MALAYSIAN JOURNAL OF BIOENGINEERING AND TECHNOLOGY

Development of TIG MIG Hybrid Welding Process: A Brief Review

Aiman Syazwan Rosmin, Sarizam Mamat*
Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan, Campus Jeli, 17600 Jeli, Kelantan, Malaysia

**Corresponding author:* sarizam@umk.edu.my

ARTICLE INFO

Received:22 November 2023
Accepted:26 December 2023
Online:06 June 2024
eISSN: 3036-017X

ABSTRACT

The purpose of this article is to review the TIG MIG hybrid welding process, which benefits from the advantages of conventional MIG welding and TIG welding. The review focuses more on the studies related to the concepts of each welding process, its advantages and disadvantages, and some applications in the industry. The TIG MIG hybrid welding is a new method that is less popular than the conventional welding process. Thus, fewer experimental studies have been conducted on the process. Since the TIG MIG hybrid welding is promising a better welding process and is potent to improve the welding process with a combination of advantages of both conventional MIG and TIG welding, hence more work needs to be done on the TIG MIG hybrid welding research study to provide more valuable information that is lacking so that it could be applied to the industry.

Keywords: TIG welding, MIG welding, Hybrid welding, Metal droplet transfer

1. Introduction

Welding can be defined as a process of fusing two or more materials in the presence of a heat source. Several types of fabrication techniques are used in industrial applications nowadays, and welding could be considered the most common [1]. Numerous welding methods exist that can be used to fuse different materials. Metal Inert Gas Welding (MIG) is a joining and fabrication process used extensively for 25 years. Its advantages include low heat input, less arc, production efficiency, less heat-effected zone, and environment friendliness [2]. Kanemaru [3] said the metal inert gas process still needs more improvement in toughness, weld metal quality, bead surface oxidation, and spatter production. Another welding method often used by industry is Tungsten Inert Gas Welding (TIG). TIG is an arc welding process in which the tungsten rod produces an arc, and a non-consumable electrode is introduced to the welding process. MIG could be a worthy candidate in cases where the joining of thin and medium-thickness materials is crucial or where metallurgical control of the welding process is needed. According to Vasudevan [4], studies stated that a few disadvantages of TIG welding when applied to austenitic stainless steel include low productivity, the limited thickness of material that can be used to weld in a single pass, and poor tolerance to cast-to-cast variations. Referring to the corresponding advantages of TIG and MIG could be an effective way of solving their limitations. Thus, a TIG MIG hybrid welding is formed to produce a better welding quality. Since neither TIG nor MIG uses special protective gas or complex welding methods, it is economically friendly, and less work power is needed. A study conducted by Abbasi [5] stated that the addition of TIG as a hybridization to MIG shows that the MIG circular segment could be steady even though an unadulterated argon shielding gas is used. Hence, the results lead to an improvement in the sturdiness and welding quality of welded metal.

2. Metal Inert Gas Welding

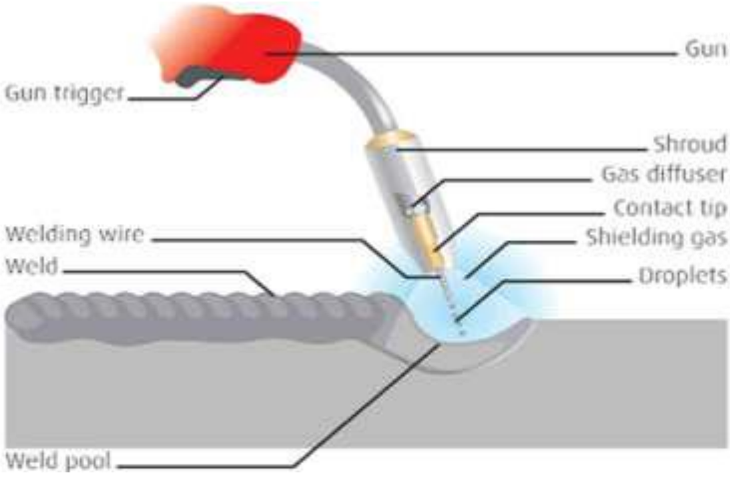

Fig. 1: MIG welding process [2]

MIG or Metal Active Gas (MAG) welding is a flexible fabrication method often used for joining either thin or thick sheet components. As shown in Fig. 1, an arc is produced from the tip of the wire electrode and struck onto the workpiece when a full circuit, either Direct Current Electrode Positive (DCEP) or Direct Current Electrode Negative (DCEN) polarity, is complete. The existence of heat from the arc melts both the wire electrode and workpiece, which creates a weld pool. Besides, both filler metal and heat source come from the same wire electrode. The wire is fed through a copper contact tube or contact tip, which conducts welding current into the wire. The most common shielding gas used, such as argon (Ar) and carbon dioxide (CO_2), is fed through a nozzle that covers the wire electrode and acts as extra protection for the weld pool from the surrounding atmosphere. The types of shielding gas used are dependent on the materials that need to be joined and their application. The machine consists of a motor drive that feeds the fire from a reel while the welder moves the welding torch during the fabrication process. Wires may be solid or cored which is composites formed from a metal sheath with a powdered flux or metal filling. As the wire was continuously fed, it would result in a higher productivity of welding.

MIG is suitable for use on all kinds of steel, aluminum, stainless steel, or nickel, despite its different thicknesses. Numerous manufacturing and commercial fabrication industries used MIG welding due to its worth. MIG is well known for its good heat input control. Hence, it can be used to join nonferrous alloys. It is a semi-automatic process that is used for continuously welding with the help of wire, high metal deposition rate, and high welding speed [2]. Since no flux is used in the filler metal wire rod, there was zero possibility of slag entrapment in the weld metal, which resulted in a high-quality joining. Therefore, it was crucial to use MIG welding in the industry to produce high-quality joining at a faster pace. In order to protect the arcs from the surrounding environment, shielding gases such as argon and CO2 were installed so that the loss of alloying elements could be controlled. In terms of spatter produced, MIG welding was much better than MAG welding since it produced less spatter. MIG is a more versatile process and can be used to join various types of alloys. However, MIG welding has some disadvantages, including less stable arc, irregular wire feedback, burn-back, more sparks, and the production of smoke and fumes in the welding process [6].

Khanna and Maheshwari [7] studied the effect of welding parameters on weld bead characteristics during MIG welding of stainless steel. They stated a high-quality MIG weld can be obtained when the process parameters are properly adjusted. A robotic welding machine is used for joining in the presence of Argon and Carbon Dioxide mixture as the shielding gas to investigate the effect of increased pressure on MIG welding. Therefore, he observed that an increase in pressure towards the weld bead penetration, welding arc, and bead geometry resulted in an extraordinary effect [5]. Singhmar & Verma [8] applied the Taguchi method on an austenitic stainless-steel grade 304 (AISI 304) specimen of dimension 110 × 40 × 3 mm using metal inert gas welding to study the influence parameter affecting the mechanical properties of the austenitic steel. Hence, arc current has the highest influence on tensile strength, followed by arc voltage and gas flow rate.

eISSN Number: 3036-017X

3. Tungsten Inert Gas Welding

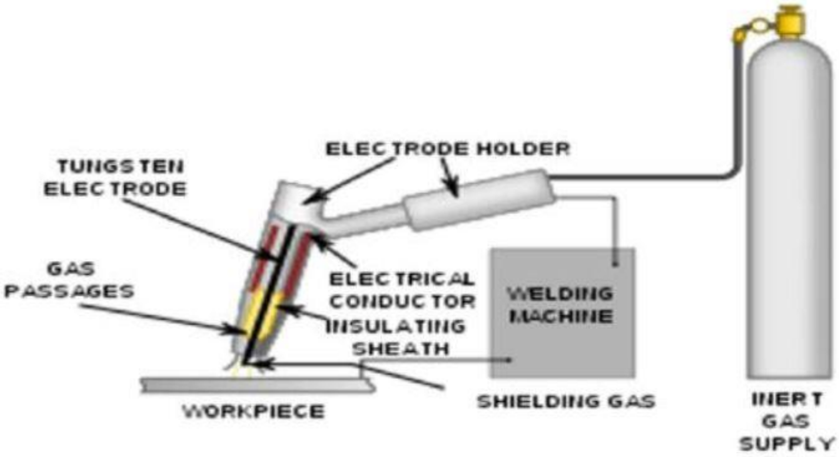

Fig. 2: TIG welding process [8]

Fig. 2 shows an illustration of the TIG welding process. TIG or Gas Tungsten Arc Welding (GTAW) is a joining process that forms a weld bead using non-consumable tungsten electrodes, and in certain cases, an external welding electrode is added to the process. Moreover, when an arc was struck from the tungsten electrode onto the workpiece, fusion energy was produced [9]. An extra protection of shielding gas such as Helium and Argon was used to protect the weld area from the surrounding environment. Shielding gas that was supplied from the gas nozzle fits the role of replacing surrounding atmospheric air from the contaminated air. A constant current welding power supply is used to produce the arc between the electrode and the workpiece. TIG welding is slightly different from MIG welding because the electrode is not consumed like the one in MIG welding. TIG welding is conventionally used in industry to join thin sections of metal such as stainless steel, copper alloys, and aluminum. But since the mechanism is less complex, it is suitable and favourable to be used in joining almost all types of metal.

TIG welding can be performed on almost all metals with high melting points. Overall, heat input to the joint significantly reduces, giving extra security against the sensitization of low-carbon austenitic stainless steels [10]. TIG welding has several advantages, such as joining a wide range of metals, joining dissimilar metals, the possibility of joining metals with thinner diameters up to 0.5 mm thickness, narrower heat affected zone (HAZ), absence of slag higher quality welds, the possibility of controlling the welding current as low as possible so that the welds are not damaged during the welding process among others [11]. Arivazhagan [12], reported welds void of cracks, which exhibited good compact toughness and high hardness value. Despite the numerous convenient uses of TIG welding, there were also a few limitations. A low weld penetration was classified as the major limitation of the TIG welding process [13]. Mishra [14] reported that the TIG welded joint has a better mechanical property compared to the MIG welded joint. However, the TIG welding process has the disadvantages of shallow penetration and low productivity.

Rao & Deivanathan [15] studied Experimental Investigation for Welding Aspects of Stainless Steel 310 for the Process of TIG Welding. The mechanical properties and microstructure of 310 austenitic stainless steel welds are investigated using stainless steel filler material of different grades. It was proved that when a current of 120A and 309L filler rod is used, a higher tensile strength joint that has fewer defects on the weld bead is produced. Borrisutthekul [16] stated that when a self-brazing technique was applied to the TIG welding mechanism, a dissimilar metal of steel and aluminum alloy could be successfully fabricated together. Therefore, the TIG welding process is suitable for joining dissimilar metals since low heat input was produced. Susmitha [11] analyzed the TIG welding process on mechanical properties and microstructure of A6063 aluminum alloy joints. They found out that if the welding current of AA6063 aluminum alloy increased, there was also an increment in the welding heat input. Also, mechanical properties are directly proportional to the fineness in the grain diffusion of Mg_2Si in the Al matrix, which depends on the process parameter, such as the current of TIG welding.

4. TIG MIG Hybrid Welding

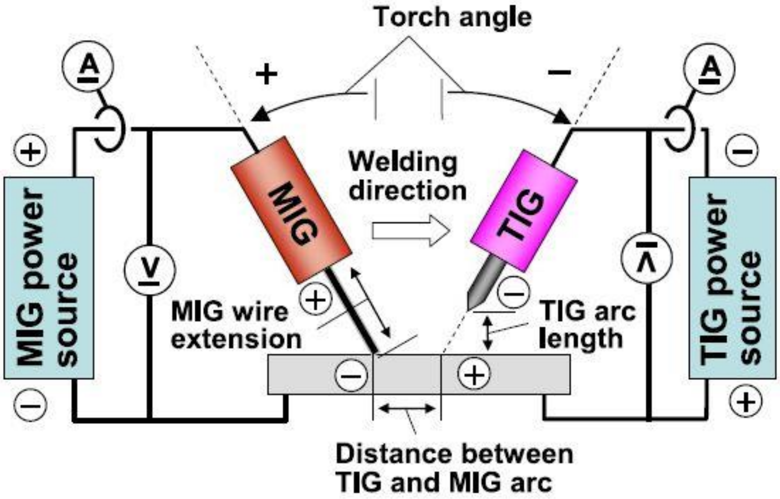

Fig. 3: The TIG MIG hybrid welding process [3]

Fig. 3 shows an illustration of the TIG MIG hybrid welding process. The definition of hybrid welding technology was simply a combination of a laser heat source with another source of joining [17]. Improvements over both conventional welding and laser welding have been reported, and hybrid welding of aluminum has shown clear advantages such as reduced amounts of pores and reduced susceptibility to cracking. By applying a hybrid welding method, the ductility of the materials can be improved, which fits the needs of using high-strength steels [18]. Fuhaid [1] stated that the TIG and MIG hybrid method proves to be a prospective alternative for TIG and MIG methods, and in most occasions and parameter sets, it is found to result in better mechanical properties.

Meng [19] studied the high-speed TIG and MIG hybrid arc welding of mild steel plates. The influences of hybrid arc welding parameters on welding speed and weld appearance were studied through orthogonal experiments, and the microstructures and mechanical properties of the weld were tested and compared with those of the conventional MAG weld. When TIG and MIG were developed together to get hybrid arc welding, the welding speed for butt and bead-on-plate welding of mild steel remarkably increased. TIG and MIG hybrid welding produces a joint with better tensile strength, narrower Heat Affected Zone (HAZ), and higher micro-hardness compared to conventional MIG welding. In addition, when TIG was introduced into the mechanism, the assist from the TIG arc could generate a spray transfer droplet that stabilized the MIG arc voltage and current effectively.

Ding [20] analyses the TIG and MIG hybrid welding of ferritic stainless steels and magnesium alloys with Cu interlayers of different thicknesses. In terms of producing an economical and light automobile in terms of weight reduction, the joining of stainless steel and magnesium alloys is much preferable. Hence, instead of applying the conventional method of welding, a TIG and MIG hybrid welding system is introduced to the project. AZ31B Mg and 430 ferritic stainless steels were successfully welded using a novel TIG–MIG hybrid welding process with 0.1 mm and 0.02 mm thickness Cu interlayer. Intermetallic compounds transition layer has been found in the 0.1 mm thickness interlayer joints, and no particle has been found in the 0.02 mm thickness interlayer joints. Moreover, the tensile-shear strength with a 0.1 mm thickness Cu interlayer was also improved by 47% compared to the 0.02 mm thickness Cu interlayer joints.

Chen [21] investigates the influence of low current auxiliary TIG arc on high-speed TIG and MIG hybrid welding. The influence of low current auxiliary TIG arc on microstructure and weld formation was studied by observing the welding droplet transfer, arc shape, and weld pool behavior. Moreover, the results were compared with conventional MIG welding. By referring to **Fig 4**, when the auxiliary TIG arc is leading, the MIG arc is stable without spatters, even though the shielding gas is pure Argon. When the TIG arc is trailing, the current-voltage characteristics of MIG and TIG arcs are increasing vigorously. MIG and TIG hybrid have poor welding stability as compared with conventional MIG welding and generate bits of spatters. Despite the increase in heat input, the microstructure of the weld zone of TIG and MIG hybrid welding showed no defects. Hence, it can be concluded that in terms of grain refinement and better weld morphology, TIG and MIG hybrid welding produce better weld microstructure compared to conventional MIG welding.

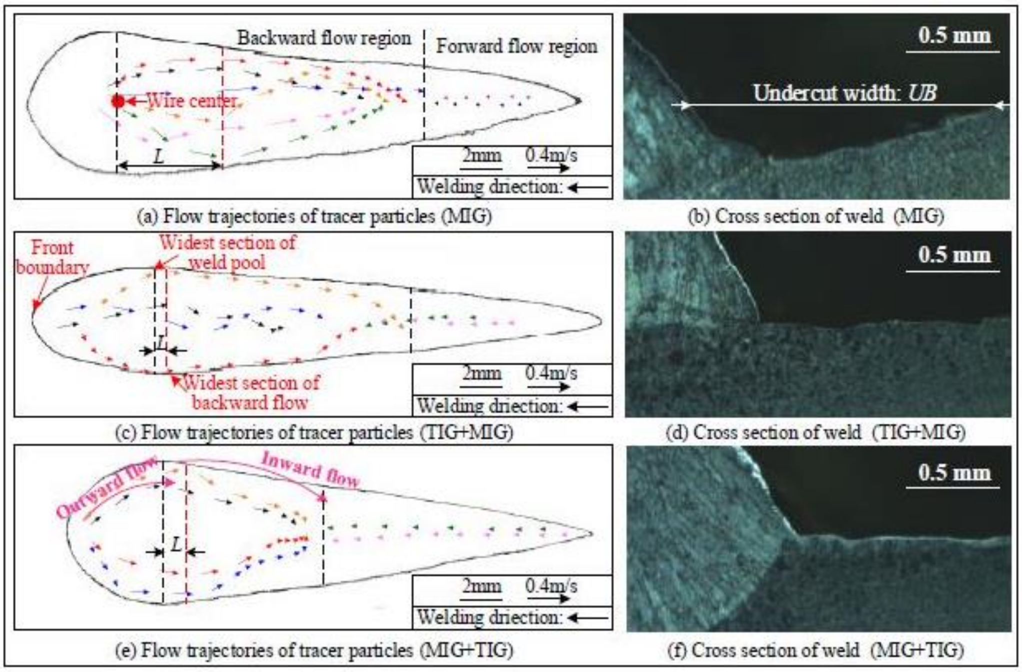

Fig. 4: Results of different type of welding effects on undercut formation [21]

Zong [22] studied the comparison of TIG and MIG hybrid welding with conventional MIG welding in the behaviors of arc, droplet, and weld pool. The studies prove that even though the TIG current was the lowest at 50A and its arc was leading, a stable MIG arc without spatters was produced. By considering the main purpose of reducing heat input, TIG and MIG hybrid welding are more suitable and preferable for heat-sensitive metal. When the TIG arc was trailing, the amount of TIG current needed in order to reach a stable welding process should be more than 100A. Moreover, in the TIG and MIG hybrid welding mechanism, the arc length of MIG increases gradually with the TIG current. Hence, the arc heat flux became lower compared with that in conventional MIG welding, which resulted in a lower temperature field and narrower weld width. Moreover, when the TIG and MIG hybrid welding is used, an increase of welding speed to 1.5 m/min occurs without an undercut defect. Hence, in the situation where the leading arc was TIG, the main factor to the undercut formation was the decrease in weld width, while when the trailing arc was TIG, the decrease in backward flow velocity was the main cause of undercut forming that caused by the forward TIG arc force.

Shen [23] investigated the effect of welding process parameters on the hybrid MIG and TIG welding process of AZ31B magnesium alloy. The effects of different welding process parameters, such as bypass current, wire extension, and the distance between the tungsten electrode and the workpiece on weld forming, were analyzed, and the optimized parameters were obtained through the technology experiment. They stated that in a certain range, there was an increment in bypass currents that caused lower welding penetration and an increase in weld bead width that is different from other parameters. Besides, when the bypass current increases, the weld grain can be refined, which promotes a better microhardness of the weld bead, which is also different from other parameters. Therefore, the bypass current play a major part during the welding process that affects the formation of the weld. The optimum welding parameters of this experiment were observed as bypass current of 140 A, welding voltage of 21 V, total current of 225 A, 2.8 m/min of welding speed, 5 mm of distance from tungsten electrode tip to the workpiece, a wire extension of 15 mm, 25 L/min shielding gas flow, 43° of angle between both of the welding torch and 2 mm of distance between tungsten electrode tip and wire.

Somani & Lalwani [24] conducted an experimental investigation of the TIG and MIG hybrid welding process on austenitic stainless steel. The experiment aims to combine two different welding processes which are TIG welding and MIG welding, in order to benefit both of the advantages and also overcome the limitations so that a better welding process can be used. The experiment was conducted using a welding speed of 230 mm/min to 370 mm/min that resulted in variations of tensile strength data, welding current, and voltage. By referring to the results of tensile strength over variance types of control parameters, it can be observed that a good tensile strength of 665.2 MPa was achieved by controlling the welding speed at 370 mm/min. By applying Response Surface Methodology (RSM) and ANOVA, the agreement between experimental data and the statistical model is present with a relative error of 5%. Hence, the process is optimized between a set of values of control parameters to obtain a good-quality weld joint.

eISSN Number: 3036-017X

Roslan [25] observed the arc behavior in the TIG and MIG hybrid welding processes. The project was done by studying the influence of the current variation of TIG on the arc stability of the TIG and MIG welding processes compared to the conventional MIG welding process. The observation of MIG arc behavior when the TIG arc was introduced is shown in **Fig 5**.

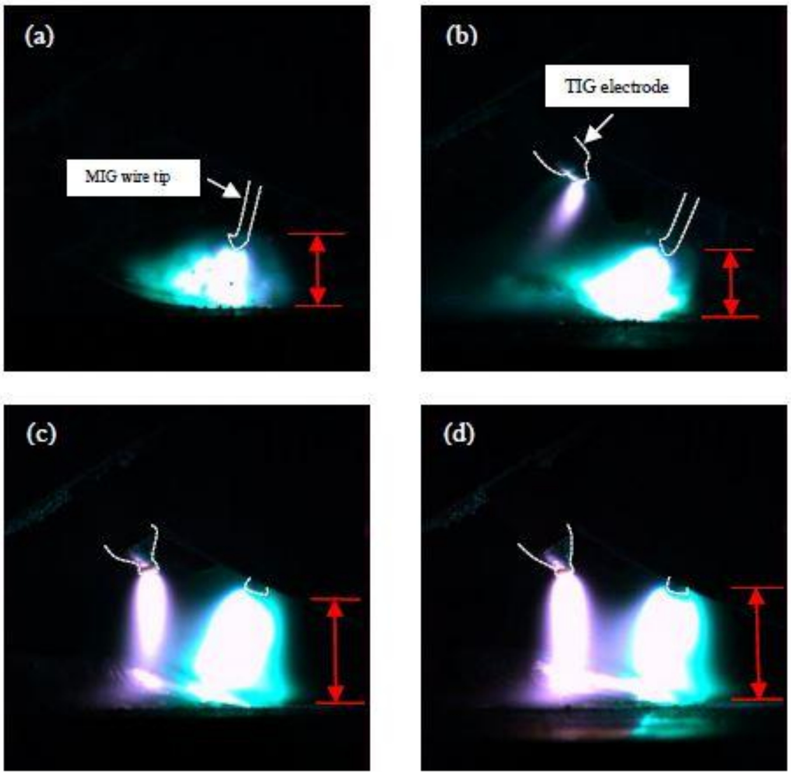

Fig. 5: Influence of TIG current on MIG arc length [25]

The increase in TIG current from Fig. 5(b) 60A, Fig. 5(c) 100A, and **Fig. 5(d)** 120A influenced the stability of the arc due to the presence of electromagnetic repulsion force from the TIG and MIG arc currents. The increase in current flow would increase the electromagnetic repulsion force and affect the arc stability as well as the droplet transfer mode. When TIG is introduced with the highest current of 120 A in the TIG and MIG hybrid system, it was observed that it produced the smallest metal droplet diameter and the highest frequency of metal droplet transfer. Hence, a decreasing droplet diameter would increase the droplet frequency due to the increasing in arc voltage that promotes higher electromagnetic force during necking.

Ogundimu [26] studied the microstructure and mechanical properties of 304 stainless steel joints by TIG and MIG hybrid welding. In this study, the effectiveness of TIG and MIG hybrid welding on 304 stainless steel is possible by when the excellent weld joint efficiency of 98.11% was achieved. It can be observed that the microstructure on the MIG weld was mainly a coarse columnar dendrite of ferrite, while the TIG shows a thinner and finer dendritic of ferrite. Meanwhile, when TIG and MIG hybrid welding were applied, the microstructure of the weld showed a well-nucleated grain and less coarse ferrites after the weld zone experienced solidification. Penetration of MIG welds is deeper than TIG welds but shows an incomplete permeation of the filler as observed at the root gap. Welding current and speed, as the common parameters, play an important role in determining the tensile strength or weld strength of the weld join. However, the application of TIG and MIG hybrid welding resulting the highest average of Ultimate Tensile Strength (UTS) of 672.38 MPa. It also shows that MIG and TIG hybrid welding has the highest strain hardening effect when compared to the other welded specimens. Moreover, for the case of hardness testing, the TIG and MIG hybrid sample that was welded at the currents of 190 A – 170 A exhibits the highest value of 249.5 HV. This was much better when compared to the conventional TIG weld that only peaks at 200 HV. Hence, this result has a direct correlation with the strength of the stainless-steel welded joint.

5. Conclusion

By reviewing the topic of TIG MIG hybrid welding, it can be concluded that there is a lack of experimental studies on this welding process despite its benefits when compared with conventional TIG MIG welding respectively. Moreover, the implementation of TIG MIG hybrid welding should be commercialized worldwide as it could increase the productivity of its high efficiency and improve the quality of weld joints. It can also be used widely in industries that intensively use dissimilar metal joining due to TIG MIG hybrid welding ability on controllable heat input and arc stability. Hence, more work needs to be done on the TIG MIG hybrid welding research study to provide more valuable info that was lacking in this study, such as in aluminum and steel dissimilar joining, so that it could be applicable to be used in the industry and also for personal purposes.

Acknowledgement

This work was financially supported by a grant from the Universiti Malaysia Kelantan (grant no : R/MTCH/A1300/00896A/003/2021/00972). The sponsorship and support are gratefully acknowledged.

References

[1] Ismail AA, Fuhaid MS, Murali RV. An experimental analysis on mechanical integrity of TIG-MIG hybrid weldments. Int J Mech Prod Eng, 2017;5(1):114-117.

[2] Mahore N, Gwalior T, Sharma T, Gwalior T, Singh R, Gwalior T. Study of MIG welding process with different type technique: a review. Int J Mech Prod Eng, 2017;4(6):1-5.

[3] Kanemaru S, Sasaki T, Sato T. Study for TIG – MIG hybrid welding process. Int J Mech Prod Eng, 2014;11(1):11-18.

[4] Vasudevan M. Effect of A-TIG welding process on the weld attributes of type 304LN and 316LN stainless steels. J Mater Eng Perform, 2017;16(1):1-16.

[5] Abbasi K, Alam S, Khan MI. An experimental study on the effect of increased pressure on MIG welding arc. Int J Mech Prod Eng, 2011;2(1):22-27.

[6] Ogundimu EO, Akinlabi ET, Erinosho MF. an experimental study on the effect of heat input on the weld efficiency of TIG-MIG hybrid welding of type 304 austenitic stainless steel. J Phys Conf Ser, 2019;1378(2):022075.

[7] Khanna P, Maheshwari S. effect of welding parameters on weld bead characteristics during MIG welding of stainless steel 409M. Int J Mech Prod Eng, 2016;19(1):3-8.

[8] Singhmar M, Verma N. Experimental study for welding aspects of austenitic stainless steel (AlSi 304) on tensile strength by Taguchi technique. Int J Mech Prod Eng, 2015;4(1):1-10.

[9] Roy P. A study on TIG welding process and its basic features as well as parametric optimization. Int J Mech Prod Eng, 2015;2(6):71-74.

[10] Patel GV. Optimization and prediction of MIG welding process parameters using ANN. Int J Mech Prod Eng, 2018;1(1):1-10.

[11] Susmitha JD, Ram MV, Srinivas K. Analysis of TIG welding process on mechanical properties and microstructure of Aa6063 aluminum alloy joints. Int J Mech Prod Eng, 2016;1(1):623-626.

[12] Arivazhagan B, Srinivasan G, Albert SK, Bhaduri AK. A study on influence of heat input variation on microstructure of reduced activation ferritic martensitic steel weld metal produced by GTAW process. Fusion Eng Des, 2011;86(2-3):192-197.

[13] Singh AK, Dey V, Rai RN. Techniques to improve weld penetration in TIG welding (A review). Mater Today Proc, 2017;4(2):1252-1259.

[14] Mishra B, Panda RR, Mohanta DK. Metal inert gas (MIG) welding parameters optimization. Int J Mech Prod Eng, 2014;1(1):637-639.

[15] Rao VA, Deivanathan R. Experimental investigation for welding aspects of stainless steel 310 for the process of TIG welding. Procedia Eng, 2014;97(1):902-908.

[16] Borrisutthekul R, Mitsomwang P, Rattanachan S, Mutoh Y. Feasibility of using tig welding in dissimilar metals between steel/aluminum alloy. Int J Mech Prod Eng, 2010;1(2):82-86.

[17] Casalino G, Campanelli SL, Maso UD, Ludovico AD. Arc leading versus laser leading in the hybrid welding of aluminium alloy using a fiber laser. Procedia CIRP, 2013;12(1):151-156.

[18] Bagger C, Olsen FO. Review of laser hybrid welding. Int J Mech Prod Eng, 2005;17(1):2-14.

[19] Meng X, Qin G, Yuqi Z, Fu B, Zou Z. High speed TIG-MAG hybrid arc welding of mild steel plate. J Mater Process Tech, 2014;1(1):1-10.

[20] Ding M, Liu SS, Zheng Y, Wang YC, Li H, Xing WQ, Dong P. TIG – MIG hybrid welding of ferritic stainless steels and magnesium alloys with Cu interlayer of different thickness. Mater Des, 2015;88(1):375-383.

[21] Chen J, Zong R, Wu C, Padhy GK, Hu Q. Influence of low current auxiliary TIG arc on high speed TIG-MIG hybrid welding. J Mater Process Tech, 2016;1(1):1-10.

[22] Zong R, Chen J, Wu C. A comparison of TIG-MIG hybrid welding with conventional MIG welding in the behaviors of arc, droplet and weld pool. J Mater Process Tech, 2019;270(1):345-355.

[23] Shen X, Ma G, Chen P, Chen P. Effect of welding process parameters on hybrid GMAW-GTAW welding process of AZ31B magnesium alloy. Int J Adv Manuf Technol, 2017;1(1):1-10.

[24] Somani CA, Lalwani DI. Experimental investigation of TIG-MIG hybrid welding process on austenitic stainless steel. Mater Today Proc, 2019;18(1):4826-4834.

[25] Roslan RA, Mamat S, Teo PT. Observation of arc behaviour in TIG/MIG hybrid welding process. J Phys Conf Ser, 2020;596(1):012025.

[26] Ogundimu E.O., Akinlabi E.T., Erinosho M.F. Study on microstructure and mechanical properties of 304 stainless steel joints by TIG – MIG hybrid welding. Int J Mech Prod Eng, 2017;25(4):1-14.

eISSN Number: 3036-017X