Influence of shot peening on bending forces for MIG dissimilar welding joint aluminum alloys

Khairia Salman Hassan1, Khalil Esmail Hanash1, Ahmed Ibrahim Razooqi2
1Department of Mechanic Technician, Institute of Technology-Baghdad, Middle Technical University, Baghdad, Iraq
2Engineering Technical College, Middle Technical University, Baghdad., Iraq
E-mail: almaden20002000@yahoo.com (Khairia Salman Hassan)

Abstract. In this paper, the influence of MIG welding method was investigated on bending quality for two aluminum alloys (2024-T3 and 6061-T6) which were joint together and metal inert gas (MIG) has been implemented on plate to get butt joints weldments in dimensions of (200 x 50 x 10) mm, a ready angle of 60 ° in V shape and square weld joint. The symbol of filler metal is ER-4043(Al-Si5), and argon has been used as a shield gas. The welded joints were exposed to X-ray radiography and faulty pieces were expected Welding joint were exposed to heat treatment in the furnace up to 190 °C for an hour then the test specimens were cooled by air to relieve welding stress. Welded and base specimens were machined into dimensions agreeing to the ASTM (E 190-92) bending standard. number of these specimens were exposed to a shot peening technique at a time (15) minutes using steel ball at a diameter of 1.25 mm. microstructure examination and Vickers hardness test were carry out . Results show a general decay in bending qualities of MIG weld joint compared with unwedded joints, and in the disparate joint unite with original metal due to the change of the microstructure during the welding process. Shot peening contributed to improving the bending strength of V and square weld joints with a percentage of 48% and 71 %, respectively.

Keywords: MIG welding process, Aluminum alloys Welding process for dissimilar alloys, Mechanical qualities.

1. Introduction

2024, 6061 Aluminum alloys have significant mechanical qualities such as high strength and ductility, so they extremely used in manufacturing of serious applications. In aluminum alloys, the best welding method is a gas metal arc welding that joins metals by heating them with an arc formed among the metals which be welded and filler metal. Helium and argon were used to protect the weld pool and the arc. Klas Weman, (2003) [1]. This type of joint method is associated to lots of difficulties, generally it connected to the existence of oxide film, great thermal conductivity, great coefficient of thermal extension, shrinkage because of solidification and dissolving of other gases and hydrogen in a liquid condition A. Squillace et al., (2004) [2]. Studied the heat input which obtained through welding method is responsible for the decreases mechanical qualities, because of phases conversions and softening occur in the metal of the alloy. So in serious uses of aerospace those special heat treatable alloys. Nazar Abdulwadood et al., (2004) [3]. The main interest is provide a satisfactorily Mg2Si ratio in the parent material with sufficient filler alloy in order to decrease weld metal crack. Type joint showed enhanced mechanical properties compared to indirect electric arc (IEA) and V-type joints Rajesh P Verma, (2012) [4]. Mechanical surface treatments like laser peening, shot peening, cold and
hot rolling have implemented on high strength aluminum, titanium alloys to increase fatigue act. All mechanical surfaces treatments increase a qualities surface roughness near surface dislocation density and improve the microscopic residual stresses. Typically, shot peened surfaces contained compressive remaining stresses and very high dislocation densities near the surface films resultant from inhomogeneous plastic deformations M. M. Rahman and A. K. Ariffin, (2005) [5]. Many factors affect the shot peening process, that are, size, type, and form of the shots, time, stream speed, air pressure on the peened element, distance from nozzle to material surface (peening distance, peening intensity, nozzle angle.

Roko Markovina, (2008) [6]. In this work, it has been used this technique for improvement bending strength for weld joint like many researchers.

Omar Bataineh, (2012) [7], clear that “the MIG welding methods, supplying good weld joints with great strength repose on the method circumstances, which used in the operation for aluminum alloys. Many factors are studied. Results observed that arc voltage and filler feed rate are the only important influences. Arc voltage and filler feed rate are reached by reversion analysis at 24 V and 7 in/s, respectively, at tensile and three-point bending tests which the mean weld strength is maximum”.

Ceyhun KÖSE and Zafer Tatli, (2016) [8], sheets of Aluminum alloys has symbol 5754 are linked by the pulsed DC Robotic MIG welding process. Many tests are implemented such as microstructure, tensile and three-point bending tests of welded joints to define the mechanical qualities of welded joints. Results show that mechanical qualities are better when welding speed increases and decrease the effect of the porosities on mechanical strength which seen in the macrostructure.

Arun M, and Ramachandran k., (2015) [9], studied “the mechanical and metallurgical qualities of AA6061 aluminum alloys lap connect using many welding methods. The prefer method is GMAW and GTAW due to being cheap and restful. Friction stir welding (FSW) is a new advanced welding method. The obtained result show that AA6061 aluminum alloy of GMAW joints have greater mechanical qualities when compared to GTAW and FSW joints”.

In the present study, a detailed investigation of the influence of MIG welding on bending quality for two aluminum alloys 2024-T3 and 6061-T6. The tests are complete for a wide range of experimental parameters. That are, welding joint was exposed to heat treatment, in the furnace up to the temperature of 190 °C for an hour and then the test specimens were cooled by air to relieve welding stress. Furthermore, some of the specimens were exposed to shot peening for about 15 minutes using steel ball with 1.25 mm diameter.

2. Experimental procedure
Numerous plates with dimensions of (100 × 50 × 10) mm for 2024-T3 and 6061-T6 aluminum alloys, were analyzed to show its chemical composition using (Thermo ARL 3460, optical Emission spectrometer). The result listed in Table 1, 2 and joined together by MIG method using a MIG-350 type semiautomatic welding machine, a filler metal rod ER4043 (Al-Si) with the chemical analyses listed in Table 3 was used. Various welded butt joints with dimensions mentioned previously and equipped V angle of 60 ° and angle of 90 ° as revealed in Figure 1. Table 4 was observed Welding parameters. Weld joints are inspected using X-ray radiography. The joints without any faults were used to equip several of specimens for bending examination. Heat input was calculated using the following equation [10]:

\[
Heat\; Input = \frac{543 \times I \times V \times 60}{S}
\]  

(1)

Where: (I in Ampere) is referred to welding current, (V in volt) is represented welding voltage, S in (m/min) is refer to welding speed, and the quantity of Heat Input is in Joule.

\[
Heat\; Input = \frac{543 \times I \times V \times 60}{S}
\]
Table 1. Listed the chemical composition AA 6061-T6 [11].

| Elements | Si%  | Cu%  | Mg%  | Cr%  | Mn%  | Fe%  |
|----------|------|------|------|------|------|------|
| Measured value | 0.6  | 0.3  | 1.0  | 0.2  | 12   | 0.4  |
| Slandered value | 0.4-0.8 | 0.15-0.4 | 0.8-1.2 | 0.04-0.35 | Max 0.15 | Max 0.7 |

Table 2. Listed chemical composition of AA 2024-T3 [11].

| Elements | Al %  | Cu%  | Zn%  | Fe%  | Mn%  | Mg%  | Si%  |
|----------|------|------|------|------|------|------|------|
| Real values | 92.6 | 4.4  | 0.1  | 0.3  | 0.6  | 1.5  | 0.4  |
| Standard values | Rem. | 3.8-4.9 | 0-0.25 | 0-0.5 | 0.3-0.9 | 1.2-1.8 | 0-0.5 |

Table 3. The filler metal (ER 4043) Chemical analyses [12].

| Elements | Si%  | Cu%  | Mg%  | Fe%  | Cr%  | Zn%  | Mn%  | Sn%  | Al%  |
|----------|------|------|------|------|------|------|------|------|------|
| Actual values | 5.0  | 0.1  | 0.06 | 0.4  | 0.25 | 0.15 | 0.08 | 0.15 | 93.44 |
| Nominal values | 4.5-6 | <0.3 | <0.2 | <0.6 | -    | <0.1 | <0.15 | -    | Rem.  |

Table 4. MIG welding parameters.

| Sample | Voltage (v.) | Current (Amp.) | Flow rate L/min | Travel speed (mm/s) | No. of passes | Heat input (Joule) | Wire diameter (mm) |
|--------|-------------|----------------|-----------------|--------------------|--------------|-------------------|--------------------|
| C      | 20          | 130            | 12              | 220                | 2            | 6310.3            | 1.2                |
| D      | 20          | 140            | 16              | 110                | 2            | 13592.7           | 1.2                |
2.1. *Compilation of MIG welded joint*
Weld joints which equipped by MIG method were categorized as shown in Table 5.

| symbol | Condition |
|--------|-----------|
| A      | AA6061-T6 base metal |
| B      | AA 2024-T3 base metal |
| C      | Dissimilar butt single V weld joint (angle 60°) |
| D      | Dissimilar Square Butt joint (angle 90°) |
| E      | Dissimilar butt single weld joint 60°+ shot peening |
| F      | Dissimilar Square Butt joint (angle 90°)+ shot peening |

2.2. *Microstructure test*
Microstructural variations were examined, with an optical microscope, of the weld zone and natural original material. Specimens equipped for microstructure examination contained grinding process by SiC emery paper in diverse grain size of (220, 300, 500, 800, and 1200). Then polishing using diamond paste of size (0.1μm) with cloth was carry out. Etching was done using Keller’s reagent containing of (1.5 ml HCl, 2.5 ml HNO₃, and 1 ml HF) with 95 ml distill water. The specimens were cleaned and dried. After that, the microstructure behavior was revealed by using ME-600 computerized optical microscope having a NIKON camera, the examined result was shown in Figure 4.

2.3. *Micro hardness examination*
Micro hardness examination was carrying out on vertical across section of the weld zone by the Vickers hardness device at a load of (30 kg) and 15 sec time loading, and Figure 6 shows the test results for all specimens.
2.4. Bending test
Bending examination specimens into typical dimensions agreeing to the ASTM (E 190-92) are fabricated from the welded joints and original alloys as shown in Figure 2. Some of bending specimens are imperiled to shot peened which is implement for times (15) min by spherically ball of 1.25mm in diameter at constant distance of 10 cm between the nozzle and the specimen and 20 m/s ball speed.

![Figure 2. Bending test specimen dimensions in mm.](image)

Further, "a 100-kN universal testing machine" was used at a chosen speed of 3.5 mm/min in bending test. All tests have been implemented at room temperature by three point's method, Figure 3. A cylinder-shaped line load has implemented at vertical direction on the weld line, specimens begins to yield due to bending load. The maximum load was recorded using the machine through bending examination was implemented to calculated the strength of all specimens. Results show in Figure 6.

![Figure 3. Bending setup.](image)

3. Results and Discussion
From microstructure, which clear in Figure 4, it seen that specimen (A) evident the microstructure of the used alloy 6061-T6 as original metal contained alloying elements are silicon and magnesium.
This is happened due to changing the microstructure in a coarse, elongated particle due to sedimentation of phases which appears in obscure particles Mg$_2$Si. Where, this offers good mechanical qualities and microstructure of original metal aluminum alloy 2024-T3, which show in Figure 4 (specimens B). This alloy has elongated grains and coarse dendritic structure with uniformly distributed fine sedimentation due to the existence of copper (Cu) element alloy which offers large increases in strength, [12]. The fusion zone of MIG welded joints for 2024-T3 and 6061-T6, were shown in Figure 4 (specimens C and D). It is clear that they have a dendritic structure, as a result of fuses between the base metal of dissimilar alloys and filler metal that is indifferent from the original metals. This also seen in the microstructure of specimens (E and F) after shot peening. Nevertheless, in fine size, it contributed to the improvement of mechanical qualities comparing with the result of the specimen without shot peening.

In Figure 5 and Table 6 the results showed that the hardness values are reduced by a slight quantity in the HAZ and augmented by a slight quantity in the basis material. Due to arising from the recrystallization in the zone and the HAZ structure, coarser grains was established in connection to the weld metal that led to a reduction in hardness value and mechanical strength in comparison to the base metal. Furthermore, the dendritic structures which established in the weld metal also formalize parameter that affect and rise weld metal hardness. Variations in the microstructure, will also influence the variations in weld metal and HAZ hardness variations through the welding method of aluminum alloys.
Additionally, the porosity found in the weld metal joints is a normal condition that can be attributed to the effect of the welding wire and shielding gas used through the welding of aluminum and its alloys. However, the size and porosity number are at acceptable levels, which is also supported by the mechanical test data. The macrostructure images prove that there were no lack of penetration defects and the test samples were joined with full penetration. This can be attributed to fact that each welded sample was joined at the most suitable parameters.

**Table 6. Mechanical tests results.**

| Sample | \( F_{B\ KN} \) | Elongation | Hardness \( Hv \) (kg/mm²) |
|--------|----------------|------------|-------------------------|
| A      | 13.42          | 12         | 110                     |
| B      | 11.25          | 10         | 120                     |
| C      | 2.81           | 8          | 82                      |
| D      | 1.19           | 10         | 84                      |
| E      | 5.40           | 9          | 87                      |
| F      | 4.1            | 8          | 88                      |

The bend test was exposed in Figure 6. It is clear that specimens C, D, E, and F were very brittle and show very low bend angle without cracks. In other words, the crack started at a very low angle and that means low bending force. Specimens C and D show a lower bending force compared with unwedded alloys. While bending in shot peening specimens has a slightly better bending result than specimen without a shot so shot peening contributed to the improvement of bending strength. Specimens B and C show better results than specimens D before and after shot peening due to the shape of preparation welding angle. Also, angle of V shape enhanced the heat amount distribution which increase the homogeneity in microstructure. Nevertheless, cavities are usual faults which were presented in mixture welds which cause that decreases.
4. Conclusions
Generally, the influence of MIG welding on bending quality for dissimilar aluminum alloys 2024-T3 and 6061-T6 was studied. The test specimens were exposed to a wide range of experimental parameters. The following findings can be withdrawn:

- Original alloys show comparatively more mechanical qualities compared to welded joints.
- The test results showed that the hardness values were reduced by in the HAZ compared to the base material. That can be attributed to the arising from the recrystallization in the zone. Further, the HAZ structure show a coarser grains which reduce the hardness value.
- Shot peening method contributed to improving bending force.
- Shot peening process improved the bending strength for V and square weld joints by 48% and 71 %, respectively.

References
[1] Klas W 2003 Welding Process Handbook Cambridge, England.
[2] Squillace A, De Fenzo A, Giorleo G, Bellucci F 2004 A comparison between FSW and TIG welding techniques: modifications of microstructure and pitting corrosion resistance in AA 2024-T3 butt joints Journal of Materials Processing Technology 152 97–105.
[3] Nazar A, Burak S, Nihat Y 2014 Effect of welding parameters on the mechanical properties of dissimilar aluminum alloys 2024-T3 To 6061-T6 joints produced by friction stir welding Niğde Üniversitesi Mühendislik Bilimleri Dergisi, Cilt 3, Sayı 1 Pp.25-36
[4] Rajesh P V, Pandey K N 2012 Investigation of fatigue life of 6061-T6 and 5083-O aluminium alloys welded by two welding processes-manual metal arc welding and metal Inert gas welding”, International Conference on Mechanical and Industrial Engineering (Icmie)-9th S Dehradun
[5] Rahman M M, Ariffin A K 2005 Effects of surface treatment on the fatigue behavior of cylinder block for a new two-stroke free piston engine International Conference on Mechanical Engineering.
[6] Roko M, Branko B A B 2008 Investigation of influential parameters on shot-peening of aluminum alloys”, *Trends in the development of machinery and associated technology, Istanbul, Turkey*, 26-30 August.

[7] Omar B 2012 Optimizing process conditions in Mig welding of aluminum alloys through Factorial design experiments *Latest Trends in Environmental and Manufacturing Engineering* 21-26.

[8] Ceyhun Kose1, Zafer Tatli, 2016, "Pulsed Dc robotic Mig welding of non-heat treatable aluminum alloys *International Journal of Electrochemical Science* **11** 1918–1927.

[9] Arun M, Ramachandran K, 2015 Effect of welding process on mechanical and metallurgical properties of Aa6061 aluminum alloy lap joint *International Journal of Mechanical Engineering and Research* **5** 162-178.

[10] Khanna O 1990 A Text Book of Welding Technology Dhan Pat Rai Publications Ltd2006, P.351.

[11] Metals Handbook, *Vol.2-Properties and selection: nonferrous alloys and special-purpose materials, Asm International 10th Ed.*, 1990.

[12] Annual book of astm standards, standard practice for calculation of corrosion rates and related information, G102-89 **03.02**.