

Grain Refinement and Modification of Hypereutectic Al-Si Alloys Mold by Two Process

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Abstract— The solidification process significantly affects the microstructure and mechanical properties of the aluminum-silicon alloys. This article discusses the effect treatment of the liquid metal, namely the refining and the modification on the microstructure and mechanical properties of a hypereutectic silicon aluminum alloy, molded by two molding processes. Sand mold and shell. The study shows that the microstructure affected

for the two treatments and in the two molding processes. On the other hand, the refining treatment has a reciprocal influence on the mechanical properties. However the modification slightly improves the mechanical properties.

Keywords: Solidification, refinement, process, cast; molding.

I. INTRODUCTION

Al-Si alloys are most widely used aluminum alloys due to their castability, high strength to weight ratio, corrosion resistance,...etc [1,2]. This fosters use is to reduce cars and aeronautic equipment's weight and other automotive applications [3,7]. Grain refinement has regarded as one of the most effective techniques to enhance the mechanical properties of metal castings and to improve the formability of metal ingots [8–10]. The currently available techniques for grain refinement of cast metals include vibration and stirring [11, 12], rapid solidification [13] and inoculation treatment [14]. For solid metals, severe plastic deformation is generally used to refine the grains to micrometer and even nanometer scales [15,16]. In industrial production, inoculation treatment through addition of proper grain refiner is widely used in metal castings [17]. For example, TiB₂ and Al₃Ti are effective grain refiners to promote heterogeneous nucleation for cast aluminum alloys [18,19]. In This work we are study the effect of inoculation and modification using tow process send shell casting.

II. EXPERIMENTAL PROCEDURE

The objective of our study is therefore to be able to control the microstructure, using liquid metal treatment in order to determine the most suitable treatment and casting process for obtaining high performance, hypersilicon aluminum parts. For this, we will have to carry out a series of experiments such as tensile tests, hardness tests, cooling rate measurements, ...

The table below presents the composition of metal using:

TABLE1: AVERAGE VALUES OF SOME THERMOMECHANICAL PROPERTIES OF ALSi17Cu4 ALLOY.

Element	Si	Cr	Fe	Ni	Cu	Zn	Mn	Al
Average content wt%	16,135	0,035	0,453	0,027	6,580	0,186	0,203	Bal

A. Production of test specimens

We cast different specimens allowing us to subsequently perform the various tests, which are a micrographic analysis, the recording of thermal curves, tensile tests, hardness tests, chemical analysis and measurement of the porosity rate.

B. Material available

To make these specimens, we heated the aluminum hypereutectic AlSi17Cu4 alloy in induction furnace. During all of our castings, the alloy was heater in the same furnace to a temperature of 650 ° C without heating any other metal. We have cast different specimens allowing us subsequently perform the various tests, which are a micrographic analysis, the recording of thermal curves, tensile tests, and hardness tests.

The objective of this study is a comparative the manufacturing of a hypereutectic AlSi17Cu4 sample using tow process.



FIG1: METAL HEATING FURNACE

The test pieces are cast in sand molds (produced by the PEP SET process) comprising five test pieces and in a shell mold

Comprising four test pieces.

To make the molds, we mixed the sand with 0.5% phenolic resin relative to the sand mass, 4% catalyst and finally 0.5% isocyanate resin.

FIG 2: SAND MOLD



FIG 3: SHELL MOLD



The tests carried out are on two treatments, the first Being A refining treatment. The second is a modification treatment.

C. Refining

For the refining treatment, we used as an additive element ALUFLUX B (Titanium and Boron) in the form of 200g pellets.

TABLE 2: PERCENTAGE OF REFINER USED

% of treatment	Number of samples
0.5% of the metal mass in the furnace	1
0.8% of the metal mass in the furnace	2
1.2% of the metal mass in the furnace	3

D. Modification

For the modification treatment, we used as an additive Element SIMODAL 77 (Sodium), in the form of a 200g tablet, 0.2%.

TABLE 3: PERCENTAGE OF MODIFIER USED

% of treatment	Number of samples
0.3% of the mass in the furnace;	1
0.5% of the mass in the furnace;	2
1.0% of the mass in the furnace.	3

E. Degassing treatment

For the degassing treatment, we used as an additive element DEGAZER 701 SM (Nitrogen and without Sodium), in the form of a 200g pellet, 0.5%.

III. RESULTS AND DISCUSSION:

To study the effect of refining and modification treatments on the solidification parameters. We have produced test specimens by which to measure, mechanical propriety and microstructure tests using the two treatments for both sand and shell molding processes.

a- Mechanical tests (R_m , E)

The various cast specimens will serve us mainly to determine the mechanical characteristics of this alloy. For this, we carried out tensile tests. Then, in the analysis of the results, we will only consider the test pieces giving consistent data, and we will take an average of these values, considering the standard deviation and the dispersion of the measurements.

TABLE 4: PERCENTAGE OF MODIFIER AND REFINING USED

Reference sand

Rate	E (Gpa)	R_m (Mpa)	A (%)
0,0%	78	156	0,15

Modification_Sand

Rate	E (Gpa)	R_m (Mpa)	A (%)
0,3%	71	160	0,21
0,5%	72,00	159	0,22
1,0%	77	150	0,13

Refining Sand

Rate	E (Gpa)	R_m (Mpa)	A (%)
0,5%	74	118	0,04
0,8%	75	95	0,03
1,2%	73	108	0,05

Reference shell

Rate	E (Gpa)	R_m (Mpa)	A (%)
0,0%	61	160	0,16

Modification shell

Rate	E (Gpa)	R_m (Mpa)	A (%)
0,3%	59	140	0,17
0,5%	61	151	0,17
1,0%	60	153	0,19

Refining shell

Rate	E (Gpa)	R_m (Mpa)	A (%)
0,5%	60	118	0,06
0,8%	62	114	0,03
1,2%	62	108	0,03

The blue tables serve as references, that is to say, they indicate the characteristics of the test pieces without treatment.

We recall that "A (%)" represents the permanent elongation of the test piece under the stress R_m . To compare these results and to be able to analyze them, let us draw up the following graphs, that is to say:

- Young's modulus: E (GPa)
- Tensile strength according to the different treatment rates (refining and modification): R_m (MPa)
- Permanent elongation: A (%)

FIG 5 CURVES OF VARIATION YOUNG'S MODULUS, TENSILE STRENGTH AND ELONGATION AS A FUNCTION OF REFINING FOR USING SAND MOLD.

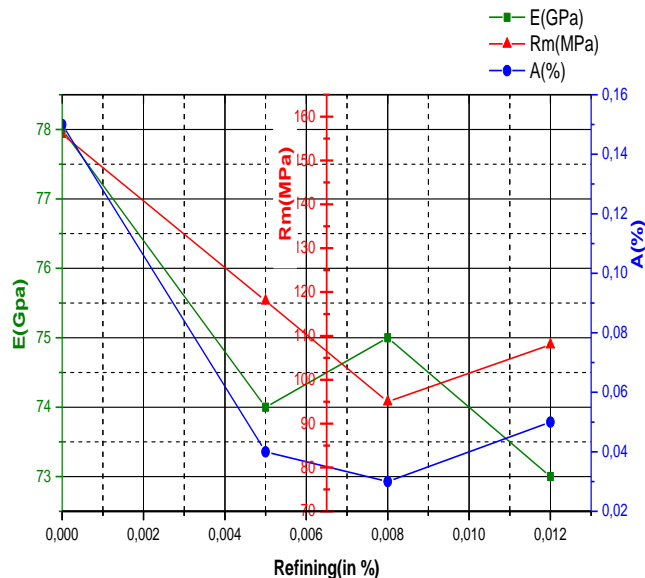


FIG 6 CURVES OF VARIATION YOUNG'S MODULUS, TENSILE STRENGTH AND ELONGATION AS A FUNCTION OF MODIFICATION FOR USING SAND MOLD.

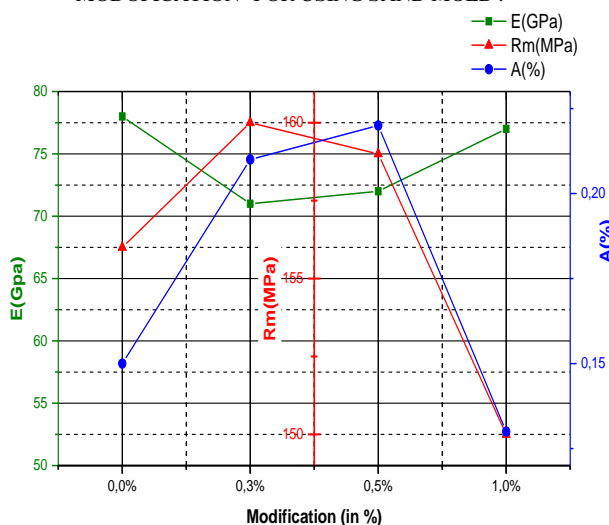
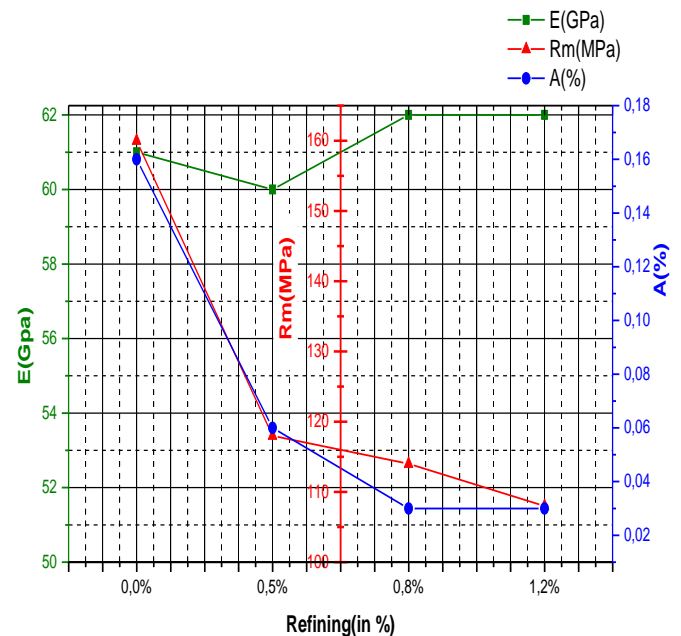
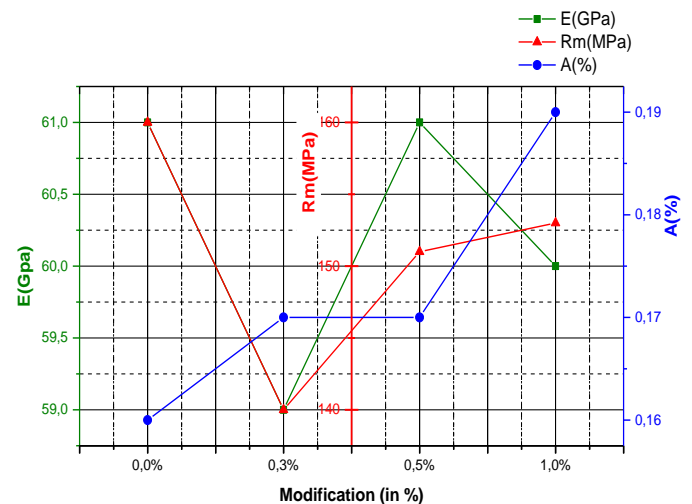


FIG 7: CURVES OF VARIATION YOUNG'S MODULUS, TENSILE STRENGTH AND ELONGATION AS A FUNCTION OF REFINING FOR USING SHELL MOLD.



With regard to permanent elongation of test pieces, the previous graph reveals some trends. First, the refining treatment does not promote strong permanent elongation, whether in shell casting or sand molding. However, we see a minimum reached for 0.6% ripening.

FIG 8: CURVES OF VARIATION YOUNG'S MODULUS, TENSILE STRENGTH AND ELONGATION AS A FUNCTION OF MODIFICATION FOR USING SAND MOLD



With regard to permanent elongation of test sample, the previous graph reveals some trends. First, the refining treatment does not promote strong permanent elongation, whether in shell casting or sand molding. However, we see a minimum reached for 0.6% ripening.

As regards the modification, the specimens cast in shells exhibit an increasingly important permanent elongation as the rate of modifier increases. Contrary to this behavior, the test pieces cast in a sand mold make it possible to demonstrate an

optimum point of maximum permanent elongation, reached for a modifying rate of 0.5%. We can explain the phenomenon of increased elongation in the case of a modification treatment through the consequence of the modifier on the microstructure of the material. Indeed, as explained in the section presenting the modification, this treatment of the liquid metal will, among other things, modify the eutectic (initially as a needle) to result in a globular morphology. However, this morphology offers more ductility to the material, hence an increase in the permanent elongation of the modified specimens.

b- Micrographic analyzes:

The object of this study will be the characterization of the microstructure of the different Al-Si 17 alloys, each of which has undergone either a modification or a refining.

For this on the micrographs taken, we sought to define:

- The density of primary Si
- The density of eutectic Si
- The density of Al
- Porosity
- The size of the porosities

We will now present the results that we obtained. For the sake of clarity, they will be presented treatment by treatment and with their respective casting process.

1-Control samples (A0)

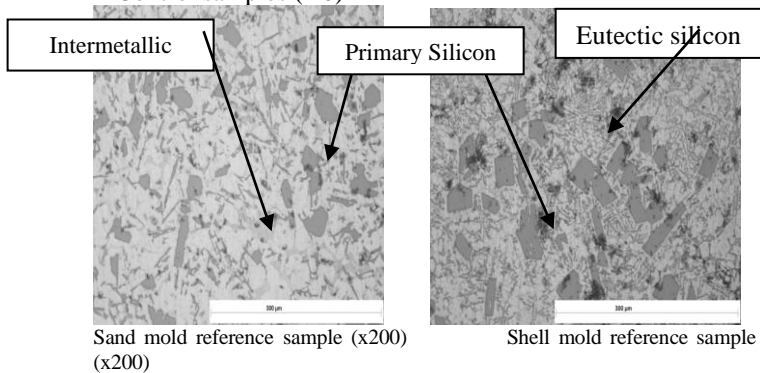


FIG 9: MICROGRAPHIC IMAGE OF THE REFERENCE SAMPLE FOR TWO PROCESSES

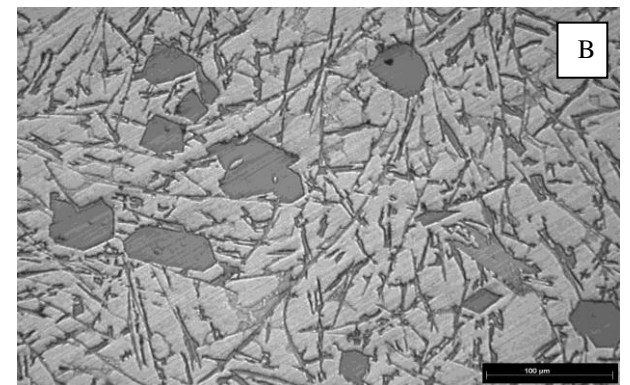
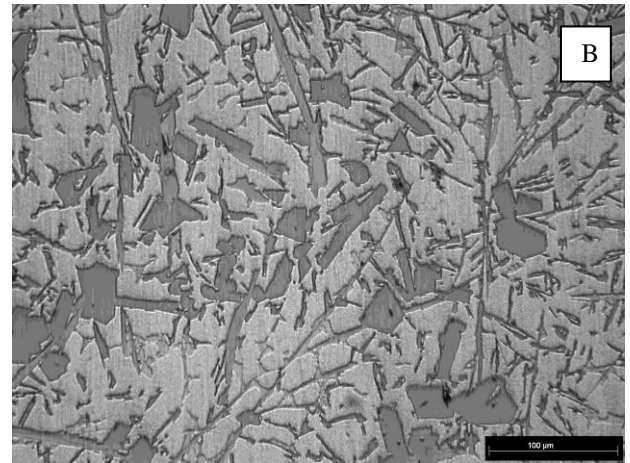
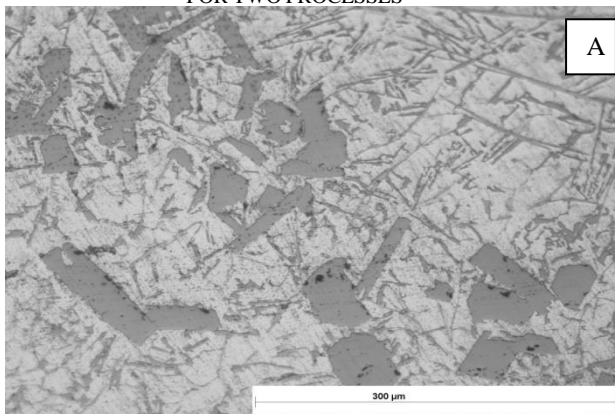
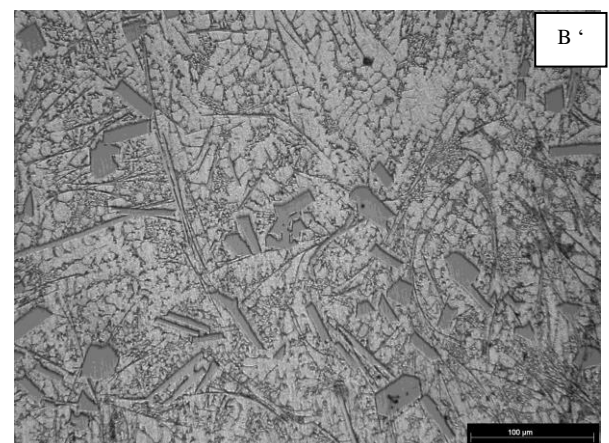
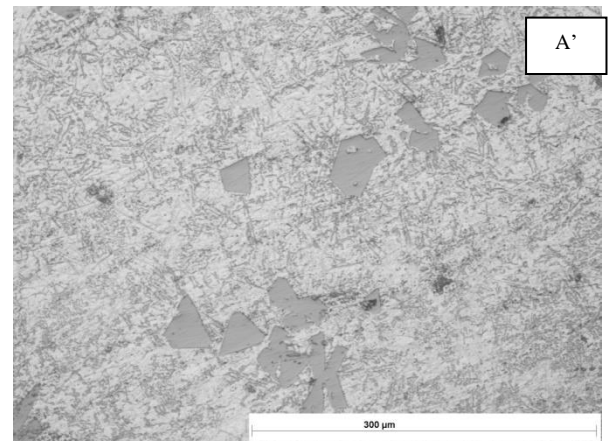


FIG 10: MICROGRAPHIC IMAGE OF SEND MOLD REFINING A0.5% B 0.8% AND C 1,2 % (X 200)



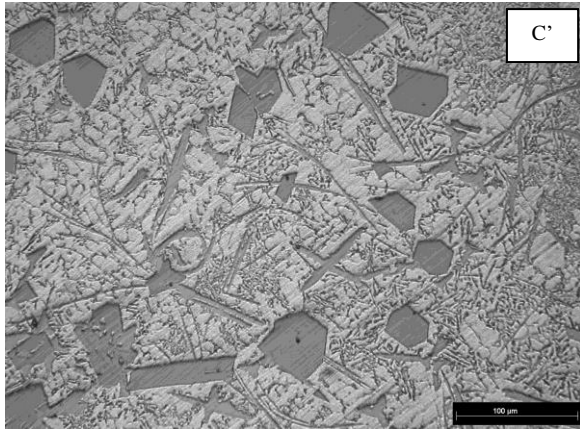


FIG 11: MICROGRAPHIC IMAGE OF SHELL MOLD REFINING A' 0.5% B' 0.8% AND C' 1.2 % (X 200)

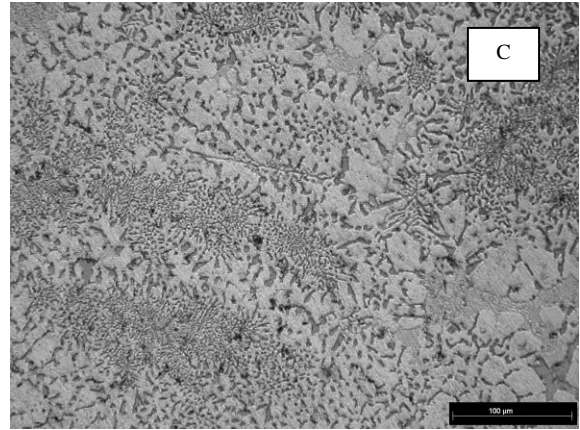


FIG 12: MICROGRAPHIC IMAGE OF SEND MOLD MODIFICATION A 0.3% B 0.5% AND C 1 % (X 200)

from the above micrographs it is concluded that the most adequate refining percentage is 0.8% for both processes. especially for shell molding. this may be justified by the reverse effect of the refining agent as its percentage increases. such that the refining element plays the role of germination for the intermetallic.

After studying the effect of refining on the microstructure in both processes. we will proceed to study the effect of the modification. the micrographs below show the results obtained

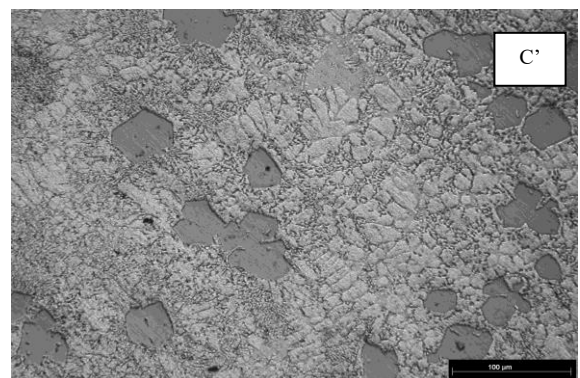
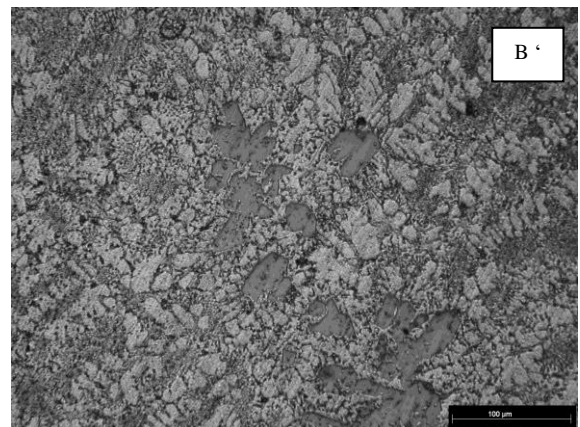
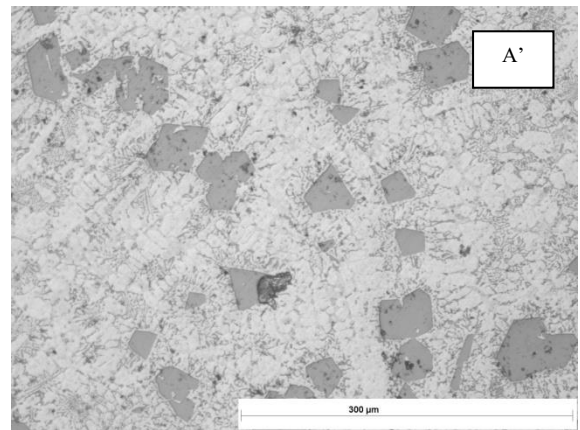
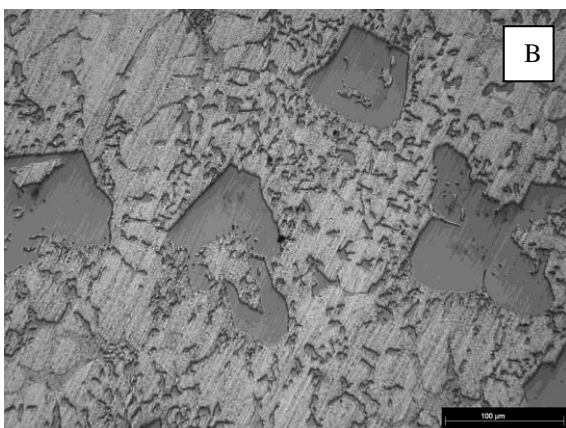
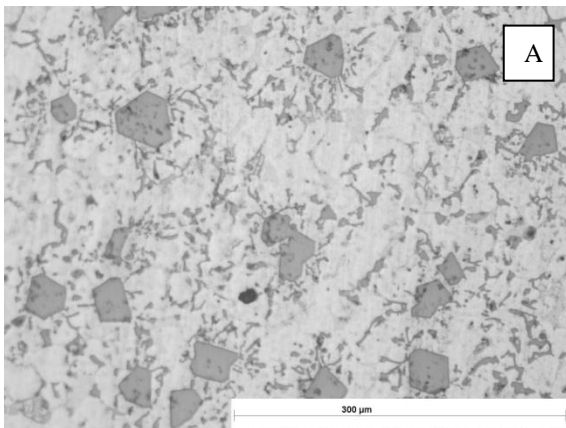


FIG 13: MICROGRAPHIC IMAGE OF SHELL MOLD MODIFICATION A' 0.3% B' 0.5% AND C' 1 % (X 200)

In the sand casting we note that from the first levels of Si modifying agent of the eutectic phase, initially present in acicular form, transformed into globular form. For a high rate of modifying agent, we can notice that the primary Si's have disappeared in favor of the eutectic Si's. The modifying agent therefore also has the properties of a refining agent. On the other hand we shell molding. on the other hand, for shell casting, it is noted that in the presence of the modifying agent that there is a presence of aluminum dendrites which, based on the phase equilibrium diagram should not be present (alloy hypersilicon). in the second part we note that from 0.3% of the eutectic modifying agent changes morphology. moreover, the modifying agent acts as a refining agent for a rate of less than 0.5%. It therefore allows the primary Si to be refined in addition to the eutectic, which improves hardness.

IV. CONCLUSION

At the end of this work, we were able to establish some optimum rates: namely a rate of 0.5% modifying agent and a rate of 0.8% refining agent. We have noticed the overall degrading effects of the refining on the mechanical strengths and the microstructure. On the other hand, the modifying agent proves to be effective because from the rate of 0.5%, we obtain a suitable microstructure, which improves the mechanical resistance.

In a more general way, we were able to determine the effects of refining and modification treatments on a hypersilicon aluminum alloy which was relatively little known until then.

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