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Weldability of Aluminum Alloy Using Pulsed Current Tungsten Inert Gas Welding Process for Mechanical Properties: A Review

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Abstract

In the TIG welding, also known as gas tungsten arc welding, metal components are bonded by applying heat or pressure. Inert gas is used in pulsed current welding to encapsulate the electrodes and welding pools. Tungsten inert gas is used in the complex welding process known as TIG welding. It alternates between amps operating at high and low levels. Here, increasing the current results in improved power production and weld quality. Pulsed current TIG welding is advantageous for aluminum alloys. Pulsating electricity is used in a type of welding known as pulse welding. It's a twist on the standard welding method. Premium alloys such as magnesium, aluminum, and stainless steel should be used to produce welding connections of the highest caliber. Pulsed TIG welding is frequently considered the most complex of all the welding processes utilized in industry. The metal aluminum was created and put to use in manufacturing in 1825. This study is based on the aluminum alloys 6060, which are among the nine types of aluminum alloys. Since they withstand corrosion well, lightweight metals such as aluminum and others are a good choice for the car body. Aluminum alloys are also used in applications related to the railroad, aerospace, automobile, and nautical sectors because of their light weight. Welders must maintain a low arc length, which requires them to employ great caution and skill to avoid electrode contact with the workpiece. TIG welding is widely used to combine thin stainless-steel pieces, non-ferrous metals such copper alloys, magnesium, aluminum, and other materials.

Keywords: AA6060, pulsed current TIG welding, tensile strength, hardness, response surface method

INTRODUCTION

Sir Humphrey Davy first proposed the existence of a metal called aluminum (Al) in the first decade of the 19th century, and Hans Christian Oersted succeeded in isolating the metal in 1825. For the next 30 years, aluminum remained a curiosity of laboratories until 1886, when limited commercial production began, and the technology of extracting aluminium from its mineral, bauxite, was developed into a fully operational industrial process. The extraction technique was invented in France concurrently by Hall and Heroult, and the fundamental process is still in use today. Aluminum is found in the Earth's crust in a number of forms, although it does not naturally occur in its metallic state owing to its reactivity [1].

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Aluminum Alloy Grades

The eight distinct categories of aluminum alloy grade series are as follows: the 1000 series uses pure aluminum, 2000 series uses copper as the main alloying element, 3000 series uses manganese, 4000 series uses silicon, 5000 series uses magnesium, 6000 series uses silicon and magnesium, 7000 series uses zinc and magnesium, and 8000 series uses lithium (tin) [1].

MATERIAL

The experimental substance, the 6060 Al alloy, is presented in Tables 1 and 2.

CHEMICAL PROPERTIES OF THE MATERIAL [2].

The chemical composition ranges for various alloys, listing the minimum and maximum percentages of elements such as Silicon (Si), Iron (Fe), Copper (Cu), and others. These values indicate the allowable concentrations for each element in the alloy.

Table 1. Chemical Properties percentage of the Material [2].

Alloys	%	
	Minimum %	maximum %
Si	0.03	0.60
Fe	0.10	0.30
Cu		0.10
Mn		0.10
Mg	0.35	0.60
Cr		0.05
Zn		0.15
Ti		0.10

Table 2. AA6060 Mechanical Properties [2].

Mechanical Property	Value
Young's modulus (MPa)	69,500
Tensile strength (MPa)	110
Elongation (%)	14
Density (g/cm^3)	2.70
Hardness (HV)	90

INTRODUCTION TO PROCESS

Welding

Welding is necessary when larger standard section lengths are required or when multiple sections need to be assembled to form the intended structure. They are typically used to fuse metal parts. Welding is a method of joining metals and plastics without the need for adhesives or fasteners [3]. Welding is a technique used to unite metal components. It can be performed with or without a filler metal, heat, or pressure [4].

Weldability

Weldability is the ability to weld into inseparable joints with specific properties such as weld strength and structural integrity [5]. The weldability of any metal is primarily influenced by five factors: the melting point, thermodynamic conductivity, thermodynamic expansion caused by heat, and surface condition changes that occur in the microstructure of the organism [5]. The American Welding Society defines weldability as a metal's ability, within manufacturing constraints, to be welded into a particular precisely planned structure and perform wonderfully in the intended service [5].

TUNGSTEN INERT GAS WELDING

Inert tungsten gas welding is commonly referred to as “gas welding.” This is particularly crucial for welding reactive metals and alloys with high strengths, such as magnesium, aluminum, and stainless steel, and when precise weld joints are required for vital applications such as nuclear reactors and airplanes. Because it uses an inert gas and a tungsten electrode to protect the welding pool from ambient gases, tungsten arc welding is known. Because none of the previous techniques (SMAW and gas welding) could adequately weld these reactive metals at the time, the discovery of this technology in the middle of the 20th century was extremely beneficial for the producers of these reactive metals. Generally, there are two disadvantages: (a) climatic gas deformation of welds and (b) weld strength. Likewise, halide motion-covered terminals can be used to weld aluminum and its compounds by utilizing protected metal curve welding by settling the issues with Al_2O_3. However, because halides are destructive, they are prescribed to weld aluminum under idle protection by utilizing strategies such as GTAW and GMAW. The TIG method is the preferred method for joining dainty aluminum sheets with a thickness of less than 1 mmg under conditions, utilizing procedures such as GTAW and GMAW, despite the multitude of improvements in welding innovation. The TIG cycle remains the preferred method for joining thin aluminum sheets under 1 mm, despite advancements in welding technology. [1]. The TIG welding machine is shown in Figure 1.

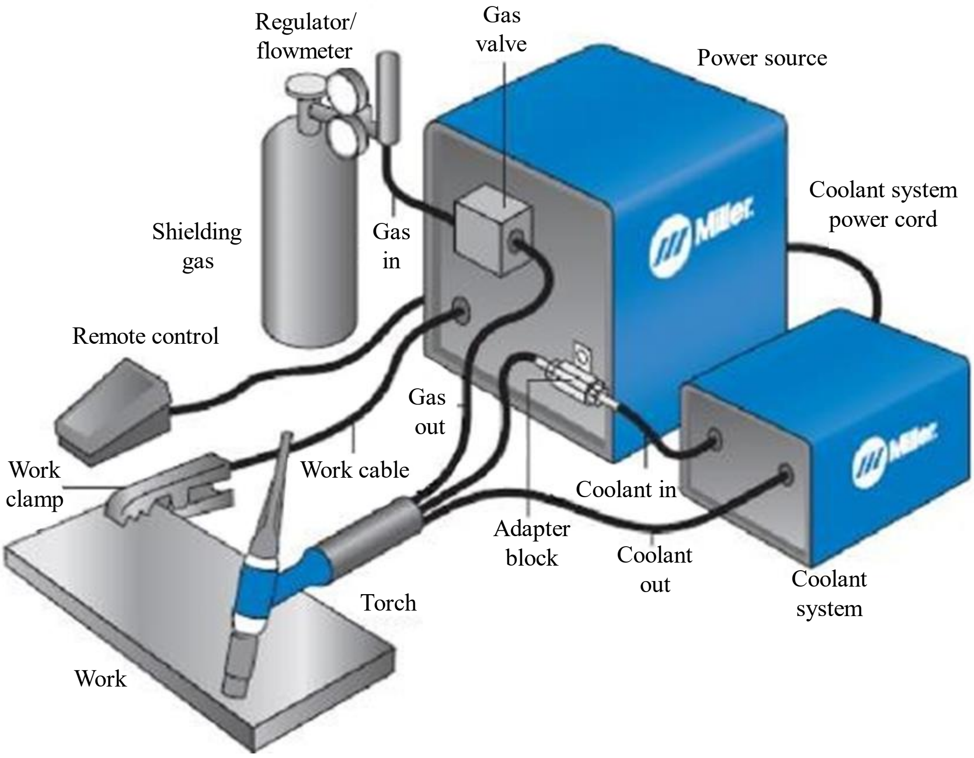

Figure 1. TIG welding machine [18].

Development

Russell Meredith, a welder at the Northrop Aircraft Corporation in Southern California, invented TIG welding in the 1940s. He devised this technology because the existing techniques were unsuitable for welding alloys made of magnesium and aluminum. It was an enormous feat that allowed the American industry to produce ships, planes, and other products at a rate never previously observed in human history. President Roosevelt praised the plan in a letter to Winston Churchill. The technique was invented by Union Carbide's Linde Division, which produced and sold a wide range of torches, parts, and consumables for the technology until their patents on the process and TIG-related goods expired in the 1960s and the 1970s, respectively. The Linde torches were powered by helium [5].

Pulsed Current TIG Welding Process Southern California Welder Russell

Meredith invented TIG welding in the 1940s while working for Northrop Aircraft Corporation. He created the procedure because the currently used techniques ae not suitable for welding Mg and Al alloys. This great achievement allowed the American industry to produce ships, airplanes, and other products at a rate never seen in human history. A letter supporting the plan was sent by President Roosevelt to Winston Churchill. The procedure was created by Union Carbide's Linde Division, which manufactures and sells a wide variety of torches, components, and consumables for TIG technology until their patents on the method and TIG-related goods expired in the 1960s and the 1970s, respectively. Helium was used to power the Linde torch [5].

Development of Pulsed Current TIG Welding Process

In pulsed-current tungsten inert gas (PC TIG) welding, the welding current is cycled from a high to a low level using a specified frequency. Their creation began in the 1950s. Generally, a low background current is utilized to maintain arc stability, whereas a high peak current is used to ensure appropriate penetration and bead shape [5].

Pulsed Current TIG Welding Process Parameters

The welding process is influenced by various factors, including inert gases, the included angle, welding speed, voltage, current, and heat treatments applied before and after welding.

LITERATURE REVIEW

1. T. Senthil Kumar, V. Balasubramanian, M.Y. Sanavullah [6] After a thorough analysis, the following results were obtained regarding the effects of pulsed-current parameters on the tensile properties of pulsed-current TIG-welded AA 6061 aluminum alloy: peak current, base current, pulse frequency, and pulse-on time. It is more practical to estimate the impact of pulsed-current welding parameters on the tensile characteristics of TIG-welded aluminum alloy joints using a factorial experimentation technique. The important main and interaction components of the pulsed-current TIG welding process are best determined using the analysis of variance method. Peak current and pulse frequency, in general, have a directly proportional relationship with the tensile characteristics of welded joints; that is, an increase in peak current corresponds to an increase in tensile strength.
2. C.A.G. Aita, I.C. Goss b, T.S. Rosendo, M.D. Tier, A. Wiedenhoft, A. Reguly [7] This study looked into whether the Taguchi approach could be used to identify a set of welding parameters that would allow the FSSW process to create overlap spot joints in 6060-T5. alloy of aluminium. Next, an equation was derived from the welding settings using the Taguchi approach to forecast joint strength. In addition to creating FSSW joints and obtaining a different strength-prediction equation, a Full Factorial Design (FFD) was employed to confirm the applicability of the Taguchi approach. Subsequently, the equations produced by Taguchi and FFD were compared.
3. H. Allachi, Chaouket F, K. Draoui [8] The electrochemical behavior of AA6060 aluminum alloy was investigated in 3.5% NaCl both with and without 10−3M CeCl3. Based on these findings, a localized corrosion process predominates in the vicinity of the- Al(Fe, Mn)Si intermetallic complex. These substances serve as sites for the oxygen reduction reaction because they are cathodic relative to the metallic matrix. This results in a localized increase in pH, which dissolves the nearby matrix and the oxide layer that surrounds the precipitates first. W finer than the high peak current aluminium granules weight loss and electrochemical linear polarization results show that cerium chlorides in 3.5% NaCl at room temperature effectively block uniform corrosion of the aluminum alloyAA6060. Additionally, we can deduce that these salts also function as pitting corrosion inhibitors because the samples dipped in CeCl3 solutions did not develop pits. The curves of linear polarization indicate the cathodic nature of the inhibitory mechanism. Precipitation of cerium compounds on the- Al(Fe, Mn)Si intermetallic, which function as permanent cathodes, inhibits the corrosion of the AA6060 alloy. As a result, the overall corrosion rate was lowered.
4. Ishteyaque Ahmad1, Somvir Arya [9] conducted a microstructural analysis of Aluminum Alloy AA-6061 welding using the TIG welding process at different welding currents and investigated the microstructure and mechanical properties of the welded joints. Optical microscopy, Vickers

microhardness testing, and surface roughness testing were used to characterize the base metal, welded zone, hardness of the welding zone, and surface roughness of the welded surface. This study aimed to determine the optimal welding current for the TIG welding of AA-6061 aluminum alloy. The results included findings on the influence of welding parameters such as current, gas flow rate, and speed on tensile strength, as well as insights into the impact of different tools on joint strength in friction stir welding. Additionally, the study highlighted the importance of shielding gases, electrode materials, and welding speed in the TIG welding processes.

5. K. Mahendra Babu, Y. Mahesh K. Siva Sankar, and K. Madhan Mohan [10] Based on a study of the data collected on input and output parameters, the following conclusions were drawn. A maximum tensile strength of 145.85 MPA was achieved with a filler rod diameter of 2 mm, moving speed of 35 mm/min, and current of 190 Amp. The ideal range of input parameters was determined to be 190 A of current, 35 mm per minute of travel time, and 2 mm of filler rod diameter, resulting in an effective weld junction with good tensile strength. By integrating grey regression analysis with the s/n ratio, it was discovered that the filler rod width has a greater impact on the yield strength, and the travelling speed has a greater impact on the tensile strength.
6. S. Yazdanian Z. W. Chen G. Littlefair [11] When utilizing a pin that barely penetrates the bottom plate for FSLW of an aged, hardened aluminum alloy (AA6060-T5), a sufficiently low welding velocity (v) permits sufficient lap plate bonding and joint strength (rLap) to approximate the FS bead-on-plate sample strength (rBoP). Greater penetration permits an increase in v, while maintaining rLap near the rBoP constant. Increasing the rotation speed (x) or reducing the rotation speed (v) at the bottom stir zone (AB-SZ) results in a large stir volume per unit length when the penetration is sufficient. When x is low, the rate of either dTSZ/dx (TSZ—stir zone temperature) or dAB-SZ/dx is high, when x increases, both decreases. This implies that x's influence on TSZ and, consequently, the zone's flexibility, has a greater influence on AB-SZ. The first rise in AB-SZ observed above the vertical distance of the hook (h) rapidly increased to a maximum value (hMax), which in this case was equivalent to 40% of the thickness of the top plate (tPlate), by the corresponding area of the spinning pin (AB-Pin, which is equal to the minimum AB-SZ). It was discovered that even with an unwelded lap serving as a pre-crack and a significant stress concentration surrounding it because of the lap geometry, rLap is extremely close to rBoP when h approaches zero.
7. Chennaiah MB, Kumar PN, and Rao KP [12] Two pulse durations, 4 ms and 6 ms, were employed to produce weldments at four different pulse frequencies, 0, 25, 50, and 100 Hz. This illustrates the effect of pulse duration on the microstructure. A short pulse length (4 ms) produced finer grains than a long pulse duration (6 ms) for a given pulse frequency. Regardless of the pulse frequency, it was discovered that aluminum grains produced with a 6 ms pulse duration were coarser than those produced by traditional TIG welding (without pulsing). An increase in pulse frequency from 25 to 100 Hz (4 ms pulse duration) may have refined the grain structure because of increased turbulence in the weld pool, which would have encouraged the fracture of developing dendrites to produce a significant number of nuclei. Grain refining occurs at a lower pulse frequency when the net heat input is increased during the 6 ms pulse duration. A high net heat input (over 50 Grain development may result from the Hz pulse frequency (6 ms pulse duration) because of a slower solidification rate and longer solidification time. Four pulse frequencies (0, 25, 50, and 100 Hz) and two peak current levels (160 and 180 A) were used to create the weldments. It is evident that a low peak current is produced at a given pulse frequency finer than high-peak-current aluminum granules.
8. K. Eazhil, S. Mahendran, and S. Ganesh Kumar et al. [13] optimized tungsten inert gas welding on 6063 aluminum alloy using the Taguchi technique. To optimize the mechanical properties of 6063 aluminum alloy weldments, pulsed TIG welding process parameters were optimized using the Taguchi method L27. Analysis of variance is necessary to determine the impact of specific components. The optimal parameters for the TIG welding procedure were determined, and the experimental results validated the proposed approach.
9. C. Parthasarathy and D. Sathyaseelan et al. [14] In this experiment, gas tungsten arc welding and pulsed current at frequencies of 2 Hz, 4 Hz, and 6 Hz were used to make weldments of aluminum

alloy (5052). A chemical analysis test was performed on the selected components, electrode, and aluminum plate to verify that the materials were correctly constructed. After successful results, it was passed through a manufactured weldment with appropriate parameters. Two distinct thick materials were subjected to non-destructive testing, liquid penetration tests and radiography, which were evaluated and compared with pulsed welding at different frequencies on 2 mm and 3 mm of 5052 aluminum alloy. This experiment aimed to investigate the effect of pulsed current on weldment quality.

10. Sandeep Verma, H.K. Arya, Pankaj Kumar et al. [15] The tensile characteristics, impact strength, microstructure, microhardness, and fractography of AA6063 aluminum alloy joints were created by alternating current tungsten inert gas (ACTIG) welding. The effects of the post-weld heat treatment (PWHT) were assessed. Because of its increased strength, ductility, and lack of discernible microstructural defects, the ACTIG welding technique was selected. As-welded (AW) and PWHT samples were obtained from the welded samples. As part of the PWHT process, the samples were subjected to solution treatment (535°C, 2h), water quenching, and artificial aging (165°C, 18h). The results of the investigation showed that the AA6063 joints' mechanical and microstructure characteristics following PWHT were significantly superior to those of the AW samples. The ultimate tensile strength and impact strength improved by 22.22%.
11. Balram Yelamasetti, Venkat Ramana G, Vishnu Vardhan T, et al. [16] ER4043 filler and the gas tungsten arc welding technique were used in this experiment to achieve AA5052 and AA6061 weld junctions. In addition to the welding current and root gap parameters, the output criteria included ultimate tensile strength, hardness, and impact toughness. Experiments were performed using a complete factorial design technique. Regression models were constructed using linear-fit methodology for each output response. An analysis of variance was performed to examine how certain factors affected the output responses. A higher tensile strength of 393 MPa and impact strength of 59 J were observed when the welding current was 210 A and the root spacing was 1 mm. The welding currents are the primary determining elements.
12. Zhaoyang Yan, Tao Yuan & Shujun Chen et al. [17] The mechanism of the microstructure refinement of metals and alloys (5052 and 6061) by arc oscillation was studied and debated using the grain size of conventional welds and those welded at different oscillation frequencies. The 5052 alloy began to develop fine columnar crystals around the “internal fusion line” during oscillating arc welding, and the low- and high-frequency oscillating arcs greatly polished the grains. Unfortunately, the unique crystal growth pattern at the fusion line and the characteristics of the material limits the amount of grain refinement that can be achieved in the 6061 Al alloy during arc oscillation welding. This is not caused by a modification in the grain refining process, but rather by distinct material properties [18].
13. P. Kah1, a, E. Hiltunen1, and J. Martikainen [19] Our findings demonstrate that the susceptibility of an aluminum base alloy to cracks is mostly influenced by its chemistry and the welding procedures used. Applying the same logic, we can deduce that the sensitivity of an aluminum weld to cracks is likewise influenced by its chemistry. An aluminum weld is typically composed of a base alloy and a filler alloy. - Liquation cracking can occur, although solidification cracking can be prevented with filler metals 4043 and 5356. - MIG produces fewer liquation cracks and greater or comparable hardness with a narrower HAZ than TIG while evaluating the sensitivity to liquation cracks in TIG and MIG welding of 6005 and 6082 base alloys.
    - Preheating has no discernible impact on the prevention of liquidation cracks. - The alloy 6082
14. M. Ema [20] Using 3.0 mm thick plates, seven different types of alloys were compared with respect to the strength of MIG welded joints in relation to the 5000 group, 6000 group and 7000 group aluminium alloys, which have recently started to be applied to the lower structural components of automobiles as well as ships, railway carriages and structures for civil engineering and construction. This led to the following conclusions. The tensile test of butt joints with weld reinforcement revealed that almost 100% of the joint strength could be achieved using 5000 group alloys, 5154-O, and 5083-O. The joint strength was approximately 70% for the 6000 group alloys, 6061-T6 and 6N01–T5, which have softened parts impacted by welding heat. The 7000

group alloys exhibited a joint strength of approximately 80– 90%, with the heat-affected softer section becoming stronger over time owing to natural aging. The tensile strength of the thermally treated alloys of the 6000 and 7000 groups was proportional to the minimum hardness of the weld heat-affected zone, and these alloys cracked at the weld heat-affected zone and at their butt joints. The tensile strength of the lap joints was lower than that of the butt joints because of the one-sided fillet welding method used to conduct the test, which resulted in fractures occurring at the weld metal for all base materials tested. Additionally, the joint efficiency was only approximately 40–70%. Furthermore, the strength of the foundation material and the hardness of the joint cannot be the only criteria that determine the joint strength.

15. C.A.G. Aita, I.C. Goss, T.S. Rosendo, M.D. Tier, A. Wiedenhöft, A. Reguly [21] This study examined whether the Taguchi technique could be used to identify a set of welding settings for the FSSW process, which creates overlapping spot joints in 6060-T5 aluminum alloy. Next, the Taguchi technique was applied to determine an equation that used the welding parameters to predict the joint strength. Additionally, a Full Factorial Design (FFD) was employed to create FSSW joints and derive an additional strength-predicting equation to confirm the applicability of the Taguchi approach. Subsequently, the equations produced by Taguchi and FFD were compared. As a first step in identifying the most important input variables (welding parameters) for the intended output variable (shear strength), the Taguchi technique can be used to identify and eliminate input factors that have no bearing on the result.
16. C. Sanjeevi1 and K. Muthukumar [22] The process of joining two pieces of metal is called welding. The porosity increased as the thickness increased during gas tungsten arc welding because of the welding process. Consequently, the metal becomes weaker. Therefore, it has been suggested that gas metal arc welding, which uses aluminum alloys, improves metal strength. Welding of aluminum alloy 5086 with a thickness of 2 mm occurs at three distinct frequencies: 2, 4, and 6 Hz. After welding, the weldments were subjected to liquid penetration and radiographic testing. The porosity of the weldments of the aluminum alloy was found to decrease in the radiography test as the thickness and pulse frequency increased. During the liquid penetration test, no defects were observed in the nonpulsed current and pulsed current weldments.
17. Arunkumar K, Dhayanithi G2 [23] Properties of aluminum alloys' ability to weld differ significantly among alloy frameworks. The hot cracking or solidification cracking propensity of aluminum alloys is the primary factor governing their weldability. Hot cracking can occur in any heat-treatable metal. The weld metal composition has a significant impact on the susceptibility to solidification cracking; therefore, selecting an appropriate filler material is crucial for controlling the solidification of cracks. A pulsed-current TIG welding method was used to create the joints. Argon (99.99 percent purity) was used as the shielding gas. The goal of this work was to better understand the effects of pulsed current parameters and optimize them for TIG-welded aluminum alloy Al 5052 to improve its mechanical and metallurgical qualities. TIG welds with current pulsing have a relatively finer and more optimized grain structure. To maximize the grain precision in the fusion zone, a technique to adjust the pulsed-current TIG welding settings has been proposed. The peak current and pulse frequency are generally closely correlated with the welded joints; that is, if the peak current is increased, the frequency is also directly correlated with the welded joints. Determining the primary and interacting components of the current pulsed TIG welding process is accomplished through the evaluation of variance approaches.
18. Mustafa* and Paulraj [24] investigated the impact of McT on the AA5083-H111 alloy during P-GTAW. The differences in the properties of the grain boundaries, emergence and distribution of intermetallic particles, and dislocation cells with respect to the McT level were examined. These Results suggest that using a shorter McT (40%) at both current levels preserved a significant amount of Mg in the FZ, which in turn promoted β-phase precipitation at the borders of the grains in Welds 1 and 3. Nevertheless, as we treated welds with a longer McT (60%), there was no evidence of grain boundary β-phase precipitates in welds 2 and 4. Utilizing a longer McT (60%) at a lower current level (130A) resulted in a small increase in the weld pool temperature and accelerated the dislocation absorption into the grain interior. Additionally, it generated more

evenly distributed finer Mn-rich intermetallic throughout the grain matrix. This event led to a higher activation energy, which improved the creep resistance and tensile strength by decreasing the driving force pushing the grain boundaries and increasing the pinning pressure at the grain boundaries via precipitation hardening. However, the loss of dislocations surrounding coarser intermetallic (Mg2Si, α-Al(Fe, Mn)Si) and their creation.

19. Hazari et al. [25] investigated the impact of different welding parameters on the overall strength and hardness of the finished components has been conducted. Based on an experimental study conducted across the welded joints of AA6082 and AA8011, the TIG welding technique led to the following deductions: the ultimate tensile strength improved noticeably as the current intensity increased, and a significant increase in its yield strength was also noted. Moreover, by improving the shielding efficiency, the ultimate tensile strength also increased in direct proportion to the gas flow rate. Although there is not much of a difference in the filler material's diameter, the material that was welded using a filler wire with a 2.5 mm diameter had the highest strength.
20. C. Xu, G. M. Sheng, Y. Q. Deng, X.J. Yuan, and K.L. Tang [26] The mechanical characteristics and microstructure of lap Mg/Ti junctions that were TIG-welded and brazed were examined. The ideal welding current of 60–70 A and the welding speed of 0.2 m min21 produced joints with exceptional and dependable mechanical strength. In the fusion zone, grain coarsening and formation of the Mg17Al12 precipitate phase occurred in tandem with a somewhat quick and non-equilibrium cooling process. At the interface of the Mg/Ti joints, a small layer of 3–5 mm-thick Mg–Ti solid solution was discovered, suggesting that metallurgical bonding between the Mg alloy and Ti occurred. Under tensile loading, the joint with the ideal welding parameter ruptured near the fusion zone of the seam, primarily owing to grain coarsening.
21. Raveendra and Kumar [27] This experimental work included radiography, liquid penetrant testing, and process parameter selection for both pulsed and nonpulsed current GTAW welding of aluminum alloy 5052 with two distinct thicknesses. The porosity was shown to increase in the weldments of aluminum alloy 5052 with an increase in thickness and pulsed frequency. During the liquid penetrant test, no defects were found on the weldments with non-pulsed current and pulsed current weldments (2HZ, 4HZ, and 6HZ). Hardness, tensile strength, and microstructure testing can be used to further investigate the impact of pulsed current on these weldments (both pulsed and nonpulsed current weldments).
22. T.E. Abioyeh. Zuhailawati Aizad A Anasyida [28] The 0.6 mm-thick AA 5052-H32 alloy was successfully welded using a pulse laser. Based on the AWS D17.1 specification, appropriate parametric combinations were obtained, which resulted in weld joints suitable for aeroplane structures. (I) High pulse energy (25 J) and high average peak power (4.2 kW), and (II) low pulse energy (17.6 J) and low average peak power (2.8 kW) are suitable parametric combinations. It was discovered that as the pulsed laser current, frequency, and duration increased, the weld width also increased. The dendritic grain structure, which became finer at a low pulse energy and low average peak power (i.e., reduced heat energy input), was a defining feature of the weld joints. Magnesium loss was observed in the weld, which was more pronounced with increased thermal energy input.
23. N. Coniglio, Cross CE [29] Cast combinations of aluminum alloys 4043 and 6060 have undergone solidification thermal analysis, which simulates the alloy compositions that are typically found in weld metal. Three distinct thermal analysis techniques were used, and each technique had special benefits for identifying certain phase responses. The microstructure and solidification path of cast 6060 aluminium have undergone significant changes due to an increase in silicon content (0.4 to 1.4 wi% Si) and a corresponding decrease in 4043 dilution (0 to 20% 4043). In particular, there was an increase in the amount of interdendritic constituents (2–14% solid fraction) and a simultaneous decrease in the solidus temperature (577–509 °C). Several stages and phase morphologies were created, where, if both ternary and three stages and a quaternary eutectic with low melting.
24. Duan, C., Yang, S., Gu, J., Xiong, Q., and Wang, Y. [30] This study describes the laser-MIG

hybrid welding process used to weld 6061 aluminum alloy. The main subjects of this study were the microstructure of the welded joint and the ratchet strain. The tensile characteristics of the laser-MIG hybrid welding joint for the 6061-aluminum alloy and equiaxed grains predominated in the weld center of the 6061 Al alloy laser-MIG hybrid welding joint, while the grains in the top portion of the weld were larger than those in the lower portion. The equiaxed grains were surrounded by an abundance of fine grains. According to the hardness analysis of the laser-MIG hybrid welded joint made of 6061 aluminum alloy, the weld along the fusion line had a higher hardness than the weld in the center, which had the lowest hardness of approximately 82 HV.

CONCLUSIONS

In this study, the mechanical attributes of the weldability of aluminum alloys utilizing tungsten inert gas welding are reviewed. The following succinctly describes the conclusions of this study.

1. Several studies have stated that different mechanical properties of aluminum alloys are optimized by the TIG welding process.
2. The recommended parameters that can be regulated during the pulse-current TIG welding process are the pulse current, base current, and pulse frequency, which are the outcomes of research into the pulsed-current TIG welding joining process.
3. Nevertheless, the welding current and inert gas flow rate have a significant impact on the quality of the TIG-welded connections. The weldment porosity decreases with increasing thickness and pulse frequency on a radiograph.
4. In addition, because AC power supplies offer greater strength and purity, they are often advised for TIG welding of aluminum.
5. The welding current and inert gas flow rate had a significant impact on the quality of the TIG-welded connection.
6. It was discovered that voltage had the greatest impact, whereas the gas flow rate had the least impact.

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