The Influence of the Nickel Content on Microstructure and Mechanical Properties of the Al-Mg Weld Metal

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Abstract

In this investigation, the microstructure and mechanical properties of the Al 5058 weld metals have been studied in respect of Nickel content in the range of 0.5 to 4.5 percent. Samples were produced by automatic TIG welding process in Butt weld condition with different wire feeder speed rate of pure nickel filler metal. The optical metallography and EDX analysis result shows that by increasing of the nickel content in the weld metal, the grain size decreased and the volume fraction of the inter-metallic compounds of Nickel rich phase was increased. The mechanical test results show that by increasing of the nickel content in the weld metal, the tensile and yield strength increased, whilst impact energy and elongation decreased.

Keywords: Nickel, Al 5000 Series, Weld Metal, Microstructure, Mechanical Properties

1. Introduction

Automatic TIG welding is an important developed joining technique in any industry owing its benefits in terms of reducing the processing costs [1]. Al-Mg Alloys (5000 series) are studied doing to their good combination of strength and density ,this aluminum alloys series used in marine and offshore industries as environmental friendly materials [2]. TIG welding of Al-Mg alloys (5000 series) has been investigated and presented concerning its fracture strength, joint efficacy which varying from 50% -95% depending on the parameters welding process and procedure [3]. These results show that the automatic TIG welding has a better property than the manual method [4]. On the other hand, some of weld metal mechanical properties functionally of chemical composition (alloying element) of weld metal in Al-Mg alloys [5]. Alloying addition, such as: Si, Mn, Fe [6] studied the effect of mechanical properties of the 5058-weld metal, the results show that by increasing of these elements hot tearing sensitivity have been increased in weld metal. Metallurgical phase diagram of Al-Mg-Ni presents that Nickel in the maximum 0.25 % is soluble in pure aluminum and increase the mechanical properties by solid solution and over the 0.25 % produced the inter-metallic compounds as Al_3Ni - Al_3Ni_2- Al_3Ni_5- Ni_3Al – Al_2Mg_2Ni - Al_3Ni_2Mg – Al_2Mg_3Ni – Mg_2Ni – $MgNi_2$ with semi-coherent interface with matrix and increase the tensile strength and hardness [7].

2. Materials and Methods

The Al5058-O alloy used as a base metal with chemical composition and mechanical properties as given in Table 1.
Plates with 3× 100 ×200 mm dimensions were prepared for this investigation, after cleaning butt joint were fixed at the fixture and prepare for automatic TIG welding with pure Nickel Filler metal. To study the effect of nickel content in weld metal used the wire feeder machine for feeding the 1 mm diameter pure wire nickel in the weld pool. For this reason, the travel speeds (welding speeds) of TIG and wire feeder machine were constant and the rate of wire feeder speed was variable, Table 2. given the welding parameters.

Table1. Chemical composition (wt. %) and mechanical properties of the Al5058-O [2].

Chemical composition	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Pb	Al
	0.38	0.49	0.11	0.12	4.85	0.15	0.21	0.22	0.12	bal

Mechanical properties in annealing condition	T.S (Kg/mm^2)	Y.S (Kg/mm^2)	%ε	HV (500)	αk (j/cm^2)
	29.4	15.4	35.1	65	75.2

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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 XRF (Hitachi 1232) used for nickel analysis of weld metal.

Table 2. Welding parameters

Process	Automatic TIG
Polarity	DCEP
Current (A)	80
Voltage (V)	14
Welding speed	0.18 m/min
Wire feeder speed	0.3-1.5 m/min
Filler metal	Pure Nickel
Filler metal diameter	1 mm
Electrode	EWTh-2
Tip of electrode	75^0
Arc length	2.5 mm
Electrode diameter	1.6 mm
Shielding gas	Pure Argon
Gas flow	12 Lit/min
Joint design	Butt weld (I)
Number of pass welding	1
Pre-heat temperature	100 ^{0}C

3. Results and Discussion

Fig. 1. shows the relation of wire feeder speed and nickel content in weld metal.

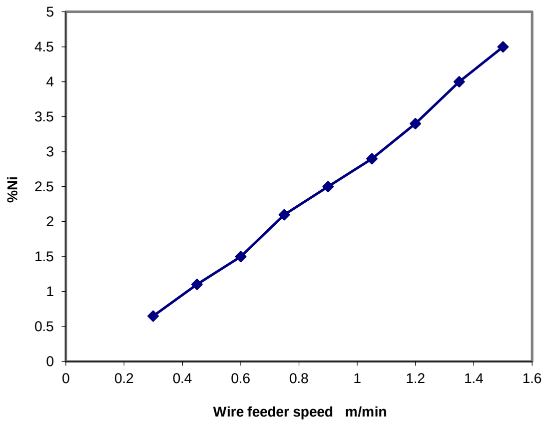

Fig. 1. Relation between wire feeder speed and Nickel content in weld metal.

Fig. 1. shows that by increasing the wire feeder speed the nickel concentration in fusion zone increases, although by changed of wire Feeder speed, feeding rate of filler metal changed and thus content of nickel differ in any condition. Table 3. represents the optical metallography and Fig. 2. shows the relationship between nickel content with grain size and volume fraction of the solid particles.

Table 3. Metallographic results.

Sample	1	2	3	4	5	6	7	8	9	10
Nickel content in weld metal	-	0.65	1.1	1.5	2.1	2.5	2.9	3.4	4	4.5
Grain size (µm)	40	38	35	33	30	28	25	22	20	18
Percentage of solid particle	2	4	6	9	11	16	18	20	23	25

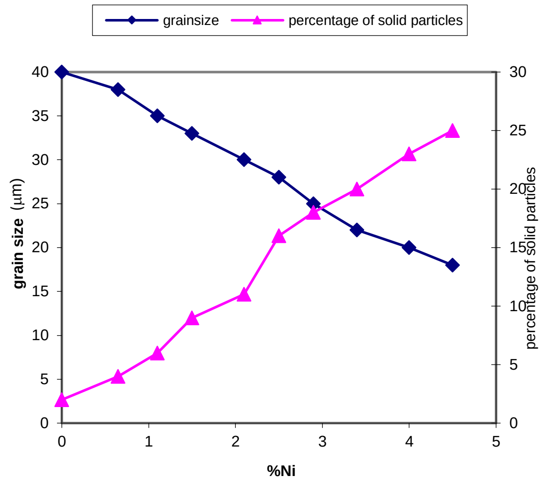

Fig. 2. Relation between Nickel content of weld metal with grain size and solid particles percentage.

Fig. 2. shows that by increasing of the nickel content, the grain size decreased and the volume fraction of solid particles increased, Fig. 3. presents the EDX point analysis of sample 8 with 3.4% nickel content in weld metal.

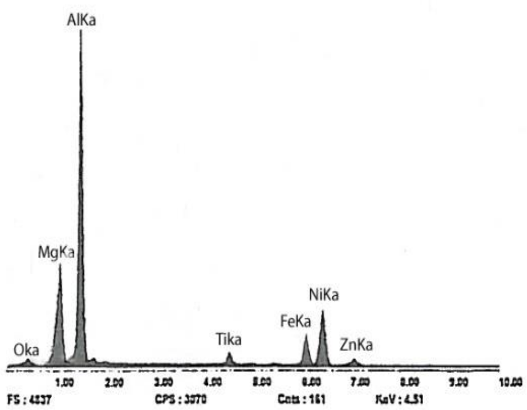

Fig. 3. EDX point analysis of sample 8 with 3.4% Nickel content in weld metal.

Fig. 3. shows that solid particles are the rich phases of the Al-Mg-Ni inter -metallic compounds, study of the Al-Mg-Ni metallurgical phase diagram explain

that Mg in less 7% by solution in solid phase and production of inter metallic Al_3Mg_2 appear their influence in microstructure. If addition nickel in 0.5-4.5 percent in Al-Mg (<7%), produced inter-metallic and present Al_2Mg_2Ni -Al_3Ni_2Mg – Al_2Mg_3Ni in microstructure [7-10]. on the other hand nickel in this range affected on solidification range of alloy and decrees this range, thus the under cooling increase and grain size decrees [10,11] . Fig. 4. showing microstructure of sample1 and 5 for compare of grain size.

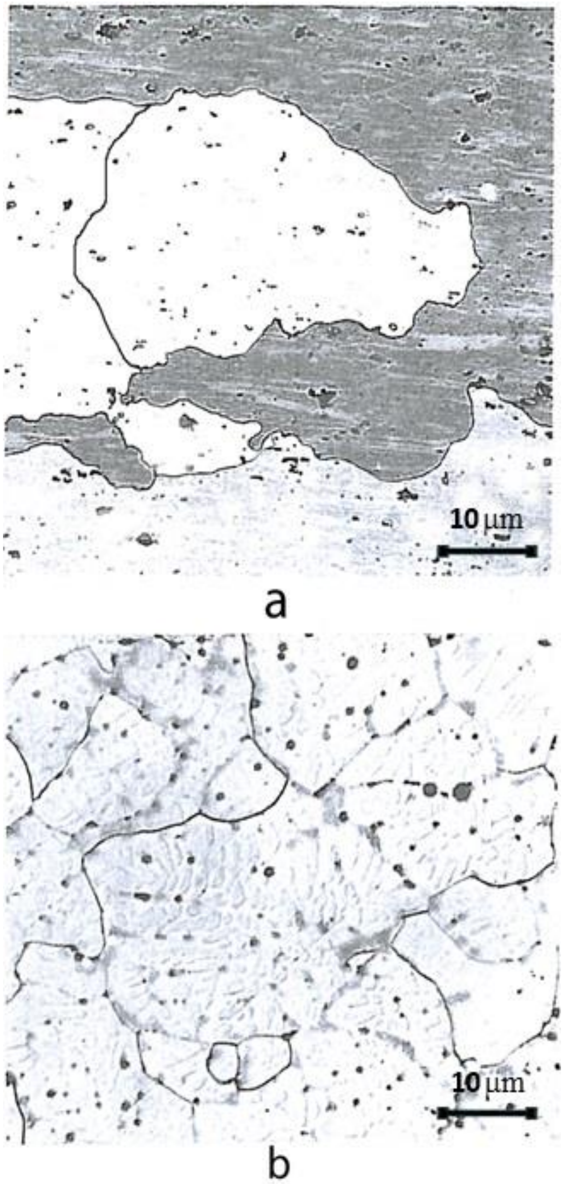

Fig. 4. Microstructure of a) sample1 (base metal) with 40µm grain size and b) sample5 (2.1% Nickel) with 30 µm grain size, Etchant with 25% Nitric acid.

Fig. 5. shows micro hardness results of various samples. It can be seen that with increase of nickel content, hardness of weld metal increased, this due from production and appears of the Ni inter metallic compounds in the weld metal [10].

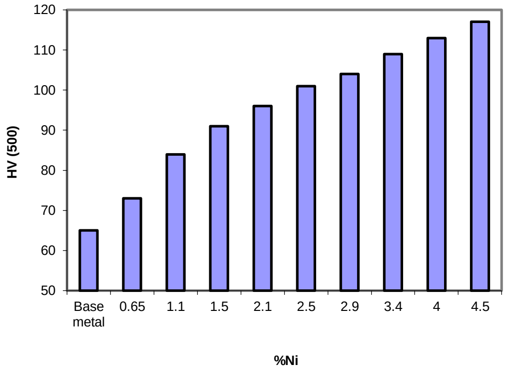

Fig. 5. Micro hardness of various samples as Nickel content in weld metal.

Fig. 6. and Fig. 7. presents the effect of nickel content on mechanical properties of weld metal, Fig. 6. shows that by increasing the nickel content in weld metal, the tensile strength and yield strength increased but Fig. 7. shows that by increasing the nickel content, the elongation and impact energy decreased.

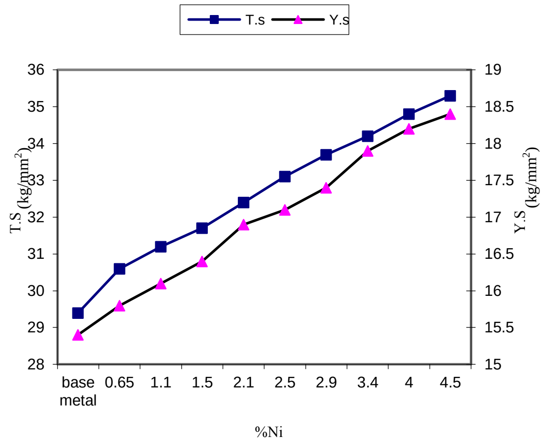

Fig. 6. Effect of Nickel content in weld metal on tensile and yield strength.

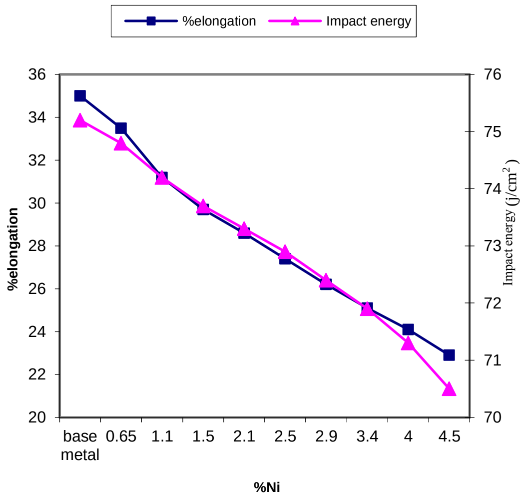

Fig. 7. Effect of Nickel content in weld metal on percentage of elongation and impact energy.

These results determining that in 5058 aluminum alloy mechanical properties depend on the microstructure, as for as, by increasing the volume fraction of the Ni inter-metallic compounds (with semi-coherent interface [7,10]) the grain size, elongation and impact energy decreased, and the tensile and yield strength increased.

4. Conclusions

The influence of the Nickel content at the range of 0.5-4.5 percentage in the fusion zone of Al5058 alloy by automatic TIG welding, has been studied and results are as follows:
1. By increasing of nickel content in weld metal the grain size decreased whilst the volume fraction of the solid inter-metallic compounds increased.
2. The EDX analysis of solid inter-metallic compounds determined that these particles are rich phases of the Al-Mg -Ni elements.
3. By increasing of the nickel content, the tensile and yield strength of the weld metal increased whilst impact energy and elongation decreased.

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