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AN EVALUATION OF ALUMINIUM PLATE TIG WELDING PARAMETRIC INFLUENCE ON WELDING CURRENT AND WELDING SPEED

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***Abstract*— To improve welding quality of Aluminum (Al) plate an automated TIG welding system has been developed, by which welding speed can be control during welding process. Welding of Al plate has been performed in two phases. During 1st phase of welding, single side welding performed over Al plate and during 2nd phase both side welding performed for Al plate by changing different welding parameters. Effect of welding speed and welding current on the tensile strength of the weld joint has been investigated for both type of weld joint. Optical microscopic analysis has been done on the weld zone to evaluate the effect of welding parameters on welding quality. Micro-hardness value of the welded zone has been measured at the cross section to understand the change in mechanical propert of the welded zone.**

***Index Terms*— Automated TIG Welding System, Micro hardness Test, Tensile Test.**

I. INTRODUCTION

Unlike manufacturing processes that generate a single component, joining techniques combine multiple parts to produce the desired complicated configuration. Obtaining such a complicated shape using solely industrial methods is either too difficult or impossible. The connection of various pieces can be temporary or permanent. Furthermore, the bonding process can be mechanical or atomic. The atomic bonding arc of a permanent character is present in all joining processes. Welding, brazing, soldering, adhesive bonding, and mechanical fastening are all procedures that are included in the word "joining." These procedures are an important part of the manufacturing process.

Welding is the process of joining similar or dissimilar metals with or without applying heat and pressure. The bonding force between the two metallic atoms decreases sharply with the interatomic distance. But the pressure increases sharply and attains a tremendous value when the distance is reduced. Weldability of a material depends upon various factors like the metallurgical changes that occur due to welding, changes in hardness in and around the weld, the extent of oxidation, and time of cracking tendency of the joint.

A. DIFFERENT TYPES OF WELDING PROCESSES

Based on the type of heat source welding process is characterized as

- Arc Welding
- Resistance welding
- Solid-State Welding
- Radiant Energy Welding
- Thermit welding
- Allied Process
- Gas welding

B. TIG WELDING

Tungsten Inert Gas Welding is an arc welding process in which a tungsten electrode is non-consumable to produce the weld. An inert shielding gas such as argon or helium and filler metal is used to protect the weld area from the atmosphere. A rectifier is used as a power source from which power is supplied, with the help of a welding torch or a handpiece. This power is delivered to the tungsten electrode, already fitted into the handpiece. An electric arc is created between the base metal and the tungsten electrode with the help of a constant-current welding power supply from which energy is produced, and this energy is conducted throughout the arc with a column of highly ionized gas and metal vapors [2|. The inert gas protects the tungsten electrode and weld zone from the atmospheric air. The temperature produced by an electric arc is approximately 20000"C, and this heat is concentrated on a particular area for melting and joining the different parts of the material. The weld area is used to enter the work piece with or without filler material. Figure I &2 shows the mechanism and working of TIG Welding, respectively.

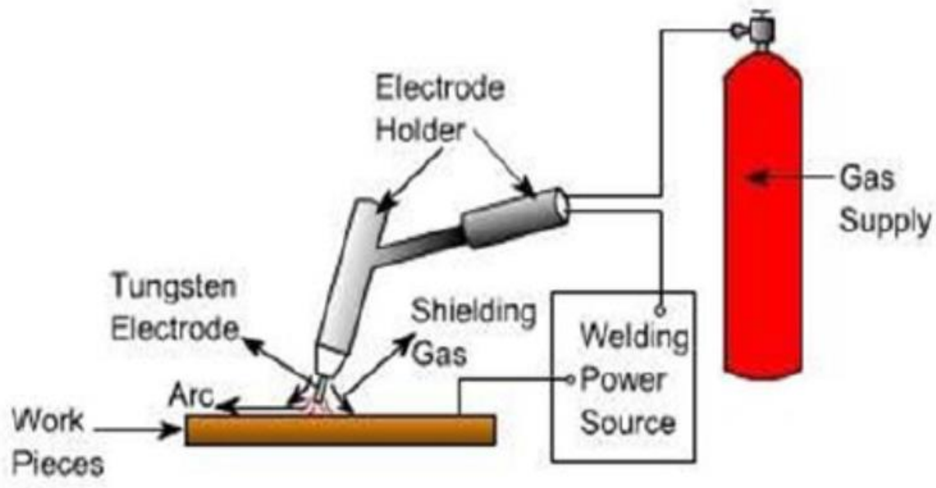


Figure 1: Schematic Diagram of TIG Welding System (Reference 1)

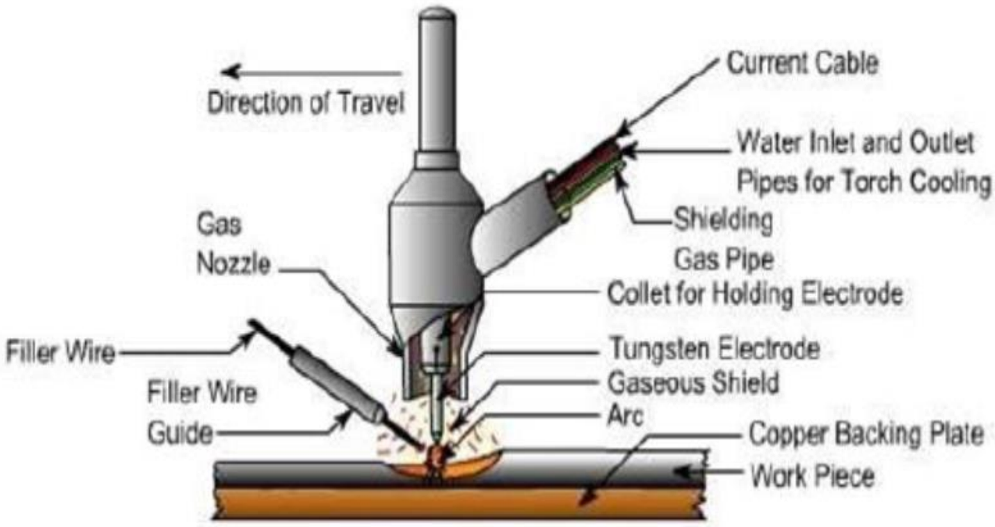


Figure 1: Principle Of TIG Welding System (Reference 1)

The tungsten electrode diameter generally varies from 0.5-6.5 mm, whereas the length of the tungsten electrode ranges from 150 to 200 mm. The current carrying capacity of the tungsten electrode is based on its size. It depends on whether the electrode is connected to the positive or negative terminal of the DC power source.

When the length of the arc varies over many millimeters, the power source required to sustain the arc has a constant c, from which stable current charitable current output is generated. The welding current is only a little affected by the size variation of the arc created during the welding operation. When the electrode is short-circuited over the workpiece, the ability to change the current to the desired value is critical. In another situation, an excessively high current will flow, resulting in electrode damage. The power source's open-circuit voltage ranges from 60 to 80 volts.

C. PROPERTIES OF ALUMINIUM

The three essential properties of aluminum are

- Low density approximately 2.7g/cm.
- High mechanical strength obtained by alloying and heat-treating the metal.
- High corrosion resistance.

High thermal and electrical conductivity, reflectivity, high flexibility, magnetic neutrality, high scrap value, and non-poisonous and colourless corrosion products are some of the other features of Aluminum that allow it to be used in chemical and food processing industries.

Aluminum is a soft metal with a yield strength of 345 N/mm2 and a tensile strength of 90 N/nun" in its purest form. With the development of alloys, the power and flexibility of materials can be varied over a wider range, and these are useful in thin foil material in the packaging industry, in making drinking bottles with ductile materials, alloys with high conductivity are used in electrical applications, and alloys with low strength are used in the construction industry. Finally, high-strength alloys are used in the airplane and armored vehicle industries.

Aluminum has a strong corrosion resistance when metal is in its purest form, which is not the case with its alloys, which are resistant yet more susceptible to corrosion.

II. LITERATURE REVIEW

Kumar and Sundarrajan [6] used the Taguchi approach to analyze pulsed TIG welding process parameters and constructed regression models to see how they may be adjusted to improve the mechanical qualities of the weld. This strategy is used to plan and assess experiments to improve quality. The Taguchi technique assesses the effects of different parameters that are independent of one another, and quality attributes like ultimate tensile strength, yield strength, hardness, and so on are identified. The Taguchi technique is used because it is a procedure that improves output quality without raising the cost of the experiment. It also reduces the number of experiments that must be carried out. All of the welds' microstructures were examined and connected with their mechanical properties. The resultant welds are subsequently subjected to a cold planishing process, which relieves internal stresses and reforms grains, hence improving mechanical qualities.

Harmish Bhatt [71] investigated the effects of process parameters such as gas flow rate and welding current during TIG welding of aluminum alloy 7075. He performed the two sets of experiments. He first set the mechanical properties such as Ultimate Tensile Strength and hardness. In 2 groups of the experiments, he tried to optimize the process parameters by limiting the values of gas flow rate and welding current to get maximum Ultimate Tensile Strength.

Ravindar and K Guru raj [8] adopted the pulsed current TIG welding method. Aluminum alloy 5053 sheets, with a thickness of 4mm, were employed. The final workpiece's dimensions must be 100x100x4 mm. Weld samples to variable circumstances by changing the process parameters, such as welding current, gas flow rate, and filler rods, and weld samples to varying conditions by changing the process parameters, such as welding current, gas flow rate, and filler rods. For process conditions such as a welding current of 180 A, a gas flow rate of 10/min, and a filler rod diameter of 1.6 mm, an impact test was performed, and a Vickers Hardness value was achieved. Due to a lack of fusion, the Vickers hardness value becomes very low, which is obtained suitable when the above process parameters values are modified, such as welding current 240A, gas flow rate 12/min, and filler rod diameter 3.2 mm. Due to a change in microstructure, the hardness value of the weld zone changed as the distance from the weld center increased. The refinement in fusion zone grain size achieved by pulsed current welding is the fundamental reason for enhancing Vickers Hardness and micro hardness characteristics.

Surendhiran. S et al. [9] The AA 5456 is used to TIG weld sheets with dimensions of 250x150x2.4 mm. Micro hardness was determined at 0.5 mm intervals throughout the weld, 1 mm intervals across the HAZ, and 1.5 mm intervals across the undamaged base metal. With a peak current of 80 A, a base current of 4 A, a welding speed of 230tnm/minute, and a pulse frequency of 2 Hz r, a coarse grain structure is achieved. The value of this study is that the mechanical properties improve as a result of the obtained optimum circumstances, and the regression models developed are useful for process automation.

A. PROBLEM IDENTIFICATION

- Aluminium forms an oxide layer over it, which is very hard and needs to be removed; otherwise, it will not allow proper fusion. So, welding should be done with reverse polarity or AC so that current How strips off the oxide as it forms.
- Due to the high thermal conductivity of aluminum, it needs more current at the start of welding than at the end. Since welds are susceptible to cold start at the beginning and high penetration at the end.
- Welds of aluminum are susceptible to cracking, improper penetration, and sudden cooling.
- Filler alloys are not flowing well, and care is needed to create a consistent bead.
- Grinding aluminum is rugged since it clogs the abrasives and milling cutters.

B. OBJECTIVE OF WORK

Welding was done on a 3 mm thick aluminum plate using an auto ma led TIG welding system. To get a higher strength union, welding parameters such as welding speed and current are modified, and only welding is done on both sides of the aluminum plate. We investigated the tensile strength, microstructure, and microhardness of the weld pool by varying welding speed and currently used techniques.

III. EXPERIMENTAL WORK AND METHODOLOGY

Figure 3: Automated TIG welding setup

A. CALIBRATION OF SPEED

To get the required welding speed, the speed of the control unit is calibrated before the start of the experiment.

Table 1: The value of speed on the speed control unit

Equipments No	Speed Values (mm/sec)
1	2
1.5	3
2	4
2.5	5
3	6
3.5	7
4	8

B. EXPERIMENTAL PLANNING

The experiment is carried out in two phases. In the first phase, an aluminum plate of thickness ^nm is butt welded at one side by varying welding speed and welding current. In the second phase, butt welding of aluminum plate is done on both sides by changing the welding wind and speed as varied previously.

C. EXPERIMENTAL PROCEDURE

The three in the thick commercial aluminum plate are used for the experiment. It is cut in 120x50 mm dimensions with the help of a band saw. Grinding is done on the edges to make the surface smooth for joining. To remove the extra material, veneers are polished with every piece of paper.

In the working table, aluminum plates are fixed with (the help of a flexible clamp after the sample is prepared, and welding is done to forma butt joint.

Alternating current is used for TIG welding since it concentrates the heat in the welding area. 3.5 inch in diameter zirconate tungsten electrode is used in the experiment. Through grinding (the rip diameter at the end of the electrode is reduced 2/3 of the original diameter, and then the arc is struck on the scrap material piece. Due to this, a ball is created at the end of the electrode. Small electrodes for the welding current will form acolossal ball. On the other hand, large electrodes will not form good balls.

The welding parameters of the experiment's first phase are shown in table 2. Several trials before the actual experiment arc were done to get the appropriate parameter range so that welding should be done without any recognized defects such as undercutting and porosity.

Table 2: Welding Parameters for one cycle of experiments

Parameters	Range
Welding Current	100J 30A
Speed	3-4 mm/s
Voltage	45V
Gas Flow Rate	7.5-10 I/min
Distance of tip from weld center	3 mm
Current type	AC
Dimension	120 mm X 50 mm X 3 mm

After the welding is done, welded specimens are cut in the dimension of 100 mm X 20 mrn for tensile testing. These dimensions are further cut into I shape. The tensile test is performed with Universal Tensile Testing Machine with a maximum load-carrying capacity of 600 kN.

Again 10mm X 5mm X 3mm specimen is cut at the cross-section for microstructural analysis and microhardness measurement of each sample. A cross-section of the welded model is polished sequentially with 220: 600 and 1200 grit size polishing paper. Microhardness was measured with a Vickers micro hardness tester, and with the help of an optical microscope optical image of the cross-section at the welded zone was taken.

Table 3 Experimental Planning

Experiment No.	Electrode Workpiece distance	Argon gas flow rate(l/mm)	Voltage(V)	Welding Speed(mm/s)	Current(A)
1	3	7.5-10	45	3	1Ü0
2	3	7.5-10	45	3	105
3	3	7.5-10	45	3	11Ü
4	3	7.5-10	45	3	120
5	3	7.5-10	45	3	130
6	3	7.5-10	45	4	10Ü
7	3	7.5-10	45	4	105
8	3	7.5-10	45	4	110
ຈ	3	7.5-10	45	4	120
10	3	7.5-10	45	4	130

IV. RESULT AND DISCUSSION

The average value of welding width is calculated by measuring the welding width of all the samples and is shown in table 4. For different welding speeds, a graph is plotted between average welding width and the applied welding current as shown in figure 4, which shows that welding width increases in linear proportion with welding current. Figure 4 shows the welded butt joint specimen where welding is performed with varying welding speed and wind, whose details are in table 3.

Figure 4 - a) Welded specimen performed with welding speed 3mm/s and welding current 100. 105, 110. 120 and I30A for samples numbers 1 to 5

b) welded specimen performed with welding speed 4mm/s and welding current 100. 105. 110120 and 130A for sample numbers 6-10, respectively

Table 4: Weld Width

Sample no	Reading 1 (mm)	Reading 2 (mm)	Reading 3 (mm)	Avg. width (mm)
1	5.53	4.67	4.31	4.83
2	7.38	6,78	7.45	7.20
3		7.67	7.37	[illegible]
4	7.36	7.75	7.85	7.65
5	10.87	10.59	10.09	10.51
6	5.12	5.08	4.88	5.026
7	5.67	5.76	5.88	5.77
8	8.43	8.17	7.79	8.13
9	9.38	8.03	8.78	8.73
10	9.19	10.09	8.52	9.26

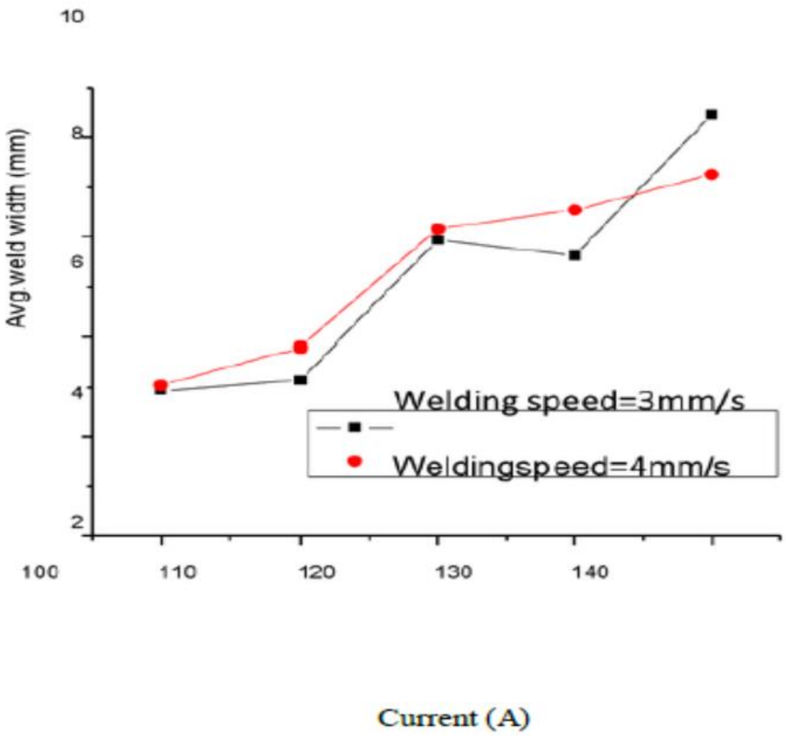


Figure 5 Specimens welding width with varying welding speed and current

The average surface roughness value for all the samples of weld zone was measured from the readings in Table 5; Roughness value ranges from I to 6 microns approximately, which is somewhat low for a welded specimen. Thus, we conclude that finishing operation is not required to use an automated system. The roughness values obtained are plotted against the applied current, and the same is shown in figure 6. But the wind does not have any effect on the surface roughness.

Table 5: Surface roughness value for different welded samples

Sample No	Reading1 (μm)	Reading2 (μm)	Reading3 (μm)	Avg. Value (μm)
1	3.442	3.385	3.034	3.287
2	1.896	1.157	1.123	1.392
3	1.768	1.299	1.476	1.514
4	0.865	1.297	1.379	1.180
5	2.835	2.896	1.233	2.321
6	1.876	4.654	3.312	3.280
7	2.398	2.145	2.234	2.259
8	3.567	3.498	3.612	3.559
9	3.229	3.411	4.121	3.587
10	1.345	1.178	1.276	1.266

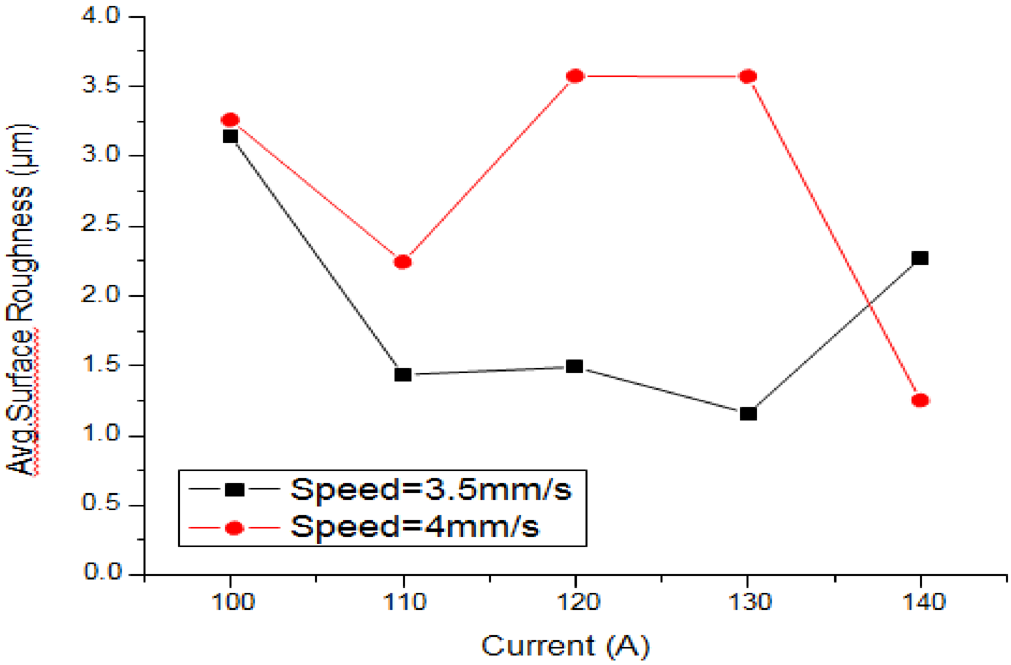
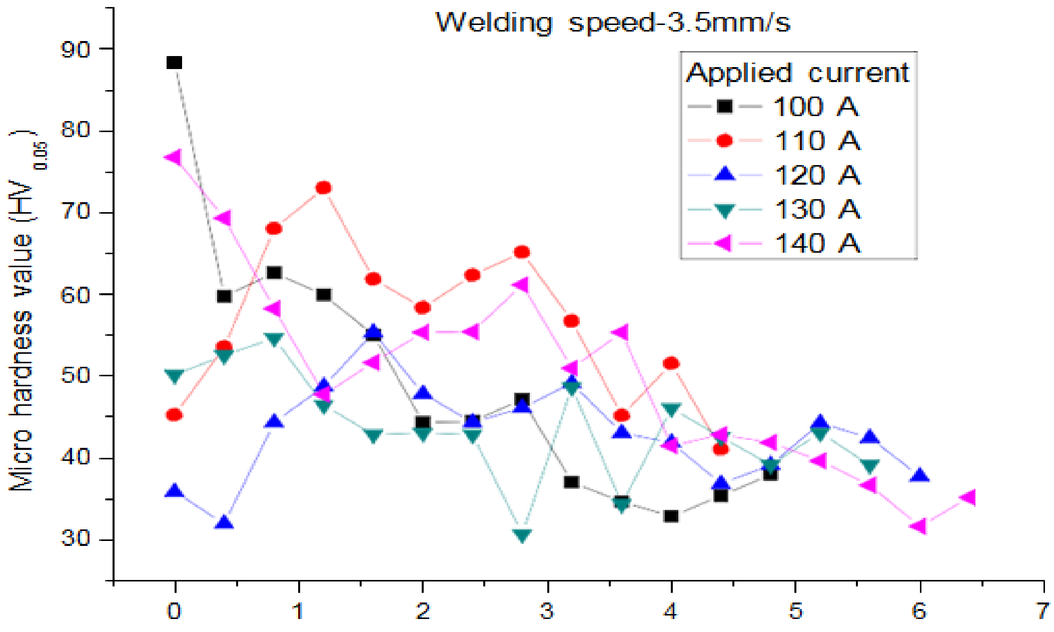


Figure 6 Surface roughness of samples with different current

A. MICROHARDNESS TEST

The cross-section is measured to understand the change in mechanical property of the welded zone micro hardness value of all the welded specimens. Figure 7 s micro hardness values of different at the welded zone taken from the center of the welding zone towards the base material for different welding speeds and the welding current.



Distance from the center (mm)

Figure 7: Micro hardness value for different specimens when welding speed is 3mm/s and the different welding current

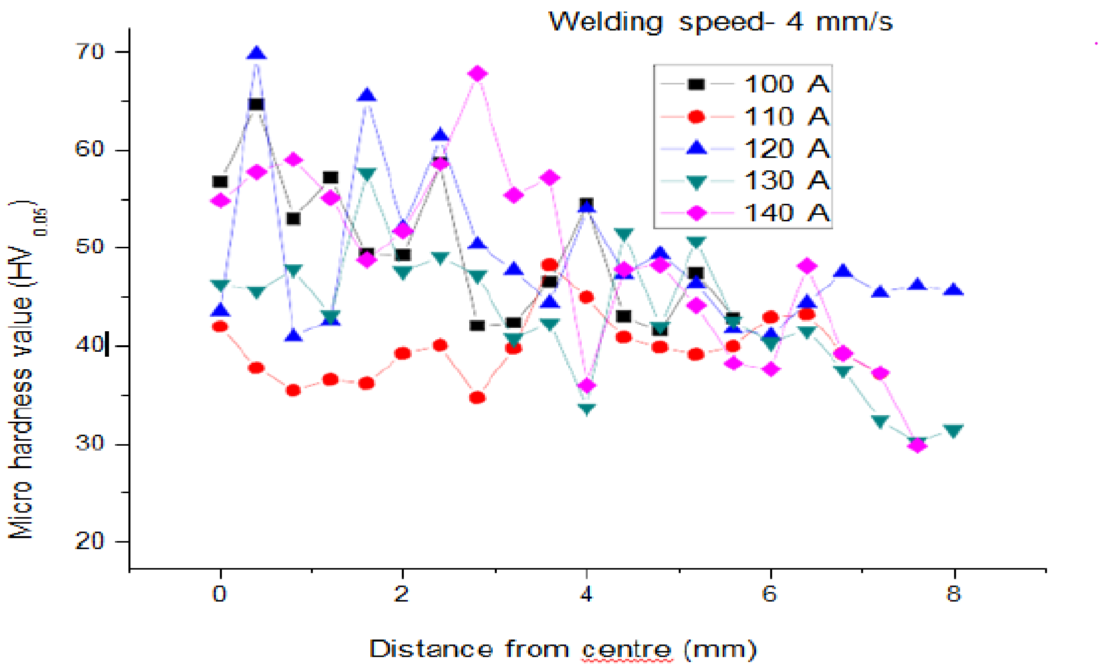


Figure 8: Microhardness value for different special when welding speed is 4mm/s and die different welding current

From the above graph, it is clear that microhardness values increase in the welding zone than the base material for all the samples, and these values range from 40 to 80 HV in the welded area. After a certain distance, these values reduce the hardness of base material for sample processed with welding speed 3mm/s as shown in figure 8 and with welding speed 4mm/s and varying current settings microhardness value reaches to That of base material after 5 to 6 mm.

B. TENSILE TEST

A universal tensile testing machine is used to perform the tensile test of the welded joint having a maximum load capacity of 600kN.

All of the welded joints' tensile strength values are acquired at various welding speeds and current settings, as shown in Arabic 6. These values are significantly lower than those of pure aluminum. The aluminum's tensile strength was discovered to be 132 Mpa. The tensile strength of welded joints is plotted versus the applied current for a welding speed of 3mm/s, as shown in figure 10. Except when welding current runs from 120 to 130 A, it can be stated that tensile strength increases in direct proportion to the increasing current setting.

Similarly, for the welding speed of 4mm/s, the tensile strength of welded joints is plotted against the welding speed of 4mm/s. The conclusion drawn from the graph is that there is no specific change observed in tensile strength when there Change in current settings. Initially, when there is an increment in contemporary locations, there is an increase in tensile strength, but this increase is only up to 120 A, and then these values decrease, We can observe that for all current settings values except 120 A. tensile strength of welded joint when welding speed is 3mm/s are greater than tensile strength values when welding speed is 4 mm/s.

Table 6; Maximum load at tensile strength and tensile strength value at the different welded samples.

Sample no	**Load at tensile strength (N)**	**Actual tensile strength (MPa)**
1	1718.31465	23.94286
2	1963.50763	25.19435
3	2877.47628	37.37904
4	2312.59820	31.81012
5	2927.53077	38.03435
6	1311.63805	18.41884
7	1285.71786	16.13438
8	3307.39748	45.06890
9	2258.41971	31.12126
10	1386.85181	19.42809

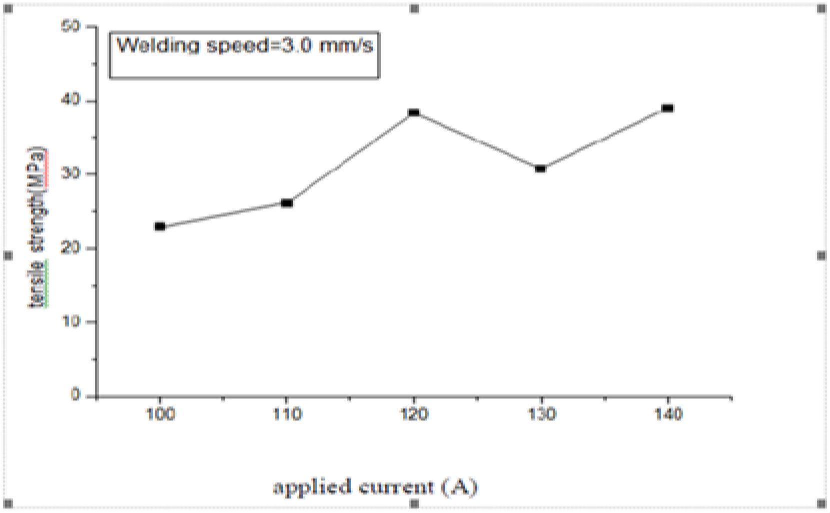


Fig. 9: Tensile strength of the welded joint against the applied current for welding speed of 3. mm/s.

Figure 10: Tensile test specimen

Fig. 11: Tensile test machine during performing

Table 7: Maximum load at tensile strength and tensile strength value of di lie rent welded samples (both side welding)

Sample No	**Load at tensile strength<N)**	**Tensile strength (MPa) UTS**
1	6712.37688	112.8959
2	5537.16367	91.3290
3	4836.28344	81.57428
4	4516.36769	74.29896
5	5963.54783	9836174
6	5751.49897	96.84798
7	6290.76234	105.8928
8	5993.47428	100.97009

For the welding current of 150 A., the tensile strength of the welded specimen is plotted against welding speed; The figure also indicates that the tensile strength of the welded joint decreases approximately from 110 to 75 Mpa when welding speed increases from 3^5 to 5 mm/s. When welding current is 1X0 A, tax (ensile strength value of the welded joint is in the range of 95 to 105 Mpa, and there is no variation in tensile strength values when welding speed is changed.

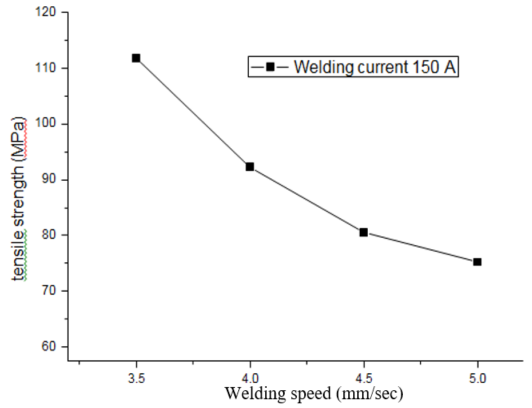


Fig. 12: Tensile strength of welded joint against different welding speeds for applied current.

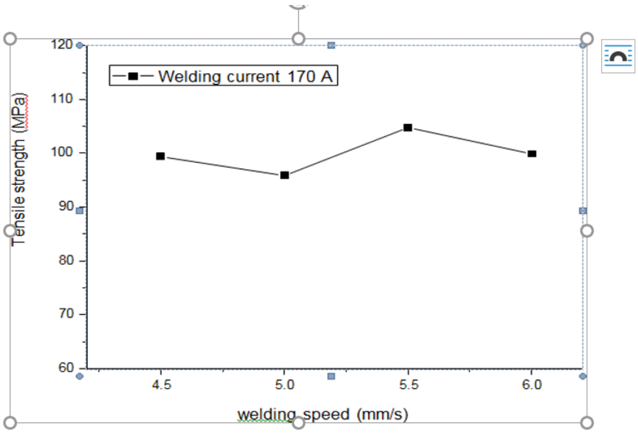


Figure 13: Tensile strength of welded joint against different welding speed for applied current of 170A

Micro hardness value for both sides welding:

When welding is done on both sides of the plate, the microhardness profile from the center of the weld zone towards the base material is done with the welding speed of 3mm and 4mm/s with the welding current of 140 A. The graph below shows that the hardness value decreases with the distance from the center,

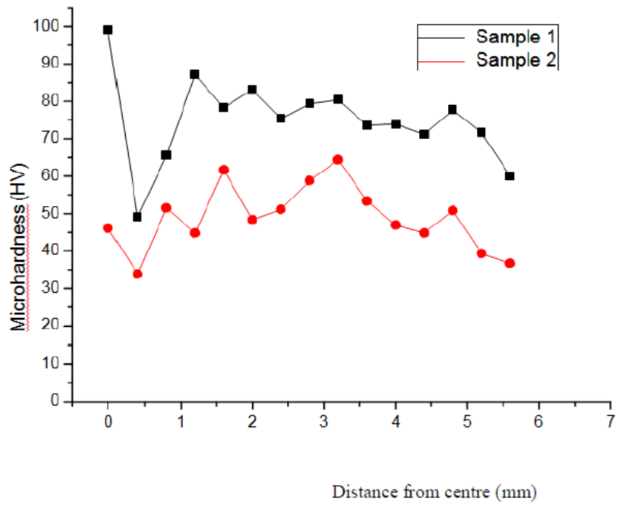


Fig. 14: Micro-hardness value from the center of the weld zone towards the base material for welding done with welding speed (3 mm/s and 4mm/s) and welding current (140 A)

V. CONCLUSIONS AND FUTURE SCOPE

A. CONCLUSIONS

The following conclusions are made with the TIG welding to aluminum.

- It is possible to uniformly weld aluminum with automated TIG welding,
- Welding speed and welding current affect the parameters such as welding and the tensile strength,
- Strength of welded joint increases linearly to increase in welding current.
- Due to changes in microstructure, hardness value changes as the distance from weld center changes.
- For both side welding, Tensile strength is almost equal to the power of base material.
- For both sides of welding, welding speed does not have any notable effect on the tensile strength of the weld joint.

B. FUTURE SCOPE

In the present study, the welding is performed without any filler material. So. in the future, welding can be done with a filler metal to weld some thicker plates. The same welding setup can also be used for some other material.

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