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ANALYSIS OF MICRO STRUCTURAL BEHAVIOUR OF DISSIMILAR WELDS

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Abstract

To improve welding quality of dissimilar steel plate, TIG welding system has been developed, by which welding speed can be controlled during welding process. Welding of dissimilar steel plate has been performed in two phases. During 1st phase of welding, pulsed TIG welding is performed over dissimilar steel plate and during 2nd phase TIG welding performed for dissimilar steel plate by changing different welding parameters. Effect of welding speed and welding current on the tensile strength of the weld joint has been investigated for both type of weld joint. Optical microscopic analysis has been done on the weld zone to evaluate the effect of welding parameters on welding quality. Micro-hardness value of the welded zone has been measured at the cross section to understand the change in mechanical property of the welded zone. Welding process is an arc welding process uses a non consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere with a shielding gas generally Argon or Helium or sometimes mixture of Argon and Helium. A filler metal may also feed manually for proper welding. GTAW most commonly called TIG welding process was developed during Second World War. With the development of TIG welding process, welding of difficult to weld materials e.g. Aluminum and Magnesium become possible. Actually Aluminum is not difficult to weld, but it is different to weld. The use of TIG today has spread to a variety of metals like stainless steel, mild steel and high tensile steels, Al alloy, Titanium alloy. Like other welding system, TIG welding power sources have also improved from basic transformer types to the highly electronic controlled power source today.

Keywords Welding process, TIG welding, Aluminum plate, Tensile strength.

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1. Introduction

Welding is a permanent joining process used to join different materials like metals, alloys or plastics, together at their contacting surfaces by application of heat and or pressure. During welding, the work-pieces are joined and melted at the interface and after solidification a permanent joint is achieved. Sometimes a filler material is added to form a weld pool of molten material which after solidification gives a strong bond between the materials. Weld ability of a material depends on different factors like the metallurgical changes that occur during welding, changes in hardness in weld zone due to rapid solidification, extent of oxidation due to reaction of materials with atmospheric oxygen and tendency of crack formation in the joint position.(1,2)

2. DIFFERENT TYPE OF WELDING PROCESSES

Based on the heat source used welding processes can be categorized as follows:

2.1 Arc Welding:

In arc welding process an electric power supply is used to produce an arc between electrode and the work-piece material to joint, so that work-piece metals melt at the interface and welding could be done. Power supply for arc welding process could be AC or DC type. The electrode used for arc welding could be consumable or non-consumable. For non-consumable electrode an external filler material could be used.

2.2 Gas Welding:

In gas welding process a focused high temperature flame produced by combustion of gas or gas mixture is used to melt the work pieces to be joined. An external filler material is used for proper welding. Most common type gas welding process is Oxyacetylene gas welding where acetylene and oxygen react and producing heat.

2.3 Resistance Welding:

In resistance welding heat is generated due to passing of high amount current (1000–100,000 A) through the resistance caused by the contact between two metal surfaces. Most common types resistance welding is Spot-welding, where a pointed electrode is used. Continuous type spot resistance welding can be used for seam-welding where a wheel-shaped electrode is used.

2.4 High Energy Beam Welding:

In this type of welding a focused energy beam with high intensity such as Laser beam or electron beam is used to melt the work pieces and join them together. These types of welding mainly used for precision welding or welding of advanced material or sometimes welding of dissimilar materials, which is not possible by conventional welding process.

2.5 Solid-State Welding:

Solid-state welding processes do not involve melting of the work piece materials to be joined. Common types of solid-state welding are ultrasonic welding, explosion welding, electromagnetic pulse welding, friction welding, friction-stir-welding etc.

Among all these types of welding processes arc welding is widely used for different types of materials. (3,4)

3 EXPERIMENTAL WORKS AND METHODOLOGY

3.1 DEVELOPMENT OF PULSED TIG WEIDING SYSTEM

For proper welding and control on welding parameters mainly on welding speed an automated welding setup has been developed in-house. The automated welding setup with its main components.

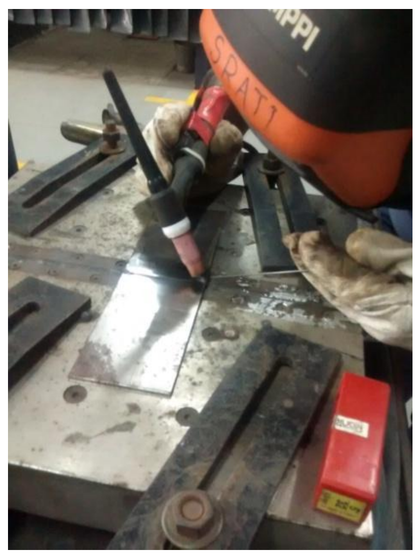


Fig. 1 – Experimental set-up for TIG welding

a)TIG Welding torch- Torch is fixed with the movable tractor unit. A tungsten electrode is fixed in the torch and Ar gas is flow through this.

b) TIG welding machine- This is the main part of TIG welding setup by which controlled amount of current and voltage is supplied during welding. A Rectifier (made by KEMPPI) with current range 10-180 A and voltage up to 230 V, depending on the current setting has been used.

c) Gas cylinder- For TIG welding Ar gas is supplied to the welding torch with a particular flow rate so that an inert atmosphere formed and stable arc created for welding. Gas flow is control by regulator and valve.

d) Work holding table - a surface plate (made of grey cast iron) is used for holding the work piece so that during welding gap between the tungsten electrode and work piece is maintained. Proper clamping has been used to hold the work piece.

e) The torch was maintained at an angle approximate 90° to the work piece.

3.2 EXPERIMENTAL PLANNING AND PROCEDURE:

For the present work, experimentation was done in two phase. In first phase, butt welding of dissimilar steel plate (2.5 mm thickness) done at pulsed TIG with different current setting and welding speed. In second phase, butt welding of dissimilar steel plate done by TIG welding speed and current setting.(5)

3.2.1 Experimental procedure:

Commercial dissimilar steel plate of thickness 2.5 mm was selected as work piece material for the present experiment. Al plate was cut with dimension of 120 mm x 50 mm with the help of laser cutting and grinding done at the edge to smooth the surface to be joined. After that surfaces are polished with emery paper to remove any kind of external material.

After sample preparation, dissimilar steel plates are fixed in the working table with flexible clamp side by side and welding done so that a butt join can be formed. TIG welding with Current (DC) was used in experiments as it concentrates the heat in the welding area. Zirconia tungsten rod of diameter 3.4 mm was taken for this experiment. The end of the electrode was prepared by reducing the tip diameter to 2/3 of the original diameter by grinding and then striking an arc on a scrap material piece. This creates a ball on the end of the tungsten rod electrode. Generally an rod that is too small for the welding current will form an excessively large ball, whereas too large an electrode will not form a satisfactory ball at all. Xuper 680 CGS of 1.6 mm filler rod taken for joints the dissimilar steel by TIG welding process For the first phase of experiment welding parameters selected are

Parameters	Range
Welding peak current	(70,80,90) A
Welding base current	(35,40,45)A
Time	1 sec
Speed	(1.5-2.0) mm/s
Distance of tip from weld center	3 mm
Gas flow rate	(8-10) l/min
Current type	DC
Dimension	120mm*75 mm*2.5 mm

shown in table Before performing the actual experiment a number of trial experiments have been performed to get the appropriate parameter range where welding could be possible and no observable defects like undercutting and porosity occurred.(6,7)

Table 1: Welding parameters for 1st phase of experiments in pulsed TIG welding

Table 2: Welding parameters for 2nd phase of experiments in TIG welding

Parameters	Range
Welding current	(70,80,90) A
Speed	(1.5-2.0) mm/s
Distance of tip from weld centre	3 mm
Gas flow rate	(8-10) l/min
Current type	DC
Dimension	120mm*75 mm*2.5 mm

Table 3: Welding specimen

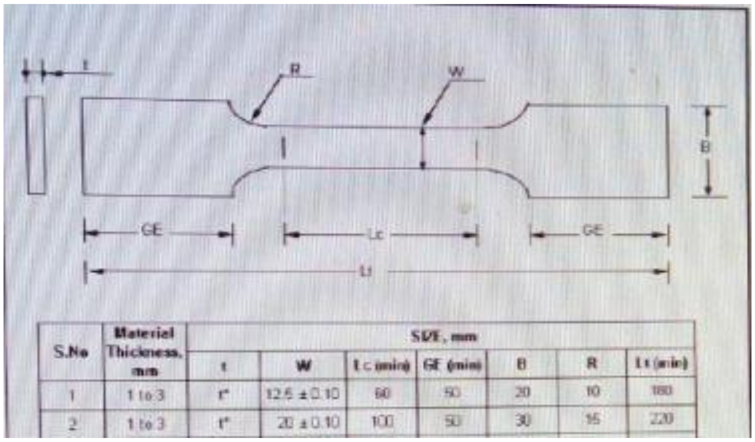
Exp.No.	Electrode Work piece Distance mm	ArgonGas Flow rate (l/min)	Welding Speed (mm/s)	Current (A)
A	3	8 - 10	1.5 - 2	90
B	3	8 - 10	1.5 - 2	80
C	3	8 - 10	1.5 - 2	70
D	3	8 - 10	1.5 - 2	90
E	3	8 - 10	1.5 - 2	80
F	3	8 - 10	1.5 - 2	70

After performing the welding, welded specimens were cut with dimension of 180 mm x 25 mm for tensile test, which were further cut in to I shape as per IS 1608-2005 Tensile test was performed with universal tensile testing machine (FUT40) with maximum load capacity of 400 kN. Further, a 60 mm *10 mm*2.5mm specimen were cut at the cross section for microstructural study and micro-hardness measurement from each sample. Before microhardness measurement cross section of the welded specimen mounted and polished with 220,600 and 1200 grit size polishing paper sequentially.

Micro-hardness was measured with Rockwell micro-hardness tester (hardness tester RBHT). Optical image of the cross section of the welded zone was taken with an scanning (FSEM).(7,8)

4 TENSILE TESTS:

Six samples for various heat input were tested for tensile strength, where the thickness is reduced from 3 to 1 mm due to the tunnel ling defects which may affect the strength of the material. Dimensions of tensile specimen are shown in figure 3



S.No	Material Thickness, mm	SIZE, mm						
		t	W	Lc (min)	GE (min)	B	R	Lt (min)
1	1 to 3	t*	12.6 ±0.10	60	50	20	10	180
2	1 to 3	t*	20 ±0.10	100	50	30	15	220

Fig 2 Dimensions of tensile specimen

Fig 3 Typical tested tensile specimen

Tensile strength = (Tensile force/original area)……………………..

For Run No A,

Ts = (90390/49.25) = 1835.53 Mpa

Table 4: Tensile strength values for various heat input

S.NO	Exp.no	Tensile strength (Mpa)	Original Area (mm^2)	Tensile force (N)
1	A	1835.53	49.25	90390
2	B	2019.09	49.25	99440
3	C	2097.64	47.52	99680
4	D	1880.57	52.92	99519
5	E	1872.53	53.19	99600

5 EVALUATION OF MICROSTRUCTURE:

5.1 Specimen preparation:

The specimen of dimension 60mm×10mm×2.5mm cut from welded plate and it is polished using emery sheets of following grit sizes 220, 280, 320, 400, 600, 800, 1000 and 1200. Then the specimens are wet polished using the diamond pastes of particle sizes 10 microns, 4-5 micons and finally with 0.5 microns. For examinig through optical microscopy (OM), the specimens have to be etched using Concentric Keller's Reagent. It is prepared in a beaker using the following compositions of chemicals.

Distilled water - 25 ml
Conc. HCL - 7.5 ml
Conc. HF - 5.0 ml
Conc. HNO3 - 12.5 ml

Then the etching is done by immersing the specimen in the beaker containing concentric keller's reagent for about 15 seconds and then in water and dried. Due to the dissimilar joint, the black shade has been produced on the retreating side (AA2014). Since the black shades has obtained, the Ordinary Keller's Reagent has been chosen. It was prepared by using the following compositions of chemicals.

Distilled water - 95 ml
Conc. HCL - 1.5 ml
Conc. HF - 1 ml
Conc. HNO3 - 2.5 ml

Then the etching is done by immersing the specimen in the beaker containing ordinary keller's reagent for about 15 seconds and then in water and dried. This reagent also producing the black shades. Now the metal immersed in reagent is reduced from 15 to 10 and 10 to 5, till now (fig 3.1) it couldn't able to overcome the black shades on the retreating side (AA2014). Fig 3 Typical over etched specimen. So, the Tucker's Reagent has been chosen. It is prepared in a beaker using the following compositions of chemicals.

Distilled water - 25 ml
Conc. HCL - 45 ml
Conc. HF -15 ml
Conc. HNO3 -10 ml

Then the etching is done by immersing the specimen in the beaker containing tucker's reagent for about 2 seconds and then in water and dried.

Compare with the above 2 reagents it's ………… Good (fig 3), finally this reagent has been chosen. (9,10)

6 ROCKWELL TEST

6.1 Hardness Testing Considerations

The following sample characteristics should be consider prior to selecting the hardness testing method to use

- Sample Size
- Cylindrical Samples
- Sample Thickness
- Scales
- Gage R&R

6.2 Sample Size

The smaller the part, the lighter the load required to produce the required indentation. On small parts, it is particularly important to be sure to meet minimum thickness requirements and properly space indentations away from inside and outside edges. Larger parts need to be fixtured properly to ensure secure placement during the test process without the chance for movement or slippage. Parts that either overhang the anvil or are not easily supported on the anvil should be clamped into place or properly supported.

6.3 Cylindrical Samples

A correction to a test result is needed when testing on cylinder shapes with small diameters due to a difference between axial and radial material flow. Roundness correction factors are added to your testing result based on the diameter of convex cylinder surfaces. Additionally, it is important to maintain a minimum spacing equal to 2~1/2 times the indentation's diameter from an edge or another indentation.

6.4 Sample Thickness

sample should have a minimal thickness that is at least 10x (ten times)the indentation depth that is expected to be attained. There are minimum, allowable thickness recommendations for regular and superficial Rockwell methods

6.5 Scales

Sometimes it is necessary to test in one scale and report in another scale. conversions have been established that have some validity, but it is important to note that unless an actual correlation has been completed by testing in different scales, established conversions may or may not provide reliable information. (Refer to ASTM scale conversion charts for non-austenitic metals in the high hardness range and low hardness range). Also refer to ASTM standard E140 for more scale conversion-information. (11)

6.6 Gage-R&R

Gage Repeatability and Reproducibility Studies were developed to calculate the ability of operators and their instruments to test accordingly within the tolerances of a given test piece. In hardness testing, there are inherent variables that preclude using standard Gage R&R procedures and formulas with actual test pieces. Material variation and the inability to retest the same area on depth measuring testers are two significant factors that affect GR&R results. In order to minimize these effects, it is best to do the study on highly consistent test blocks in order to minimize these built in-variations. New age Testing Instruments hardness testers operate are ideally suited for these studies. Unfortunately, since these studies can only be effectively done on test blocks, their value does not necessarily translate into actual testing operations. There are a host of factors that can be introduced when testing under real conditions. Some New age testers excel at testing in real-world conditions by reducing the effects of vibration, operator influence, part deflection due to dirt, scale, a specimen flexing under load.(12,13)

Table 5: Microhardness value

Sample no	**Microhardness**								
	Distance from the center of the welding zone								
	-2	**-1.5**	**-1**	**-0.5**	**0**	**0.5**	**1**	**1.5**	**2**
A	**185**	**144**	**140**	**135**	**126**	**128**	**133**	**140**	**149**
B	**189**	**140**	**135**	**129**	**125**	**127**	**132**	**141**	**155**
C	**220**	**142**	**135**	**130**	**123**	**125**	**129**	**138**	**196**
D	**182**	**141**	**136**	**131**	**122**	**125**	**130**	**139**	**150**
E	**215**	**142**	**139**	**137**	**134**	**138**	**140**	**144**	**182**
F	**298**	**143**	**138**	**135**	**129**	**133**	**136**	**142**	**181**

7 RESULT AND DISCUSSION

Welding width for all the samples were measured and calculated average welding width as shown in table 4. Average value of welding width then plotted against the applied welding current for different welding speed as shown in Fig. 4. From the plot it is clearly seen that weldin width increases almost linearly with increase of welding current. the welded butt joint specimen, where welding performed with different welding speed and current setting as described in table 3.

Fig. 4–welded specimen performed with (a) welding speed 3.5 mm/s and welding current 100, 110, 120, 130 and 140 A for sample no 1, 2,3,4,5 respectively (b) welding speed 4 mm/s and welding current 100, 110, 120, 130 and 140 A for sample no 6,7,8,9,10 respectively

7.1 MICRO-HARDNESS TEST:

Micro-hardness value of the welded zone was measured for all the welded specimens at the cross section to understand the change in mechanical property of the welded zone. Fig. 8 and 9 shows the micro-hardness value at the welded zone taken from the centre of the welding zone towards the base material for different samples performed with different welding speed and welding current. From the graph it is found that for almost all the sample micro hardness value increases in the welding zone than the base material and these values are in the range of 40 to 80 HV in the welded zone. After a certain distance these value reduces to the hardness of the base material for the sample processed with welding speed 1.5 mm/s and different current setting. However for the welding done with welding speed 4 mm/s and different current setting micro-hardness value reaches to the micro-hardness value of base material after 5 to 6 mm.(14,15)

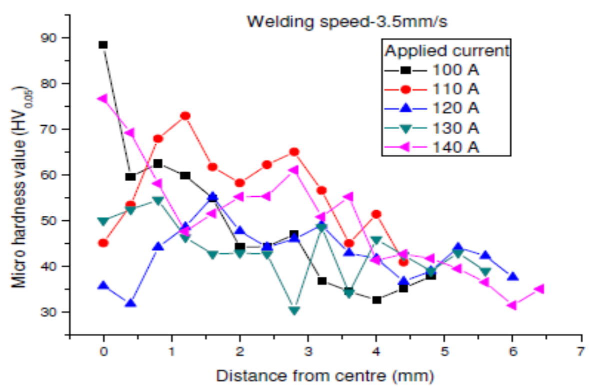


Fig. 6 Micro-hardness value from the centre of the weld zone towards the base material for welding done with welding speed 1.5 mm/s and different welding current in pulsed TIG

TENSILE TEST:

Tensile test of the welded joint was performed with universal tensile testing

tensile strength of the welded joints are plotted against applied current for welding speed of 1.5 mm/s. From the it is also found that tensile strength value almost increasing for increasing current setting when welding speed is 1.5 mm/s (except for welding current form 70 A to 90A)(16,17)

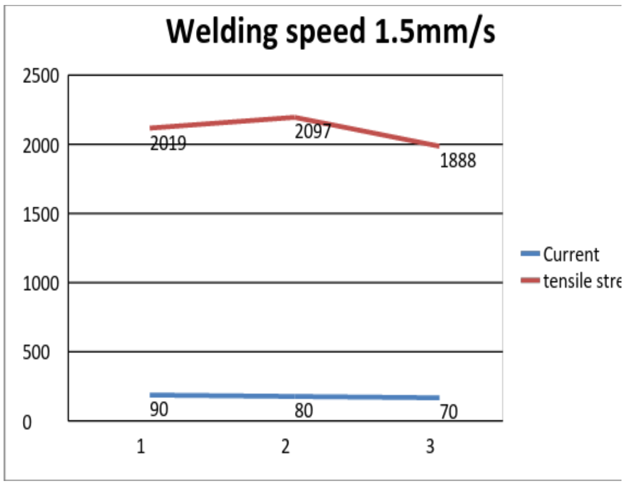


Fig. 7 Tensile strength of the welded joint against applied current for welding speed of 1.5 mm/s

8 CONCLUSION

From the experiment of TIG welding of dissimilar plate following conclusion can be made

machine (FUT40) with maximum load capacity 400 kN 1 mm/min. Table 6 shows the tensile strength value for all the welded joints produced at different welding speed and current setting. Tensile strength of the as received steel HRC and CRC has been found a310 and 450 respectively.

- With the TIG welding system uniform welding of Aluminum plate can be possible.
- Welding strength or tensile strength of the weld joint depends on the welding parameters like welding speed and welding current.
- With the increase in current, tensile strength of the weld joint increases.
- Hardness value of the weld zone change with the distance from weld center due to change of micro structure.
- At lower welding speeds strength is more due to more intensity of current.

REFRENCES

[1] Kumar, S.(2010) Experimental investigation on pulsed TIG welding of aluminium plate. *Advanced Engineering Technology*.1(2), 200-211

[2] Indira Rani, M., & Marpu, R. N.(2012). Effect of Pulsed Current Tig Welding Parameters on Mechanical Properties of J-Joint Strength of Aa6351. The International Journal of Engineering And Science (IJES),1(1), 1-5.

[3] Hussain, A. K., Lateef, A., Javed, M., & Pramesh, T. (2010). Influence of Welding Speed on Tensile Strength of Welded Joint in TIG Welding Process. *International Journal of Applied Engineering Research, Dindigul*, *1*(3), 518-527.

[4] Tseng, K. H., & Hsu, C. Y. (2011). Performance of activated TIG process in austenitic stainless steel welds. *Journal of Materials Processing Technology*, *211*(3), 503-512.

[5] Narang, H. K., Singh, U. P., Mahapatra, M. M., & Jha, P. K. (2011). Prediction of the weld pool geometry of TIG arc welding by using fuzzy logic controller. *International Journal of Engineering, Science and Technology*, *3*(9), 77-85.

[6] Karunakaran, N. (2012). Effect of Pulsed Current on Temperature Distribution, Weld Bead Profiles and Characteristics of GTA Welded Stainless Steel Joints. *International Journal of Engineering and Technology*, *2*(12).

[7] Raveendra, A., & Kumar, B. R.(2013). Experimental study on Pulsed and Non-Pulsed Current TIG Welding of Stainless Steel sheet (SS304*). International Journal of Innovative Research in Science, Engineering and Technology*, 2(6)

[8] Sakthivel, T., Vasudevan, M., Laha, K., Parameswaran, P., Chandravathi, K. S., Mathew, M. D., & Bhaduri, A. K. (2011). Comparison of creep rupture behaviour of type 316L (N) austenitic stainless steel joints welded by TIG and activated TIG welding processes. *Materials Science and Engineering: A*, *528*(22), 6971-6980.35

[9] Yuri,T., Ogata, T.,Saito.M.,& Hirayama,Y.(2000). Effect of welding structure and δ- ferrite on fatigue properties for TIG welded austenitic stainless steels at cryogenic temperatures. *Cryogenics*, 40, 251-259

[10] Norman, A. F., Drazhner, V., & Prangnell, P. B. (1999). Effect of welding parameters on the solidification microstructure of autogenous TIG welds in an Al–Cu–Mg–Mn alloy. *Materials Science and Engineering: A*, *259*(1), 53-64.

[11] Song, J. L., Lin, S. B., Yang, C. L., & Fan, C. L. (2009). Effects of Si additions on intermetallic compound layer of aluminum–steel TIG welding–brazing joint.

Journal of Alloys and Compounds, *488*(1), 217-222.

[12] Wang, Q., Sun, D. L., Na, Y., Zhou, Y., Han, X. L., & Wang, J. (2011). Effects of TIG Welding Parameters on Morphology and Mechanical Properties of Welded Joint of Ni-base Superalloy. *Procedia Engineering*, *10*, 37-41.

[13] Kumar, A., & Sundarrajan, S. (2009). Optimization of pulsed TIG welding process parameters on mechanical properties of AA 5456 Aluminum alloy weldments. *Materials & Design*, *30*(4), 1288-1297.

[14] Preston, R. V., Shercliff, H. R., Withers, P. J., & Smith, S. (2004). Physicallybased constitutive modelling of residual stress development in welding of aluminium alloy 2024. *Acta Materialia*, *52*(17), 4973-4983.

[15] Akbari Mousavi, S. A. A., & Miresmaeili, R. (2008). Experimental and numerical analyses of residual stress distributions in TIG welding process for 304L stainless steel. *journal of materials processing technology*, *208*(1), 383-394.

[16] Durgutlu, A. (2004). Experimental investigation of the effect of hydrogen in argon as a shielding gas on TIG welding of austenitic stainless steel. *Materials & design*, *25*(1), 19-23.

[17] Rui, W., Zhenxin, L., & Jianxun, Z. (2008). Experimental Investigation on Out-of-Plane Distortion of Aluminum Alloy 5A12 in TIG Welding. *Rare Metal Materials and Engineering*, *37*(7), 1264-1268.

[18] Li, D., Lu, S., Dong, W., Li, D., & Li, Y. (2012). Study of the law between the weld pool shape variations with the welding parameters under two TIG processes. *Journal of Materials Processing Technology*, *212*(1), 128-136.

[19] Lu, S. P., Qin, M. P., & Dong, W. C. (2013). Highly efficient TIG welding of Cr13Ni5Mo martensitic stainless steel. *Journal of Materials Processing Technology*, *213*(2), 229-237.

[20] Urena, A., Escalera, M. D., & Gil, L. (2000). Influence of interface reactions on fracture mechanisms in TIG arc-welded aluminium matrix composites. *Composites Science and Technology*, *60*(4), 613-622.