THE EFFECT OF FILLER ON WELD METAL STRUCTURE OF AA6061 ALUMINUM ALLOY BY TUNGSTEN INERT GAS (TIG)

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ABSTRACT

Innovative welding technology for joining Aluminum alloys in automobile, aviation, aerospace and marine industries would achieve weight reduction, high specific strength as well as increase the fuel efficiency and reduce the environmental pollution. This research introduced appropriate welding filler selecting to joint similar AA6061 aluminum alloys by Tungsten Inert Gas (TIG) process. TIG welding of AA6061 was butt joined with three different filler which are ER5356 (4.5-6% Mg), ER4043 (4.5-6% Si) and ER4047 (11-13% Si). The experiments are conducted in order to investigate the macrostructure and microstructure of the samples as well as mechanical properties. The effect of preheating was also investigated. The effect of different filler used on weld joint was analyzed by its visual appearance, microstructures, hardness and strength. It was found that, welding using filler ER5356 produced finer grain size at fusion zone is 25.69 µm compared to filler ER4043 and ER4047 with the grain size of 52.75 µm and 76.78 µm, respectively. ER5356 specimen also shows highest hardness value which is 72.9HV compared to ER4043 and ER4047 counterpart, which is 59.3HV and 57.6HV, respectively. As for tensile test result, the weld joints using filler ER5356 has highest strength which is 171.53 MPa compared to weld joints using ER4043 and ER4047 filler with value 167.34 MPa and 168.03 MPa, respectively. It can be concluded that TIG welding using ER5356 filler yields better joint compared to ER4043 and ER4047.

Keywords: AA6061, GTAW, ER5356, ER4043, ER4047, Response Surface Method,

INTRODUCTION

Aluminum alloys is silverish white metal that has strong resistance to corrosion. Compared to other materials like steel, brass or nickel, this material is lighter. Aluminum alloys are currently employed in various sectors because of their higher quality of characteristic like low specific gravity, corrosion resistance and recyclability (Mosneaga et al. 2002). Nowadays, their application is still expanding mostly in automobile and aerospace industries (Karunakaran, 2013). The main application of aluminum products were in transportation (27%), construction (20%), packaging (16%), electricity supply (10%), machinery and equipment (8%) and also in sectors in addition to sustainable products (7%) were predicted an extraordinary growth reaching 60 million tons by 2020 (Fortain and Gadrey, 2013).

The alluminium alloys from family of 6000 series was the most been considered for substantial used in industries. This ensues from its appropriate weldability and high corrosion behavior (Fahimpour et al. 2012). Especially, the most commonly used material in this family such as 6061 which are the main alloying elements is Silicon (Si). Due to this behavior in AA6061, finds wide usage in welded structural members such as truck and marine frames, railroad cars and pipelines (Balakrishna and Rao, 2012;Luijendijk, 2000).

In order to fulfill these demand in industries, the fabrication of structural bodies involve, in most instances, the application of a joining process, which is, combining one part with another. The most popular joining process involve is by (Mosneaga et al., 2002). The preferred welding process for this alloys are frequently Gas Tungsten Arc Welding (GTAW) or also known as Tungsten Inert Gas (TIG). Undeniably, this type of welding is most popular due to its simplicity, versatility, rapidness and easiness of the training (Sevim et al. 2012;Zakaria et al. 2013)

However, welding of this alloy still remains a challenge. Usually, welded Al-Mg-Si alloys have some problems such as low fracture toughness in the heat-affected zone (HAZ) near a weldment due to liquation cracking (Mosneaga et al., 2002). The existence of liquation crack has a negative effect on the mechanical properties. Other difficulties on the joint such as presence of oxide layer, high solubility of hydrogen and other gas in molten state, and solidification shrinkage can occur during welding process (Lakshminarayanan et al. 2007;Mutombo & Toit, 2011). The deterioration in its mechanical properties is due to the heat applied during welding process

From previous study the problems that occur during joint alloy 6061 by MIG welding is clear can be encountered by choosing a right filler. As stated by (Mosneaga et al., 2002), by using filler with addition of small amount of Mn is effective to suppress recrystallization, which leads the drastic decrease in fracture toughness by liquation crack.

Therefore, the selection of filler metal is one of the most important aspects that need to be considered in TIG welding. In this study, the effect of (Si-Rich) and (Mg-Rich) filler which is ER5356 (Mg-Rich), ER4043 (Si-Rich) and ER4047 (Si-Rich) on mechanical properties of welding joints is investigated. Moreover, the microstructure changes also were identified.

EXPERIMENTAL DETAILS

Materials

In this investigation, the materials used were Al-Si-Mg aluminum alloys, namely AA6061. The materials' thickness is 2 mm and the compositions of materials and filler metals used as shown in Table 1.

Table 1: Compositions of materials and filler metals

	Al	Si	Fe	Cu	Mn	Mg	Zn
AA6061	97.3	0.890	0.33	0.29	0.025	0.86	0.007
ER5356	Bal	0.25	0.4	-	-	5.5	0.10
ER4043	Bal	6.0	0.8	-	-	0.05	0.10
ER4047	Bal	13.0	0.8	-	-	0.10	0.10

Experimental Design

The aluminum alloy of 6061 was cut in rectangle shape with dimension of 150 mm ×150mm by using the MVS-C 6/31 shearing machine. After the cutting process, aluminum 6061 was butt joined to similar base material by using the TIG Syncrowave200 Model Miller welding machine and the process was carried out by AC-TIG welding sources with the several parameters which is welding current and temperature of preheating. The current involved were 60 A and 70 A and preheating temperature is 80ºC and 120ºC as shown in Table 2. The tensile strength of welded specimen can be improved by increase the preheating temperature. [6] After that, the specimens were cut into 10 mm as shown in Figure 1. The specimens were then hot mounted, grinded and polished. The specimens were etched by Keller Reagent for microstructural observation. The hardness of weld was measured by Matsuzawa MMT-X7 Vickers hardness test.

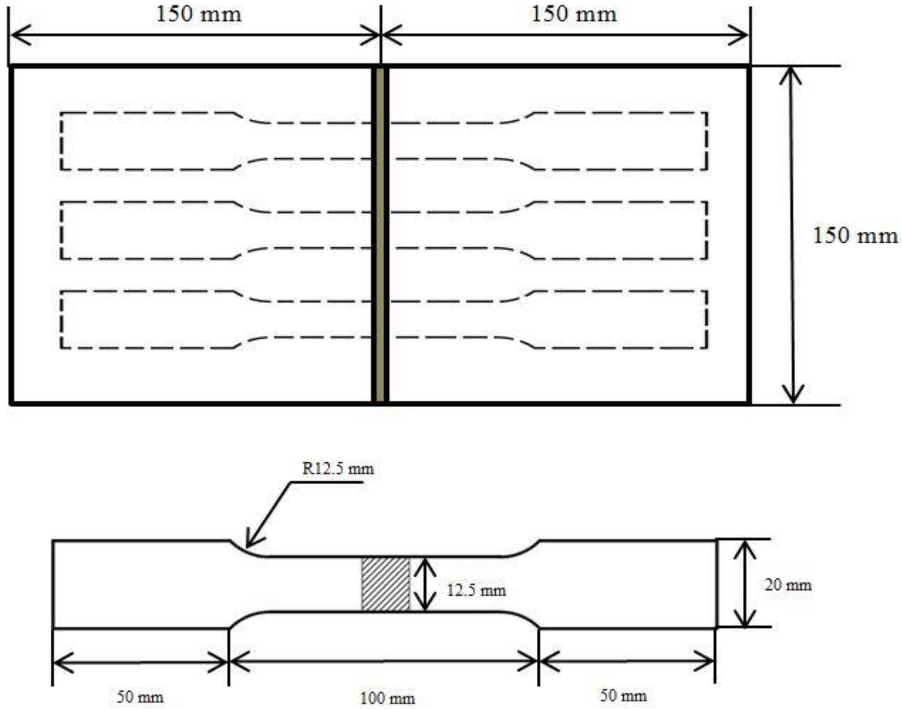


Figure 1: Schematic illustration butt joint welding setup and design for tensile test

RESULTS AND DISCUSSION

Macrostructures

The macrostructures of weld cross sectional area AA6061 is obtained by using optical microscope. Twelve (12) specimens are observed. The specimens welded using ER5356, ER4043 and ER4047 is shown in Figure 2, Figure 3 and Figure 4, respectively. In these specimens, defect such as lack of fusion and distortion is observed. However, among these twelve specimens, three specimens are selected to analyze their microstructures, namely specimen's no3, no8 and no10 as shown in Figure 2(3), Figure 3(8) and Figure 4(10). These specimens are selected due to less defects and high tensile value among their respective group. The result of tensile test for all specimens is shown in Table 2.

The high tensile value on filler ER5356 is specimen's no3 at 70A and 80°C preheat with heat input given is 812.90 J. While, on filler ER4043, specimen's no8 produced highest tensile strength value by using parameter of 70A and 120°C preheat with heat input applied is 482.05 J. Filler ER4047, specimen's no10 produced highest tensile strength value at 60A and 120°C preheat with heat input applied at 593.18 J.

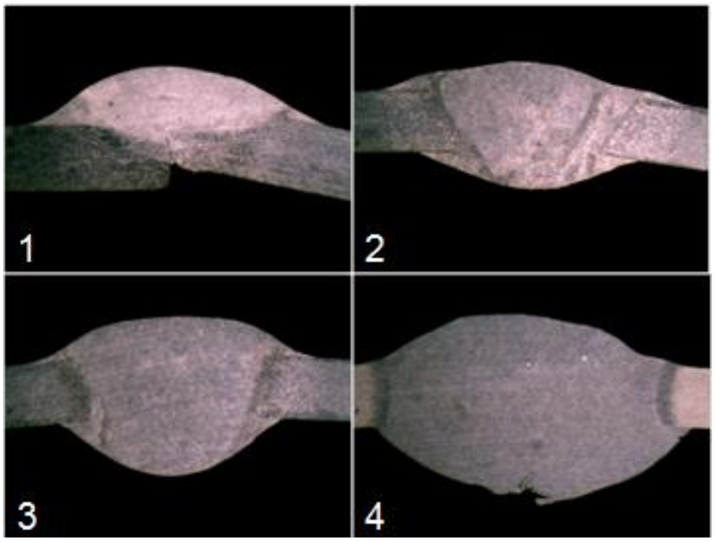


Figure 2: Cross section of welding samples with respective numbering by using filler ER5356

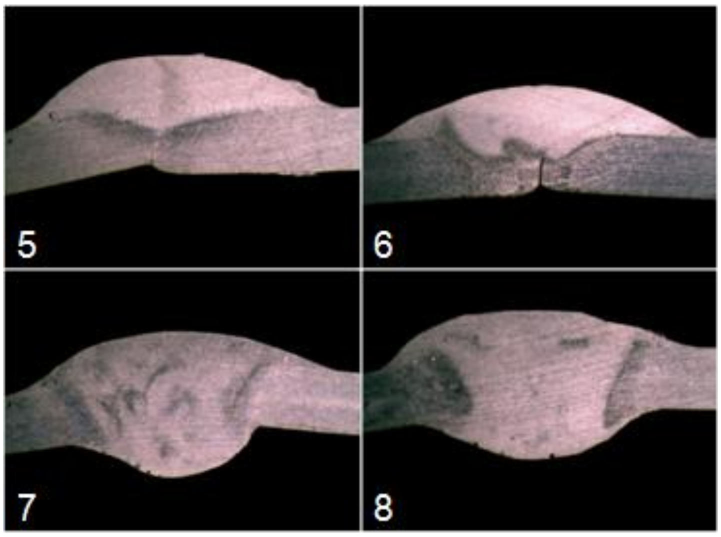


Figure 3: Cross section of welding samples with respective numbering by using filler ER4043

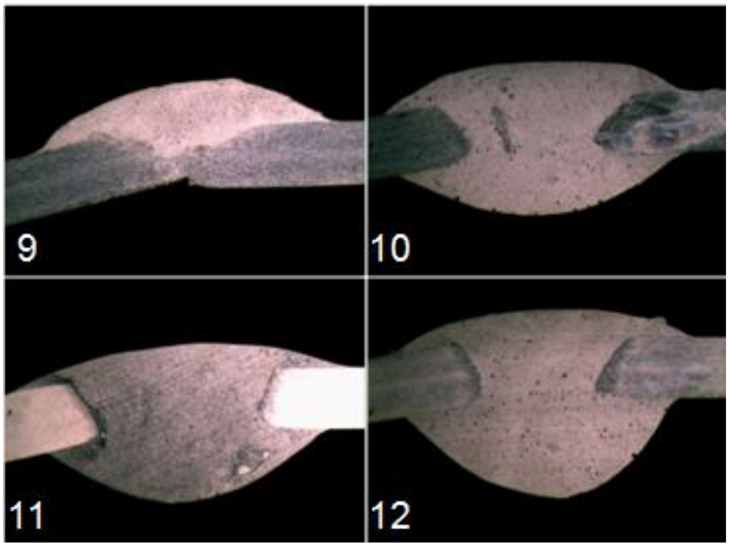


Figure 4: Cross section of welding samples with respective numbering by using filler ER4047

Table 2: The welding parameters of welding aluminum alloys

Parameters						
No	Current (A)	Preheat (ºC)	Voltage (V)	Time Taken (L=150mm)	Heat Input (J)	Tensile Test (MPa)
ER5356						
1	60	80	17.1	2 min 46 sec	1140.0	83.75
2	60	120	17.4	1 min 53 sec	784.96	165.51
3	70	80	18.0	1 min 37 sec	812.90	171.53
4	70	120	18.4	1 min 10 sec	601.87	162.04
ER4043						
5	60	80	17.4	1 min 53 sec	784.96	47.68
6	60	120	17.4	1 min 3 sec	438.66	48.92
7	70	80	18.3	1 min 17 sec	656.92	166.80
8	70	120	18.8	55 sec	482.05	167.34
ER4047						
9	60	80	17.4	2 min 2 sec	848.78	25.86
10	60	120	17.4	1 min 25 sec	593.18	168.03
11	70	80	18.3	1 min 3 sec	538.24	166.49
12	70	120	18.8	53 sec	465.02	166.19

Microstructures

The cross section and microstructures of the specimen's no 3, 8 and 10 are shown in Figure 5, Figure 6 and Figure 7, respectively. The microstructures have been labeled with the type of several formations of boundaries such as fusion zone (FZ), heat affected zone (HAZ), partially melted zone (PMZ) and base metal (BM). The grain size observed at FZ is 25.69 μm welds with ER5356. While, welds with filler ER4043 and ER4047 yields the results grain size of 52.75 μm and 76.78 μm, respectively.

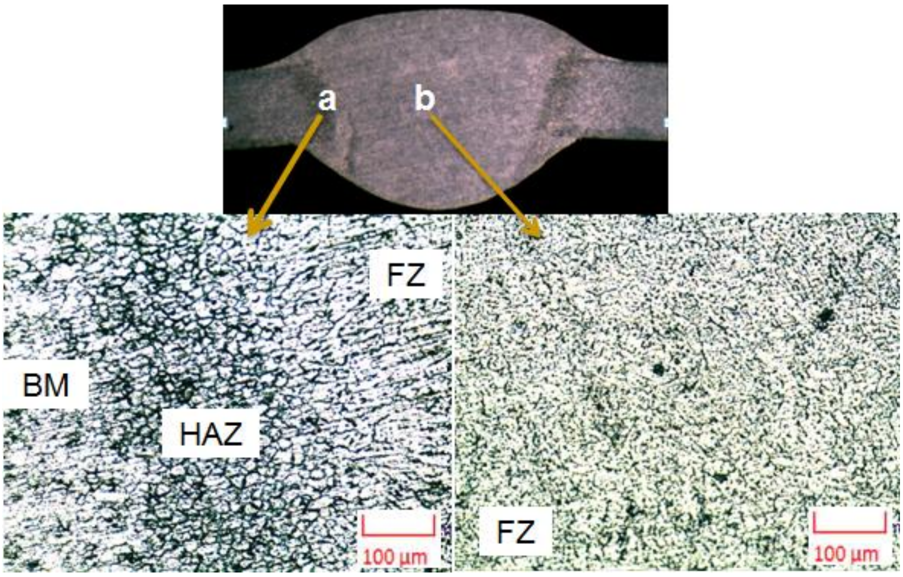


Figure 5: Weld microstructure using filler ER5356

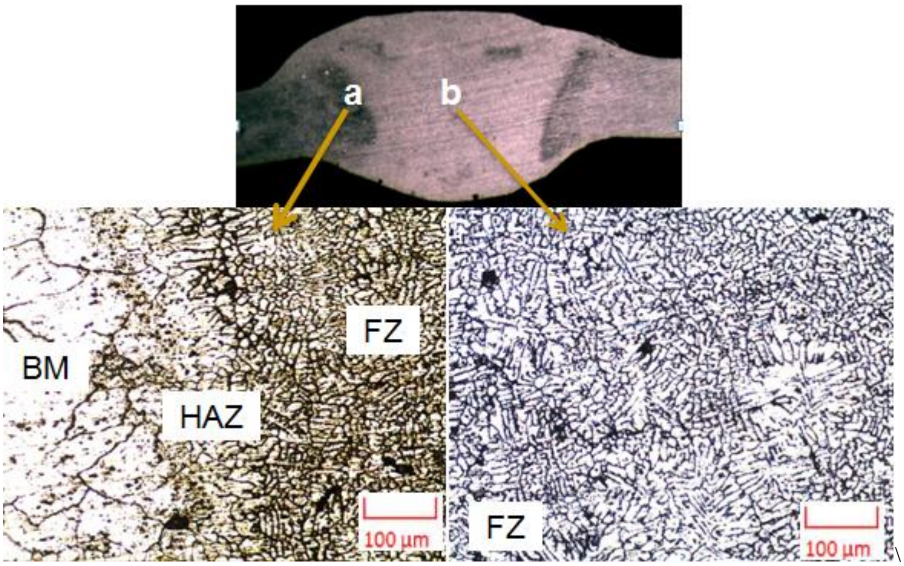


Figure 6: Weld microstructure using filler ER4043

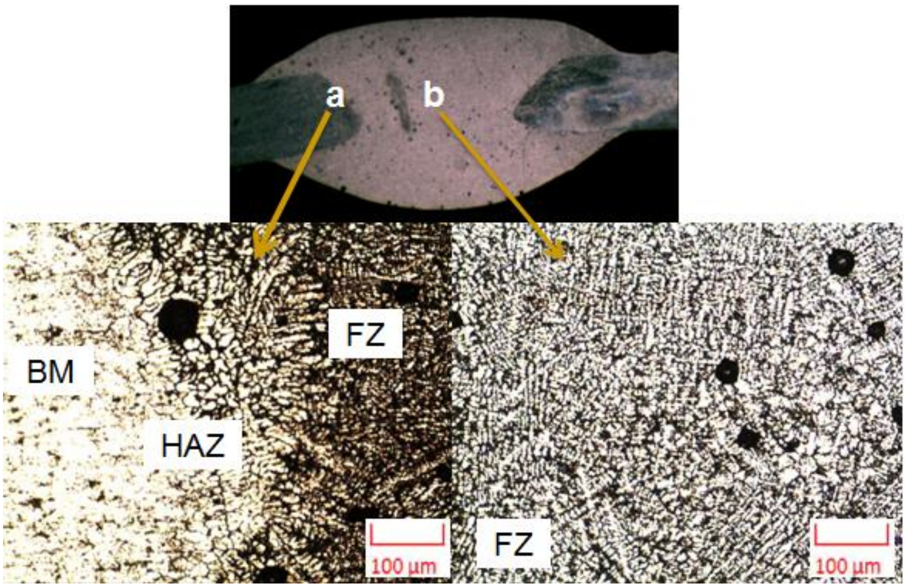


Figure 7: Weld microstructure using filler ER4047

Hardness Test

The hardness value across the weld cross section is illustrated using a Vickers Hardness testing machine and the results are plotted as shown in Figure 8, Figure 9 and Figure 10. These figures show the graph of hardness profile of all three selected samples at different section which is BM, HAZ and FZ. At FZ, the highest average hardness value was obtained which is 67.07 HV by using ER5356 filler at 70A current and 120°C preheating temperature. The average hardness value at FZ for another two samples by using filler ER4043 and ER4047 which is 60.05 HV and 56.9 HV, respectively.

On the other hand, at HAZ section shows reduction value compare at FZ for all samples by using filler ER5356, ER4043 and ER4047 with the average hardness value obtained 61.9 HV, 59.08 HV and 55.25 HV, respectively. This reduction can be explained due to the changing of grain structure during the welding process.

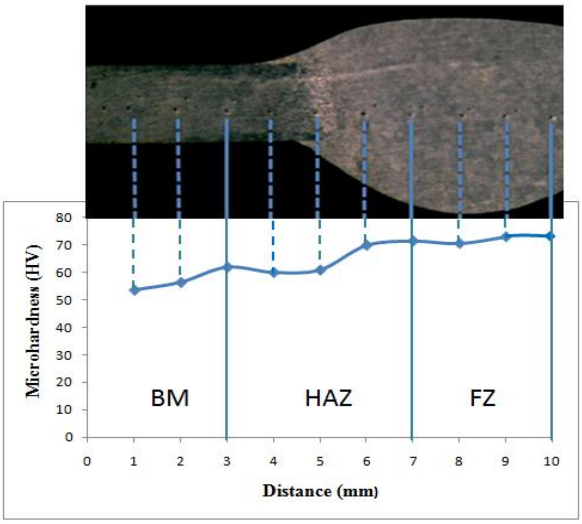


Figure 8: Hardness value of weld joint AA6061-AA6061 using filler ER5356

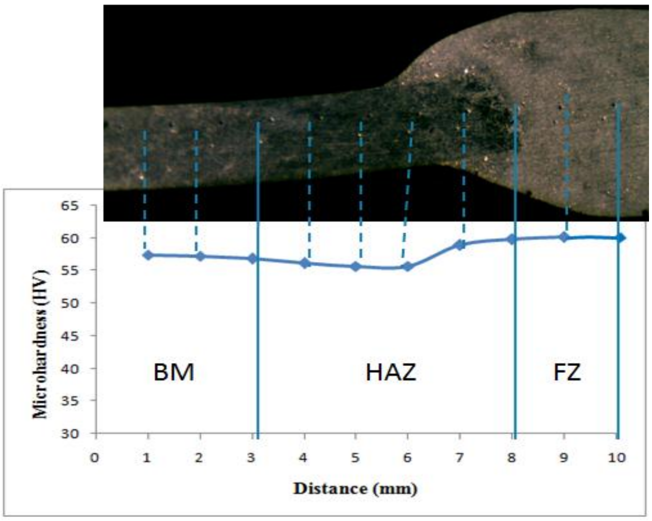


Figure 9: Hardness value of weld joint AA6061-AA6061 using filler ER4043

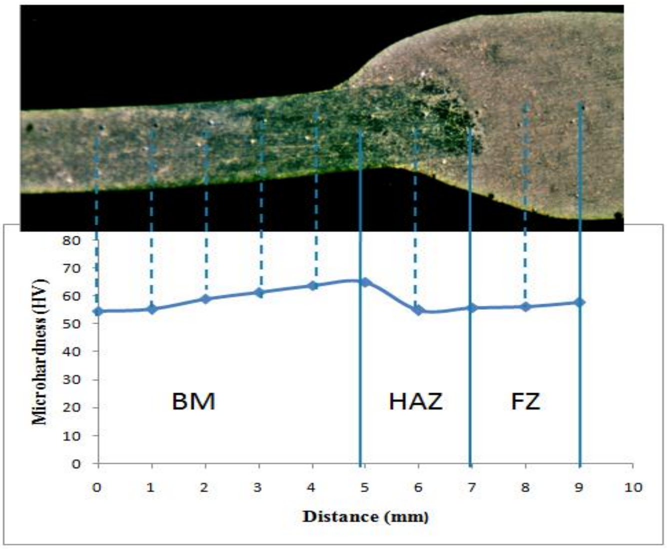


Figure 10: Hardness value of weld joint AA6061-AA6061 using filler ER4047

Tensile Test

Figure 11 illustrates the tensile test by using the three different filler metals. The load given to perform this process is 50 kN and crosshead speed to pull the specimens is 1 min/mm. The tensile strength values increase up for all three specimens to a certain point. The strength of joining by using ER5356 yields the highest value which is 171.53 MPa compared to joining using filler ER4043 and ER5356 which yields 167.34 MPa and 168.03 MPa, respectively.

While, for Figure 12(a) and Figure 12(b) shows the effect of average tensile stress in preheat conditions. For Figure 12(a), the graph obtained by using current at 60A and Figure 12(b) shows the graph at current 70A. All specimens are given a preheating at temperature of 80ºC to 120ºC. Preheat is a process of heating or increase the temperature at the facing surface before welding was performed.

The tensile stress results were improved as the preheating temperatures were increased. However, the results of joining strength are stronger at current of 60A compared to joining at current of 70A.

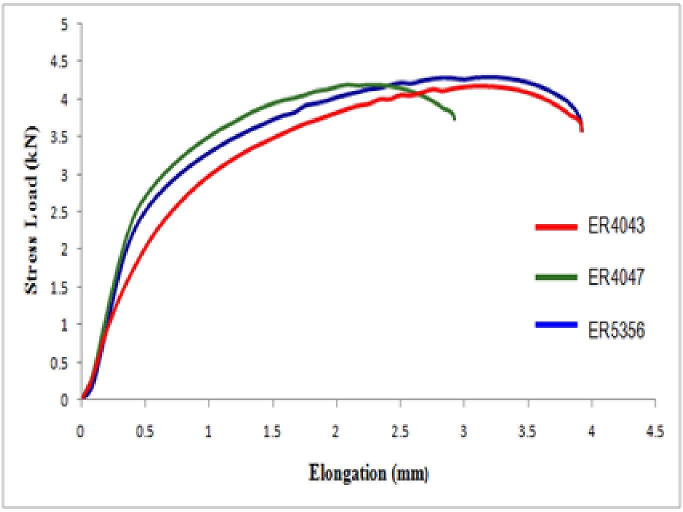
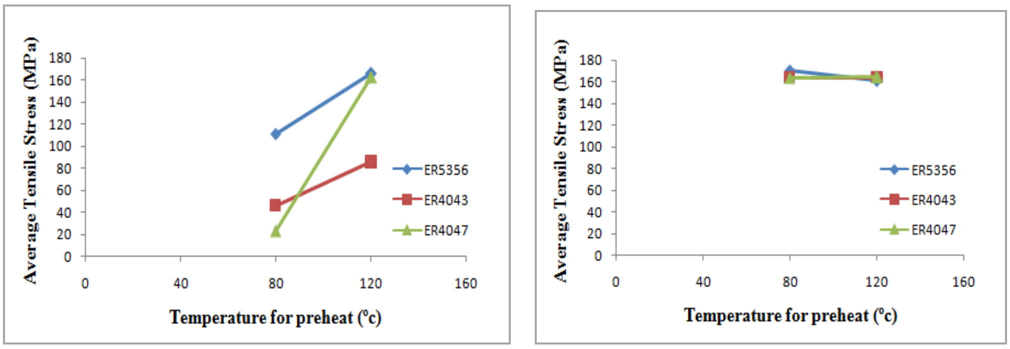


Figure 11: The tensile test graph of different filler metals used.



(a) (b)

Figure 12: The graph of preheat effect on tensile test (a) at current 60A (b) at current 70A

CONCLUSION

In this paper, the effects of different filler wire used on TIG process were investigated. Based on the present investigation, the following conclusion can be drawn. Firstly, it was found that, welding using filler ER5356 produced finer grain size at fusion zone is 25.69 µm compared to filler ER4043 and ER4047 with the grain size of 52.75 µm and 76.78 µm, respectively. By using filler ER5356 also shows highest hardness value which is 72.9HV compared to ER4043 and ER4047 counterpart, which is 59.3HV and 57.6HV, respectively. As for tensile test result, the weld joints using filler ER5356 has highest strength which is 171.53 MPa compared to weld joints using ER4043 and ER4047 filler with value 167.34 MPa and 168.03 MPa, respectively. It can be concluded that TIG welding using ER5356 filler yields better joint compared to ER4043 and ER4047.

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