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EVOLUTION OF THE MICROSTRUCTURE OF AL-ZN ALLOYS MANUFACTURED BY THE SQUEEZE CASTING PROCESS

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Abstract. *The squeeze casting process is a casting process in which the molten metal in the liquid state is solidified under pressure into a metal mold closed by a punch. In general, components made by squeeze casting have fine granulation, excellent surface finish and almost porosity free, the same can be of different sizes and shapes, the mechanical properties are significantly increased compared to the traditional casting method and, in addition. Parts manufactured by squeeze casting possess have superior weldability and are suitable for heat treatments, and finally compared to gravity casting, parts manufactured by squeeze casting are formed in a single operation with a lower power consumption. The objective of this work is to analyze the influence of the pressure as well as the zinc content of alloys in the secondary dendritic spacing. The Al-1% Zn, Al-3% Zn and Al-5% Zn compositions by weight were used for this purpose, solidified with the squeeze casting process using the pressures of 0 MPa, 50 MPa, 100 MPa and 150 MPa, with a pressing time of 5 seconds. It is observed that in general the increase in pressure causes a decrease in the secondary dendritic spacing up to the pressure 100MPa, from this point variations of up to 150 MPa cause increase in the secondary dendritic spacing.*

Keywords: *squeeze casting, Al-Zn alloys, microstructure.*

1. INTRODUCTION

The foundry is one of the oldest and most versatile manufacturing process of metal components.. The various casting processes allow to produce from millions of pieces of small size to few pieces weighing several tons. Metals have played an important role in the development of human civilization. In this development there was no metal, other than steel, as versatile as aluminum, because of its unique intrinsic characteristics (Murakami, 1985, 1991).

In 1981 the American Foundrymen's Society listed 38 different casting methods (Kanicki, 1988), which are grouped into five major categories; one of these categories being that of innovative molding and casting processes. Within these innovative processes highlights the squeeze casting process literally cast by tightening (compression), also known as liquid metal forging, extrusion casting or pressure crystallization (Hu, 1998). The squeeze casting process basically consists of the solidification of the metal in a metal mold under the application of high pressures.

In the squeeze casting process, the metal, upon melting and pouring, solidifies under pressure into a permanent mold positioned between the plates of a hydraulic press, as shown schematically in Figure 1:

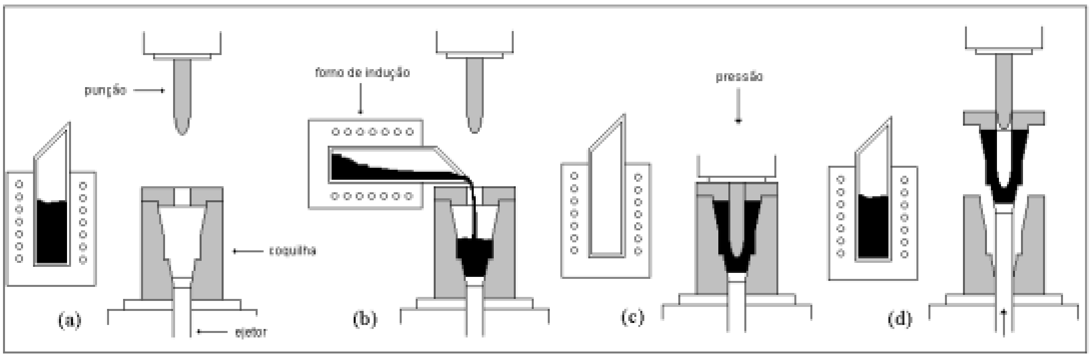


Figure 1 Schematic representation of the squeeze casting process

Pure aluminum has some attractive properties such as low density, about 2.7g / cm³, high corrosion resistance even in environments such as salt water, excellent thermal and electrical conductivity which leads to applications in heat exchangers, evaporators, heaters, cylinders and automotive radiators, highly reflective surface, high ductility, allowing its use in many forming applications, low toxicity being applied in packaging for food products. Some aluminum alloys may overcome the strength of some structural steels, though pure aluminum and some aluminum alloys exhibit relatively low mechanical strength. Its main limitation is the low melting temperature (660 ° C), which restricts its application to high temperatures, but which can still be seen as an advantage, since melting of the alloy at low temperatures means a relatively low energy consumption.

All industries, especially aerospace and automotive, are currently looking for light alloys or alloys whose properties are favorable as high mechanical strength values in counterpart with low weight, good ductility, hardness, corrosion resistance, among others. In addition to its low weight, there are other advantages of aluminum alloys which include relatively low melting point, good meltability, good machinability, good surface finish and high thermal and electrical conductivity.

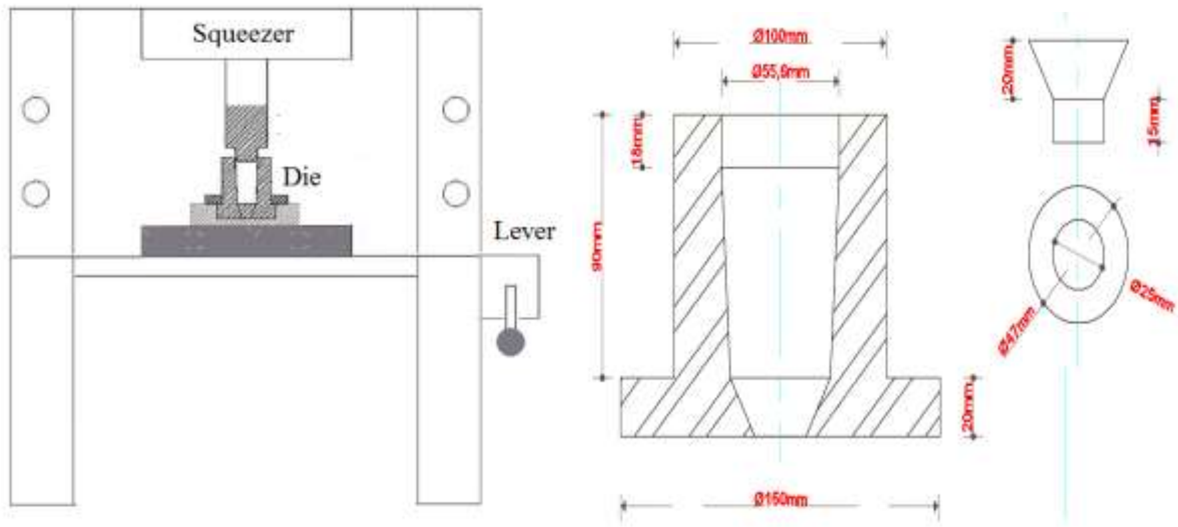
The Al-Zn system is very convenient, and particularly attractive for the study of microstructures and phase transitions, especially in the supersaturated state. The solubility of zinc in aluminum is the highest among all elements, obtaining a maximum of 67% (molar fraction) at 654K. This is due to the fact that zinc and aluminum do not form intermetallic phases, that is, the interaction between aluminum and zinc is relatively weak (Zeljko, 2009).

Zinc as an alloying element is used to increase the strength of the alloy, although it is necessary to add a surface protection, these alloys are used when the strength / weight factor is the main one. In addition, Al-Zn alloys can be produced with lower energy consumption due to their low melting point 692.5 K (MONDOLFO, 1976).

2. EXPERIMENTAL PROCEDURE

12 ingots were obtained with three different compositions being Al-1% Zn, Al-3% Zn and Al-5% Zn, solidified under the pressures: 0 MPa, 50 MPa, 100 MPa and 150 MPa, weighing about 450 g each. To obtain the ingots, the aluminum was first melted in a silicon carbide crucible, internally coated with a layer of alumina in a muffle furnace, and then the zinc was added.

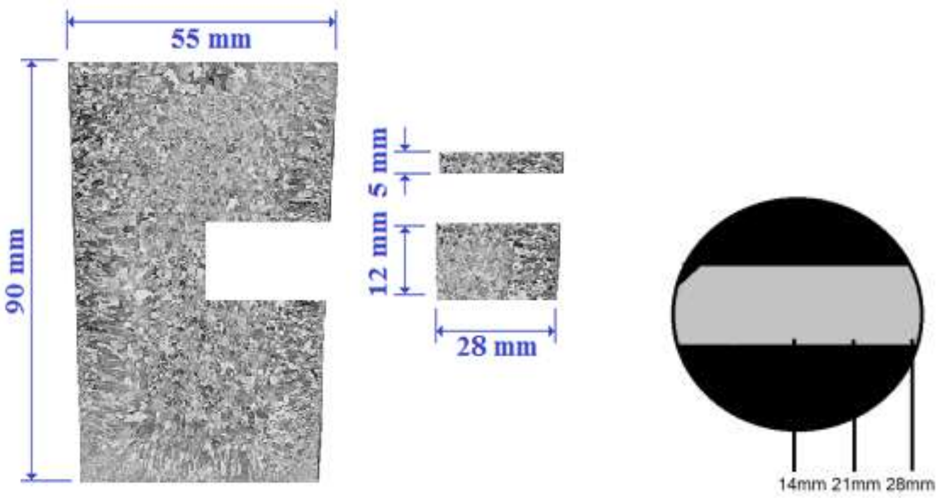
After the zinc was added after a 40 minute interval, the crucible was removed from the furnace for slag removal and then a 1.5 mm diameter type K thermocouple was inserted for monitoring the temperature after the temperature reached leakage temperature corresponding to 983K (7.5% of overheating). The alloys were cast in the 1020 steel ingot with its dimensions shown in Figure 2 b). Immediately after the casting, the pressure was applied with a semi-automatic hydrostatic press with a capacity of 60 tons according to the schematic drawing of figure 2 a). the pressure is maintained for five seconds, being relieved soon after resulting the ingot ready.



a) b)

Figure 2 a) Schematic representation of the press and the billets b) dimensions of the billets

For measurement of the secondary dendritic spacing, the ingot was sawn in half longitudinally, then a further longitudinal cut was made in one of the halves by removing a slice of approximately 7 mm thick, from that layer a rectangular portion was taken from the center of the ingot , finally the rectangular part was cut in the middle, and the sample used in the measurements was one of the two symmetrical halves of the rectangular part that is embedded to be sanded. This process is represented schematically in Figure 3:



a) b)

Figure 3 - a) Position of the sample in relation to the ingot b) Position of the measurements with respect to the sample.

After the inlays the samples were sanded with the granulometries varying from 100 to 1200 mesh and then polished with alumina in solution. After polishing, the sample was attacked with the Keller solution of composition: 50% water, 25% nitric acid, 15% hydrochloric acid and 10% hydrofluoric acid.

The secondary dendritic space was obtained based on the methodology used in solidification studies of the Al-Cu system (Güduz, 2000) and shown schematically in Figure 4:

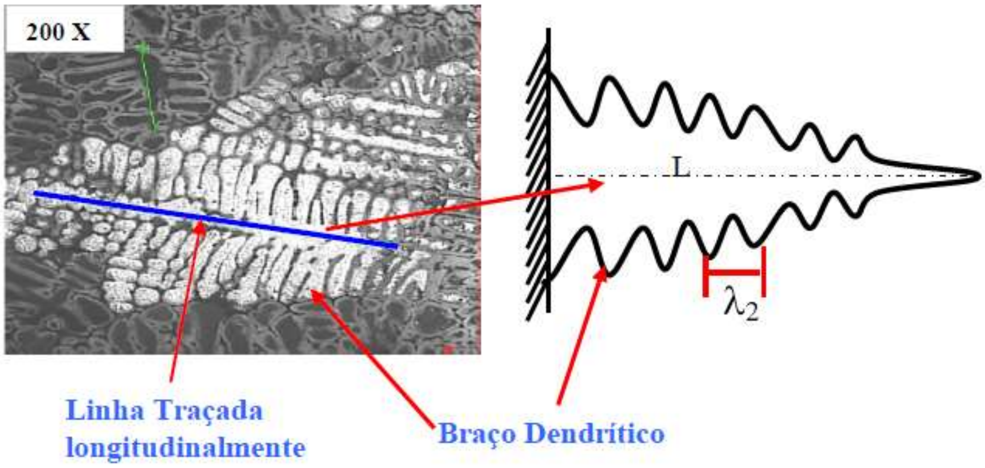


Figure 4 - Micrograph showing the methodology used to measure secondary dendritic spacing.

Following the scheme shown in Figure 4, the dendritic spacing is defined by equation (1):

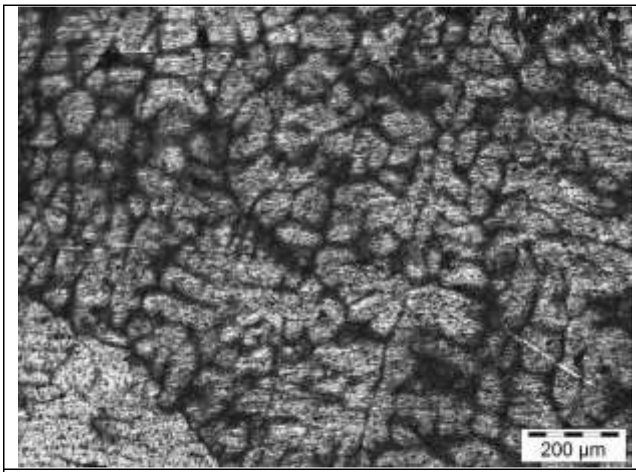
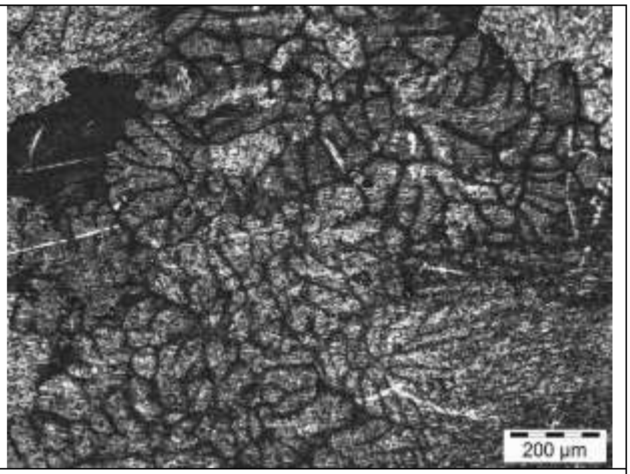
$$\lambda_2 = \frac{L}{(n-1)} \qquad (1)$$

Where is the secondary dendritic spacing, is the number of arms intercepted, and L is the segment length, where n = 3 was used. Following the methodology described, secondary dendritic spacing measurements were taken, where measurements were taken in three regions of the specimens located at 14 mm, 21 mm and 28 mm from the edge of the ingot, and then averaged the measurements. Figure 3 b) shows the regions where measurements of the dendritic spacings were made:

3. RESULTS AND DISCUSSIONS:

Table 1, 2 and 3 show the values obtained in the measurements of the secondary dendritic spacing for alloys Al-1% Zn Al-3% Zn and Al-5% Zn solidified with pressure variations of 0 MPa, 50 MPa, 100 MPa and 150 MPa.

Table 1 - Secondary dendritic spacing for alloy Al-1% Zn a) Ambient pressure, b) 50 MPa, c) 100 MPa and d) 150 Mpa

	
a) 0 MPa λ_2 = 62,97 µm	b) 50 MPa λ_2 = 42,70 µm

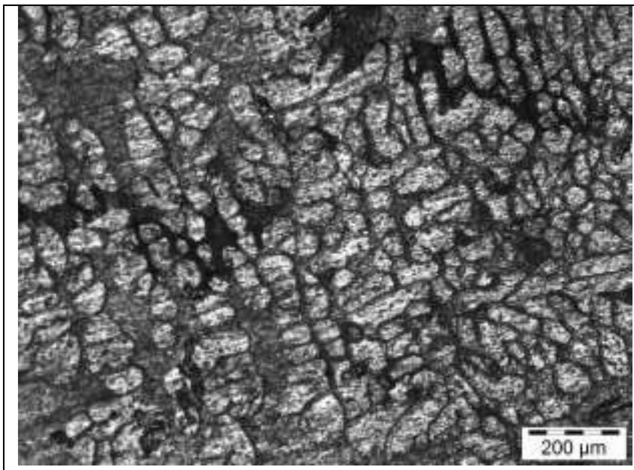
	
c) 100 MPa λ_2 = 39,90 µm	d) 150 MPa λ_2 = 48,79 µm

Table 2 - Secondary dendritic spacing for Al-3% Zn alloy a) Ambient Pressure, b) 50 MPa, c) 100 MPa and d) 150 Mpa

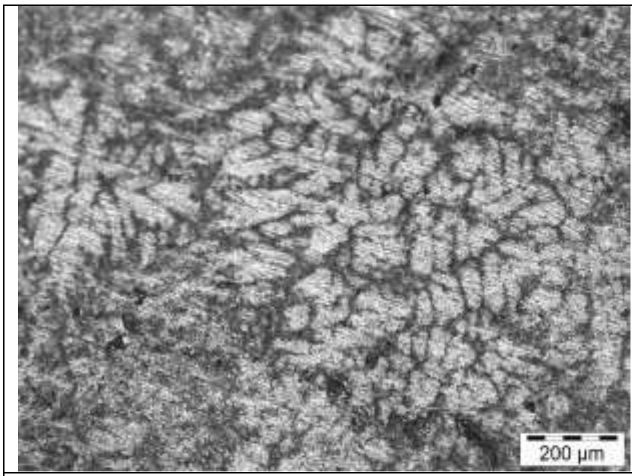
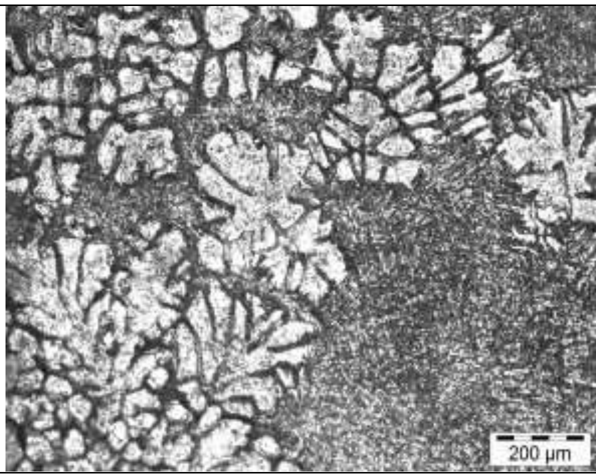
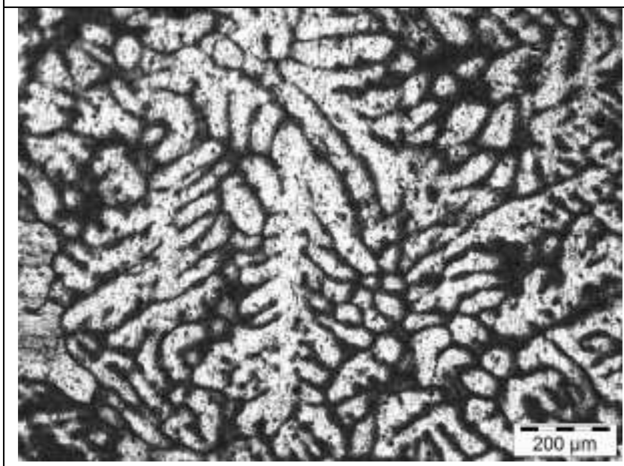
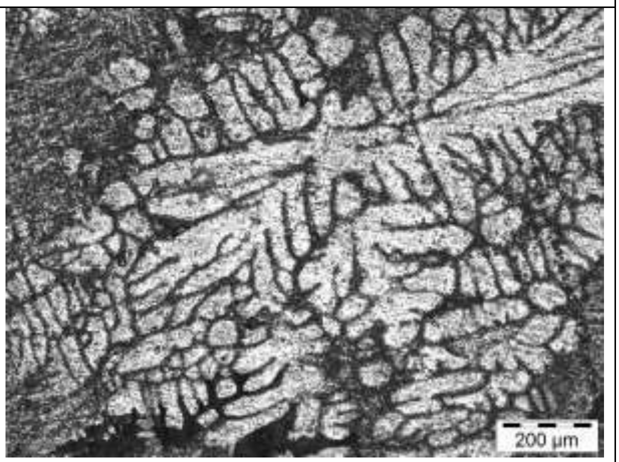
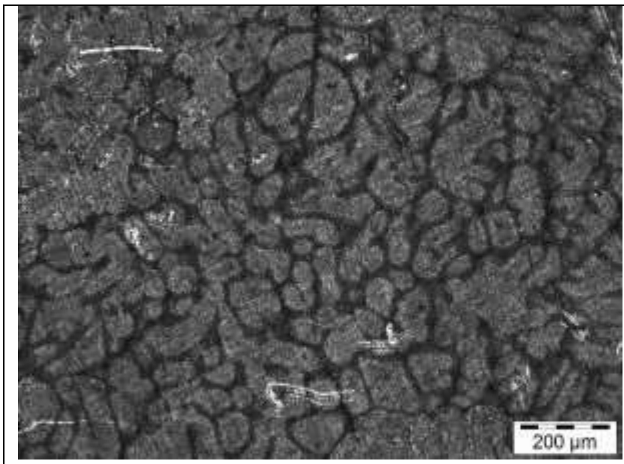
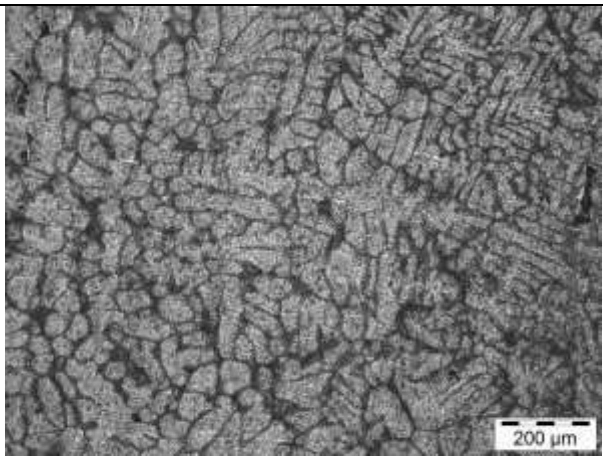
	
a) 0 MPa λ_2 = 42,64 µm	b) 50 MPa λ_2 = 50,12 µm
	
c) 100 MPa λ_2 = 38,87 µm	d) 150 MPa λ_2 = 35,40 µm

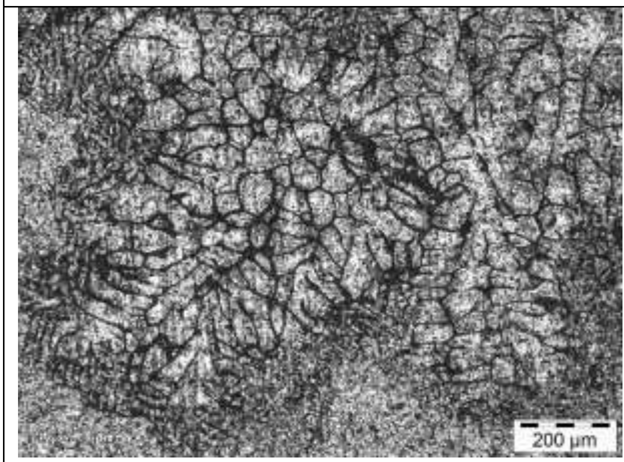
Table 3 -Secondary dendritic spacing for alloy Al-5% Zn a) Ambient pressure, b) 50 MPa, c) 100 MPa and d) 150 Mpa.



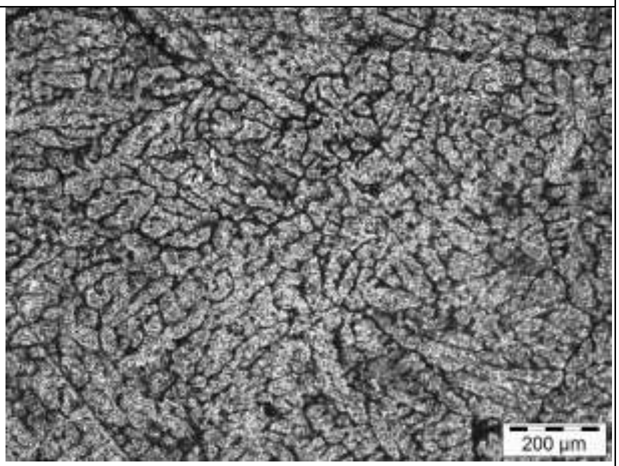
a) 0 MPa λ_2 = 45,76 µm



b) 50 MPa λ_2 = 42,46 µm



c) 100 MPa λ_2 = 34,44 µm



d) 150 MPa λ_2 = 39,28 µm

Figure 5, 6 and 7 show the graphs of the secondary dendritic spacings as a function of the pressure for Al-1% Zn, Al-3% Zn and Al-5% Zn alloys.

Considering the variation of the pressure and according to the graphs of Figures 5, 6 and 7, we note in general that with increasing pressure causes a decrease in secondary dendritic spacing for all compositions, this reduction is verified in the characteristic equations where if it has the same slope (angular coefficient) according to the increase in pressure.

In relation to the solute content, we notice in general that with the increase of the zinc concentration in the alloy we have a decrease in the secondary dendritic spacings, if verified with decrease of the independent term of the equations of the graphs 5, 6 and 7..

For the Al-3%Zn alloy point at the pressure of 50 MPa in the graph of Figure 7, we observe an increase in spacing, this value can be explained by the presence of a shrinkage defect in the ingot referring to this measure, as can be , as shown in Figure 8 (a), the vacuum caused by this defect causes a variation in the temperature gradient, due to a variation in the directions of the convection currents, as shown in Figure 8 (b) (Kattamis & Flemings, 1965)

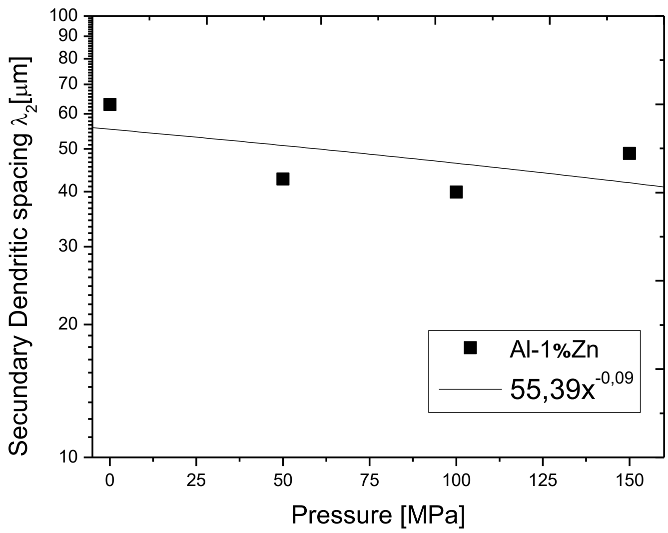


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Figure 5 - Secondary dendritic spacing as a function of pressure for alloy Al-1%Zn

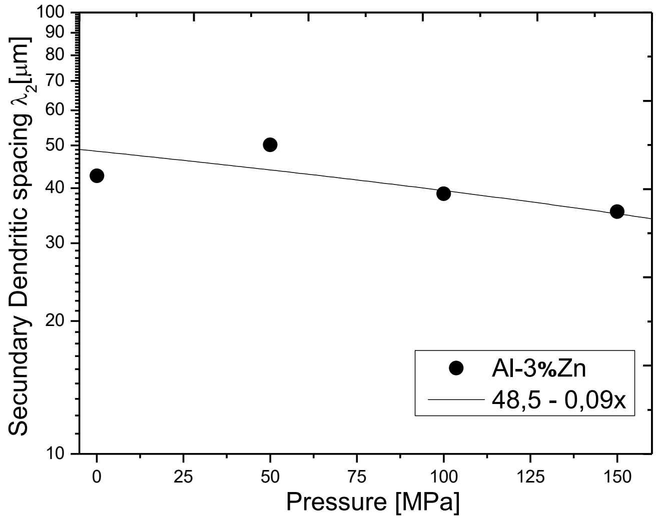

Figure 6 - Secondary dendritic spacing as a function of pressure for alloy Al-3%Zn

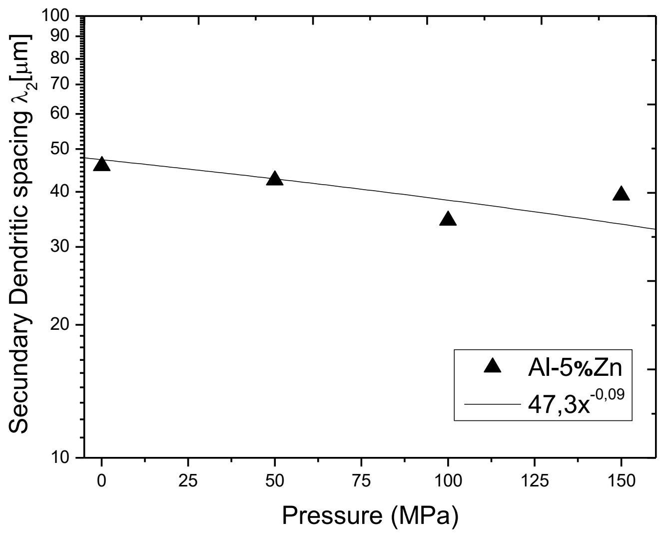

Figure 7 - Secondary dendritic spacing as a function of pressure for alloy Al-5% Zn

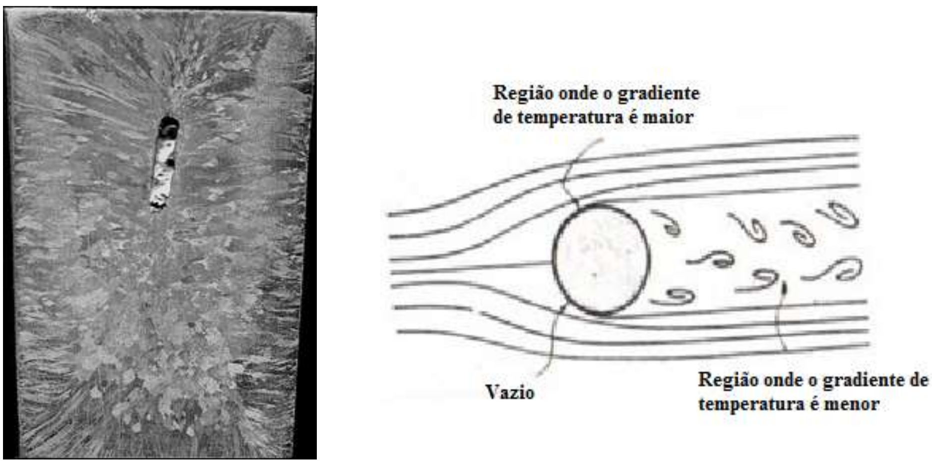

Figure 8 (a) Ingot from where the sample for the Al-3% Zn measurement was taken with further details of the macrostructure can be found in Lima (2014). (b) Schematic representation of a possible variation in the directions of the convection currents.

4. CONCLUSIONS

For the Al-1% Zn, Al-3% Zn and Al-5% Zn alloys, it can be generally concluded that with increasing pressure there is a decrease in secondary dendritic spacings as well as increased composition, this decrease may be through the characteristic equations of the graphs.

We can also conclude that for the ingots that suffered solidification defects, the values of secondary dendritic spacings were higher than expected because of the thermal gradient, prolonging the solidification time and, consequently, increasing the secondary spacing.

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6. RESPONSIBILITY NOTICE

The authors Araújo, F.T; Silva, D.V; Lima, D.F ; Siqueira, C.A; Lima, R. A and Bernardo, R.M are the only responsible for the printed material included in this paper.