -Effect of Welding Speed on Ultimate Bending Load for Face Bend Test

International Journal of Scientific & Engineering Research, Volume 12, Issue 7, July-2021
ISSN 2229-5518

Face bend test in which weld face is in tension and weld root is in compression. It was conducted by slowly increasing bending load till weld specimen cracks or breaks. Different bend angles and ultimate bending load were observed for all five samples which were welded by varying welding speed keeping welding current constant.

According to data from table 3.11 and figure 3.11, It is observed that on increasing value of welding speed from 270 mm/min to 440 mm/min value of ultimate bending load increases and angle at which specimen cracks or breaks also increases till a point where it becomes maximum i.e., 5.6 kN and 35 degrees at 440 mm/min welding speed.

Then on further increasing value of welding speed above 440 mm/min value of ultimate bending load and angle at which specimen cracks decreases.

Table 3.12: -Macro Examination: Test Method: IS 3600-1997

Parameter Observed	Sample: 1	Sample: 2	Sample: 3	Sample: 4	Sample: 5
Cracks	Observed	Not Observed	Observed	Observed	Observed
Undercut	Observed	Not Observed	Not Observed	Observed	Observed
Discontinuity	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed
Burning	Not Observed	Not Observed	Not Observed	Observed	Observed
Lack of Fusion	Observed	Not Observed	Not Observed	Not Observed	Not Observed
Weld Penetration w.r.t. Base Metal	1.6mm	2mm	2mm	2mm	2mm
Bead Size	5.9mm	6.6mm	7.2mm	7.8mm	8.2mm

Macro Examination was done of all five samples welded by varying welding speed. In this examination all samples were categorised based on defects like cracks, undercut, discontinuity, burning and lack of fusion.

At low welding speed i.e., below 440 mm/min defects like undercut, burning and cracks were observed and at high welding speed i.e., above 440 mm/min defects like undercut, lack of fusion and cracks were observed.

Figure 3.12: -Effect of Welding Speed on Weld Penetration w.r.t. Base Metal

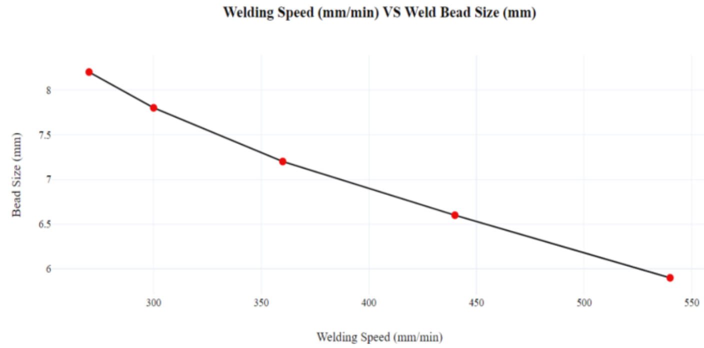

Figure 3.13: -Effect of Welding Speed on Bead Size

From, above figure 3.12 and figure 3.13, It is observed that weld penetration increases as value of welding speed decreases, since base metal is of 2mm thickness so after a point on further decreasing the value of welding speed below 440 mm/min weld penetration will remain constant. Weld bead size increases on decreasing the value of welding speed.

Table 3.13: -Micro Examination: Test Method: IS 3600-1997

Observed	Sample: 1	Sample: 2	Sample: 3	Sample: 4	Sample: 5
At 100 X Magnification	Lack of Fusion, Porosity and Cracks	No Defects Observed	Cracks, Porosity Not Visible	Cracks, Porosity Not Visible	Cracks, Porosity Not Visible

Microscopic examination was also done at 100x magnification of all five samples welded by varying welding speed.

In sample 1 which was welded at high welding speed i.e., at 540 mm/min lack of fusion, porosity and cracks were observed in microstructure of weld.

In sample 3, 4 and 5 which were welded at low welding speed i.e., at 360 mm/min, 300 mm/min and 270 mm/min cracks were found but porosity was not visible.

In sample 2 which was welded at 440 mm/min welding speed no defects were observed at 100x magnification.

Table 3.14: -Vickers Hardness Test: Test Method: IS 1501-2002

Sample Side	Sample: 1 Vickers Hardness (HV-10)	Sample: 2 Vickers Hardness (HV-10)	Sample: 3 Vickers Hardness (HV-10)	Sample: 4 Vickers Hardness (HV-10)	Sample: 5 Vickers Hardness (HV-10)
Base Metals (Al/Mg)	105/83	105/83	105/83	105/83	105/83
Weld	129	140	157	165	174
Heat Affected Zone	106	115	126	129	133

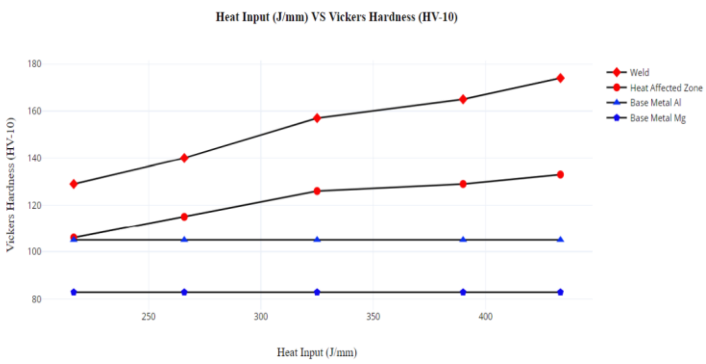

Figure 3.14: -Effect of Heat Input on Vickers Hardness at Base Metal, Weld and Heat Affected Zone

Vickers hardness test was performed on all five samples welded by varying welding speed. Since the base metal were unaffected by heat its hardness remained same for all five samples i.e., for Al its 105 HV and for Mg its 83 HV.
According to the data from table 3.14 and figure 3.14, It is observed that on decreasing the value of welding speed the amount of time that the arc is over a particular point along the joint increases because of that heat input increases so hardness of weld and heat affected zone increases. High hardness value in sample 4 and 5 causes brittle fracture and cracks at weld.
For any particular welded sample, it is observed that hardness value at heat affected zone is less then hardness value at weld.

4 Conclusions

Magnesium and Aluminium metals were butt joined successfully using AL822 (Zn78Al22) i.e., zinc-based filler wire by Tungsten Inert Gas welding process. Conclusions of this study are as follows:

1) Optimum parameters for TIG welding of Al/Mg metals are 130A welding current at 440 mm/min travel speed. It is found out that neither low welding speed and welding current nor high welding speed and welding current is optimum for weld. At optimum parameters maximum depth of penetration and fusion with uniform bead size is obtained. Based on test results it is found out that welding at non optimum parameter causes weld defects like porosity, lack of penetration, lack of fusion, undercut, cracks, burning and spatter.
2) The maximum value of ultimate tensile strength of the joint is found out to be 123 Mpa when welded at optimum welding parameters. When compared to the Magnesium/Aluminium junction created by other fusion welding, this is a huge improvement. Welding at non optimum parameters causes decrease in ultimate tensile strength.
3) Maximum ultimate bending load for face bend test and root bend test is found out to be 5.8 kN at 37◦ bend angle and 5.2 kN at 43◦ bend angle. These maximum values of ultimate bending load were obtained at optimum welding parameters. Welding at non optimum parameters causes decrease in value of ultimate bending load. Ultimate bending load for face bend test is greater than root bend test.
4) Hardness increases as heat input increases i.e., by increasing welding current or decreasing welding speed. High hardness value causes failure in weld like brittle fracture and cracks. Low hardness value is also not good for weld. Optimum hardness of 141 HV and 115 HV is observed at optimum welding parameters. In comparison to base metals, there is an increase in hardness at the weld and heat affected zone as heat input increases. Because of higher heat input at the weld than at the heat affected zone during the welding process, the hardness at the heat affected zone is lower than the hardness at the weld.

Acknowledgment

I would like to express my heartfelt gratitude to Prof. Rajamurugan G and Manoj K for providing me with the wonderful opportunity to do this project work on the topic “Characterization of Butt-Welded Aluminum Alloy with Magnesium Alloy by TIG Welding”, which helped me in gaining a lot of knowledge and exposure towards welding technologies.
Second, I'd want to thank all of the Maxwell Technology employees who assisted me much in completing this project within the time constraints.

References

[1] Welding and joining of magnesium alloys to aluminium alloys. L. LIU.
[2] Effect of Zn alloy interlayer on interface microstructure and strength of diffusion-bonded Mg–Al joints. L.M. Zhao and Z.D. Zhang.
[3] Characterization of Mg/Al butt joints welded by gas tungsten arc filling with Zn–29.5Al– 0.5Ti filler metal. Fei Liu, Hongyang Wang, Liming Liu.
[4] Effect of Ce on microstructure and properties of Mg/Al butt joint welded by gas tungsten arc with Zn–30Al–xCe filler metal. L. M. Liu and F. Liu.
[5] Effect of Al foils interlayer on microstructures and mechanical properties of Mg–Al butt joints welded by gas tungsten arc welding filling with Zn filler metal. Fei Liu, Daxin Ren, Liming Liu.
[6] Study on Mg/Al Weld Seam Based on Zn–Mg–Al Ternary Alloy. Liming Liu, Fei Liu and Meili Zhu.
[7] A Review of Dissimilar Welding Techniques for Magnesium Alloys to Aluminium Alloys. Liming Liu, Daxin Ren and Fei Liu.
[8] Behaviors and effects of Zn coating on welding-brazing process of Al-Steel and Mg-steel dissimilar metals. R. Cao, J.H. Chang, Q. Huang, X.B. Zhang, Y.J. Yan, J.H. Chen.
[9] Microstructure characteristics in TIG welded joint of Mg/Al dissimilar materials. Peng Liu, Yajiang Li, Haoran Geng, Juan Wang.
[10] Microstructure of Al–Mg–Si Weld Joints Produced by Pulse TIG Welding. Rajesh Manti and D. K. Dwivedi.
[11] Joining of aluminum and magnesium via pre-roll-assisted A-TIG welding with Zn interlayer. H.T. Zhang, X.Y. Dai, J.C. Feng.
[12] Techniques to improve weld penetration in TIG welding (A review). Akhilesh Kumar Singh, Vidyut Dey, Ram Naresh Rai.

International Journal of Scientific & Engineering Research, Volume 12, Issue 7, July-2021
ISSN 2229-5518

[13] Effect of Welding Speed in High-Speed Laser-TIG Welding of Magnesium Alloy. Chenbin Li, Minghua Chen, Shengtao Yuan and Liming Liu.

[14] Influence of welding parameters on the IMCs and the mechanical properties of Ti/Al butt joints welded by MIG/TIG double-sided arc welding-brazing. Yufeng Zhang, Jihua Huang, Zheng Ye, Zhi Cheng, Jian Yang, Shuhai Chen.

[15] Effects of Si additions on intermetallic compound layer of aluminum–steel TIG welding– brazing joint. J.L. Song, S.B. Lin, C.L. Yang, C.L. Fan.

[16] Investigating the Effect of Welding Current on the Tensile Properties of SMAW Welded Mild Steel Joints. Rohit Jha, A.K. Jha.

[17] Effect of Welding Current on Mechanical Properties and Microstructure of TIG Welding of Type-304 Austenite Stainless Steel. E. O. Ogundimu, E. T. Akinlabi and M. F. Erinosho.

[18] Effect of welding variables on mechanical properties of low carbon steel welded joint. S.I. Talabi, O.B. Owolabi, J.A. Adebisi and T. Yahaya.

[19] Effect of welding speed on microstructure, hardness and tensile properties in laser welding of advanced high strength steel. Y. Y. Zhao, Y. S. Zhang and W. Hu.

[20] Study of Effect of Process Parameters of Welding during TIG welding of AA 7075 and its optimization. Harmish Bhatt.

[21] Effect of Current on Characteristic for 316 Stainless Steel Welded Joint Including Microstructure and Mechanical Properties. Navid Moslemi, Norizah Redzuan, Norhayati Ahmad, Tang Nan Hor.

[22] AC TIG welding with single-component oxide activating flux for AZ31B magnesium alloys. Zhaodong Zhang, Liming Liu, Hao Sun, Lai Wang.

[23] Effect of welding process parameters on hybrid GMAW-GTAW welding process of AZ31B magnesium alloy. Xu Shen, Guohong Ma, Peng Chen.