

IMPROVEMENT OF BENDING STRENGTH FOR INERT GAS WELD JOINT ALUMINUM ALLOYS 6061-T6 USING SHOT PEENING

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ABSTRACT: The present study aims at investigating the effect of MIG welding process on the bending strength of aluminum alloys 6061 -T6. Metal inert gas (MIG) has been carried out on rolled sheet of about 8mm thickness to obtain many butt welding joints with dimension of (200 *100* 8) mm with welding preparation angle in the shape of single V of 65° and double V of 65° weld joint by ER- 4043(Al-Si5) as a filler metal and argon as a shielded gas. The welded joints were tested by X-ray radiography and faulty pieces were excluded, i.e., the welding joint were subjected to heat treatment including heating the joint in furnace to 150°C for about half an hour, followed by air cooling to relief welding stress. Several specimens were machined into standard test specimen dimensions according to the ASTM (E 190-92). Some of the specimens were then subjected to shot peening process for 15 minutes using a steel ball with a diameter of 1.25 mm. Vickers hardness test and microstructure examination were made. The results of the current study show a general decay of bending strength of MIG weld joint in comparison with unwelded metal due to the microstructure change during the welding process. Shot peening contributed in the improvement of the bending strength for weld joint.

KEYWORDS: *Aluminums Alloy, MIG Welding Joining, Bending Stress, Shot Peening*

1.0 INTRODUCTION

Gas metal arc welding (GMAW) is a welding process that melts and joins metals by heating an electric arc established between a continuous wire (electrode) and metals to be welded. Shielding protection of the arc and molten metal is carried out by means of a gas, which can be active or inert. In the case of aluminum alloys, non-ferrous alloys and stainless steel Ar gas or mixtures of Ar and He are employed, whereas for steels the base of the shielding gases is CO₂. The use of an inert gas

in a welding process is known as MIG (Metal Inert Gas) process while for metal active gas it is called MAG. GMAW process is one of the most employed to weld aluminum alloys[1].

The welding of aluminum and its alloys is always representing a great challenge for designers and technologists. As a matter of fact, a lot of difficulties are associated to this kind of joint process, mainly related to the presence of a tenacious oxide layer, high thermal conductivity, high coefficient of thermal expansion, solidification shrinkage and, above all, high solubility of hydrogen, and other gases, in molten state[2]. Further problems can arise when attention is focused on heat-treatable alloys since heat provided by welding process is responsible of the decay of mechanical properties due to phase transformations and softening induced in alloys. These aluminum alloys are generally classified as non-weldable because of the poor solidification microstructure and porosity in the fusion zone. Also, the loss of mechanical properties as compared to the base material is very significant. These factors make the joining of these alloys by conventional welding processes unattractive. Some aluminum alloys can be resistance welded, but the surface preparation is expensive, with surface oxide being a major problem [3]. type joint shows enhanced mechanical properties compared to indirect electric arc (IEA) and V-type joints[4] mechanical surface treatments such as laser peening, shot peening, cold and hot rolling are performed on high strength aluminum, titanium alloys in order to improve fatigue performance. All mechanical surfaces treatments lead to a characteristic surface roughness increasing near surface dislocation density (cold work) and development of microscopic residual stresses. Typical characteristics of shot peened surfaces are compressive residual stresses and extremely high dislocation densities in near surface layers resulting from inhomogeneous plastic deformations [5].

The number of influential parameters on the shot-peening process is large: type, size and shape of the shots, time of peening, stream velocity, air pressure on the peened element, distance from nozzle to material surface (peening distance), nozzle angle, peening intensity and surface coverage percentage. Experience showed that some of the parameters may be taken as constant while others must be evaluated through experiments and numerical simulations. Shot peening is commonly conducted in a closed cabinet which is designed to safely confine the media and provide proper aiming of the shot blast stream [6]. Experience showed that poorly chosen peening parameters may even decrease the properties of treated materials [7].

Henri-Paul Lieurade [8] described the mechanical properties after shot peening, for two TIG weld joint aluminum alloys 5083 and 6061 which were welded by many weld joint designs. In order to optimize the shot peening process, the researcher chooses different parameters to show its effect on mechanical properties, and to emphasize the effect of the initial weld quality. The fatigue results show a significant improvement in the fatigue strength of shot peened welded joints, particularly where a long life is concerned. An improvement from 50 to 150% is found, with respect to the initial quality of the welded joint.

Roko Markovina [6] studied the improvement of fatigue properties for aluminum alloys 2024-T3 by shot-peening method at some influential parameters, like nozzle angle and peening distance. The results obtained show that the careful selection of shot-peening parameters leads to the determination of material properties. Mustafa Kemal Kulekci [9] compared the mechanical properties of welded joints of EN AW-6061-T6 aluminum alloy. The joint obtained using friction stir welding (FSW) and conventional metal inert gas welding (MIG). FSW welds were made on a semi-automatic milling machine. The experimental of FSW and MIG welded joints were recognized using tensile, fatigue, hardness, and impact tests. The joints obtained with FSW and MIG processes were also assessed for distortion that accompanied the welding processes. Taking into consideration the process conditions and requirements, FSW and MIG processes were also compared with each other to understand the advantages and disadvantages of the processes for welding applications of studied Al alloy. Tensile, fatigue, and impact strength were better obtained with FSW welded joints. The width of the heat affected zone of FSW was narrower than MIG welded joints. The results show that FSW improves the mechanical properties of welded joints [10]. This study deals with surface hardening by using laser peening to improve mechanical properties of TIG weld joint of 6061 T6 aluminum alloy. The welded pieces were tested by X-ray radiography and faulty pieces were excluded. Tensile test specimens were prepared from weld joint in the dimensions according to ASTM 176000 and then subjected to laser peen pulse without coating. The tested by X-ray diffraction to measure the compressive residual stresses and microstructure to show the weld zone crystal distribution. Then all specimens were subjected to tensile test, Vickers hardness test to show the effect of laser hardening on the mechanical properties of weld joint. From the result a general decay of mechanical properties of TIG joints is observed in comparison with base alloy that is due to the microstructure change during the welding process. While the laser peen welds joint shows an improvement in mechanical properties than the TIG welded joint. This is due to the rise

of compressive residual stresses. The aim of this paper is to investigate the effect of shot peening process on improving the bending stress of Aluminum alloy 6061-T6.

2.0 EXPERIMENTAL WORK

2.1 Metal Selection

The composition of the alloys used is shown in Table 1. The chemical analysis was done by using ARL Spectrometer.

Table 1: Chemical Analysis of the used metal 6061- T6

Elements w%	Si	Fe	Cu	Mn	Mg	Cr	Zn	Al
Measured value	0.6	0.4	0.3	0.12	1.0	0.2	0.18	Rem.
Standard value [8]	0.4-0.8	Max 0.7	0.15-0.4	Max 0.15	0.8-1.2	0.04-0.35	Max 0.25	Rem.

2.2 Welding Process

Two pieces of 8 mm thick plates aluminum alloy 6061-T6 were machined to the required dimensions (200*100*8) mm and with geometry of single and double V at 65° and as shown in Figure 1. The plates were cleaned with a scraper and acetone before the welding procedure and then they were butt welded (two pass for each side) using the MIG process. In the MIG welding process, a suppermig-460 type semiautomatic welding machine was used for welding the plates with parameters in Table 2 using argon as shielding gas at a flow rate of (10L/min), and ER 4043 of 1.2 mm diameter as a filler material. Its chemical composition is shown in Table 3 with a welding speed of (10 mm /sec) was used to carry out the MIG welds Figure 2.

Table 2: Welding parameter of MIG welding

symbol	Current (A)	Voltage (v)	Travel speed (mm/s)	Flow rate L/min	NO. pass	Wire diameter (mm)
B	140	25	10	10	2	1.2
C	110	25	10	10	3	1.2
D	120	22	10	10	3	1.2

All welded pieces were tested by X-ray radiography and faulty pieces were excluded.

$$\text{Heat Input} = \frac{543 \times I \times V \times 60}{S}$$

Where:

I= welding current (Ampere)

V= welding voltage (volt)

S= welding speed (m/min)

Heat Input= Joule

The joints without defects were used to prepare many specimens for bending test.

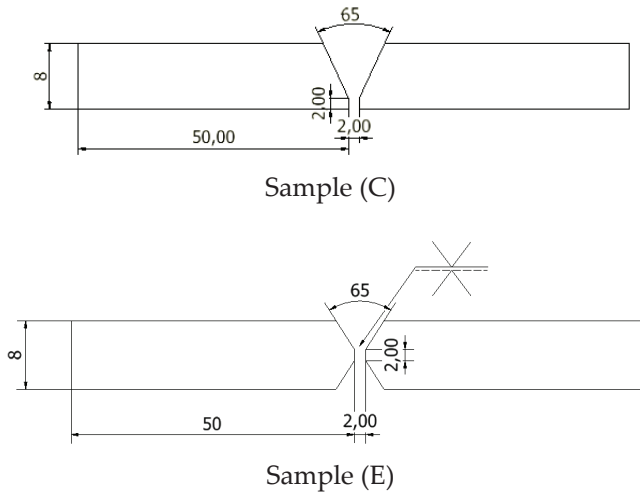


Figure 1: The weld joint dimension



Figure 2: Macrograph of MIG welded joint

Table 3: Chemical composition of the filler metal (Filer wire ER 4043) Al Si5

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

2.3 Shot Peened

Bending specimens permit to shot peening which was carried out for times (15) min using spherically ball of 1.25 mm in diameter at constant distance between the nozzle and the specimen of 10 cm. The specimen is rotating continuously during peening to ensure 100%, the ball speed is 20 m/s. The shot peening device used was shot tumblast control model STB –OB machine Figure 3.



Figure 3: Shot peening device with shot balls

2.4 Categorizing of Specimens

After specimen preparation and shot peening were completed, they were categorized to groups as shown in Table 4.

Table 4: categorization of corrosion test specimens

Symbol	Condition
A	As received
B	As received +Shot peening
C	Butt joint with single V angle 65°
D	Butt joint with single V angle 65° + shot peening
E	Butt joint with double V angle 65°
F	Butt joint with double V angle 65°+shot peening

2.5 Microstructure Test

Micro structural changes from weld zone to the unaffected base material were examined with optical microscope. Specimens were prepared for microstructure test including wet grinding operation using emery paper of SiC with different grits of (220, 400, 600 and 1000). Polishing process was done by using diamond paste of size (0.3 μ m) with special

polishing cloth. They were cleaned with water and alcohol then dried with hot air dryer. Etching for the structure was done by using Keller's reagent consisting of 95 ml distill water, 2.5 ml HNO₃, 1.5 ml HCl and 1 ml HF. This is then followed by washing after that with distill water then dried by hot air dryer. The welded joint samples and base metal were examined by Nikon ME-600 computerized optical microscope provided with a NIKON camera. The results are shown in Figure 4.

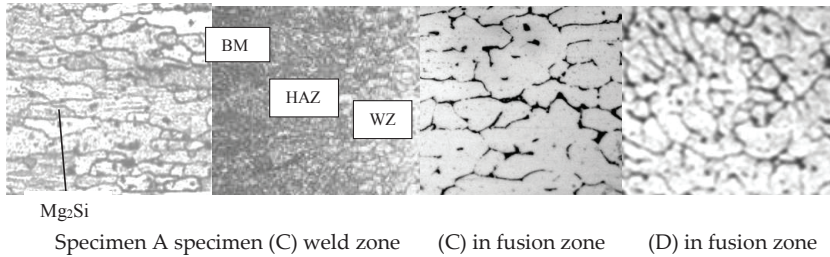


Figure 4: Microstructure for specimens (A, C, D)

2.6 Surface Roughness

The average value of the free surface roughness, which was measured at the surface area of all specimens in Table 4 indicated by the parameter Ra which is the center-line average of adjacent peaks results are shown in Table 5.

2.7 Micro Hardness Test

The Vickers hardness profile of the weld zone was measured on a cross section perpendicular to the welding direction by micro hardness tester with 200 gm load for 15 sec. as shown in Figure 5.

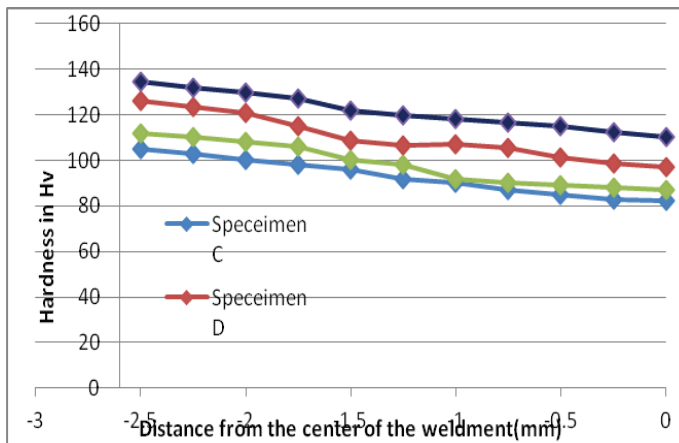


Figure 5: Micro hardness result for all specimens

2.8 Bending Test

The welded joints were machined into standard bending test specimen dimensions according to the ASTM (E 190-92) (200*38*8) mm as shown in Figure 6.

Face bending tests were carried out at room temperature using three-point method Figure 7. A cylinder-shaped line load is applied against the weld line, also the center line, of the specimen. As the specimen is supported on the sides by a steel fixture, it begins to yield due to bending. This test was conducted out on a 100-kN universal testing machine at a speed of 3.5 mm/min. The maximum load registered by the machine during bending was used to indicate the strength of the weld joint.

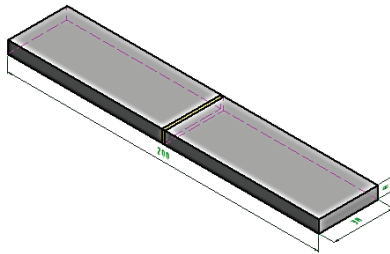


Figure 6: Bending test specimen dimensions in mm



Figure 7: Bending setup push travel technique

Table 5: Mechanical Tests result

Sample	F_b KN	Hardness (Hv) (kg/mm ²)	Surface roughness (Ra) μm
A	13.42	125	0.16
B	13.44	130	2.21
C	2.48	105	0.86
D	5.40	126	2.32
E	2.18	112	0.78
F	6.19	134.5	2.42

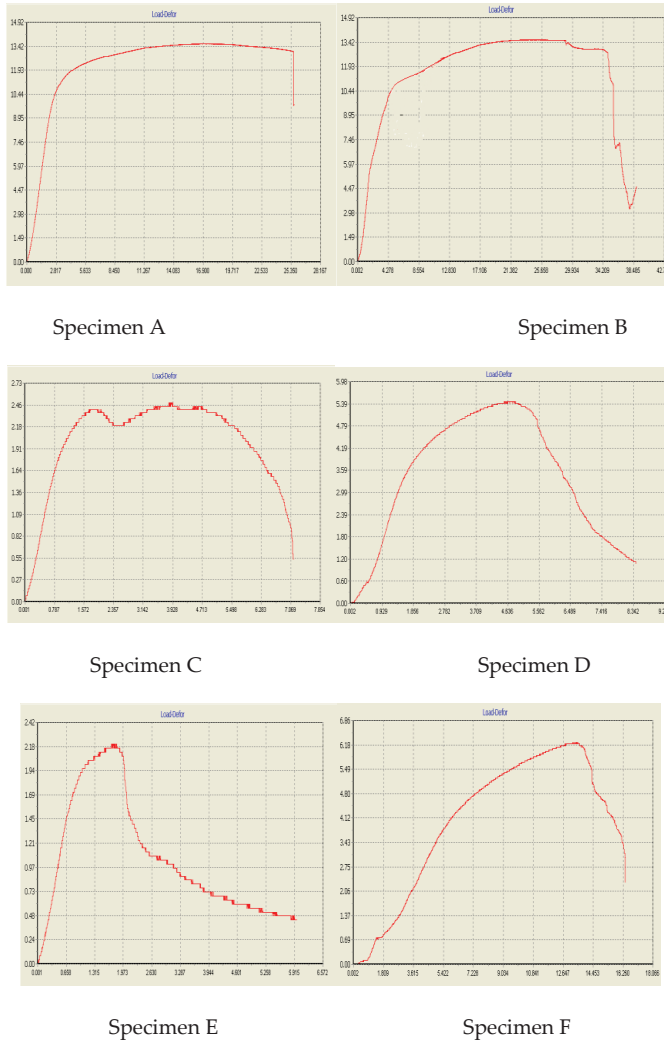


Figure 8: Graphs of bending test

In Figure 4, this study found that the microstructure revealed a coarse, elongated grain structure in the 6061-T6 base metal (A) due to presence of alloying elements such as silicon and magnesium precipitation as shown by darken particles Mg₂Si but symbol (C, E) in fusion zone give the lower amount of strengthening precipitates compared to the base metal specimen (A). Therefore, the strengthening of Mg₂Si precipitate is weak in MIG and contain dendritic microstructure is the result of melting which fuses the base metal and filler metal to produce a zone with a composition that is different from that of the base metal. Excess silicon in composition of wire filler is generally believed to be beneficial for increasing the ductility of the welded structure.

Specimens (C,D) in Figure 4 consists of a weld a transition from wrought base metal through an HAZ and into solidified weld metal and include three micro structurally distinct regions normally identified as the fusion zone, the unmixed region, the partially melted region. These specimens witness reduction in bending strength (Table 5) due to the high temperature required for fusion welding The HAZ region was large as well and the subsequent melting and solidification that occur, voids are common defects found in fusion welds which contributed in that decay.

In the joints welded in all welding conditions were very brittle and subjected to very low bend angle. Fig.(8) shows that specimens (C,E) give a lower bending force compared with unwelded specimens, that goes with [13, 14, and 15].

Table 5 results show that when comparing specimens (C) with (D) and (E) with (F), specimens (D) and (F) shows an improvement in bending strength since the Shot peening is a cold working process and commonly used to produce layer of compressive residual stress at the surface of components, and these layer contribute in improvement in bending strength. When comparing bending results of specimens (D, F) it shows that sample (F) gives better results because of the welding angle preparation, where double V shape angle contributed to heat input distribution causing a homogeny in microstructure, and that is the same reason for the improvement in bending resistance when comparing between specimens (C,E).

Table 5 shows the hardness values of all specimens. It can be seen that specimens (B, D, F) recorded high hardness value than the rest due to shot peening effect in producing compressive residual stress and increasing the heat of surface specimens and air cooling cause this increase this effect was clear in Fig (5) which consist the distributions of all specimens hardness.

3.0 DISCUSSION

In Figure 4, this study pointed that the micro structural revealed a coarse and elongated grain structure in the 6061-T6 base metal (A) due to the presence of alloying elements such as silicon and magnesium precipitation as shown by darken particles Mg₂Si while symbols (C, E) in fusion zone give the lower amount of strengthening precipitates compared to the base metal specimen (A). Therefore, the strengthening of Mg₂Si precipitate is weak in MIG and contains

dendritic microstructure which is the result of melting which fuses the base metal and filler metal to produce a zone with a composition that is different from that of the base metal excess silicon in composition of wire filler. It is generally believed to be beneficial for increasing the ductility of the welded structure.

Specimens (C,D) in Figure 4 consist of a weld transition from wrought base metal through an HAZ, solidified weld metal and include three micro structurally distinct regions normally identified as the fusion zone, the unmixed region, and partially melted region. These specimens witness reduction in bending strength. Table (5) shows the high temperature required for fusion welding;

the HAZ region was large and the subsequent melting and solidification that occur, voids are common defects found in fusion welds which contributed in that decay.

Due to that joints welded in all welding conditions were very brittle and subjected to very low bend angle. Figure 8 shows that specimens (C,E) give a lower bending force compared with unwelded specimens, that growth [9, 10, 11].

4.0 CONCLUSION

1. The chemical composition of the weld zone has been changed in MIG welding due to the filler that is used with MIG which influence the chemical composition.
2. Higher heat intensity in the MIG process has a negative influence on the bending properties of the welded material.
3. Compressive residual stress was main inducing in increasing bending strength.
4. Shot peening process improved bending strength by a percentage of 35.21% for the double V weld joint, while using double V welded joint improved the strength by 12.76% more than the single V weld joint.
5. Hardness change in the welded material is affected by the amount of the heat input during the welding process.

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