STRUCTURAL ANALYSIS OF ALLOY Al-2,5 Mg SOLIDOFY THROUGH THE PROCESS SQUEEZE CASTING

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ABSTRACT

The Squeeze Casting process is an innovative process in the foundry, this that often comes to be considered one of the oldest, or even the most versatile process for manufacturing metal components. The Squeeze Casting process within the casting of Aluminum Alloys and Magnesium modifies the structure of the metal compared to the conventional method, where the metal is poured in the liquid solidified under pressure within a closed metal tube material by a puncture, this pressure varies eutectic reaction of the solidifying metal. A disadvantage of conventional casting processes is the formation of bubbles, pores, defects and macro segregation Shrinkage which directly influence the mechanical properties of cast products. This study examined the structural modification of the Alloy Al-2,5wt% Mg solidifying liquid metal under pressure: ambient pressure, 40, 80 and 120 MPa in a ASTM 1045 steel ingot for an estimated time of 30 seconds to load. It was observed that the pressure exerted influence on the macrostructure decreasing the presence of casting defects in the final microstructure, increasing the pressure decreased the secondary dendrite arm spacing, thereby being observed an increase in cooling rate. This process helped to obtain an Al-Mg alloy without macro-defects, where with increasing pressure and increases its rate of cooling possible to obtain a finer microstructure.

Keywords: *Squeeze Casting, structural analysis, Alloy Al-2,5 Mg.*

1. INTRODUCTION

Among the methods of production of metal parts, casting is one of the oldest, if not the most versatile process for manufacturing metal components. The various casting processes allow producing millions of parts from small size to a few parts weighing several tons. Among all the known methods of casting and squeeze casting has to be highlighted among the innovators.

The squeeze casting process is basically the solidification of metal in a metal mold under the application of high pressure combining quality, economy and simplicity. The process tries to combine the advantages of casting and forging technologies. The pressure applied and the instantaneous contact metal - liquid mold surface creates a condition of rapid heat transfer and produces a number of open pores and fine-grained, this number has mechanical properties close to those of a forged product combined with the forms and low cost of castings [Dorcic and Verma,1998;] Ferreira,1999].

In general there are two types of squeeze casting: direct and indirect pressing [Hu, 1998]. The technique of direct pressing is characterized by the imposition of pressure directly on the total surface of the piece, providing maximum density and an extremely rapid heat transfer resulting in a fine-grained material with excellent mechanical properties.

Currently, components of aluminum alloys, copper, magnesium, iron, stainless steels and nickel based super alloys are easily manufactured by squeeze casting [Hu, 1998]. Applications include automotive components such as pistons, brake discs, wheels and hubs, missile components and gears [Dorcic and Verma,1998]. Recently, the squeeze casting technique has been widely studied for use in the manufacture of metal matrix composites, especially in magnesium alloys, aluminum and copper [Rohatgi, 1988].

The Alloy Al-2, 5wt% Mg seconds [Alcan, 2001] are widely used for its characteristics of mechanical strength, storage tanks, boats, vans and bus bodies, Shutters, commonly used in printing and more. View these range applications in various sectors of engineering and heavy dependence on the properties of metals and their particle size, casting method and chemical composition. The attempt to add the method of solidification pressure (squeeze casting) in order to obtain this league was inevitable.

This work aims at an analysis of the influence of pressure on the macrostructure and microstructure of the Alloy Al-2, 5wt% Mg solidified through the process "Squeeze Casting" by different pressures.

2. MATERIAL AND METHODS

2.1. Material

For the production of the Alloy Al-2, 5wt% Mg were used commercially pure materials considered. This study analyzed the structure of the alloy when solidified under pressure from macrostructure to microstructure analysis. The alloy was obtained by fusing the aluminum with a superheat of 700 ° C providing enough energy for the diffusion of magnesium in their addition, which occurred outside the smelter. Subsequently the alloy was remitted and then poured the ingot under the press where it was carried pressurization. The analysis of macro and microstructure was performed in all ingots, even for the sake of better comparative analysis.

The determination of the mass quantity of alloying elements and then merge them occurred through calculation based on Equation (1) [Callister, 2006], which takes into account the density of each element, solute concentration in the league, and total volume Alloy.

Equation (1) shows the calculation performed to obtain the value of the mass of magnesium and aluminum Alloy for fabrication.

2.2 Process Parameters

To perform the experiment we used a ASTM 1045 steel ingot with the following dimensions: external diameter 115 mm, internal diameter 55 mm, external height 145 mm and 90 mm internal height, as shown in Figure 1.

With use of a SiC crucible model Salamander AS8 metals were melted and homogenized. The ingot was removed from the support and pre-heated to a temperature of 300 ° C in muffle furnace, the molten metal was poured at 700 ° C for the punch was adopted 100 ° C temperature achieved by heat exchange / Lancing ingot mold prior to casting. The time pressure applied immediately after the casting of metal in the ingot was 30 s.

To exert the necessary pressure to the process used a hydraulic press HIDRAUMAX PEH 100 with a maximum capacity of 400 MPa, where pressures have been applied to ingots Environment, 40, 80 and 120 MPa.

The Figure 2 shows how the assembly was the experimental system and placement of thermocouples in the ingot and the puncture for monitoring the temperature of process parameters using temperature recorder.

2.3. Microstructural and macro structural analysis

Analysis for both the ingots were used sandpaper water granulation of 100, 200, 320, 400, 600, 800 and 1200 mesh, polished on polishing dripped with Diamond Polishing Paste-6 microns, so the macrostructure was revealed with chemical attack of Keller's reagent [Brito et al, 2010] (15 ml HF, 15 ml HNO3, 45 ml HCl and 25 ml H2O) was used to measure grain a optical microscope with 800Xclosest approach of the computer-aided software Motic Image Plus 2.0.

In the microstructural analysis, samples were taken from each ingot and then polished to be taken to a SEM (Scanning Electron Microscope) HITACHI TM Model 3000 coupled to an EDX (Energy Dispersive X - ray) Model SwiftED3000, where then the analysis of the microstructure and chemistry was performed on each sample. Variation images of defects and microstructures changed with the variation of pressure were collected.

2.4 Mathematical equations

$$m_{Al} = \frac{C_{Al} \times V \times d_{Al} \times d_{Mg}}{((C_{Al} \times d_{Mg}) + (C_{Mg} \times d_{Al}))} \qquad \text{Equation (1)}$$

Where:
C = concentration
V = volume of material
d = density
Al = aluminum
Mg = Magnesium

2.5 Figures

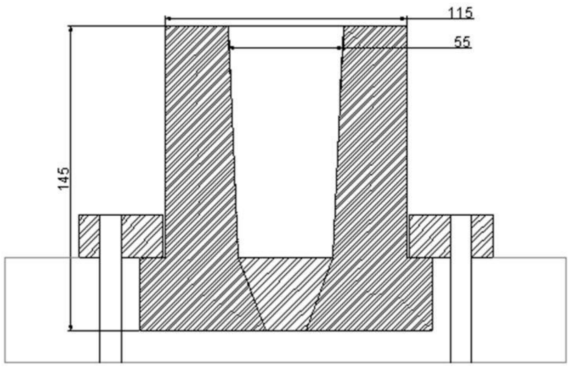


Figure 1 - Layout of the casting used in the research.

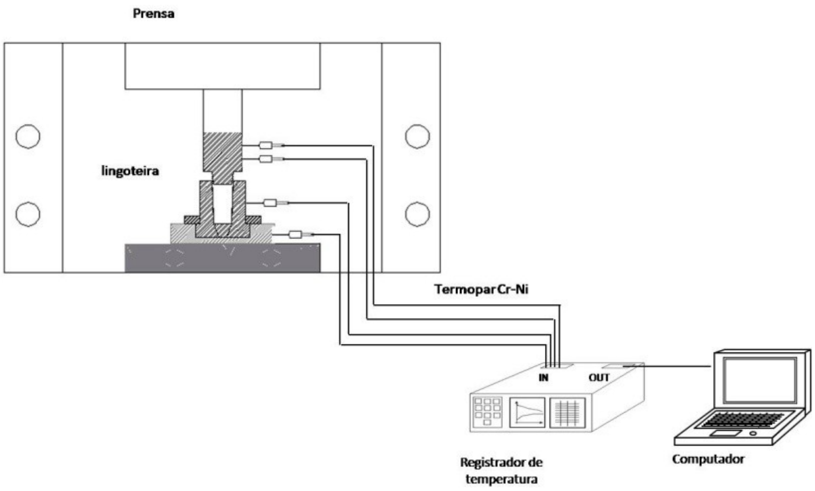


Figure 2 - Position of thermocouples to obtain temperature.

3. RESULTS AND DISCUSSION

3.1. Chemical Analysis

The chemical analysis of the Alloy Al-2,5wt% Mg collected by means of EDX in samples taken from each ingot. There was a range of up to1% more or less of composition, such a change from possibly sound vibration or mechanical, Chart 1, given the great sensitivity of these equipment.

The analysis was performed on samples taken from different points of each ingot, from then analyzed and compared with no significant variation. Having general composition as expected at the beginning of the analysis, Al-2, 5wt% Mg.

3.2. Analyze macrostructural

• Macrostructure by alloy

The Alloy Al-2, 5wt% Mg showed equiaxed grain structure refined as the course structure predominant. Com of increased pressure on the solidification of the Alloy, there was a slight variation in the size of grains at this composition. All ingots were also a small percentage of chill zone and does not vary significantly with solidification without pressure and with pressure as shown in Figure 4.

The percentage of area was controlled chilled possibly due: the leak to be carried out with an overheating combined with a considerable heating of the mold which forms a small chill area or even nonexistent [Garcia, 2001]. The convection currents formed in the casting to 700 ° C also caused the detachment of most of the grains formed and chilled recast within the Alloy would form a well chilled small area, possibly from the potential nuclei of mold and a heat diffusivity higher than the liquid [Garcia, 2001].

Applying pressure in the Alloy led to a rise in the rate of heat transfer by reducing the solidification time in which aluminum could be reduced by half [Hu, 1998], there by preserving the solidification occurred chill zone formed within the range expected for pressurisation (time between the leak and pressure application).

The non-presence of the columnar ingot without pressure was the second [Muller, 2002]: due from the concentration and potential of the solute nuclei accompanied by the size of the ingot cross section for large ingots decreases the effect of overheating with the heat exchanging surface and increasing the formation of grain equiaxiais. In the case of ingots solidified by squeeze casting, in addition to the factors mentioned above, the addition of pressure provides mechanical agitation and rapid solidification rate, adding that with the previous factors makes it impossible for the columnar growth.

• Grain Size

With use of ASTM E 112/88, it was possible to obtain the grain size for all different ingots. In practice metallographic measurement of "grain size" view of their geometric irregularities, generally refers to the average of measurements that are necessary so that we can get an approximate diameter of the grain. According to the procedures described in the Standard took place 20 measures for each grain selected as the example in Figure 5.

The grains had a degree of refinement in their measurements, with the increase of pressure during solidification of the League, explains how the average grain size shown in Figure 2 and its standard deviation in Table 1.

With the addition pressure there was a grain refining, this possibly due to mechanical agitation provided by the additional pressure that eventually produced greater dynamic nucleation and thereby increasing the number of nuclei forming grains, which generates a higher percentage of grains per volume of solid in the play.

• Defects in the macrostructure

Because the parameters in the process of solidification of the Alloy, the macro-structural changes were more evident as the rechupe, occurring only in the solidified ingot without pressure and fading to the other ingots.

In the solidified ingot no pressure is present primary inclusions, possibly coming from oxides great view of ease in oxidation of magnesium and exogenous fragments Fusion System / Leak, what this made the occurrence of macrosegregation in normal gravity and macrostructure of the piece being shown both centrally and in rechupe..

The solidified the other pressures showed only the occurrence of macro segregation normal, due to a fast solidification rate experienced by the Alloy, possibly due to excessive pressure offered, causing an instantaneous increase of the Melting point, greater contact between metal / mold and also increasing rate of heat transfer which reduces the range of solidification. With increased speed of processing liquid / solid ends in not providing a possible shift of gravity segregation.

Presence of surface defects such as pores and defects were not found in Shrinkage macrostructure of the alloy. What caused a lower rate of macro-structural defects in the Alloy Al-2, 5% Mg ingot solidified even when no pressure, except rechupe.

3.3. Microstructural Analysis

Microstructural analysis in the presence of major defects occurred possibly due to: strong oxidation tendency of aluminum alloys -Magnesium, moderate trend of casting defects, shrinkage characteristic of aluminum and the presence of exogenous fragments in the system Fusion /Alloy casting [Hu, 1998].

The microstructure of all ingots showed a certain percentage of micro segregations as can be seen in Figures 6(a);7(a),(d) e 8(a),(b). A chemical analysis was performed using the EDX and a small percentage change of elements was found, as shown in Figure 9 and Chart 3, chemical analysis result is derived from an average of percentage changes in all analyzed images.

This defect in large percentage when the cause preventing the movement of dislocations and thus causes brittleness of the metal in its conformation.

The elements found in macro segregation than aluminum and magnesium, as showed the chemical analysis of the chart 3 are the oxygen and silicon, possibly from exogenous fragments of the strong trend of oxidation of magnesium and silicon at high temperatures comes from the use of SiC in the crucible of molten Alloy.

In case of figures 7 (b) and 8 (c) confirmed the presence of a certain percentage of carbon than the other items already found in other additions, this coming from the crucible fragments (SiC)used. Soon this became possibly responsible for the visual difference from one type of structure with micro segregation more fragile and brittle, giving up some degree of cracking as seen in the images.

The presence of micro pores in the matrix Al-2, 5wt% Mg occurred only in the solidified ingot without pressure as shown in Figure 6 (b), these micro pores present in the contours and even in individual grains is due to the contraction characteristic of metals and very evident in aluminum alloys. The other ingots showed no micro pores in the analysis possibly due to the thicker sections of the piece, where there is a higher probability of occurrence of porosity, the pressure causes the liquid metal that is found in hot spots is moved to fill the pores that are forming, thus preventing its development [Ferreira,1999; Rohatgi, 1988].

In the case of the appearance of dendrites Figures 6 (c) and (d) 7 (d), 8 (d) and 9 (b) show the occurrence in all the ingots, and offering possible pressure beyond the fragmentation of primary dendrites , provided a fast speed of solidification at the interface solid / liquid and among other parameters that decreased the secondary dendrite spacing and size of dendrites formed within a higher pressure. This behavior of the structure can be explained by the relationship between the speed at which the solidification proceeds and secondary dendrite spacing, which tends to increase with decreasing cooling rate [Cruz et al, 2007].

The larger dendrites found, Figure 7 (a) and (c), even greater than those found in the solidified ingot without pressure, were observed in the inclusions present in all ingots and this possibly due to a dendritic morphology within these more favorable to growth than in the proper morphology of the matrix Alloy[Garcia, 2001].

3.4 Figures and Charts

- **Chemical Analysis**

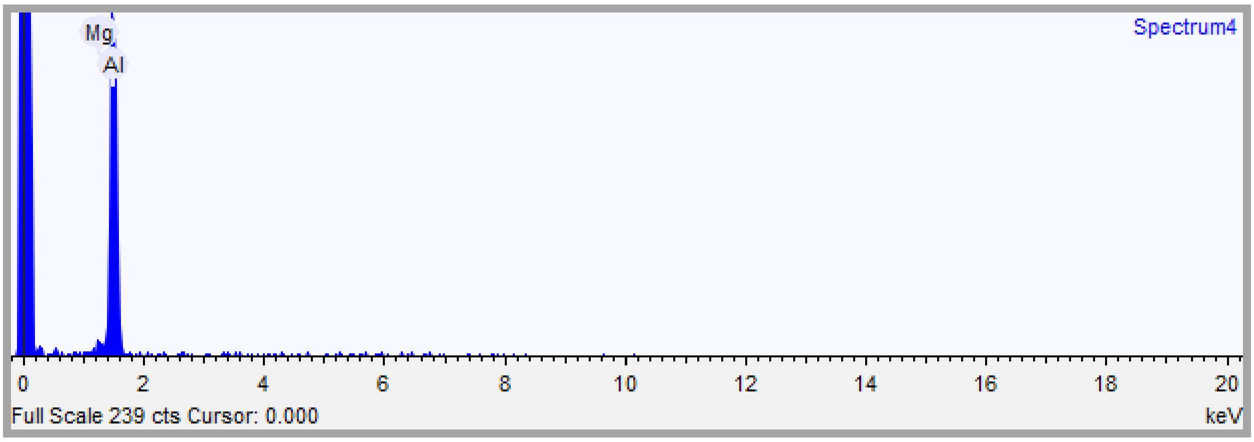


Figure 3 – Spectrometer of the Alloy Al-2, 5wt% Mg

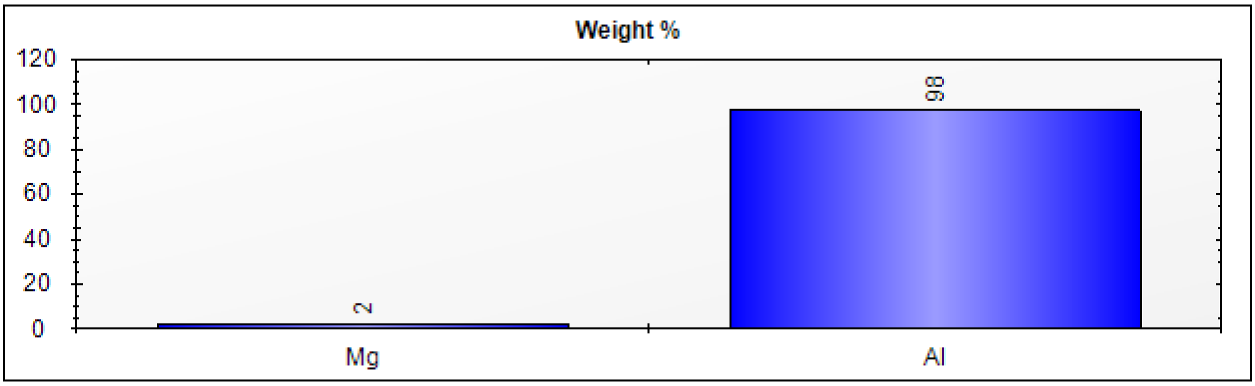
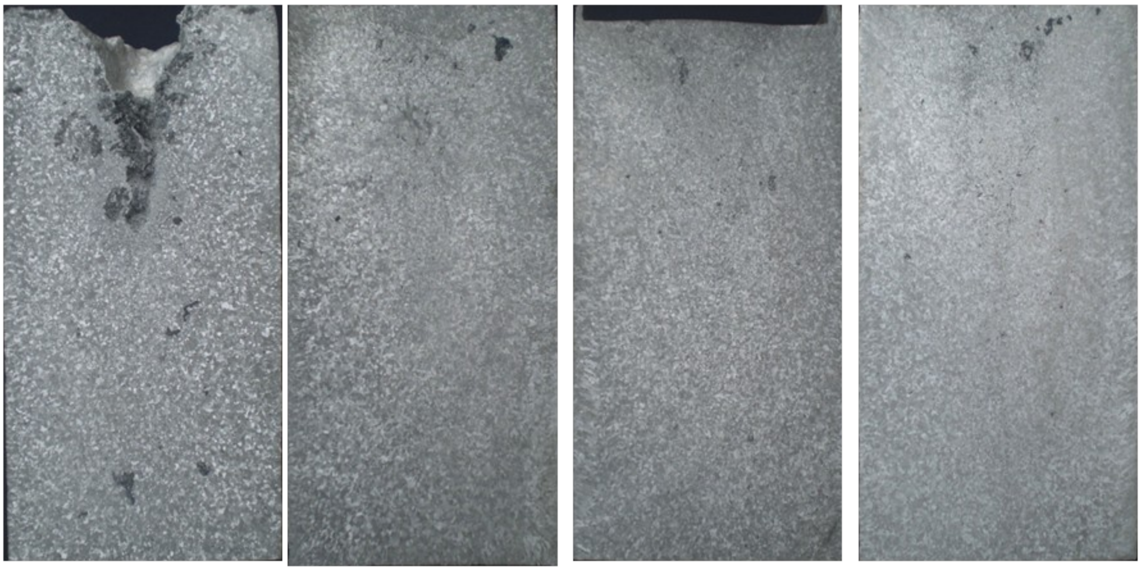


Chart 1 - Composition of the Al-2, 5wt% Mg

- **Macrostructural Analyze**



(a) (b) (c) (d)

Figure 4- Macrostructure Alloy Al-2, 5wt% Mg: (a) Without pressure, (b)40 MPa, (c) 80 MPa and (d) 120 MPa.

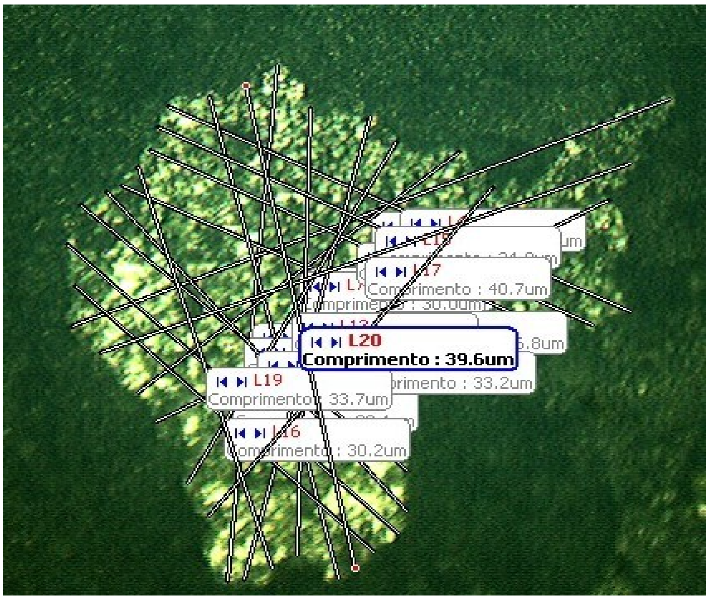


Figure 5 - Measurement of grain

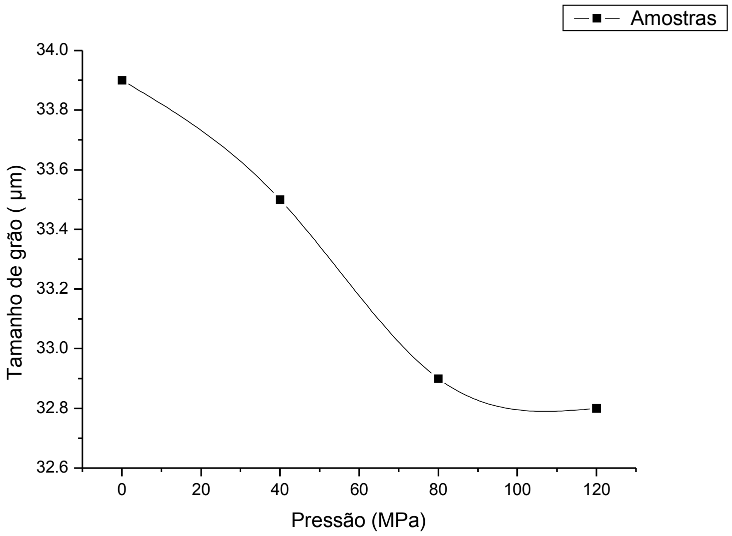
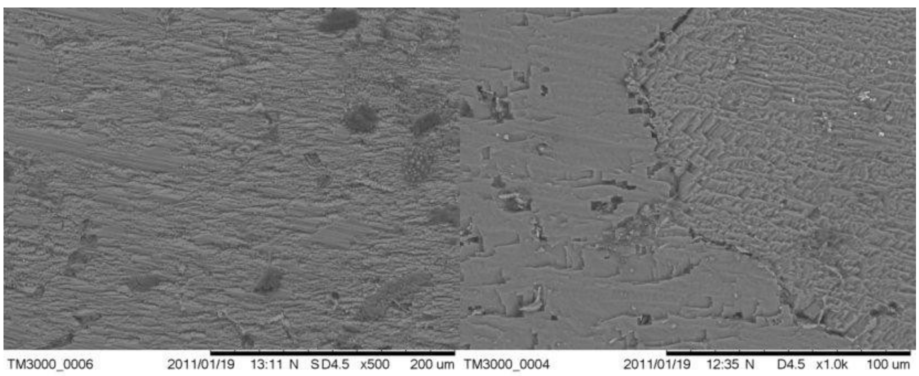


Chart 2 - Variation of grain size

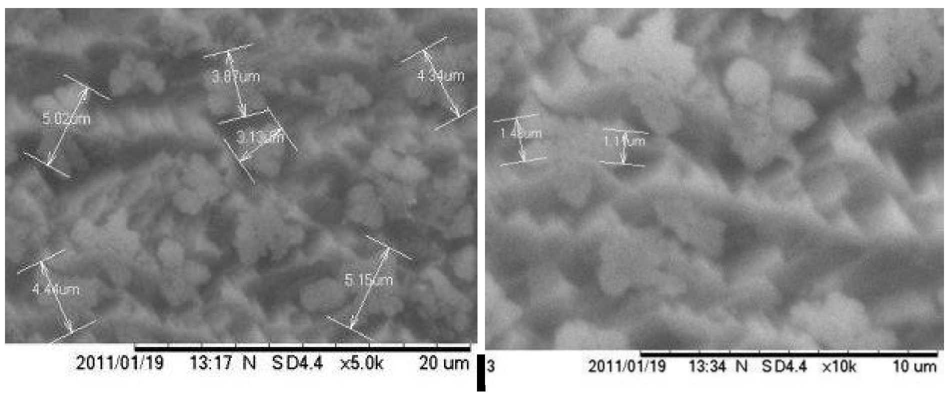
Table 1. Standard deviation of grain size.

SAMPLES SOLIDIFIED	STANDARD DEVIATION (µm)
Without Pressure	16.42
40 MPa	13.56
80 MPa	12.79
120 MPa	11,33

- **Microstructural Analysis**

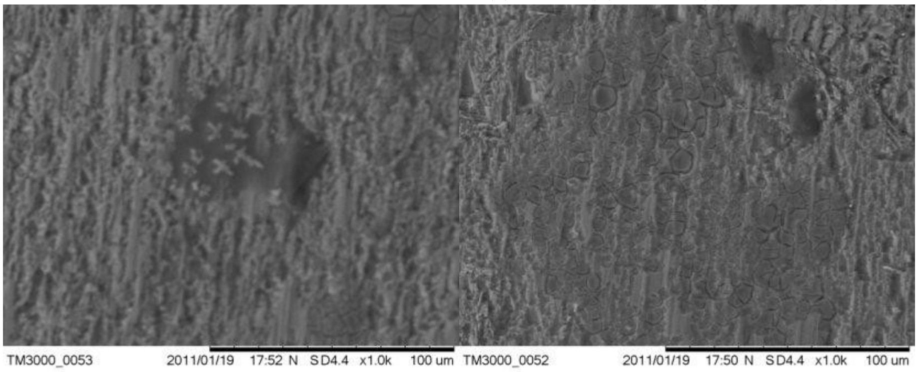


(a) **(b)**

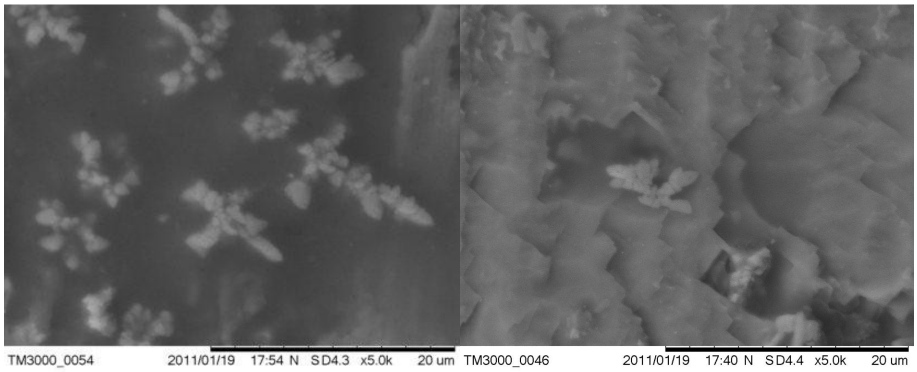


(c) **(d)**

Figure 6 - Microstructure solidified Without Pressure (a) 500X (b)1000X (c) 5000X (d) 10,000X. MEV

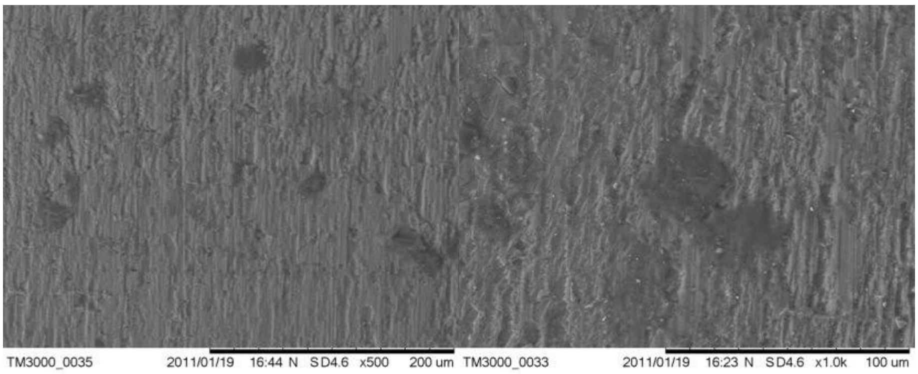


(a) **(b)**

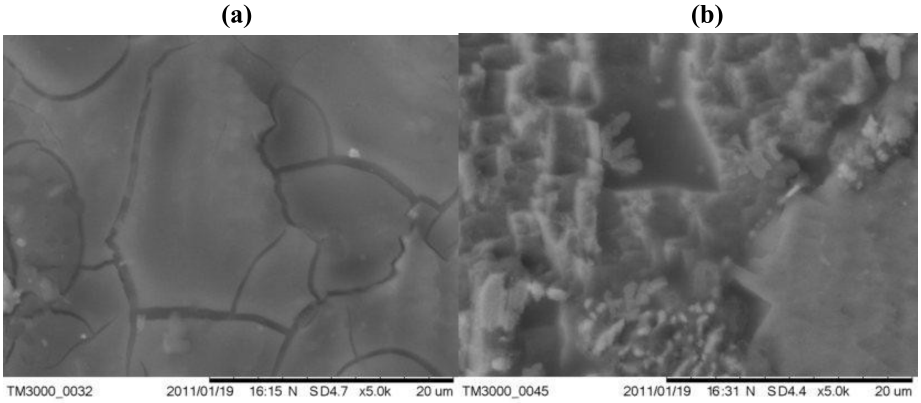


(c) **(d)**

Figure7 - Microstructure solidified with pressure of 40 MPa (a) 1000X (b) 1000X (c) 5000X (d) 5000X. MEV

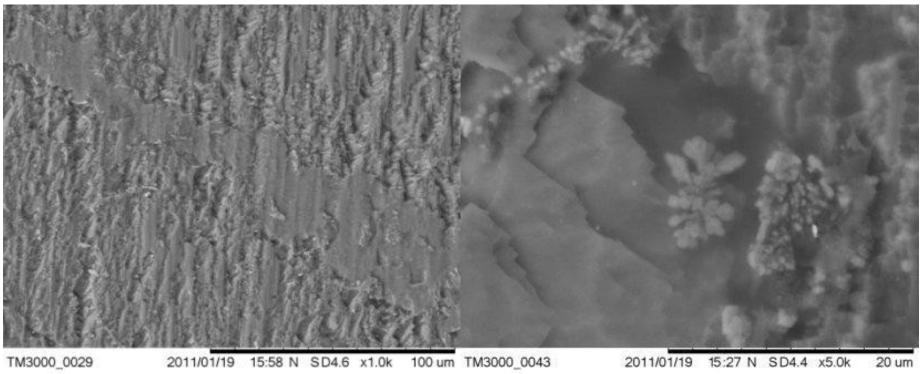


(a) **(b)**



(c) **(d)**

Figure 8 - Microstructure solidified with pressure of 80 MPa (a) 500X(b) 1000X (c) 5000X (d) 5000x. MEV



(a) **(b)**

Figure 9 - Microstructure solidified with pressure of 120 MPa (a) 1000X (b) 5000X. MEV

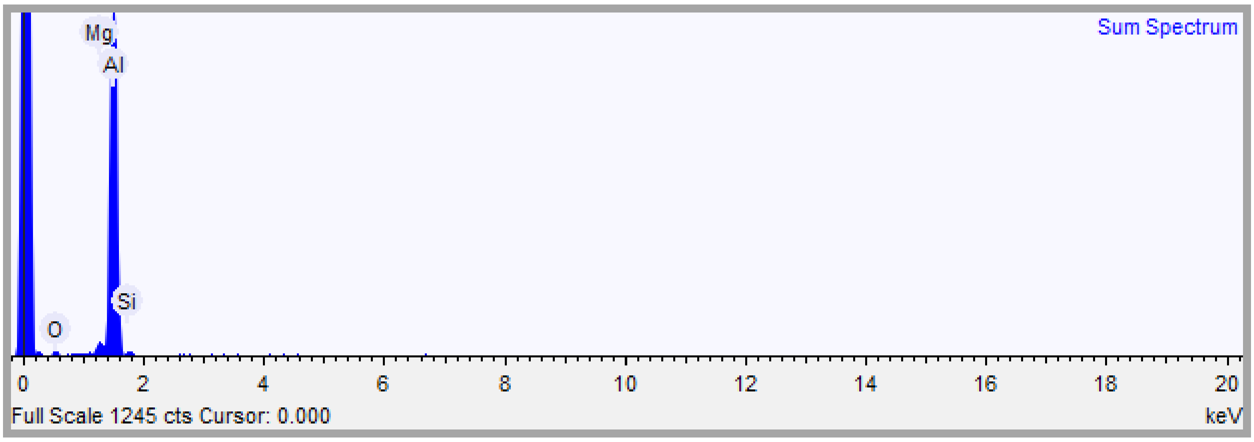


Figure 10 - Spectrometer inclusions of the Alloy Al-2, 5wt% Mg

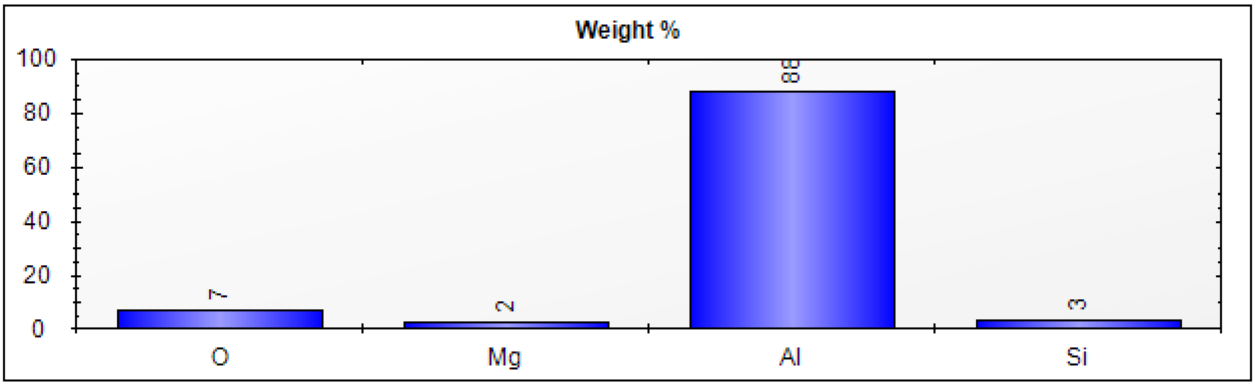


Chart 3 - Composition of inclusions of the Alloy Al-2, 5wt% Mg

4. CONCLUSIONS

Based on the results of this work, we can conclude that:

- The solidification of this alloy using the direct method Squeeze Casting and parameters available, exerted influence on the elimination of casting defects thus enabling a low percentage of pores, gas bubbles and shrinkage in the macrostructure of the solidified alloy when compared with ambient pressure. The size of the grains also showed variations, decrease in size was observed with increasing pressure.

- The solidification of the Alloy Al-2,5wt% Mg generally showed a significant change in the structure of the grains, verifying preferably equiaxed structure. In the case of grain size, a measurement that occurred in their areas decreased progressively with the increase of pressure.
- The emergence of macro and micro segregation became evident, however did not show much change compared with their occurrence in the compositions and structure with the variation of pressure.
- In the case of the microstructure: the micro pores, the dendrites, and inclusions aroused great curiosity, allowing even say they are among the most important changes caused by varying pressure, so there is the disappearance of the first, reduced size of dendritic and the appearance of dendritic morphology in the largest inclusions compared the morphology of the matrix Alloy.

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6. RESPONSIBILITY NOTICE

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