Effect of PWHT Variables on Microstructure and Mechanical Properties of the Al-Zn Weld Metal

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Abstract

In this investigation the microstructure and mechanical properties of Al-Zn (Al 7075) MIG weld metal were studied in respect to T5 post weld heat treatment variables. Samples were cut from butt weld which were produced by automatic MIG welding with the same heat treatment in different times (10 to 480 minute) and temperatures (85 to 225 $^{\circ}C$). The mechanical test results showed that the optimum mechanical properties (as: tensile and yield strength, impact energy and hardness) gained in 155 $^{\circ}C$ and 120 minute. XRD, Optical metallographic and EDX point analysis results of the sample with best mechanical properties (155℃ - 120min) showed that the microstructure consists of fine grain above 15 µm diameter with 15% precipitate, in addition the precipitates were distributed at the grains and grains boundary, at the grains boundary $Al_2Mg_3Zn_3$ and in the grains $CuAl_2$ were precipitated.

Keywords: PWHT, Al-Zn, Weld Metal

1. Introduction

Automatic MIG welding is an important developed joining technique in any industry owing its benefits in terms of reducing the processing costs [1]. Al-Zn alloys (7000 series) have good combination of strength and hardness and applicable in marine and aerospace industry [2]. These series of aluminum alloys are heat treatable, with precipitation hardening mechanism increases the strength of this alloys [3]. MIG welding of 7075 (Al-Zn) alloy has been investigated from the point of weldability of this alloy which consists of [3]: a. Susceptibility of solidification cracks (SSC) b. Softening of HAZ by coarsening of precipitates (SHAZ) c. Decrease of mechanical properties of weld metal; For control of these items necessary to observe as[4]: a. Proper choice of filler metal b. Post weld heat treatment (PWHT) c. Reduction of heat input d. Reduction of dilution with base metal. Investigations [5] showed that ER 5356 (Al-Mg) if used as filler metal with automatic pulse MIG welding of 7075 alloy, decreases the SSC and SHAZ and to control the mechanical properties of weld metal selection of proper variable of PWHT is important. In Al-Zn alloys the mechanical properties of weld metal is directly to chemical composition size, distribution) and matrix (size, shape of grain) [5], the chemical composition of weld metal consists of filler metal composition and dilution, with base metal or previous run, by using of ER 5356 filler metal with automatic pulse MIG, the chemical composition almost has been constant in one pass butt welding, therefore PWTH significant process for improved Mechanical properties of weld metal in 7075 alloy [6]. PWHT of the 7075 alloy affected on mechanical properties by control of (microstructures) grain size- and amount of volume fraction precipitates [7].

2. Materials and Methods

The 7075-O alloy was used for this investigation as base metal. Plates with 4×100×200 mm dimensions were prepared. After cleaning, butt joint were fixed in fixture and prepare for automatic MIG welding with ER 5356 filler metal. The welding parameters are given in Table. 1.

Table. 1. Welding parameters in this investigation.

Process	Automatic MIG
Joint design	Butt weld (I)
Number of pass welding	1
Filler Metal	ER 5356
Polarity	DCEP
Current	140A
Voltage	23V
Wire diameter	1.2mn
Shielding gas	Pure argon
Gas flow	14lit/min
Welding speed	0.38m/min
Wire feeder speed	4.5 m/min

After welding cut weld metal and T5 PWHT was carried out in different conditions, Table. 2. denote the post weld heat treatment conditions and codes.

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Table. 2. PWHT (T5) Condition and code of samples.

Temp(C) \ Time (min)	10	45	90	120	240	480
85	No 1	No2	No3	No4	No5	No6
155	No 7	No8	No9	No10	No11	No12
225	No 13	No14	No15	No16	No17	No18

The tensile and impact test samples were prepared according to AWS B.4 and testing of instron 1114 and charpy machine, the metallography sample has been prepared by Spark machining and studied by optical microscope (Olympus- CK 40M) and the Vickers micro hardness (HVS 1000) have been used, the EDX point analysis (SEM model VEGA TESCAN) used for determining the chemical analysis of solid particles in weld metal, the OES (Master Foundry QS22) used for analysis of weld metal, in addition The XRD (Philips 332) used for determining of the phases type on weld metal.

3. Results and Discussion

Table. 3. given the chemical analysis of the weld metal and Table. 4. denotes the mechanical test results of various PWHT samples.

Table. 4. presents that by increasing the time of PWTH in constant aging temperature a. the T.S, Y.S, HV increased and then decreased, b. α_K , $\%\varepsilon$ firstly decreased and then increased. Similar behavior had been obtained with the increase in ageing temperature in constant time.

Table. 3. Chemical analysis (wt. %) of weld metal.

Element	Weld metal
Al	Bal
Ti	0.08
Cr	0.13
Cu	0.82
Si	0.31
Fe	0.33
Mn	0.12
Mg	4.98
Zn	2.12

The reason of this behavior caused change in microstructure [6].

Investigation showed that increasing the time or temperature of aging (T5) heat treatment of Al 7075 made the coalescence of precipitates and decreased the T.S, Y.S and HV [7].

Table. 4. Mechanical properties of various PWTH samples.

No	T.S (Mpa)	Y.S (Mpa)	$\%\varepsilon$	Hv (500)	α_k (J/cm^2)
1	309	211	27.1	69	77.1
2	316	228	25.9	73	74.9
3	339	234	24.6	76	73.6
4	349	247	24.2	80	72.1
5	341	235	25.2	72	74.5
6	333	231	25.2	72	74.5
7	315	219	25.2	73	74.2
8	341	236	23.6	76	72.8
9	359	249	22.1	79	70.6
10	386	281	18.6	85	66.6
11	366	263	20.2	81	69.3
12	335	233	24.3	75	72.6
13	323	221	25.1	75	73.6
14	352	243	21.6	79	70.4
15	377	271	18.9	84	66.9
16	374	269	19.3	82	67.6
17	358	251	22.6	78	71.3
18	318	214	25.9	74	74.7
Base metal	319	220	27.8	68	77.6

Accuracy in data result of mechanical test in Table. 4. showed that optimum values of mechanical properties were obtained in 155º c and 120 minute (Sample No 10). Optical metallographic test result is shown in Fig. 1. This figure shows that sample No10 (155º c -120 min) had been made maximum amount of precipitates and minimum of grain size in microstructure, therefore gained best mechanical properties. These results determined that mechanical properties of weld metal dependence on amount of percentage precipitates and size of grains.

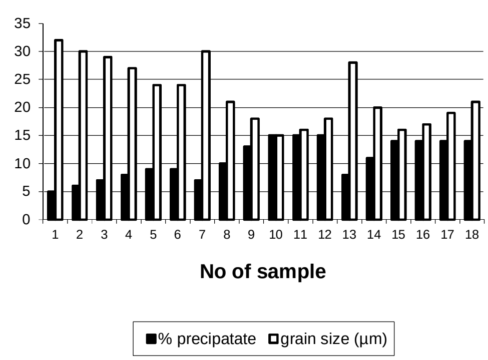

Fig. 1. Percent of precipitates and grains size of various samples.

Fig. 2. shows the XRD result test of sample No 10. This figure shows that phases of this sample contains of $CuAl_2$, $Al_2 Mg_3 Zn_3$ and α (solid solution).

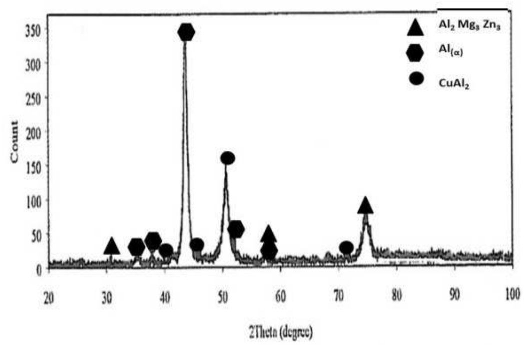

Fig. 2. XRD Result of sample No 1.

Fig. 3. shows the microstructure of sample No10, in this figure two different precipitate can be obtain, the gray precipitate in grain boundaries and black in grains.

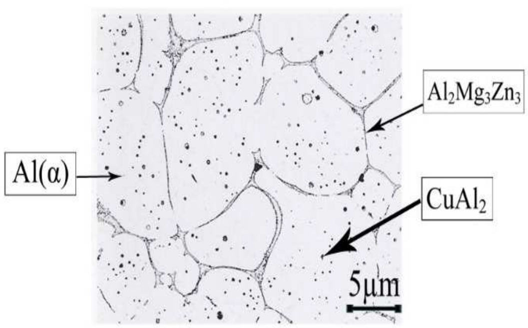

Fig. 3. Microstructure of sample No10- 15 µm grain size with Al_2 Mg_3 Zn_3 precipitate in grain boundaries and $CuAl_2$ in grain- etchant keller's reagent.

The EDX point analysis of these precipitates present in Fig. 4., can be obtained the grain boundary precipitates is $Al_2 Mg_3 Zn_3$ and $CuAl_2$ in grain.

$Al_2 Mg_3 Zn_3$ precipitates, present in grain boundary because Zn and Mg during solidification had positive segregation and gained high concentration of this elements in grain boundaries and produced the micro precipitates, when doing PWHT these micro precipitates coalescence with them and modify in grain boundaries [8-10].

Also $CuAl_2$ precipitate present in grain because of the existence of Zn and Mg in weld metal, changed Cu segregation to negative condition [8], therefore the Cu concentrated at grains and during of PWHT diffused inside $CuAl_2$ micro particles and this precipitates have been growth [9,10].

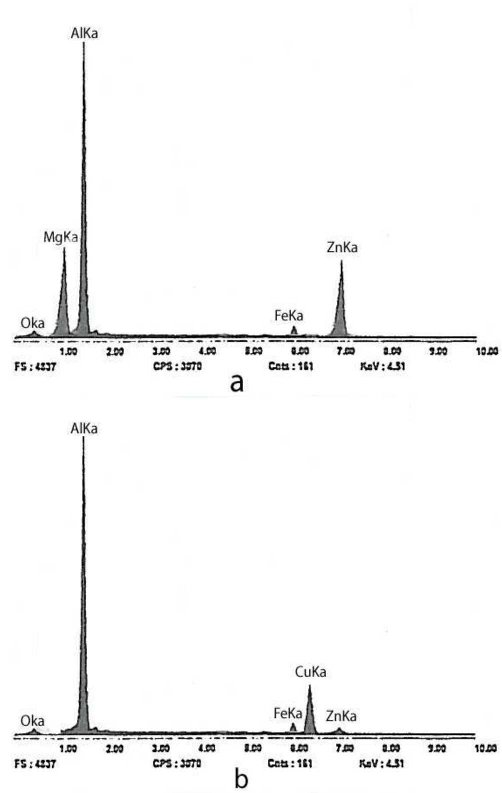

Fig. 4. EDX Point analysis of precipitated sample No 10 a- Al_2 Mg_3 Zn_3 b- $CuAl_2$.

4. Conclusions

Effect of T5 PWHT on the mechanical properties and microstructure of Al7075 O MIG weld has been studied and the results are as follows:

1. With the increase in the time of PWHT in constant temperature the mechanical properties such as tensile strength, yield strength and hardness decreased and impact energy, percentage elongation increased.
2. The optimum mechanical properties were obtained in 155^o c and 120 minute.
3. The microstructure of optimum mechanical properties sample contained of grains fine 15µm with %15 precipitates.
4. The precipitates of optimum sample were $Al_2Mg_3Zn_3$ and $CuAl_2$ at grain boundaries and grains.

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