تحسين الخواص الميكانيكية لسبيكة الألمنيوم 360 بإضافة عنصري التيتانيوم والبورون ومعالجة مصهورها بالأرغون

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ملخص:

تم إجراء هذا البحث للتحكم بجودة مصهور الألمنيوم قبل سكبه، وذلك للحصول على مسبوكات خالية من المسامية ذات مواصفات ميكانيكية عالية.

تفترض الدراسة أن معالجة مصهور الألمنيوم *360.0* بالأرغون النقي مع إضافة مواد تحسين البنية *(Al Ti5B)* تنتج عنه مسبوكات عالية الجودة. حيث أن فقاعات الأرغون ترتفع في المصهور حاملةً فقاعات الهيدروجين والشوائب إلى سطح المصهور بهدف التخلص منها.

يتطلب الإجراء العملي جهاز إزالة غازات دوار، واسطوانة أرغون، وفرن صهر ألمنيوم، وأجهزة اختبار.

تم إجراء ست تجارب لمقارنة المعالجة بغاز الأرغون، وأقراص إزالة الغازات *(FOSECO Degasser 200)* مع وبدون استخدام مواد تحسين البنية *(Al Ti5B)*، بينت النتائج أن استخدام غاز الأرغون مع مواد تحسين البنية *(Al Ti5B)* كان له أثر جيد جداً على الخواص الميكانيكية التي تم قياسها، وتضمن ذلك:

قساوة عالية حتى *(80 HB)*، قوة شد *(337 MPa)*، مسامية منخفضة، بنية ناعمة، قوة صدم عالية *(0.573 kgm/cm^2)*، قوة خضوع *(187 MPa)*، مطيلية *(3.4%)*، عامل يونغ مرتفع *(85966 MPa)*.

كلمات مفتاحية : سبيكة الألمنيوم 360.0 ، جهاز إزالة الغازات الدوار، أرغون، Al Ti5B، أقراص إزالة الغازات.

Improving the mechanical properties of Aluminum Alloy 360 by adding Titanium or Boron, and degassing the melt with Argon

Abstract

This research was carried out to control the quality of the liquid Aluminum before casting, in order to obtain porosity free castings with high mechanical properties. It' was supposed that treating Al 360.0 melt with pure Argon in conjunction with adding structure refining (Al Ti5B) materials produces high quality castings. Since Argon bubbles rise in the melt holding Hydrogen bubbles and impurities to the melt surface in order to get rid of them.The practical procedures required a rotary degassing device, Argon cylinder, Aluminum melting furnace and test equipment. Six experiments were done comparing the use of Argon gas, Degassing tablets (FOSECO Degasser 200) with/ without using refining materials (Al Ti5B). The results showed clearly that using Argon gas with had very good results on the mechanical properties measured which (Al Ti5B) included high hardness up to 80 HB, tensile stress 337 MPa, low porosity, fine structure, high impact strength 0.573 kgm/cm2, yield strength 187 Mpa, ductility 3.4% and elevated young modulus 85966 MPa

Key words: *Aluminum Alloy 360.0 , Rotary Degasser, Argon, Al Ti5B, Degassing tablets.*

Introduction:

In order to obtain sound castings of Aluminum 360.0, mechanical properties must be adopted well. That can't be achieved with the presence of Hydrogen in the melt. So that, it's important to get rid of this harmful gas and other impurities found in the melt.

Some casting plants use special degassing tablets which are not always available. Furthermore, it has harmful affection on human's health.

A lot of researches are carried out to study the results of treating the Aluminum melt with inert gasses, especially Argon and Nitrogen.

A.Bahmani et al.[1] studied the effects of Hydrogen ratio and cooling rates on the tensile strength of commercial grade Aluminum Al-319. The results showed that high Hydrogen content in the melt reduced the tensile strength. While increasing cooling rate couldn't cease the bad effects of high Hydrogen levels. However, increasing cooling rates resulted in higher tensile strength in all Hydrogen levels.

Another study on the effect of Hydrogen and Oxides on tensile properties of Al-Si-Mg was carried out by G. Eisaabadi et al. [2] Results showed that Hydrogen has a worse affection on the tensile properties compared with Oxides. Also, Hydrogen bubbles changed the changed morphology of oxides from two dimensional (2-D) to three dimensional (3-D) one.

Ga´bor Gyarmati et al.[3] studied the effect of using rotary degassing treatment with Nitrogen on the melt quality of AN Al-Si casting alloy. They found that degassing the melt using the rotary degasser, with adding melting fluxes raises the quality of melt.

However, degassing the melt without flux addition caused impurities which increased the porosity in castings produced.

M. Mostafaei et al. [4] evaluated the results of degassing variables on the quality of Aluminum alloy A357 castings. The degassing variables are the device rotating speed and gas flow rate. As the combination of these two factors can cause the casting structure not to develop or even descend.

This study assumes that degassing Aluminum Alloy 360.0 with Argon using rotary degasser and structure refining material Al Ti5B produces a high quality melt before casting, which is Hydrogen and oxides free. That reflects on the low porosity of final solid casting with fine particles. Obtaining high mechanical properties especially tensile strength, hardness, impact strength, ductility, yield strength and young modulus.

In order to prove the previous assumption and compare using Argon gas with degassing tablets Degasser 200, 6 experiments were done as follows:

1- Melting AA 360.0 without degassing or any addition of structure refining materials Al Ti5B.

2- Melting AA 360.0 with adding Degasser 200 tablets, but without adding Al Ti5B.

3- Melting AA 360.0 with adding Degasser 200 tablets and Al Ti5B.

4- Melting AA 360.0 with Argon degassing, but without adding Al Ti5B.

5- Melting AA 360.0 without degassing, but with adding Al Ti5B.

6- Melting AA 360.0 with Argon degassing and with adding Al Ti5B.

Other parameters of degassing were fixed values:

- Melting furnace: Aluminum induction melting furnace with Graphic crucible 100 kg .

- Furnace actual charge: 50 kg.

- Gas pressure : 0.2 bar.

- Gas flow rate: 5 l/min.

- Degassing period: 12 min.

- Degasser 200 addition: 0.1 kg.

- Al Ti5B addition: 3 kg.

- Degasser rotational speed: 300 rpm.

- Argon gas purity: 99.998 - 99.999 %

All the experiment were computed accurately with an excel program, which calculates the addition ratios needed.

A spectro-metal analyzer was used to validate the charge composition during and after melting.

1. Problem Identification:

Improving the mechanical properties of Aluminum Alloy 360.0 in the liquid status in order to obtain porosity free sound castings.

2. Materials and methods:

The material selected for the research is AA 360.0 which is composed of the chemical elements shown in table 1:

Table 1. AA 360.0 chemical composition [5]

Chemical element	Cu	Mg	Mn	Si	Fe	Ni
Percentage %	≤ 0.6	0.4-0.6	≤ 0.35	9-10	≤ 2.0	≤ 0.5
Chemical element	Zn	Sn	Others	Al		
Percentage %	≤ 0.5	≤ 0.15	≤ 0.25	Remainder		

To obtain this chemical composition accurately the charge was calculated with an Excel program designed for this purpose considering the oxidization ratios of every cast element. Then Pure Aluminum ingots and other cast elements were prepared according to the addition ratios shown in Table 2.

Table 2. Charge calculation with the Excel program

Main charge			Fluxes		
Material	Qu. (kg)	Purity %	Material	Qu. (kg)	Trade code
Pure Al	7	99.8	Coveral	0.5	11
Al-Si	41	11.7			
Al Ti5B	0.4	4.2			
Mg	0.331	99.5			

In the experiments contain Degasser 200 degassing tablets it was added 200 g for each 100 kg melt charge i.e. for 50 kg of melt, 100g of Degasser200 was added.
After each experiment three specimens were taken as described in table 2.

Table 2. Specimens used for each experiment

Test type	***No. of specimens***
Tensile strength	*3*
Yield strength	*3*
Hardness	*3*
Spectro-metal Analysis	*3*
Ductility	*3*
Micro- structure	*3*
Impact strength	*3*
Young's modulus	*3*

Then the average values were taken for each experiment.

3. *Results and discussion:*

The best results were attained from experiment No.6 which are shown in table 3.

Table 3. Specimens used for each experiment

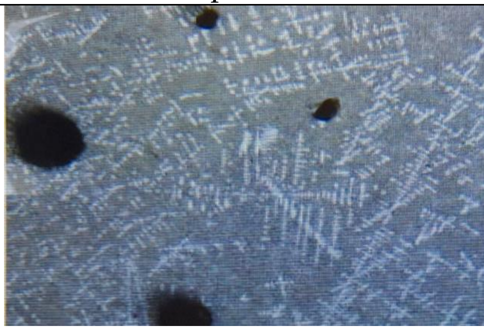
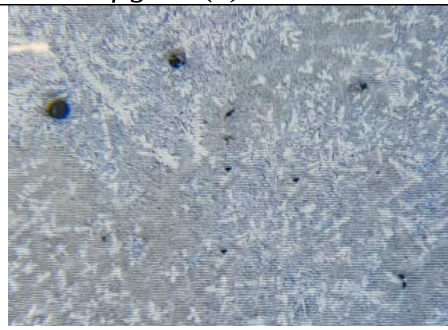
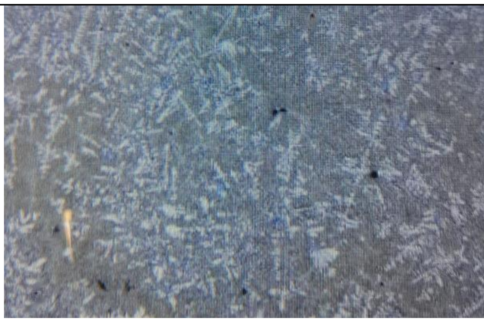
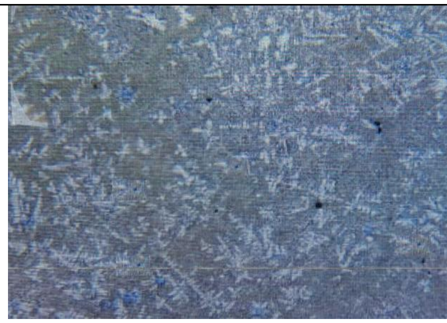
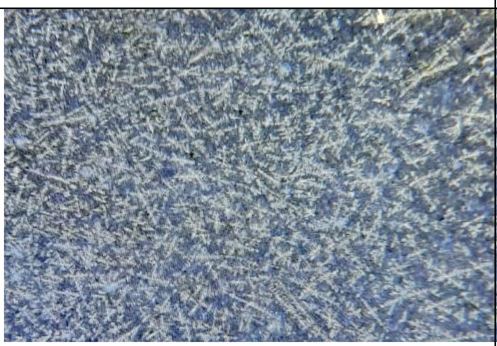
Test type	***Average test value***	***Unit***
Tensile strength	*337*	*MPa*
Yield strength	*187*	*MPa*
Hardness	*80*	*HB*
Impact strength	*0.573*	$Kg.m/cm^2$
Young's modulus	*85966*	*MPa*

The chemical composition attained in experiment No.6 is shown in table 4:

Table 4. Specimens used for each experiment

Chemical element	*Cu*	*Mg*	*Mn*	*Si*	*Fe*	*Ni*
Percentage %	*0.11*	*0.53*	*0.21*	*9.7*	*0.05*	*0.02*
Chemical element	*Zn*	*Sn*	*Others*	*Al*		
Percentage %	*0.03*	*0.04*	≤ 0.25	*Remainder*		

Micro-structural images were taken by Nikon SMZ800 stereoscopic zoom microscope .The results are shown in figure (1) :

 *a)Without treatment* *Scale 200%*	 *b) With Al Ti5B addition* *Scale 200%*
 *c) Treated with Degasser 200 tablets Scale 200%*	 *d) Treated with Argon gas* *Scale 200%*
 *e) Treated with Degasser 200 tablets and Al Ti5B Scale 200%*	 *f) Treated with Argon gas and Al Ti5B Scale 200%*

In figure (1-a) large gas pores appeared in the micro-structure because the melt wasn't treat at all. However, adding Al Ti5B the micro-structure was finer but still has large pores which must be treated as shown in figure (1-b).

Treating with Degasser 200 tablets only (figure (1-c)), the pores obtained were smaller and the particles were coarse so that they had to be treated.

So another experiment was done using Degasser 200 tablets and Al Ti5B (figure 1-e) to obtain approximately pores free structure with finer particles.

Another experiment was conducted using Argon gas only, which achieved very good porosity results as shown in figure (1-d).

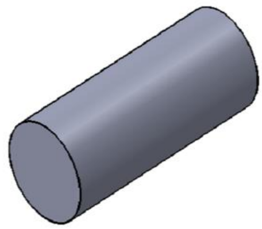
The best results were achieved by treating with Argon gas and Al Ti5B together, since a fine micro-structure with the least percentage of pores was obtained as illustrated in figure (1-f).

To validate the results, volume density method of measuring porosity [6] was used. This method calculates the percentage of pores in the specimens. However it doesn't show how the pores are distributed or where are their positions.

The volume density is measured by dividing the actual density by the theoretical density. Since the actual density is the mass divided by the volume according to the relation:

$$\rho_{act} = m/v$$

The volume is a fixed value in all sample, because the samples were operated with the same dimensions as shown in figure (2).



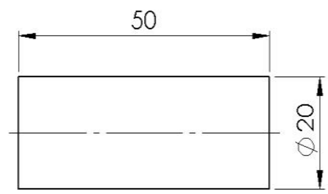


Figure 2. Actual density specimens

The results are illustrated in table (5) :

Table 5. Pores percentage in the specimens

Specimen No.	*Treatment Method*	*Specimen Dimensions*			*Density Obtained*	*Mass (g)*	*Pores %*
		Diameter (cm)	*Length (cm)*	*Volume (cm^3)*			
1	*No treatment*	2	5	62.832	2.387	150	9.227
2	*Al Ti5B*	2	5	62.832	2.403	151	8.622
3	*Degasser 200 tablets*	2	5	62.832	2.515	158	4.386
4	*Degasser 200 tablets & Al Ti5B*	2	5	62.832	2.546	160	3.176
5	*Argon gas*	2	5	62.832	2.562	161	2.571
6	*Argon gas & Al Ti5B*	2	5	62.832	2.594	163	1.360

Figure (3) illustrates the percentage of pores in specimen (1), which includes large pores ratio indicated by the density obtained.

***Figure 3. Pores percentage in the specimens** (1)*

Figure (4) illustrates the percentage of pores in specimen (2) using Al Ti5B only. The pores are smaller but still large which reduces the mechanical properties of the alloy.

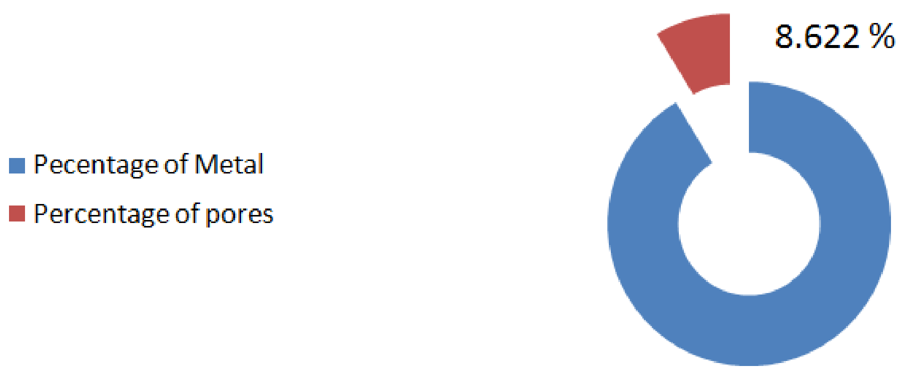


***Figure 4. Pores percentage in the specimens** (2)*

Figure (5) illustrates the percentage of pores in specimen (3) using Degasser 200 tablets only. A small pores ratio is obtained.

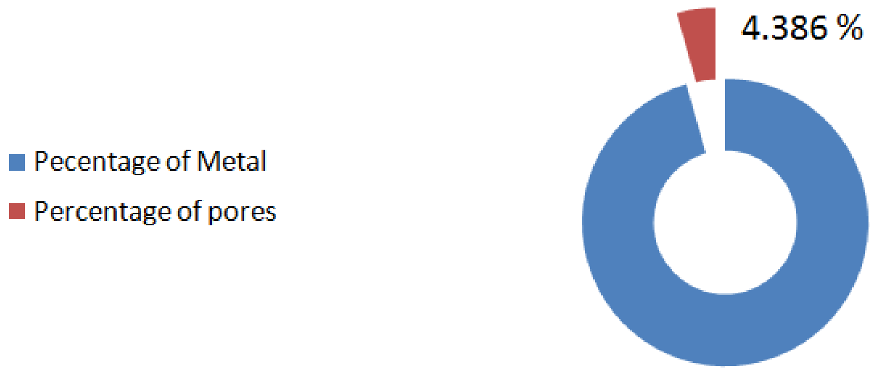


Figure 4. Pores percentage in the specimens *(5)*

Figure (6) illustrates the percentage of pores in specimen (4) using Degasser 200 tablets with Al Ti5B. The pores percentage is obviously smaller.

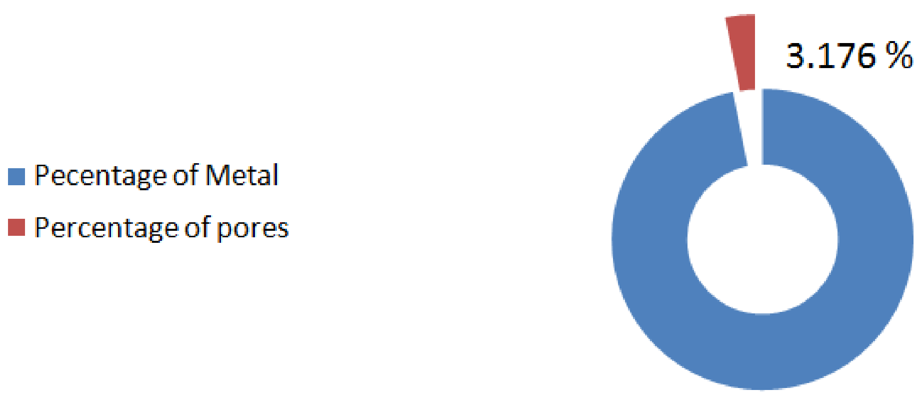


Figure 6. Pores percentage in the specimens *(4)*

Figure (7) illustrates the percentage of pores in specimen (5) using Argon gas only. The pores percentage is about 2.5% and the density is near to the standard density of AA 360.0 .

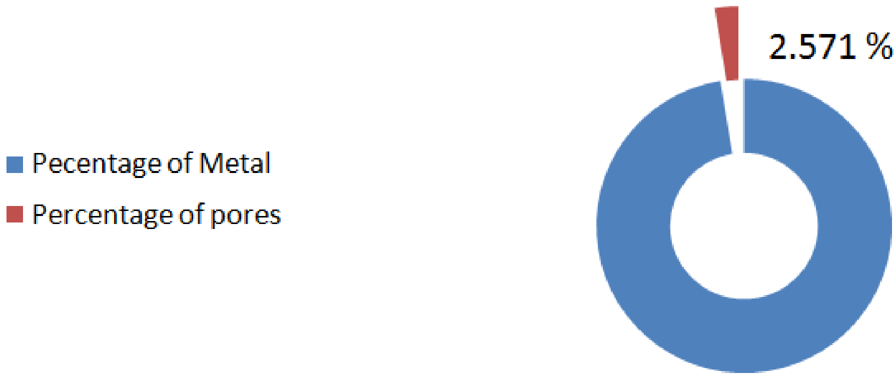


Figure 7. Pores percentage in the specimens *(5)*

Figure (8) illustrates the percentage of pores in specimen (6) using Argon gas with Al Ti5B, which obtained the best results and the best mechanical properties as mentioned above in table (3) and the finest .

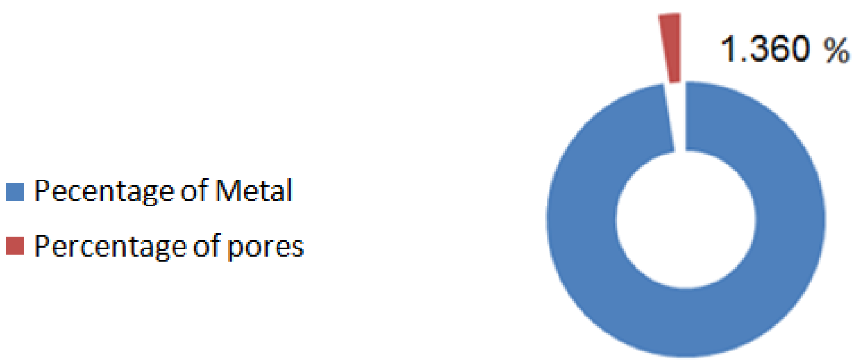


Figure 8. Pores percentage in the specimens *(6)*

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