A Comparative Study on the Joint Hardness and tensile properties of Dissimilar Aluminum Alloy using Tungsten Inert Gas (TIG) Welding

Atif Shazad[1] ,Muhammad Uzair[1]* ,Tariq Jamil[1]
and Noorhafiza Muhammad [2]

[1]Department of Mechanical Engineering, NED University of Engineering and Technology, Karachi, Pakistan
[2]Faculty of Mechanical Engineering Technology, Universiti Malaysia Perlis, Perlis, Malaysia
[3]Mechanical Engineering Department, NED University, Karachi, Pakistan
Uzair@neduet.edu.pk

Abstract. This study aims to elucidate the impact of welding methods on the hardness and tensile properties of weld joints. Findings revealed that double pass welding significantly increased hardness in the weld zone compared to single pass welding. This difference is attributed to the rapid heating and cooling in single pass welding, resulting in lower hardness values. The additional pass in double pass welding enhanced the hardness by promoting better mixing and homogenization of the filler material with the base metal. Single pass heat affected zone (HAZ) showed variable hardness, increasing with distance from the centerline due to different thermal exposures. Double pass HAZ, when subjected to two heat cycles, experienced more extensive thermal exposure. The additional filler material in double pass welding improved ultimate tensile strength and yield strength by 20% and 15%, respectively. These results highlight the significant impact of double pass welding on both hardness and tensile strength.

Keywords: Hardness, TIG welding, Dissimilar, Weld zone, Heat Affected Zone

1 Introduction

Aluminum, renowned for its lightweight properties, stands as one of the most prominent engineering metals, surpassing steel in terms of strength-to-weight ratio [1]. Its significance extends to various industries, particularly aerospace, where aluminum and its alloys play a critical role [2]. Additionally, these materials find substantial applications in transportation and structural domains. Despite their widespread usage, welding aluminum and its alloys presents numerous challenges owing to their unique characteristics [3]. Notably, the high thermal conductivity, substantial hydrogen solubility, and pronounced reactivity with oxygen are among the factors that have historically posed difficulties in achieving successful fusion welding of aluminum alloys [4]. Consequently, these inherent complexities have hindered the seamless integration of aluminum alloys in welding processes [5]. During the welding process, a significant amount of heat is generated, which has a profound impact on the mechanical

I. U. Ahad (ed.), *Proceedings of the 4th International Conference on Key Enabling Technologies (KEYTECH 2024)*, Atlantis Highlights in Engineering 35,
https://doi.org/10.2991/978-94-6463-602-4_25

properties of the joint metals, such as hardness and tensile strength [6]. The distribution of heat varies depending on the welding technique employed [7]. For instance, in techniques like Sheet Metal Arc Welding (SMAW) and Gas Welding, the heat generation is not as concentrated [8,9]. However, in processes like Tungsten Inert Gas (TIG) welding, the heat is highly concentrated in the Weld Zone (WZ) and Heat Affected Zone (HAZ) [10]. This concentrated heat can lead to the degradation of the mechanical properties of the joint. Tensile strength may reduce by as much as 50%, and ductility tends to decline to low values [11,12]. Furthermore, FSW is environmentally friendly as it eliminates grinding waste, does not generate harmful emissions, and requires minimal surface cleaning [13]. FSW is renowned technique for welding of dissimilar joint welding, however TIG welding also utilized significantly in welding of dissimilar metals [14,15].

In the current research study, a comprehensive investigation was conducted to examine the effects of TIG welding on the hardness characteristics of dissimilar joint WZ and HAZ regions in the context of welding aluminum alloys 2219 and 6082. The primary objective of this study was to gain a deeper understanding of the alterations in hardness that occur within these critical regions as a consequence of the welding process.

2 Experimental Methodology

A sheet with dimensions of 150 x 150 x 3mm was selected for the experimental investigation. The chemical composition of the material was assessed through material spectroscopy. The welding process was conducted using a Precision 350 TIG machine. Welding speed was 180mm/min and current were maintained at 110ampere. The welding process employed filler wire ER 2319 which comprises 93% aluminum and 6.3% copper. To evaluate the material's hardness, an Ernst hardness tester was utilized. Hardness was measured in HV (Hardness Vicker) unit. Sampling for tensile testing was performed as per standard ASTM-E16. Comparative analyses of hardness on the sample were performed by creating single pass and double pass welding joints. Aluminum alloys 2219 and 6082 were selected as the base materials for this experiment due to their widespread industrial applications and dissimilar metallurgical properties.

3 Results & Discussions

The analysis of hardness in the WZ of a dissimilar joint was conducted to assess the impact of single pass and double weld techniques. In order to obtain representative hardness measurements, five distinct indent marks were strategically chosen. Figure 1 displays the variations in hardness observed in the double pass weld joint. It is noteworthy that the hardness values fall within the range of 70-78 HV. Due to the intense concentration of heat, a wide range of hardness values were obtained, but the behavior of the double pass joint exhibited a reinforcing effect, leading to enhanced hardness compared to the single pass joint.

Additionally, the hardness results following the single pass welding technique are depicted in Figure 2. The single pass welding process resulted in a lower hardness value for the WZ compared to the double pass technique. This disparity in hardness can be attributed to the reinforcing action exerted by the filler wire during the welding process.

Figure 3 and Figure 4 shows a detailed comparison of the hardness of the HAZ. In this analysis, the hardness measurements were conducted from the centerline to a distance of approximately 20mm away from the centerline. The base metal Al 2219 and Al 6082 have hardness values of approximately 130 HV and 85 HV respectively. The range of hardness values observed in the single pass HAZ varies from 88 HV to 100 HV. It is important to note that as we move away from the centerline, the hardness values tend to increase. The HAZ experiences varying levels of thermal exposure, resulting in changes in its microstructure and hardness. Similarly, the hardness of the single pass HAZ in Figure 3 and Figure 4 is found to be greater than that of the double pass HAZ. On the other hand, in a double pass weld, the HAZ is subjected to two passes of concentrated heat. As a result, the HAZ undergoes two cycles of thermal exposure, leading to a more extensive heat-affected region.

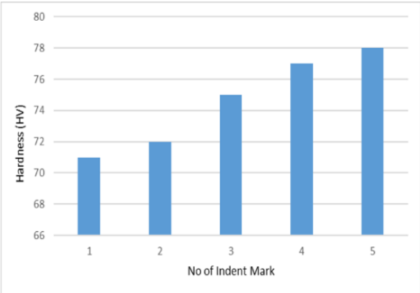


Fig. 1. Double Pass WZ Hardness

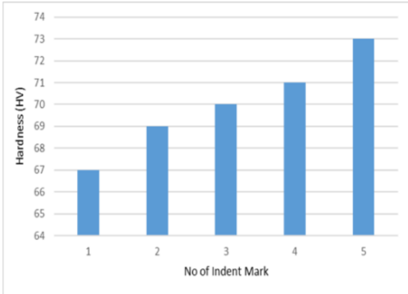


Fig. 2. Single Pass WZ Hardness

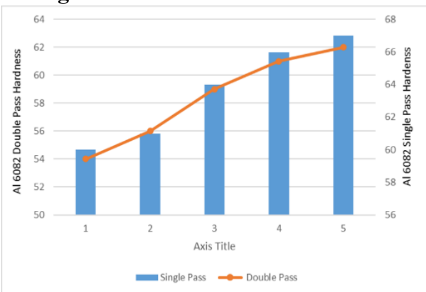


Fig. 3. HAZ of Al 2219

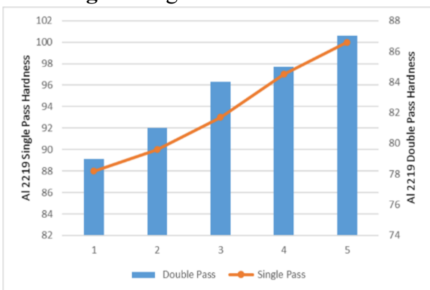
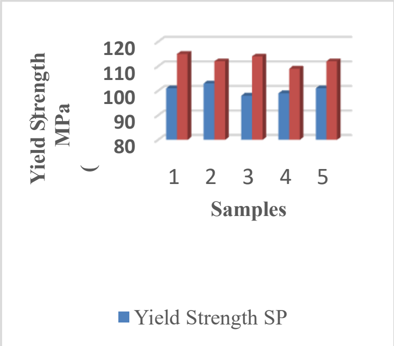


Fig. 4. HAZ of Al 6082

Tensile testing was performed to assess variations in strength after reinforcement, comparison of yield strength (YS) between single pass weld and double pass weld is shown in Figure 5. Enhancement in YS is observed after reinforcement, almost 15% percent improvement in YS is achieved. Reinforcement after first welding pass enhanced the YS due to high input heat which is responsible for precipitation hardening. Strengthening effect is witness after second pass of weld due to flawless welding joint and increased hindrance for dislocations movement across grain boundaries. Beyond elastic limits, dissimilar joints are tested under tensile testing machine to assess variations in Ultimate tensile strength (UTS) of weld joints. Figure 6 shown comparative data between single pass and double pass welds of UTS. Almost 20 percent amelioration in UTS after reinforcement was attained; enhancement in UTS of welding joint is due to reinforcement of extra material and precipitation hardening of material at joint area. Figure 7 depicted variations in elongation which ultimately indicated joint ductility. Increment in hardness after double pass is another practical justification of strength increment. Figure 8 illustrate sample after tensile testing.



. **Fig. 5.** YS Comparison

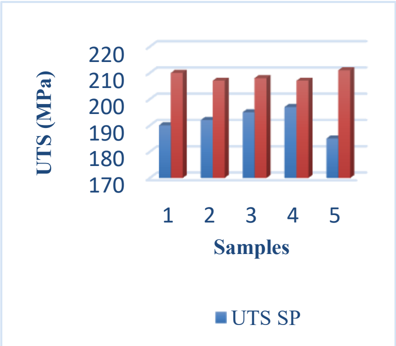


Fig. 6. UTS Comparison

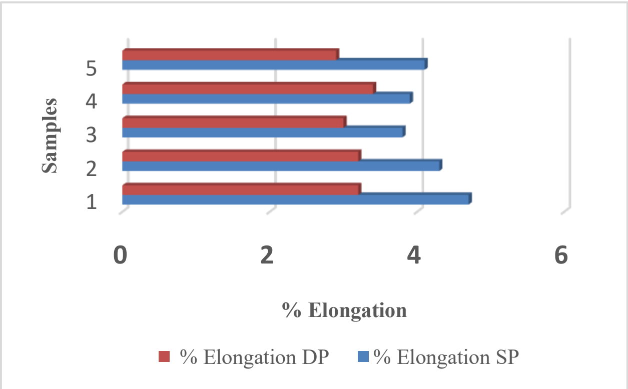


Fig.7. Percent Elongation Comparison

Fig. 8. Sample after Tensile Testing

4 Conclusion

The results demonstrated that the double pass welding technique exhibited a reinforcing effect, leading to enhanced hardness in the weld zone compared to the single pass welding technique. The disparity in hardness between the two techniques can be attributed to several factors. The rapid heating and cooling cycle during single pass welding resulted in a lower hardness value in the WZ, while the additional pass in the double pass technique created a reinforcing effect, resulting in a higher hardness value. The reinforcing action of the filler wire in the double pass welding process was attributed to improved mixing and homogenization of the filler material with the base metal, promoting the formation of a stronger bond and enhancing the overall hardness of the weld zone. The single pass HAZ exhibited a range of hardness values, increasing as we moved away from the centerline due to varying levels of thermal exposure. The double pass HAZ, subjected to two cycles of concentrated heat, experienced more extensive thermal exposure and consequent changes in microstructure and hardness. Additionally, a comprehensive comparison between single pass and double pass welds of two different aluminum alloys, Al 2219 and Al 6082, demonstrated a substantial decrease in hardness after the single pass weld. However, hardness values gradually improved as the distance from the centerline increased, indicating a more uniform cooling process and approaching levels observed in the bare metal region. The double pass weld exhibited more significant changes in hardness due to the greater overall thermal exposure. The welding process of dissimilar materials will be utilized in industries due to strong requirement of dual properties. Automobile sector can be effectively employed this technique to gain respective advantages.

Acknowledgments. The authors acknowledge the support provided by NED university of Engineering and Technology and Higher Education Commission of Pakistan.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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