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Evaluation on the Mechanical Strength of TIG Welded 6061Aluminium Alloy Joints

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Abstract

Aluminum alloy Al-6061 is extensively used in aerospace, automotive, and marine industries due to its excellent mechanical properties, lightweight nature, and corrosion resistance. However, welding this alloy presents challenges such as porosity, hot cracking, and strength reduction in the heat-affected zone (HAZ). Tungsten Inert Gas (TIG) welding, known for its precision and quality, is commonly employed for joining Al-6061. This study investigates the tensile strength of TIG-welded butt joints of Al-6061 alloy, focusing on the influence of key welding parameters. Tensile tests were conducted on welded samples to evaluate their mechanical performance. The results demonstrate the relationship between process parameters and joint strength, providing valuable insights for optimizing TIG welding conditions to achieve stronger and more reliable welds. In addition, the study examines the effects of welding current, travel speed, shielding gas flow rate, and filler material selection on weld quality and tensile behavior. Standardized specimen preparation and testing procedures were adopted to ensure repeatability and accuracy of the results. Fracture characteristics of the tensile-tested specimens were also analyzed to identify the predominant failure locations, particularly within the weld metal or the HAZ. The findings reveal that appropriate control of TIG welding parameters significantly improves joint efficiency and minimizes common welding defects. The outcomes of this work contribute to a better understanding of TIG welding behavior in Al-6061 alloy and serve as a practical guideline for industrial applications requiring high-strength and defect-free aluminum welds.

Keywords: Al 6061; TIG welding; Tensile Strength, HAZ; Porosity; Hot cracking.

INTRODUCTION

Aluminum alloys are widely used in various industries, including aerospace, automotive, and marine sectors, due to their excellent strength-to-weight ratio, corrosion resistance, and good thermal conductivity. Among these alloys, Al 6061, a precipitation-hardened aluminum alloy, is particularly popular for structural applications because of its superior mechanical properties, weldability, and versatility. However, achieving strong and reliable weld joints in Al 6061 presents challenges, especially due to the formation of defects like porosity, hot cracking, and loss of strength in the heat-affected zone (HAZ). Tungsten Inert Gas (TIG) welding, also known as Gas Tungsten Arc Welding (GTAW), is a preferred welding technique for aluminum alloys. TIG welding ensures high-quality welds with excellent control over heat input, which is crucial for minimizing distortions and defects. When welding Al 6061, it becomes imperative to analyze the tensile strength of the resulting butt joints to assess their performance under loading conditions and understand the impact of process parameters on weld quality. This study focuses on the analysis of

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the tensile strength of TIG welded butt joints of Al 6061 alloy. This research aims to provide insights into the factors influencing joint strength, such as welding current, travel speed, and filler material.

Jia, L., and Liu, J. [1] studied the effect of welding parameters such as current, travel speed, and shielding gas on the tensile strength of TIG-welded Al 6061 joints. The authors found that an increase in welding current enhances penetration, improving joint strength, also increases the risk of defects such as porosity if not properly controlled. Liu, Z., et al. [2] have studied the microstructure and mechanical properties of TIG welds in Al 6061. They explored the microstructural changes in the heat-affected zone (HAZ) of TIG-welded Al 6061 joints. They concluded that controlling heat input is crucial to minimize grain coarsening, which negatively affects tensile strength and overall weld performance. Suthar, A., and Mahapatra, M. M. [3] have studied the influence of welding parameters, including filler material and welding speed, on tensile strength and defects in Al 6061 TIG welds. The study emphasized the importance of optimizing parameters to reduce defects like cracks and porosity that degrade weld strength. Li, S., et al. [4] investigated the influence of welding current on the tensile properties of Al 6061 TIG welds. Their study concluded that higher welding currents lead to deeper penetration, but excessive heat input can cause porosity and cracking, reducing tensile strength.

Bhattacharjee, S., and Ghosh, S. [5] have studied the effect of filler materials such as ER4045 and ER5356on the tensile strength of Al 6061 TIG welds. The authors demonstrated that ER5356 provides better tensile strength and resistance to defects compared to ER4045. Kumar, R. and Kumar, S. [6] studied the post-weld heat treatment effects on the mechanical properties of TIG welded Al 6061. Their study showed that solution heat treatment followed by aging significantly improves the tensile strength by reducing the brittleness in the heat-affected zone. Srinivasan, R. and Karthikeyan, R. [7] explored the influence of welding speed and current on the tensile strength of Al 6061 welds. The study concluded that optimizing these parameters helps achieve a balance between strong joints and minimal defects. Yin, L., and Zhang, L. [8] studied the influence of shielding gases, including pure argon and argon-helium mixtures, on the quality of TIG welds in Al 6061. They found that argon-helium mixtures enhance penetration and reduce porosity, improving the mechanical properties of the weld.

Kolli, P., and Mukkavilli, R. [9] focused on the correlation between the heat input and tensile properties of Al 6061 TIG Welds. Their study highlighted that lower heat input minimizes grain growth, preserving the strength of the welded joint. Patel, P., and Mehta, S. [10] provided a thorough review of the challenges involved in TIG welding Al 6061, focusing on defects such as porosity and hot cracking. They discussed the strategies to mitigate these issues and optimize tensile strength. Zhou, X., and Ma, Y. [11] evaluated the relationship between the microstructure of TIG-welded Al 6061 and its tensile strength. They find that a fine-grained microstructure in the weld zone and HAZ results in higher tensile strength, while coarse grains reduce weld quality. Mishra and Bhanumurthy [12] investigated the optimization of TIG welding parameters for Al 6061, including welding current, travel speed, and filler material. Their study demonstrated that careful optimization leads to improved tensile strength, reduced defects, and enhanced overall weld quality.

METHODOLOGY AND EXPERIMENTATION

The objective of the current work is to evaluate the tensile strength of TIG-welded butt joints in Al 6061 alloy. The material used is Al 6061 plates having Dimensions 8x30x300 mm. The experimental work is to be carried out to investigate the tensile strength of single V grooved, butt welded joints obtained using TIG welding and by varying included angles. As included angle increases, the contact area will also increase, thereby increasing the strength. The Al 6061 specimen parameters required for experimentation are shown in the Table 1. The dimensions of the tensile test specimen to be prepared as per the ASTM standard is shown in Figure 1. The specimens are to be prepared with varying groove angles (0°, 45°, 60° and 75°) and constant bevel height 2mm. The prepared Al 6061 tensile test specimens are shown in Figure 2. The tensile testing machine (Universal Testing Machine) is shown in Figure 3. In addition to groove angle variation, strict control of welding parameters such as welding current, arc voltage, welding speed, and shielding gas flow rate is maintained to ensure

Table 1. Specimen parameters for tensile test

S.N.	Sample	Groove angle	Bevel height
1	V1	0°	2 mm
2	V2	45°	2 mm
3	V3	60°	2 mm
4	V4	75°	2 mm

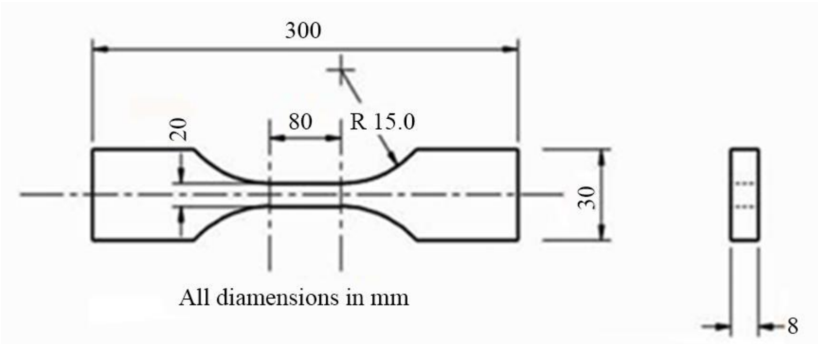

Figure 1. Tensile test specimen dimensions

Figure 2. Al 6061 tensile test specimens

Figure 3. Tensile testing machine.

consistency across all specimens. Proper surface preparation, including cleaning and oxide removal, is carried out prior to welding to minimize contamination and welding defects. The TIG welding process is selected due to its ability to provide stable arc characteristics and high-quality welds, especially for aluminum alloys. After welding, the specimens are allowed to cool under controlled conditions before machining them into standard tensile test coupons. The tensile tests are performed at room temperature, and the obtained stress–strain data are used to evaluate ultimate tensile strength and joint performance. The experimental methodology adopted in this work ensures reliable comparison of results and facilitates a clear understanding of the influence of groove angle on the tensile behavior of TIG-welded Al 6061 alloy joints.

RESULTS AND DISCUSSION

The tensile test was conducted for each Al 6061 specimen. Two specimens for each groove angle were prepared and hence there were total 8 specimens. The bevel height was kept constant at 2mm. Table 2 shows the results of the tensile test conducted on different specimens.

In all the specimen combinations, it was observed that location of fracture lies in the weld only. Figure 4 shows the variation of the tensile strength of Al 6061 specimens with different groove angles.

Table 2. Tensile test results

Groove angle	Yield stress (MPa)	UTS (MPa)		Location of fracture
		Sample 1	*Sample 2*	
0°	113.12	149.03	161.75	Weld
45°	102.25	149.19	165.18	Weld
60°	119.38	174.75	167.37	Weld
75°	106.69	163.65	155.62	Weld

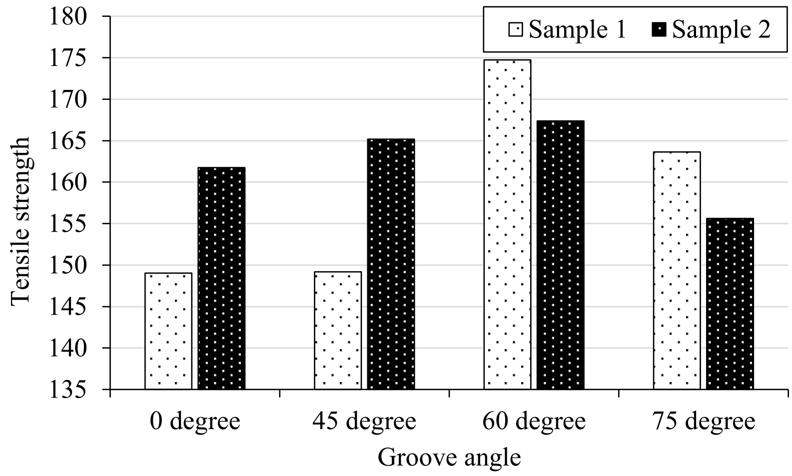

Figure 4. Groove angle Vs tensile strength for different Al 6061 specimens

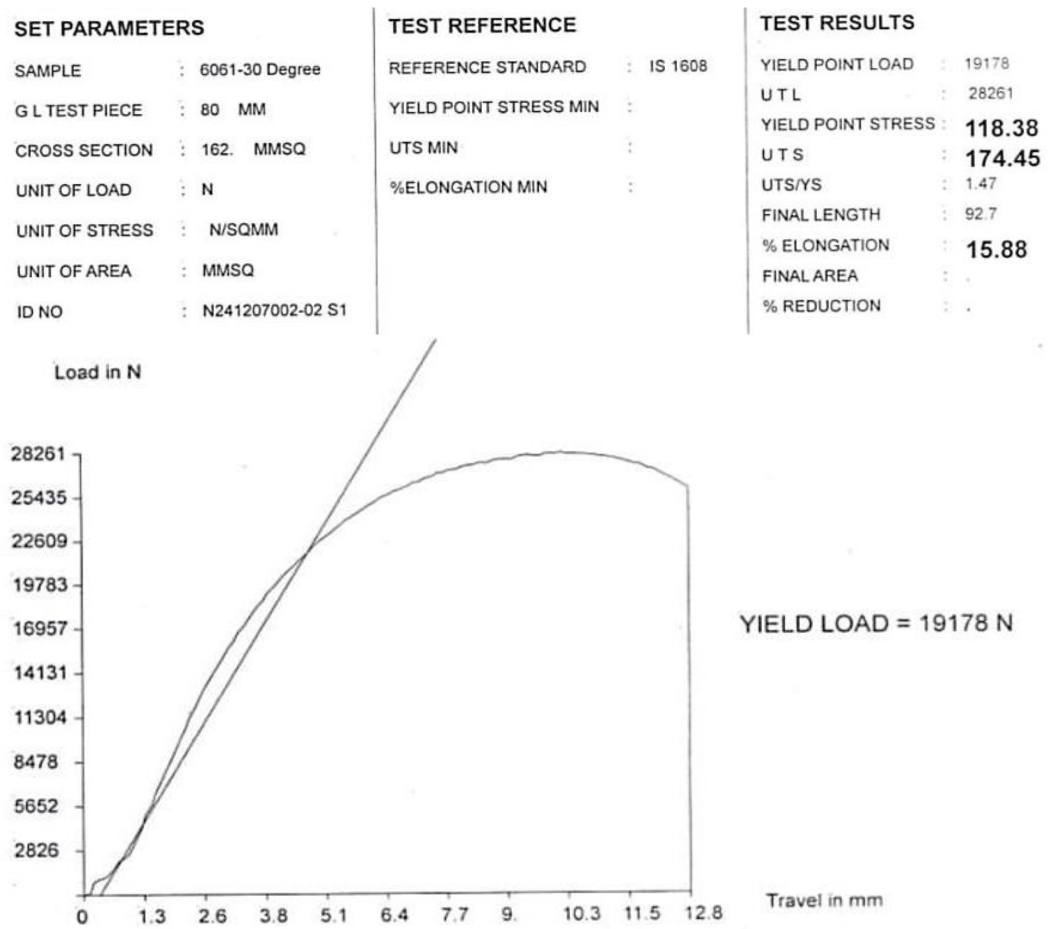

Figure 5. Sample tensile behavior of the specimen with 60° groove angle (Specimen 1)

It was observed that as the groove angle of the specimen increases, the ultimate tensile strength (UTS) also increases and it becomes maximum for the groove angle of 60°, after which the value decreases. The optimum groove angle of the specimen was found to be 60° at which maximum tensile strength was observed. Figure 5 shows the sample tensile behavior of the Al 6061 specimen having a groove angle of 60° (Specimen 1 for 60° groove angle).

CONCLUSION

The Al 6061 alloy was considered for this research work due to its superior mechanical properties and applications in the area of aerospace, automotive, and marine industries. The tensile strength of the V grooved, butt welded (using TIG welding) standard Al 6061 specimens were tested as per the ASTM standard. The groove angle of the specimens was varied from 0° to 75°, while the bevel height was held constant at 2mm. The tensile strength of the welded joint was found using standard universal testing machine. The tensile strength of the joint was found to increase from 0 to 60 degree groove angle and reduced thereafter, indicating the optimum value. These results clearly indicate that groove geometry plays a significant role in determining the mechanical performance of TIG-welded Al 6061 joints. An optimum groove angle promotes adequate weld penetration and fusion while minimizing excessive heat input and weld metal dilution. Beyond the optimal groove angle, the reduction in tensile strength can be attributed to increased weld volume, higher thermal exposure, and the possible formation of welding defects or microstructural degradation in the heat-affected zone. The study confirms that proper selection of groove angle is essential for achieving maximum joint efficiency. The findings of this research provide useful guidelines for welding engineers and fabricators in selecting suitable joint designs for TIG welding of Al 6061 alloy, thereby improving weld quality, structural integrity, and overall service performance of welded components.

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