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Influence of Groove Angle on Pitting Corrosion Resistance, Mechanical, and Metallurgical Properties of Gas Tungsten Arc Welded AISI 304 Stainless Steel Joints

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Abstract- This study aims to investigate the influence of groove angle on the welding process, pitting corrosion resistance, mechanical properties, and metallurgical characteristics of Gas Tungsten Arc Welded (GTAW) joints in 6mm thick AISI 304 stainless steel (SS) plates. Three different groove angles are employed in the welding process, and the resulting joints are subjected to comprehensive analysis. The research reveals significant findings regarding pitting corrosion resistance, impact toughness, ultimate tensile strength (UTS), heat dissipation characteristics, and hardness of the welded joints. Notably, joints with smaller groove angles exhibit superior pitting corrosion resistance, higher UTS, impact toughness, and hardness. Additionally, variations in groove angle lead to differences in heat dissipation characteristics across the joints. Based on these findings, recommendations are made to prioritize smaller groove angles for achieving better pitting resistance and mechanical properties in GTAW welded joints of AISI 304 SS. This study contributes valuable insights into optimizing welding processes and enhancing the performance of welded joints in stainless steel applications.

Keywords- Groove angle, Gas Tungsten Arc Welding (GTAW), AISI 304 stainless steel, Pitting corrosion resistance, Mechanical properties

I. INTRODUCTION

In modern industries, products are predominantly created by welding, a process that fuses together similar or dissimilar materials, typically metals. This welding, essential for strength and durability, has replaced older methods like hammering. Welding techniques have evolved significantly, reflecting the technological advancements of our time. It's now a cornerstone in the fabrication of diverse products, from automobile chassis to domestic appliances [1]. Since the advent of science and technology, various joining methods have emerged, including soldering, brazing, riveting, and welding [2]. Among these, welding stands out for its versatility and impact on product quality and longevity. Welding involves melting materials together, often with the application of pressure, to form a strong joint. Crucial welding parameters such as speed, current, temperature, and electrode type must be precisely controlled to ensure the integrity of the joint [3,4].

Preparation of surfaces is paramount for successful welding, as is ensuring compatibility between materials. Creating an optimal environment for welding is essential to facilitate a smooth joining process. Overall, welding represents a pivotal aspect of modern manufacturing, enabling the creation of high-quality products with enhanced durability and functionality.

Gas Tungsten Arc Welding (GTAW), also known as TIG Welding according to AWS (American Welding Society), is extensively used for welding thin walled plates, sheet metals, and pipes up to 3mm thick. In this process, a fusion arc is formed between a tungsten electrode and the base metal, generating heat to melt the metal edges for welding. To maintain quality, shielding gas, typically an inert gas, is directed through a nozzle to prevent oxidation in the weld area.

Unlike other arc welding methods, GTAW does not consume the electrode. However, to optimize efficiency, the electrode tip is usually ground to a fine point. Additionally, filler material, matching the base metal, is fed into the weld pool to build up the weld. GTAW is renowned for producing high-quality welds and technological advancements have expanded its applications, offering greater control over the welding process in various industries [5].

Welding parameters play a crucial role in achieving high-quality weld joints as they directly impact weld geometry characteristics. These parameters, such as welding current, electrode diameter, torch position relative to the base plate, polarity, arc voltage, arc travel speed, shielding gas, and power source (AC & DC), can be adjusted to improve weld quality ([6], [7], [8], [9]). For instance, welding current affects both penetration and reinforcement, where higher current increases fusion depth but also leads to increased electrode consumption. Electrode diameter influences weld bead shape and penetration, with smaller diameters offering better penetration due to higher current density. Electrode work angle and stick-out also influence bead configuration, while polarity affects deposition rate and mechanical properties. Arc voltage and travel speed impact weld stability and penetration, with shielding gas crucial for protecting the weld pool from atmospheric gases. Finally, the power source, preferably DC with positive polarity for GMAW, provides constant voltage during the fusion process. These parameters, when carefully controlled, ensure optimal weld quality and performance.

TIG welding finds its role in welding metal plates typically around 5-6mm thick, although thicker materials can be welded using multiple passes, albeit with potential drawbacks like distortion and reduced mechanical properties. Its precision and control over heat input and filler addition allow for high-quality welds with minimal finishing required, making it suitable for a range of applications in various industries such as aircraft, automotive, maintenance and repair, and nuclear. The process offers several advantages, including the absence of slag formation, superior weld quality, versatility in welding different materials, suitability for thin sections due to low heat input, minimal distortion, and the production of a narrow, concentrated arc, with no spatter or fumes [6]. Overall, TIG welding stands out for its ability to deliver precise, clean, and high-quality welds across a diverse range of materials and applications.

Reviewing the literature in a particular area of interest is crucial to avoid duplicating work, which could lead to the wastage of valuable resources, efforts, and time without contributing scientific value. It is especially important for maximizing the potential of engineering materials concerning their processing methods. Several studies have been conducted in this regard. Gowrisanker et al. [9] investigated the effect of multi-pass welds on AISI 316L stainless steel using submerged arc welding, focusing on the mechanical properties influenced by the number of passes. Murugan et al. [10,11] studied low carbon steel and AISI 304 stainless steel, respectively, using Manual Metal Arc Welding (MMAW), highlighting temperature distribution and plastic deformation during welding. El Sway et al. [12] examined GTA welding of super ferritic stainless steel alloys, observing the microstructure of welded specimens. Mousavi et al. [13] analyzed residual stress distribution during TIG welding of SS 304, emphasizing the influence of groove geometry. Bahman and Alialhosseini [14] studied MAG welding of St 37 low carbon steel, correlating welding speed and current with mechanical properties. Kumar Suresh L et al. [15] compared TIG and MIG welding on SS materials, analyzing ultimate tensile strength and hardness. Kumar Subhodh et al. [16] studied the influence of heat input on GTAW welded AISI 304 stainless steel joints, examining joint strength and microstructure. Ipeak Nazli Ezgi et al. [17] compared different groove designs, emphasizing their impact on joint strength. Singh Taljeet et al. [18] investigated multi-layer welding on AISI 304 stainless steel, focusing on heat input and joint strength. Chakrabarti et al. [19] studied GMAW process parameters on clad quality of duplex stainless steel, examining corrosion and toughness. Kumar Sateesh et al. [20] analyzed the effect of shielding gas on mechanical properties of SS-316L, emphasizing gas composition. Prajapati et al. [21] investigated GMAW welding variables on the yield strength of AISI 1045, optimizing parameters using the Taguchi method. Sudhakaran R et al. [22] studied welding process variables on microstructure and corrosion of AISI 202 GTA weld joints, emphasizing welding gun angle and current. Markushov et al. [23] presented welding methodologies for thicker materials, comparing single-pass and multipass laser welding techniques. Ganesh et al. [24] used FE modeling to analyze thermo-mechanical behavior in welded joints, comparing single-pass and multipass TIG welding. Gite Kailas A et al. [25] analyzed UTS and micro-hardness of AISI 304 SS in TIG welding, optimizing parameters for joint strength. Paulraj Prabh et al. [26] investigated welding variables on pitting behavior of GTAW weldments, emphasizing heat input and shielding gas composition. Ravi kumar Yadav [27] analyzed welding variables on mechanical properties of AISI 304SS GTA weld joints, highlighting groove angle and welding parameters.

These studies collectively provide valuable insights into optimizing welding processes and enhancing the mechanical properties of welded joints across various materials and techniques. Based on the literature reviewed, several gaps in the existing research have been identified. Firstly, there appears to be a lack of systematic experimental studies that specifically investigate the influence of groove angle on the pitting corrosion, impact toughness, and metallurgical properties of GTA Welded AISI 304SS joints. This gap suggests a need for focused research aimed at understanding how variations in groove angle affect the performance of welded joints in terms of both corrosion resistance and mechanical properties. Secondly, considering that groove angle influences heat input and heat dissipation during welding, it would be valuable to conduct further investigations to determine the optimal groove angle that enhances resistance against pitting corrosion and improves the overall mechanical properties of these joints. By addressing these gaps, researchers can contribute to a deeper understanding of the factors influencing the quality and durability of welded joints, thereby informing the development of more effective welding techniques and materials. The objective of this study is threefold. Firstly, it aims to establish the welding process for 6mm thick AISI 304 stainless steel plates utilizing three distinct groove angles, employing the gas tungsten arc welding (GTAW) process. Secondly, the study seeks to investigate the impact of these varying groove angles on the pitting corrosion resistance and mechanical properties of the resulting AISI 304 SS welds. By systematically varying the groove angles, researchers aim to discern any correlation between groove geometry and the performance of welded joints under corrosive environments, as well as their mechanical strength and toughness. Finally, the study aims to conduct a comprehensive analysis of the metallurgical properties of the welded joints, assessing factors such as microstructure, grain size, and phase composition, to gain insights into how different groove angles influence the material's structural integrity and weld quality. Through these objectives, the research endeavors to contribute valuable knowledge to the optimization of welding processes and the enhancement of welded joint performance in AISI 304 SS applications.

II. MATERIALS AND METHODS

1. Workpiece Material

Material selection is a critical aspect in the design process, forming the basis for engineering applications. Through extensive literature review and research, the choice of material and associated processes are carefully determined.

Table 1: Composition of AISI304 SS

Element	Composition (%)
Carbon (C)	0.08 max
Manganese (Mn)	2.00 max
Silicon (Si)	0.75 max
Phosphorus (P)	0.045 max
Sulfur (S)	0.030 max
Chromium (Cr)	18.00 - 20.00
Nickel (Ni)	8.00 - 10.50
Nitrogen (N)	0.10 max
Iron (Fe)	Balance

Table 2: Composition of Filler Metal

Element	Composition (%)
Carbon (C)	0.03 max
Manganese (Mn)	1.0 - 2.5
Silicon (Si)	0.30 - 0.65
Phosphorus (P)	0.03 max
Sulfur (S)	0.03 max
Chromium (Cr)	19.5 - 22.0
Nickel (Ni)	9.0 - 11.0
Molybdenum (Mo)	0.75 - 1.50
Iron (Fe)	Balance

In this study, AISI 304 stainless steel (SS) is selected due to its widespread industrial applications and availability. AISI 304 SS possesses desirable characteristics such as ease of weldability and machinability, excellent corrosion resistance, and suitable mechanical properties for diverse industrial components. These factors collectively contribute to its suitability for the investigation, ensuring compatibility with the experimental procedures and meeting the requirements of the intended applications. Table 1.

2. Filler Materials

The chosen filler material for the research is 308 L, which is predominantly utilized for austenitic steels such as types 301, 302, 304, and 305, along with cast alloys CF8 and CF3. This wire is particularly suitable for applications in cryogenic temperatures. Maintaining a consistent wire diameter is crucial to ensure proper current flow from the contact tip. Undersized wire can lead to arcing between the wire and the tip's inner diameter, causing erosion and fusion issues. Conversely, oversized wire can result in feeding difficulties, tip blockage, and downtime.

The 308 L filler material finds extensive use in various sectors, including pulp and paper mills, stainless pipes and tubing, among others. When selecting a filler wire, several factors must be considered, such as ensuring compatibility with the base metal's properties, matching chemical compositions, and assessing service conditions like impact loading, corrosive environments, and temperature variations.

These considerations are vital to ensure the effectiveness and reliability of the welding process. This table presents the composition of 308 L filler material commonly used in welding applications, particularly for austenitic stainless steels.

3. Experimental setup

Experimental setup is a critical aspect of any investigation, requiring careful consideration to ensure effective outcomes. This encompasses various components involved in the research process, including the welding procedure, power source, and associated machinery. The power source plays a pivotal role in delivering electrical energy to the workpiece and electrode to generate the welding arc, with arc stability being dependent on prior adjustments and settings. For high-quality welding, effective control of arc length is essential, typically achieved using a constant current type power source with a range of current and voltage settings suitable for Gas Tungsten Arc Welding (GTAW). Tungsten electrodes, particularly those with a ball-shaped tip and operated with direct current electrode negative (DCEN), contribute to arc stability. The TIG torch, comprising components such as collet, nozzle, and tungsten electrode, is integral to the GTAW process, facilitating electrode support, gas shielding, and arc direction. Proper nozzle selection is crucial for uniform gas shielding and weld pool protection. Shielding gas, typically inert, plays a vital role in creating the required atmosphere for arc formation and preventing oxidation of the electrode and weld pool. Gas regulation is managed by a gas regulator, ensuring a consistent flow of gas to the weld area, with different types available based on application requirements. Additionally, a stopwatch is utilized to measure the time taken for welding operations, aiding in the calculation of welding speed and ensuring consistency in experimental procedures. These components collectively form the experimental setup, contributing to the accuracy and reliability of the research findings.

4. Experimental Procedure

Conducting experimental work efficiently and cost-effectively is crucial to achieving desired results in research endeavors. The experimental procedure involves meticulous planning and execution, encompassing various phases from raw material acquisition to the final product and subsequent testing of prepared samples. Sample preparation prior to welding is imperative, involving the selection of appropriate materials, such as hot-rolled stainless steel plates of grade AISI 304 SS, and cutting them into equal lengths. Surface preparation is essential to ensure the quality of the weld joint, with techniques like grinding and machining commonly employed. Subsequent surface finishing of the plates is conducted using a milling machine, followed by cutting them into standardized sizes and providing specific groove designs to facilitate welding.

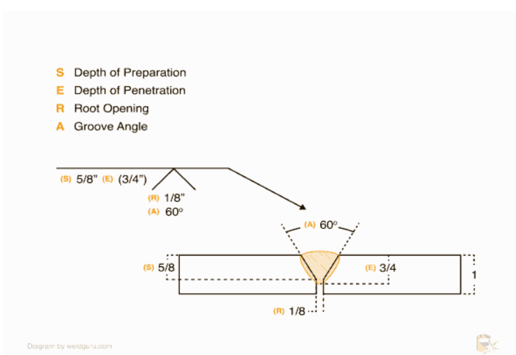

Figure 1: Schematic Sketch Of Groove Design

The welding procedure commences with meticulous surface cleaning to remove any contaminants, followed by joint fit-up and assembly of welding equipment. Welding operations are then carried out on prepared samples using predefined parameters, with three passes of welding applied to each sample. Figure 1 shows the schematic sketch of Groove Design.

After welding, samples undergo grinding to remove foreign material and achieve surface finish. The experimental procedure extends to the preparation of samples for various tests, including Charpy V-notch impact strength, micro-hardness, tensile testing, and pitting corrosion assessment. Each test requires specific sample preparation and testing methodologies, ensuring comprehensive evaluation of the welded joints' mechanical and corrosion resistance properties.

Figure 2: Top View of Sample with different groove angle

5. Preparation of Charpy Test Specimens

Charpy test samples were also extracted from the AISI 304 SS hot rolled steel plate specimen after welding. The dimensions of the specimen were again according to the "ASTM E23-02a". According to the standard the dimensions of specimen should be 55mm ×10mm ×10mm with a 2mm deep groove (45 degree) at center. Diagram shows the dimensions of Charpy V-notch test samples.

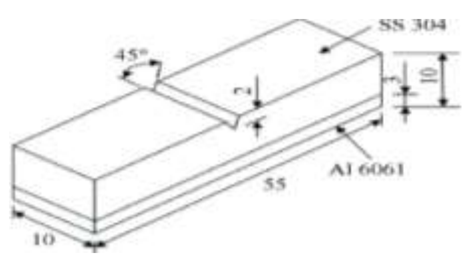

Figure 3: Sample for charpy test

6. Micro-Hardness Test

Micro-hardness was performed for the purpose of checking the influence of multiple layers of welding on the micro-hardness in different zones (weld metal, HAZ and base metal) of the AISI 304 SS

GTAW welded joints in normal direction to the welding. The test samples for micro-hardness were extracted from the GTA welded plates in such a manner so that the variation of micro- hardness can be checked in both the directions from the weldment. To explain in a simple manner, variation of micro- hardness is measured towards left hand side and right hand side of weld center line. Before the micro- hardness testing the specimens were prepared by using belt grinding, different grades of abrasive papers (from 100 grade to 200 grade) to remove the oxide layers and scratches from the surface.

7. Tensile Testing

Whenever there comes something about the development of new products and improving the existing one's quality, durability and forecasting its life then it stuck an engineer to think of evaluation of fundamental properties of the product to be designed. Testing of material helps the designer to have on controlling the quality of components that will be used in construction or design work.

The tensile test was conducted using universal testing machine (UTM). The model used for performing test was UTM-100 which is a versatile machine able to do tensile testing, compressive testing and transverse test of metal and other materials. The capacity of machine is 60 tons and talking about accuracy it is ±1KN.

8. Pitting Corrosion

An extremely localized attack, responsible for producing holes in the metal or alloy is referred to as pitting corrosion. It is one of the most destructive, localized forms of corrosion. The pits are generally small holes or cavities with different cavities with a depth equal to the surface diameter or may even greater. They penetrate the metal, causing equipment failure due to preformation with minimal weight loss. This may be due to fact that aggressive anions penetrate the film at such places and form small pits. The severity of pitting corrosion is curbed by chloride concentration, environment, electrolyte acidity, oxidizer concentration, temperature, structural characteristics, metal or alloy composition, dissolved oxygen concentration, potential and potential scan rates. Surface pitting is proportional to the logarithm of chloride concentration in the electrolyte. To initiate pitting corrosion, the electrolyte must act as a strong oxidizer to favour the passive state. Oxidizing metal ions such as ferric and cupric halides act as electron acceptors (cathodic reactants) and are very aggressive because they do not requireoxygen to initiate and propagate pitting corrosion localized mechanical or chemical damage to a passive oxide, insufficient inhibitor coverage and non- uniformities in the metal structure due to non-metallic impurities contribute to pitting corrosion. Pitting potential is defined by ASTM as the potential beyond which pitting propagates.

The experimental procedure is meticulously designed and executed to generate reliable data and insights for the research investigation.

III. RESULTS AND DISCUSSION

1. Analysis for Toughness

In pursuit of suitable outcomes, a series of experiments were conducted, as detailed in the preceding chapter, involving multi-layer Gas Tungsten Arc Welding (GTAW) on three weld joints of AISI 304 SS (Austenitic).

Table 3: Observation of Charpy Test

Joint	Specimen	Impact Strength	Avg. Impact Strength
Joint-1	1	169	168
	2	165	
	3	170	
Joint-2	1	131	130
	2	132	
	3	127	
Joint-3	1	98	98
	2	90	
	3	106	

Subsequently, mechanical and metallurgical testing was performed to achieve the desired objectives, with the results presented in tables and graphs. To analyze the effect of groove angle on the strength of AISI 304 SS GTA weld joints, Charpy V-notch impact toughness tests were carried out. The test specimens, prepared according to ASTM E-23 standards, consisted of three samples from each joint with varying groove angles (45°, 60°, and 75°), each subjected to three repetitions.

The results, tabulated in Table 3, revealed a maximum Charpy V-notch toughness of 168 Joules for Joint 1 with a groove angle of 45°, and a minimum of 98 Joules for Joint 3 with a groove angle of 75°. The fractured surfaces of the Charpy V-notch specimens, depicted in Figures 4, Figure 5 and Figure 6 exhibit distinct zones such as fracture width, V-notch and crack initiation zone, shear lips, and final fracture.

Figure 4: Fractured view of charpy V-notch (Groove Angle 45^0)

Figure 5: Fractured view of charpy V-Notch (Joint-2, Groove angle 60^0)

Figure 6: Fractured view of charpy V- notch (Joint-3, Groove angle 75^0)

These variations in toughness can be attributed to the differing thermal cycles experienced during solidification post-welding, leading to microstructural variations across different zones of the weldments. Notably, Joint 1 experienced a relatively faster cooling rate, resulting in a finer-grained microstructure in the weld zone and relatively fewer grains in its Heat Affected Zone (HAZ).

2. Ultimate Tensile Strength

The design of the groove, coupled with welding parameters such as the number of passes, arc travel speed, and welding current, plays a significant role in determining the ultimate tensile strength (UTS) of a material. In this study, three samples of welded joints were prepared to investigate their UTS as shown in Figure 7.

Figure 7: Transverse tensile test specimens

Transverse tensile test specimens were utilized for this purpose. As experimental results, Table reveals the effect of groove angle on the UTS and the maximum UTS recorded was 652 MPa with a corresponding percentage elongation of 14.12% for a joint with a groove angle of 45°.

Table 4: Observations of Tensile test

Joint	Ultimate tensiel Strength (MPa)	% Elongation
Joint-1	652	14.12
Joint-2	644	10.78
Joint-3	631	8.03

Conversely, the minimum ductility, with a percentage elongation of 8.03% and a UTS of 631 MPa, was observed for a joint with a larger groove angle. This decrease in UTS with increasing groove angle suggests a trade-off between strength and ductility. The trend observed in these joints can be attributed to the faster dissipation of welding arc heat in joints with smaller groove angles, resulting in a finer-grained microstructure in the weld zone. This finer microstructure enhances the load-carrying capacity of the joint, contributing to the higher UTS observed. However, this strength enhancement comes at the expense of reduced ductility, highlighting the intricate balance between strength and ductility in welded joints influenced by groove design and welding parameters.

3. Pitting Corrosion

The evaluation of pitting corrosion test (mass loss) for the welded joints was conducted by immersing the samples in ferric chloride solution for a duration of 72 hours at room temperature.

Table 5: Observations of pitting corrosion Test

Joint	Sample	No of Passes	Groove Angle	Root Gap	Mass Before Test (mg)	Mass after Test (mg)	Total Mass Loss (mg)
Joint-1	1	3	45	1	28.4828	27.0026	1.4802
Joint-2	2	3	60	1.5	28.0662	26.2206	1.8456
Joint-3	3	3	75	2	28.1048	25.5664	2.5384

The experimental findings reveal that Joint-1, characterized by a groove angle of 45^0, exhibited the maximum pitting corrosion, as evidenced by the lowest mass loss recorded (Minimum mass loss = 1.4802 mg). Conversely, Joint-3, with a groove angle of 75^0, demonstrated minimal pitting corrosion, with nearly double the mass loss compared to Joint-1 (maximum mass loss = 2.5384 mg). These results are summarized in Table 5, illustrating the pitting corrosion of Joint-1, Joint-2, and Joint-3 of AISI 304 SS. Furthermore, Figure 8, Figure 9 and Figure 10 depict the views of Joint-1, Joint-2, and Joint-3 after pitting corrosion, respectively, providing visual insights into the corrosion behavior of the welded joints under investigation.

Figure 8: View of Joint-1 after pitting corrosion

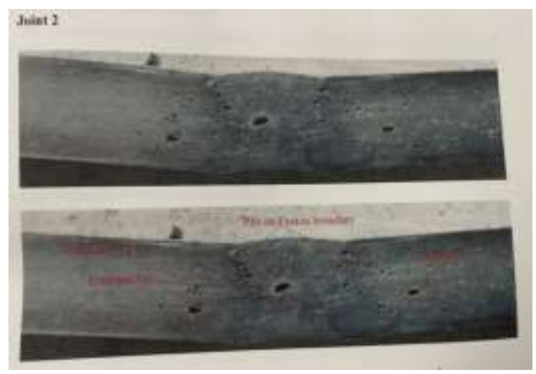

Figure 9: View of Joint-2 after pitting Corrosion

Figure 10: View of joint-3 after Pitting Corrosion

4. Microhardness

The micro hardness of welded joints is influenced by three key process parameters: the number of weld passes, welding current, and arc travel speed.

Before obtaining micro hardness readings from specimens, it is imperative to grind flat surfaces on both sides of the specimens. The surfaces are then polished using various grades of abrasive paper ranging from 100 to 1200. The micro hardness test is conducted using a micro-hardness tester with a 500-gram load applied for a 20-second dwell period across different zones of the welded plates, including the weld metal, heat-affected zone (HAZ), and base metal. Readings are taken in the transverse direction to the welding, with a distance of 0.5mm between successive readings and illustrated in Figure 11, Figure 12, Figure 13 and Figure 14

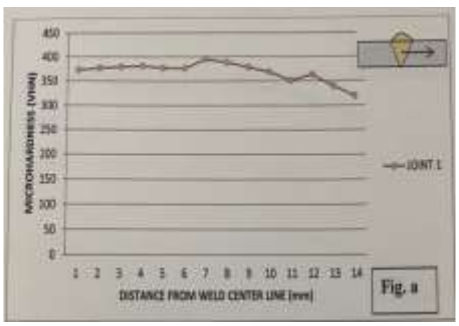

Figure 11: Hardness profile of GTAW Joint-1 with groove angle 45^0.

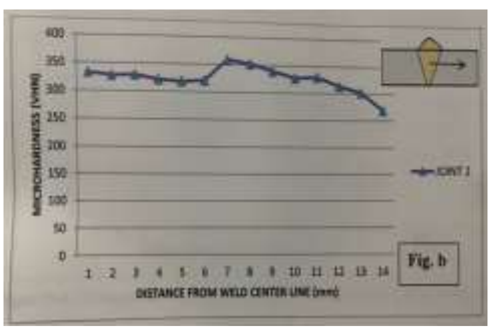

Figure 12: Hardness profile of GTAW Joint-2 with groove angle 60^0.

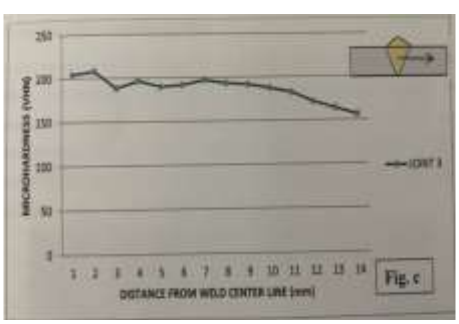

Figure 13: Hardness profile of GTAW joint-3 with groove angle 75^0

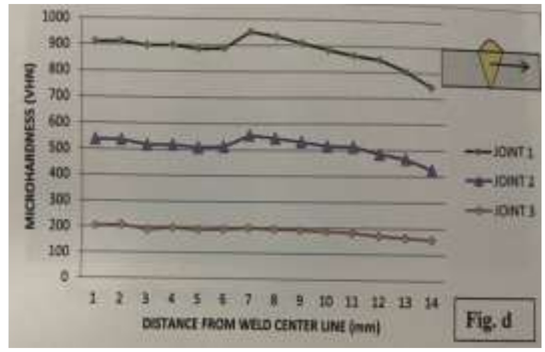

Figure 14: Hardness profile of GTAW Joints 1, 2 & 3.

The hardness profiles depict the variation of micro-hardness from the weld centerline to the right side of the weldment. The plots reveal notable differences among joints with varying groove angles. Joint 1 exhibits relatively higher micro-hardness values compared to Joint 2 and Joint 3. Peaks in the hardness profiles indicate areas of high micro-hardness, typically corresponding to the fusion boundary zone where partially melted grains are present. This observation underscores the significance of groove angle selection in influencing the micro hardness distribution within the welded joints.

5. Microstructure study

To analyze the influence of groove angle on the weld zone and heat-affected zone (HAZ), microstructural studies were conducted on various welded samples. Micrographs of these specimens, treated with Villella's reagent etchant, were obtained to observe the microstructure.

Figure 15: Micrograph of Joint 1(groove angle45^0)

The etching process involved a mixture of hydrochloric acid, picric acid, ethanol, and a few drops of hydrogen peroxide, applied for 10 to 15 seconds. The micrographs, presented in Figures 14, Figure 15 and Figure 16, depict the weld metal of AISI 304 SS welded joints corresponding to different groove angles (Joint 1: 45°, Joint 2: 60°, and Joint 3: 75°).

Figure 16: Micrograph of joint 2 (groove angle 60^0)

Figure 17: Micrograph of Joint 3 (groove angle 75^0)

An initial observation from these micrographs is that the weld zone of Joint 1 appears finer, characterized by small dendrites with a small interdendritic spacing, in contrast to Joints 2 and 3. This phenomenon can be attributed to the lesser amount of weld metal deposited in the smaller groove of Joint 1, leading to steeper thermal gradients and a faster cooling rate, resulting in a finer microstructure. Conversely, larger groove angles require more weld metal to fill the groove, leading to a slower heat dissipation rate and, consequently, a coarser microstructure in Joints 2 and 3. These microstructural observations provide insights into the relationship between groove angle and microstructure in welded joints, informing the understanding of welding processes and their outcomes.

IV. CONCLUSION

The experimental results of the current investigation work indicate that variation in the weld groove design (groove angle) exerts a significant influence on the pitting resistance, Ultimate Tensile strength and energy absorption behavior along with metallurgical properties of GTA welded AISI 304 SS(Austenitic) joints

1. Groove Angle and Pitting Corrosion Resistance

Joint-1 (groove angle 45°) exhibited the highest pitting corrosion resistance with a minimum mass loss of 1.4802 mg. Joint-3 (groove angle 75°) showed the lowest pitting corrosion resistance, with nearly double the mass loss compared to Joint-1 (maximum mass loss = 2.5384 mg).

2. Impact Toughness and Ultimate Tensile Strength (UTS)

Groove angle significantly influenced UTS and Charpy V-notch (CVN) values of the welded joints. Joints with smaller groove angles demonstrated higher tensile strength and impact toughness, which decreased with increasing groove angle.

3. Heat Dissipation Characteristics

Variation in groove angle resulted in changes in heat dissipation characteristics across the welded joints.

4. Hardness

Maximum hardness was observed in welded joints with the smallest groove angle. The rapid cooling rate of weld metal in these joints contributed to the higher hardness due to faster solidification.

5. Recommendations

Based on the experimental findings, it is recommended to prefer smaller groove angles for better pitting resistance and mechanical properties in GTA welded joints of AISI 304 SS.

REFERENCES

1. Hussain Ahmed Khalid, Lateef Abdul, Javed Mohd, T. Pramesh (2010), “International journal of applied engineering research, Dindigul, Vol. 1, PP. 518-527.
2. Norish John, “Advance welding processes, technologies and process control, 2006 Edition, Wood Head Publishing Limited, Cambridge, England.
3. Owolabi Oluwasegun Biodun, Aduloju Sunday Christopher, Metu Chidiebere Sobechukwu, Chukwunyelu, Okwuego Emeka Charles(2016), “Evaluation of the effects of welding current on mechanical properties of welded joints between mild steel and low carbon steel”, American journalof material science and application, Vo4, PP.1-4.
4. Shanmugasundar G, KarthikeyanB, Ponvell Santosh P, Vignesh V (2019), "Optimization of process parameters in TIG welded joints of AISI 304L-Austenitic stainless steel using Taguchi's experimental design method", Materials today proceedings, Vol. 16, PP.1188-1195.
5. Kau Sindu, "Welding metallurgy", 2002 Edition, Wiley-Interscience publication', New Jersey, USA.
6. Kumar C. Labesh, Vanaja T, Murti KGK, Prasad VVSH (2017), "Optimization of MIG Welding Process Parameters For Improving Welding Strength of Steel", International Journal of Engineering Trends and Technology (UETT), Vol. 50, PP. 26-33.
7. Chavda Satyaduttsingh P, Desai Jayesh V, Patel Tushar M (2014), " A review on optimization of MIG Welding Parameters using Taguchi's DOE Method", International journal of engineering and management research, Vol. 4, PP. 16-21.
8. Dixit Rahul, Kaushik Kuldeep, Mittal Promise (2018), "Modeling, Analysis & Optimization of Parameters for Great Weld Strength of the Chassis for off-Road Vehicles', International Research Journal of Engineering and Technology (IRJET), Vol. 05, PP. 1907-1915.
9. Gowrisankar I, Bhaduri A. K, Seetharaman, Verma D. D. N, Achar D. R. G (1987), "Effect of the Number of Passes on the Structure and Properties of Submerged Arc Welds of AISI Type 316L Stainless Steel", welding research supplement, PP. 147-157.
10. Murugan.S, Kumar P.V, Raj.B, Bose M.S.C (1998), "Temperature distribution during multipass welding of plates", International journal of pressure vessels and piping, vol. 75, PP. 891-905.
11. Murugan.S, Rai Sanjay.K, Kumar P.V, Raj, Kumarjaya, T, Baldev, Bose M.S.C 2001), "Temperature distribution and residual stresses due to multipass welding in type 304 stainless steel and low carbon steel welds pads", International journal of pressure vessels and piping, vol. 78, PP. 307-317.
12. H. Ahmed, Sawy. EL (2001), "Characterization of GTAW fusion line phases for superferritic stainless steel weldments", Journal of materials processing technology, Vol.118, PP. 128-132.
13. Mousavi S.A.A. Akbari, Miresmaili R (2008), "Experimental and numerical analyses of residual stress distributions in TIG welding process for 304L stainless steel", journal of materials processing technology, Vol. 208, PP. 383-394.
14. Bahman A.R, Alialhosseini E (2010), "Change in hardness, yield strength and UTS of welded joints produced in St 37 grade steel", Indian journal of science and technology, Vol. 3, pp. 1162-1164.
15. Kumar Suresh L, Verma S.M, Prasad P.Radhakrishna, kumarP.Kiran, Shanker Siva T (2011), "Experimental Investigation for Welding Aspects of AISI 304 & 316 by Taguchi Technique for the Process of TIG & MIG Welding", International Journal of Engineering Trends and Technology, Vol. 2,Issue-2, PP. 28-33.
16. Kumar Subhodh, Sahi A.S (2011), "Effect of heat input on the microstructure and mechanical properties of gas tungsten arc welded AISI 304 stainless steel joints", Materials & Design, Vol. 32, PP. 3617-3623.

17. Ipek Nazli Ezgi, Elaldi Faruk (2012), "Analysis of Welding Groove Angle and Geometry on Strength of Armor Steel", Materials and Manufacturing Processes, Vol. 27, pp. 1437-1441.
18. Singh Taljeet, Shahi A.S, Kaur Mandeep (2013), "Experimental studies on the effect of multipass welding on the mechanical properties of AISI 304 stainless steel SMAW joints", International Journal of Scientific & Engineering Research, Vol.4, PP. 951-960.
19. Chakrabarti. B, Das. H, Das. S, Pal. T. K (2013), "Effect of Process Parameters on Clad Quality of Duplex Stainless Steel Using GMAW Process", Trans Indian Inst Met 66(3), pp. 221-230.
20. Kumar K. V. Satheesh, Gejendhiran S, and Prasath M (2014), "Comparative Investigation of Mechanical Properties in GMAW/GTAW for Various Shielding Gas Compositions", Materials and Manufacturing Processes, pp. 996-1003
21. Prajapati. Rakesh. B, Patel. Disha. B, Patel Tushar. M (2014), "Experimental Investigation of GMAW for AISI 1045 Material using Taguchi Method", International Journal of Scientific & Engineering Research, Vol. S, pp. 15-19.
22. Sudhakaran R, Sivasakthivel. P.S, Nagaraja.S and Eazhil. K.M (2014), "The Effect of Welding Process Parameters on Pitting Corrosion and Microstructure of Chromium-Manganese Stainless Steel Gas Tungsten Arc Welded Plates', 12th Global Congress On Manufacturing And Management, GCMM 2014, Vol. 97, PP. 790-799.
23. Mousavi S.A.A. Akbari, Miresmaili R (2008), "Experimental and numerical analyses of residual stress distributions in TIG welding process for 304L stainless steel", journal of materials processing technology, Vol. 208, PP. 383-394.
24. Ganesh K.C, Balasubramanian K.R, Vasudevan M, Vasantharaja P, Chandrasekhar N (2016), "Effect of Multipass TIG and Activated TIG Welding Process on the Thermo-Mechanical Behavior of 316LN Stainless Steel Weld Joints", Metallurgical and Materials Transactions B, Vol. 29. pp. 903-909.
25. Gite Kailas A. Pawar Ramkisan S (2016), "Analysis of Tensile Strength, Ultimate Tensile Strength and Micro Hardness for TIG Welding on Material AISI 304 Stainless Steel", IJSRD - International Journal for Scientific Research & Development| Vol. 4, Issue 09, 459-462.
26. Paulraj Prabh, Garg Rajnish (2016), "Effect of welding parameters on pitting behavior of GTAW of DSS and super DSS weldments", Engineering Science and Technology, an International Journal, Vol. 19, PP. 1076-1083.
27. Jadav Ravi kumar, Acharya G.D, Kikani Pratik (2017), "Experimental Investigation of Welding Process Parameters on Mechanical Properties for TIG Welded Austenitic Stainless steel 304 Joints", Journal of Experimental & Applied Mechanics, Vol. 8, PP. 1-3.