Application of MIG and TIG Welding in Automobile Industry

O.S. Ogbonna¹, S.A. Akinlabi²-³, N. Madushele¹, P.M. Mashinini², A. A. Abioye³

¹Mechanical Engineering Department, University of Johannesburg, South Africa
²Department of Mechanical and Industrial Engineering, University of Johannesburg, South Africa
³Department of Mechanical Engineering, Covenant University Ota, Nigeria
stephenakinlabi@gmail.com

Abstract

Emission and weight reduction have been identified over the years by the automobile industries as the most efficient ways to maintain fuel economy and to meet the demand of the government agencies on global warming. These challenges of reducing emission and weight are even being compounded with consumers taste for luxury features which adds to the weight of the traditional vehicle designs. To meet these demands, alloys such are Aluminium Alloys, Magnesium Alloys and Titanium Alloys have been identified as the suitable materials to replace conventional steel structures due to their superior properties such as high strength-to-weight ratio, high tensile strength and high-temperature performance. With the identification of suitable materials to replace the traditional materials, the welding of alloy materials remains a challenge faced by vehicle manufacturers. Although electron beam welding, ultrasonic welding and friction stir welding have proven to give quality weld joints of alloys used in automobile fabrication, their application is limited by the high cost of equipment, need for vacuum environment in electron beam welding, size and shape of base metals. Laser welding with its reduced heat affected zone (HAZ), good seam appearance and deep penetration has widely been applied in an automobile. However, it is not without its shortcomings such as poor gap bridging capability, difficulty in welding reflective materials and high cost. Arc welding with its low cost compared to other welding techniques and high energy efficiency, therefore, remains a useful welding process in an automobile. In this paper, a review of the various investigations by researchers on MIG and TIG welding of alloys used in the automobile have been documented.

Keywords: MIG, TIG, Welding, Automobile, Light-Weight

1. Introduction

Welding is an indispensable fabrication process which involves the joining of two metals (similar or dissimilar) by heating them to a molten state to form a formidable bond upon solidification [1]. Due to the wide application welding technology in key industries such as construction, marine, railway, aerospace and automobile industries, several welding techniques have been adopted. Some of these welding techniques include metal inert gas welding (MIG), tungsten inert gas welding (TIG), ultrasonic welding (USW), submerged arc welding (SAW), laser beam welding (LBW), electron beam welding (EBW), resistance spot welding (RSW), friction stir welding (FSW) and plasma arc welding (PAW) [2]. Among all these welding techniques, arc welding especially MIG and TIG welding stand out due to some of their advantages over other joining
processes. These advantages include low equipment cost, ability to weld various metals and alloys, high electrical efficiency, high gap bringing probability and less base metal preparation [3,4].

The automobile industry is no doubt one of the fastest growing industry due to the ever-increasing demand for mobility of both human beings and goods. As the world vehicle fleet increases, there is corresponding concern among vehicle manufacturers and researchers to replace heavy parts with lightweight parts without compromising the performance and at the same maintain efficient fuel economy and reduce harmful emissions [5]. Magnesium alloy, Aluminium alloy and titanium alloy [6] have been identified as suitable materials to replace conventional steel for weight reduction in the automotive industry. The subsequent sections of this paper is the summary of several studies by researchers in welding of these alloys by MIG and TIG welding techniques.

2. Welding of Aluminum Alloy

Aluminium alloys have distinguished properties such as high strength-to-tensile ratio, low density and reliable corrosion resistance [6] which make them suitable for light-weight applications. However, studies have shown that there are difficulties challenge experienced in welding of Aluminium such as the formation of surface oxide that is has melting temperature higher than Aluminium and high thermal conductivity which leads to welding defects (cracking, porosity and incomplete fusion) [6, 7]. However, as transportation industry especially the automobile is focused on the reduction of weight and harmful emissions, welding of light-weight Aluminium alloys as suitable materials to replace traditional steel in automobile becomes a significant forward stride towards realizing this dream [8]. This section, therefore, summarizes some of the efforts so far in MIG and TIG welding of Aluminium alloys. Fortain and Gadrey [9] in order to make MIG and TIG welding more competitive in welding of Aluminium alloys, carried out a study to obtain appropriate shielding gas for optimum performance of Aluminium alloy joints. The study revealed that the addition of oxygen and nitrogen in argon and argon-helium gas increases the welding speed and depth penetration of both processes. However, for TIG welding, the percentage of nitrogen must exceed 2 %.

Due to the concentration of heat at the fusion zone, the grains at this region are always coarse and this can lead to low resistance to hot cracking during solidification and hence reduced joint integrity. Then in order to reduce the heat input and hence enhance the properties of welded joint, Kumar et al [8] improved the tensile properties of AA 6061 Aluminium alloy welded joint with pulsed current tungsten inert gas welding (PC-TIG). Ye et al [6], in a similar study, obtained quality T-joint weld of AA 6061-T6 Aluminium alloy by double-pulsed MIG welding. It was observed that the best joint quality was obtained when the average current and current differences were 90 A and 40 A respectively. However, in another related study still with 6061 Aluminium alloy, Singh et al.[10], established a different way of improving mechanical properties the alloy apart from the proper regulation of heat input. In their study, it was observed that the tensile strength and toughness of the welded joint increased with increase in notch radius at the weld zone. However, these properties decreased at higher strain rate. The samples without notch fractured at
the base metal while the samples with notch fractured at the weld metal. The hardness of the weld metal was 60% lower than the base metal.

Apart from weight and emission reduction in automobile, cost reduction is also an important factor to be considered. One of the ways of achieving this is through dissimilar welding of materials which otherwise would necessitate the use of costly and scarce material. In view of this, Bajpei et al.[11], knowing full well of the challenge created by differences in thermal properties of dissimilar materials investigated the residual stresses and distortions in MIG dissimilar welded joint of AA 5052 and AA 6061 Aluminium alloy. Both the longitudinal, transverse stresses and distortion in AA 5052 were higher than in AA 6061. However, AA 5052 Aluminium alloy is still widely used in an automobile due to its good formability, weldability and excellent corrosion protection ability [12]. Hence, Vijayan et al.[12], achieved an ultimate tensile strength of 186.58 MPa and yield strength of 101.06 MPa in double-sided butt similar TIG welding of AA 5052 H32 at welding current, voltage, speed and gas flow rate of 180 A, 20 V, 100 mm/min and 11 rpm respectively. For maximum weld penetration in AA 5052 Aluminium alloy, Raveendra et al.[13], still with TIG welding process reported welding current, voltage, speed and glass rate of 210 A, 20 V, 147.78 mm/min and 12.5 Lit/min respectively as the optimal welding parameters. Salazar et al.[14], reported successful joints of AA 6061 and AA 7020 Aluminium alloys by MIG and TIG welding techniques without cracking, oxidation and porosity. A depth penetration of 2-3.5 mm was obtained in the study.

The choice of welding wire has a huge impact on the final properties of a welded joint. Ishak et al.[15], in their study, compared the effect of three different welding wires on TIG weld butt joint of similar AA 6061aluminum alloy. ER 5356 displayed better microstructure and mechanical properties than ER 4043 and ER 4047. Salleh et al.[16], also compared ER 5356 and ER 4043 welding wires in welding of the most durable and strongest Aluminium alloy 7075. Similarly, ER 5356 wire gave a joint with higher tensile strength and hardness value. The joint welded with ER 5356 and ER 4043, fractured at the heat affected zone and fusion zone respectively. This was attributed to the oxidation and porosity for ER 5356 and ER 4043 respectively. However, the tensile strengths of the joints were lower than the base metal. Wang et al.[17], successfully welded AA 6082-T6 Aluminium alloy used in engine casting by TIG welding method with filler rod, AA 4043 modified with titanium and strontium 0.08 and 0.025 % respectively. The addition of titanium and strontium in the welding wire improved the properties of the welded joint.

The effect of post weld heat treatment on the Aluminium alloy used in the automobile was investigated by Sachin et al.[18]. It was observed that AA-5083 Aluminium alloy TIG welded joint at a higher welding current of 80 A showed higher ultimate tensile strength after cryogenic treatment compared with those welded at lower currents of 75 A and 70 A. The two arc processes have been compared in welding of Aluminium alloy for the automotive industry. Fauzi et al.[19], compared MIG and TIG welded AA 6082-T6 Aluminium alloy joint. The joint integrity of the TIG welded samples were 25 % better than those welded by MIG process in terms of tensile strength, microhardness, the size of the heat affected zone (HAZ) and grain size. The welding parameters for the two processes were as follows: welding current, voltage, speed and gas flow rate of 132 and 250 A, 22 and 21 V, 9.7 and 12 mm/min and 20 L/mm for TIG and MIG welding.
respectively. Contrary to Fauzi et al. [19], Gupta et al.[20], reported that MIG welded AA6062 Aluminium alloy showed better microstructure as well as tensile, hardness and impact properties compared to TIG welded samples. Table 1 summarizes the welding of Aluminium in an automobile.

Table 1: MIG and TIG welding of Aluminium alloys in automobile

| Author          | Workpiece                  | Welding method and parameter optimized. | Findings                                                                 |
|-----------------|----------------------------|----------------------------------------|--------------------------------------------------------------------------|
| Kumar et al. [8]| 5 mm thick AA 6061 Al alloy with 3mm AA 4043 (Al-5%Si) as filler metal. | TIG welding. Effect of pulsed-current. | Tensile strength increased with an increase in peak current and pulse frequency while the reverse was the case with a pulse on time and base current. |
| Yi et al.[6]    | 2 mm thick 6061-T6 Al alloy with 1.2 mm ER5356 (Al-Mg) as welding wire. | MIG welding. Effect of double-pulsed current. | Due to the improved droplet transfer with the double-pulsed current, there was an enhancement in the bead appearance and also refinement in the microstructure of the fusion zone. |
| Singh et al.[10]| 3.2 mm AA 6061 Al alloy with 3.15mm ER 4043 (Al-4-6%Si) as filler metal. | TIG welding. Effect of notch radius. | Tensile strength and toughness of specimen with notch were higher than those without a notch. Fracture propagated through the base metal for samples without notch while fracture propagation was through the weld metal for samples with a notch. Both the longitudinal, transverse stresses and distortion in AA 5052 were higher than in AA 6061. |
| Bajpei et al.[11]| 3 mm x 150 mm x 200 mm plates of AA 5052 and AA 6061Al alloy with ER 5356 welding wire. | MIG welding. | Welding current, voltage, speed and gas flow rate of 180 A, 20 V, 100 mm/min and 11 lpm respectively gave the best joint quality. |
| Vijaya et al.[12]| 6 mm x 50 mm x 100 mm AA 5052 Al alloy with 1.6 mm AA 4043 filler rod. | TIG welding. Effect of welding current and gas flow rate. | A depth penetration of 2.02 mm was obtained at the optimal welding parameters. |
| Raveendra et al.[13]| 2.5 mm x 50 mm x 100 mm plate of AA 5052 Al alloy with AA 4043 filler rod. | TIG welding. Effect of welding parameter on the depth of weld penetration. | Joints without cracking, porosity and oxidation defects. |
| Salazar et al.[14]| AA 6061 and AA 7020 Al alloys | MIG and TIG welding | |
plates of thickness 6 and 5 mm respectively. Effect of the welding techniques on the microstructure. Better microstructure and mechanical properties obtained with ER 5356.

**Ishak et al. [15]**

2 mm x 50 mm x 50 mm plates of 6061 Al alloy with ER (5356, 4043 and 4047) filler wires. TIG welding. Effect of three different welding wires. ER 5356 showed better tensile strength and Vickers hardness than ER 4043.

**Salleh et al. [16]**

2 mm x 150 mm x 150 mm 7075 Al alloy with ER 5356 and ER 4043. MIG welding. Effect of two different welding wires. Samples welded at higher welding current have higher ultimate tensile strength and better grain refinement.

**Sachin et al. [18]**

3 mm x 50 mm x 125 mm plate of AA-5083 Al alloy with ER 5356 filler rod. TIG welding. Effect of cryogenic treatment at different welding currents. Modified microstructure and mechanical properties due to the titanium and strontium modified filler rod.

**Wang et al. [17]**

12 mm x 175 mm x 350 mm AA 6082-T6 Al alloy with 9.5 mm AA 4043 filler rod modified with titanium and strontium. TIG welding. Effect of titanium and strontium addition in AA 4043 filler rod. TIG welding showed better microstructural and mechanical properties compared to MIG welding process.

**Fauzi et al. [19]**

Hollow pipes to obtain K-joint. The chord (4.75 mm in thickness) and brace (3.2 mm in thickness) have a diameter of 50.8 mm with AA 4043 filler wire. MIG and TIG welding techniques. The two techniques were compared. TIG welding process showed better microstructural and mechanical properties compared to the TIG welding process.

**Gupta et al. [20]**

6 mm x 50 mm plate of AA6062 Al alloy. MIG and TIG welding. The two welding processes were compared. MIG welding process showed better microstructural and mechanical properties compared to the TIG welding process.

### 3. Welding of Magnesium Alloy

The quest for efficient fuel economy and reduction in CO₂ emissions by the automobile industry has revolutionized the use of magnesium alloys as lightweight materials. In Friedrich and Schumann [21] study on the prospects of magnesium alloy in the automotive industry, it was stated
that magnesium alloy has potential application in the automotive drive train, interior, body and chassis. Interestingly too, the same study observed that magnesium alloy has the capability of weight reduction in gear housing of about 20-25% compared to Aluminium alloy counterpart. Also, the study [21] stated that a total of 60 kg magnesium alloy is feasible in an automobile. With this information, it makes technical sense to observe some of the attempts by some researchers on MIG and TIG welding of magnesium alloys.

For lightweight application and also facilitate a smooth transition from conventional steel used in an automobile to magnesium, Wang et al.[22], successfully welded AZ31 B Mg alloy and Q235 steel by MIG welding process. With proper process parameters (6.20% weld Al content and heat input of 1919-2254 J/cm), 80% improvement (192 MPa) in the tensile strength of the Magnesium alloy base metal was realized. Tsujikawa et al.[23], obtained joint efficiency above 90% in TIG welded joints of two different magnesium alloys, AZ31 and AZ61. The fatigue test was also carried out on the welded samples and fatigue strength joint efficiency of 60% was obtained in rolled and extruded AZ61 alloy. For the AZ31 alloy, the fatigue joint efficiency for the rolled and extruded plates was 60 and 80% respectively. Adequate care is required in welding magnesium alloy to avoid deterioration of the properties of the base metals. However, Peter and Rosso [24], successfully welded ZE43 Mg alloy by TIG welding process without deterioration in the mechanical performance of the welded samples. Tuz et al.[25], also observed improvement in the tensile and bending strength of MIG welded magnesium alloys AZ91, AM-Lite and AM50 with AZ61A as welding wire. All the welded samples fractured at the base metal during the static tensile and bending tests. The findings on welding of magnesium alloys have been summarized in Table 2.

Table 2: MIG and TIG welding of magnesium alloy in an automobile.

| Author         | Workpiece                                      | Welding method and parameter | Findings                                                                 |
|----------------|-----------------------------------------------|------------------------------|--------------------------------------------------------------------------|
| Friedrich and Schumann [21] | -                                             | -                            | Magnesium has a high potential in an automobile. 60 kg of magnesium alloy is achievable in an automobile. |
| Wang et al.[22] | AZ31B Mg alloy and Q235 steel plates (3 mm x 50 mm x 200 mm) with AZ31 and AZ61 welding wires. | MIG welding. Effect of weld Aluminium content and heat input. | 80% improvement in the tensile strength of the Mg alloy base metal. |
| Tsujikawa et al.[23] | Rolled and extruded AZ31 and AZ61 Mg alloy plates of 2 mm thickness. | TIG welding. Effect of the welding process on the joint and fatigue efficiency. | Joint efficiency above 90% obtained for all the joints and fatigue strength efficiency of 60% in all the welded samples except for the extruded AZ31 Mg alloy. The welding process did not reduce the mechanical |
4. Conclusion

From the survey of the literature on MIG and TIG welding in the automobile industry, the following conclusion can be drawn:

- Aluminium and Magnesium alloys have been identified as suitable materials to replace traditional steel for weight reduction, CO₂ emission reduction and also for effective fuel economy in the automobile industry.
- Welding of Aluminium alloy can be a challenge due to its oxidation at high temperature to form an oxide with a melting point higher than base Aluminium.
- MIG and TIG welding as cost effective with high gap bridging capability have successfully been used to obtain Aluminium and magnesium alloy joints with satisfactory properties.
- For improved performance of Aluminium and magnesium alloy joints, optimum welding parameters must be selected.

5. Recommendation

Corrosion and wear resistance of welded joints as an important phenomenon that affects the performance of alloys structures has not been given adequate consideration. So, there is a need for further studies to be carried out in this regard.

Also, high impact resistance is so much required for automobile component structures especially in case of collision. Therefore, there is a need for impact resistance of the welded alloy joints used in an automobile to be considered.

Titanium alloys have superior properties such as high strength to weight ratio and high corrosion resistance which make them suitable for lightweight applications for aerospace, marine and automobile applications. Despite this fact, MIG and TIG welding of similar titanium alloys with its competitive advantages over other welding processes are very limited in the literature. Hence, there is an urgent need for more studies to be carried out in this regard.
References

[1] Sen, R., Choudhury, S.P., Kumar, R. & Panda, A. (2018). A comprehensive review on the feasibility study of metal inert gas welding. Materials Today: Proceedings, 5, 792–801. https://doi.org/10.1016/j.matpr.2018.06.104

[2] Bu, Y. & Gardner, L. (2019). Finite element modelling and design of welded stainless steel I-section columns. Journal of Constructional Steel Research, 152, 57–67. https://doi.org/10.1016/j.jcsr.2018.03.026

[3] Acherjee, B. (2018). Hybrid laser arc welding: State-of-art review. Optics and Laser Technology, 99, 60–71. https://doi.org/10.1016/j.optlastec.2017.09.038

[4] Kumar, A., Singh, R. & Singh, I. (2017). A review of metal inert gas welding on aluminium alloys. International Journal of Engineering Sciences & Research Technology 6, 453–456.

[5] Mathew, J., Joy, J. & George, S.C. (2018). Potential applications of nanotechnology in transportation: A review. Journal of King Saud University - Science, https://doi.org/10.1016/j.jksus.2018.03.015

[6] Yi, J., Cao, S., Li, L., Guo, P. & Liu, K. (2015). Effect of welding current on morphology and microstructure of Al alloy T-joint in double-pulsed MIG welding. Transactions of Nonferrous Metals Society of China, 25, 3204–3211. https://doi.org/10.1016/S1003-6326(15)63953-X

[7] Barnes, T.A. & Pashby, I.R. (2000). Joining techniques for aluminum spaceframes used in automobiles. Part I - solid and liquid phase welding. Journal of Materials Processing Technology, 99, 62–71. https://doi.org/10.1016/S0924-0136(99)00367-2

[8] Kumar, T.S. & Balasubramanian, V. (2007). Influences of pulsed current tungsten inert gas welding parameters on the tensile properties of AA 6061 aluminium alloy. Materials & Design, 28, 2080–92. https://doi.org/10.1016/j.matdes.2006.05.027

[9] Fortain, J.M. & Gadrey, S. (2013). How to select a suitable shielding gas to improve the performance of MIG and TIG welding of aluminium alloys. Welding International, 27, 936–47. https://doi.org/10.1080/09507116.2012.753257

[10] Singh, R., Chauhan, S. & Gope, P.C. (2016). Influence of notch radius and strain rate on the mechanical properties and fracture behavior of TIG-welded 6061 aluminum alloy. Archives of Civil and Mechanical Engineering, 16, 513–23. https://doi.org/10.1016/j.acme.2016.01.002

[11] Bajpei, T., Chelladurai, H. & Ansari, M.Z. (2017). Experimental investigation and numerical analyses of residual stresses and distortions in GMA welding of thin dissimilar AA5052-AA6061 plates. Journal of Manufacturing Processes, 25, 340–50. https://doi.org/10.1016/j.jmapro.2016.12.017

[12] Vijayan, D., Rao, V.S., Shamsudeen, S., Edwin, J. & Dhas, R. (2017). Weldability of AA5052 H32 aluminium alloy by TIG welding and FSW process – A comparative study. Materials Science and Engineering, 247. https://doi.org/10.1088/1757-899X/247/1/012016
[13] Raveendra, A., Kumar, B.V.R.R. & Sivakumar, A.N. (2014). Effect of welding parameters on 5052 aluminium alloy weldments Using TIG welding. International Journal of Innovative Research in Science, Engineering and Technology, 3, 10302–10309.

[14] Salazar, J.M.G. De, Ureña, A., Villauriz, E., Manzano, S. & Barrena, I. (2010). TIG and MIG welding of 6061 and 7020 aluminium alloys . Microstructural studies and mechanical properties. Welding International, 13(4), 293-294. https://doi.org/10.1080/09507119909447381

[15] Ishak, M., Noordin, N.F.M., Razali, A.S.K., Shah, L.H.A. & F.R.M. (2015). Effect of Filler on Weld Metal Structure of AA6061Aluminium Alloy by Tungsten Inert Gas Welding. International Journal of Automotive and Mechanical Engineering, 11, 2438–2446.

[16] Salleh, M.N.M., Ishak, M., Shah, L.H. & Idris, S.R.A. (2016). The effect of ER4043 and ER5356 filler metal on welded Al 7075 by metal inert gas welding. High Performance and Optimum Design of Structures and Materials II, 1, 213–24. https://doi.org/10.2495/hpsm160191

[17] Wang, B., Xue, S., Ma, C., Han, Y. & Lin, Z. (2017). Effect of combinative addition of Ti and Sr on modification of AA4043 welding wire and mechanical properties of AA6082 welded by TIG welding. Transactions of Nonferrous Metals Society of China, 27, 272–281. https://doi.org/10.1016/S1003-6326(17)60031-1

[18] Sachin, L.S., Mayur, S., Pavan, K.M., Chandrashekhar, A. & Ajaykumar, B.S. (2014). Evaluation of Structural and Mechanical Properties of TIG Welded Aluminium Alloy AA-5083 Subjected to Post Cryogenic Treatment. The Research Pubblications, 3(2),14–18.

[19] Fauzi, E.R.I., Jamil, M.S., Samad, Z. & Muangjunburee, P. (2017). Microstructure analysis and mechanical characteristics of tungsten inert gas and metal inert gas welded AA6082-T6 tubular joint: A comparative study. Transactions of Nonferrous Metals Society of China, 27, 17–24. https://doi.org/10.1016/S1003-6326(17)60037-7

[20] Gupta, Y., Tanwar, A. & Gupta, R. (2016). Investigation of Microstructure and Mechanical Properties of TIG and MIG Welding Using Aluminium Alloy. Journal of Mechanical and Civil Engineering, 13, 121–126. https://doi.org/10.9790/1684-130508121126

[21] Friedrich, H. & Schumann, S. (2001). Research for a ” new age of magnesium ” in the automotive industry. Journal of Materials Processing Technology, 117, 276–281.

[22] Wang, X., Sun, D., Yin, S. & Liu, D. (2015). Microstructures and mechanical properties of metal inert-gas arc welded Mg – steel dissimilar joints. Transactions of Nonferrous Metals Society of China, 25, 2533–2542. https://doi.org/10.1016/S1003-6326(15)63872-9

[23] Tsujikawa, M., Somekawa, H., Higashi, K., Iwasaki, H., Hasegawa, T. & Mizuta, A. (2004). Fatigue of Welded Magnesium Alloy Joints. Materials Transactions, 45(2), 5–8.

[24] Peter, I & Rosso, M. (2018). Investigations on Tungsten Inert Gas Welded Magnesium Alloy. 7th International Conference on Advanced Materials and Structures. https://doi.org/10.1088/1757-899X/416/1/012030
[25] Tuz, L., Kolasa, A. & Pfeifer, T. (2016). Structure and mechanical properties of MIG welded butt-joints of magnesium alloys. Welding International, 30, 202–207. https://doi.org/10.1080/09507116.2014.937625

[26] Xing, S. & Dong, P. (2017). Fatigue of Titanium Weldments: S-N Testing and Analysis for Data Transferability Among Different Joint Types. Marine Structures, 53, 1–19.