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The Directional Solidification of Al-Zn Alloys as a function of the Level of Convective Heat Transfer

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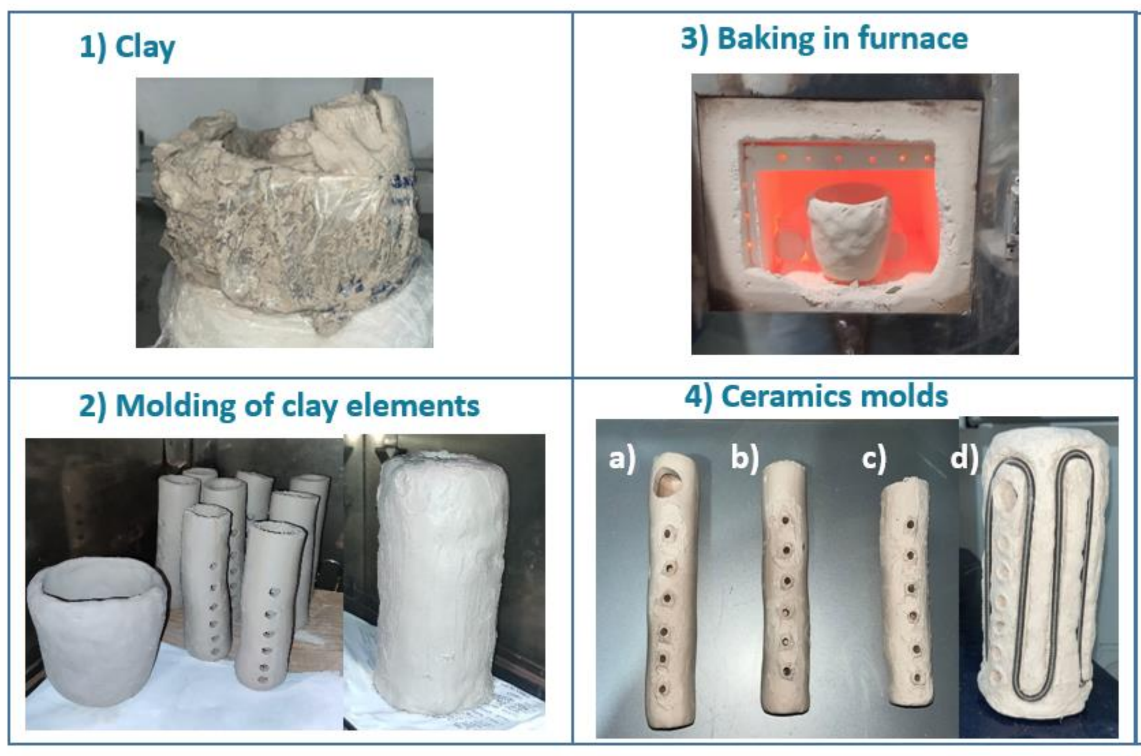
INTRODUCTION & AIM

In this study, an analysis of the directional solidification of Al-Zn alloys using a Brigdman-type rotary directional solidification device is presented. For this purpose, the device can be rotated at three tilt angles (0°, 90°, and 180°). Directional solidification tests were performed with Al and Zn (commercial grade) and with Al-5%Zn and Al-10%Zn alloys (weight percent). The aim is to analyze how the furnace inclination (which generates different levels of convective heat transfer in the solidifying specimen) and the alloy composition influence the cooling rate of the metallic solid, the thermal gradients, and the size of the macrostructure and microstructure present. It has been observed that by varying the furnace inclination angles, for the same composition, the cooling rate tends to decrease; it is also important to highlight that the minimum temperature gradients coincide with the position of the CET. For commercial purity Al, average cooling rates of 2.21 °C/s at 90°, 2.05 °C/s at 45°, and 1.98 °C/s at 0° were obtained for each of the tests. For the Al-10wt. %Zn alloy, average cooling rates of 2.43 °C/s at 90°, 2.14 °C/s at 45°, and 1.99 °C/s at 0° are obtained, with a clear decrease in the cooling rate as the furnace tilt angle is varied. Similarly, when the CET occurs, the critical gradient value is -0.5 °C/cm for Al, 0.1 °C/cm for Zn, 1.4 °C/cm for Al-5wt. %Zn, and -1.2 °C/cm for Al-10wt. %Zn. On the other hand, when analyzing the behavior of Zn, it can be highlighted that the cooling rate values decrease significantly when compared with Al (both commercial grades) and with the Al-5wt. %Zn and Al-10wt. %Zn alloys. These data indicate that the alloy composition and the inclination of the solidification device influence the cooling rate and the thermal gradients.

METHOD

- **The process of shaping, preparing, and firing clay to create ceramic products**



5) Ceramic dimensions

Molds

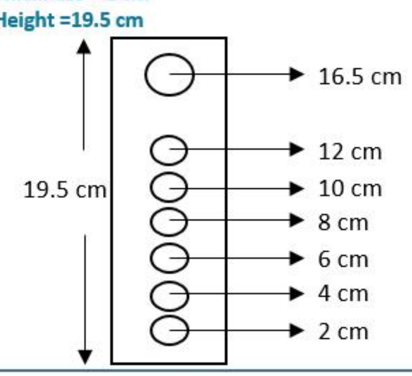
a. Internal diameter = 2.5cm
Thickness = 0.5cm
Height = 12 cm

b. Internal diameter = 2.5cm
Thickness = 0.5cm
Height = 15 cm

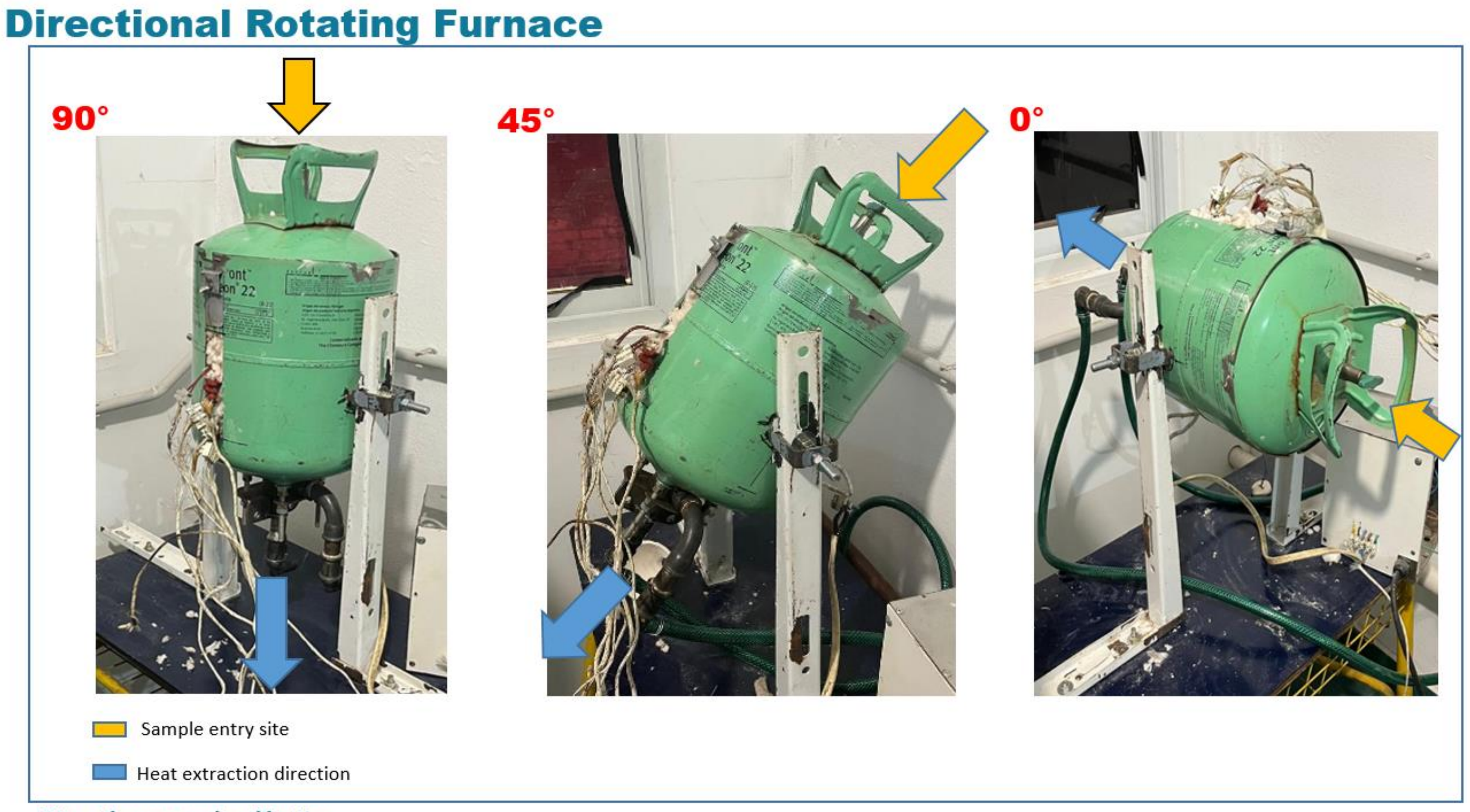
c. Internal diameter= 2.5cm
Thickness = 0.5cm
Height =17 cm

Center of furnace

d. Internal diameter = 5 cm
Thickness = 2 cm
Height =19.5 cm



Directional Rotating Furnace

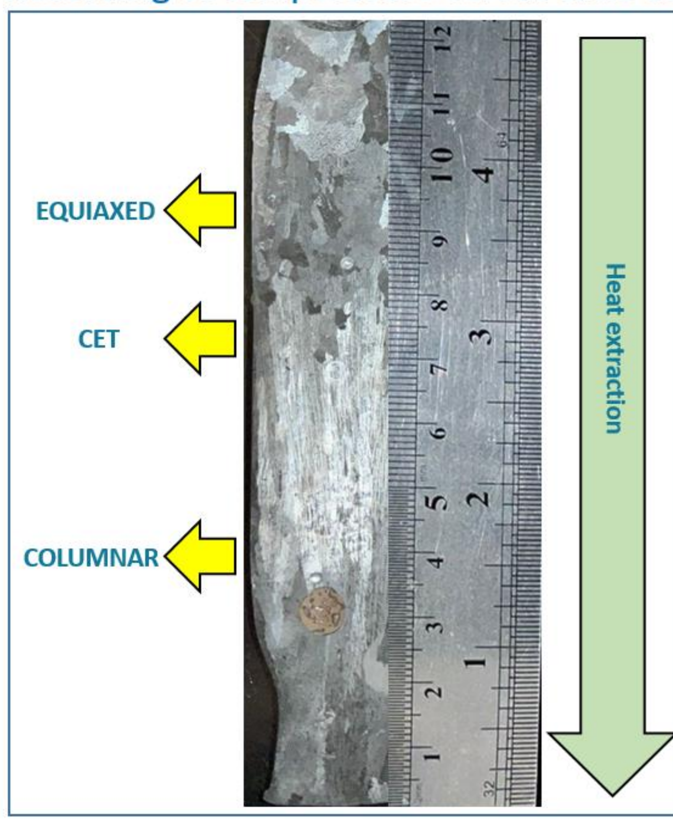


K-type thermocouple calibration

Experimental device

RESULTS & DISCUSSION

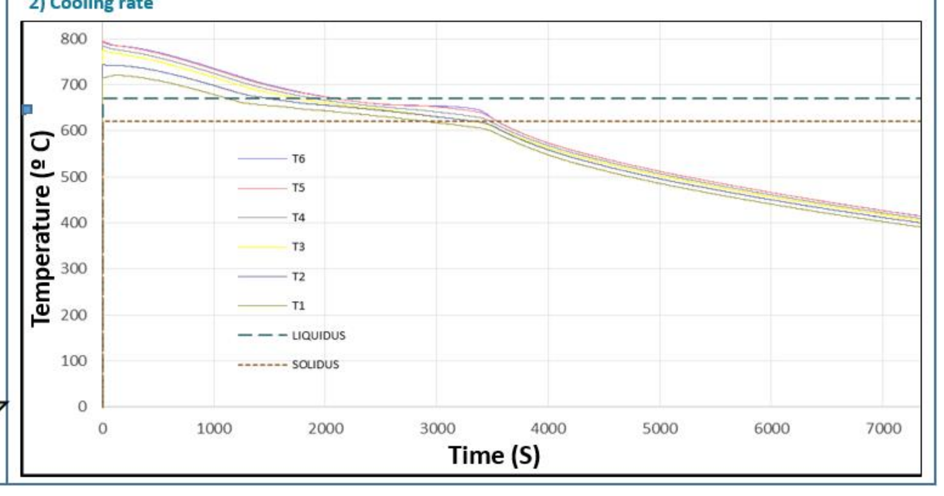
Recording of temperature versus time data



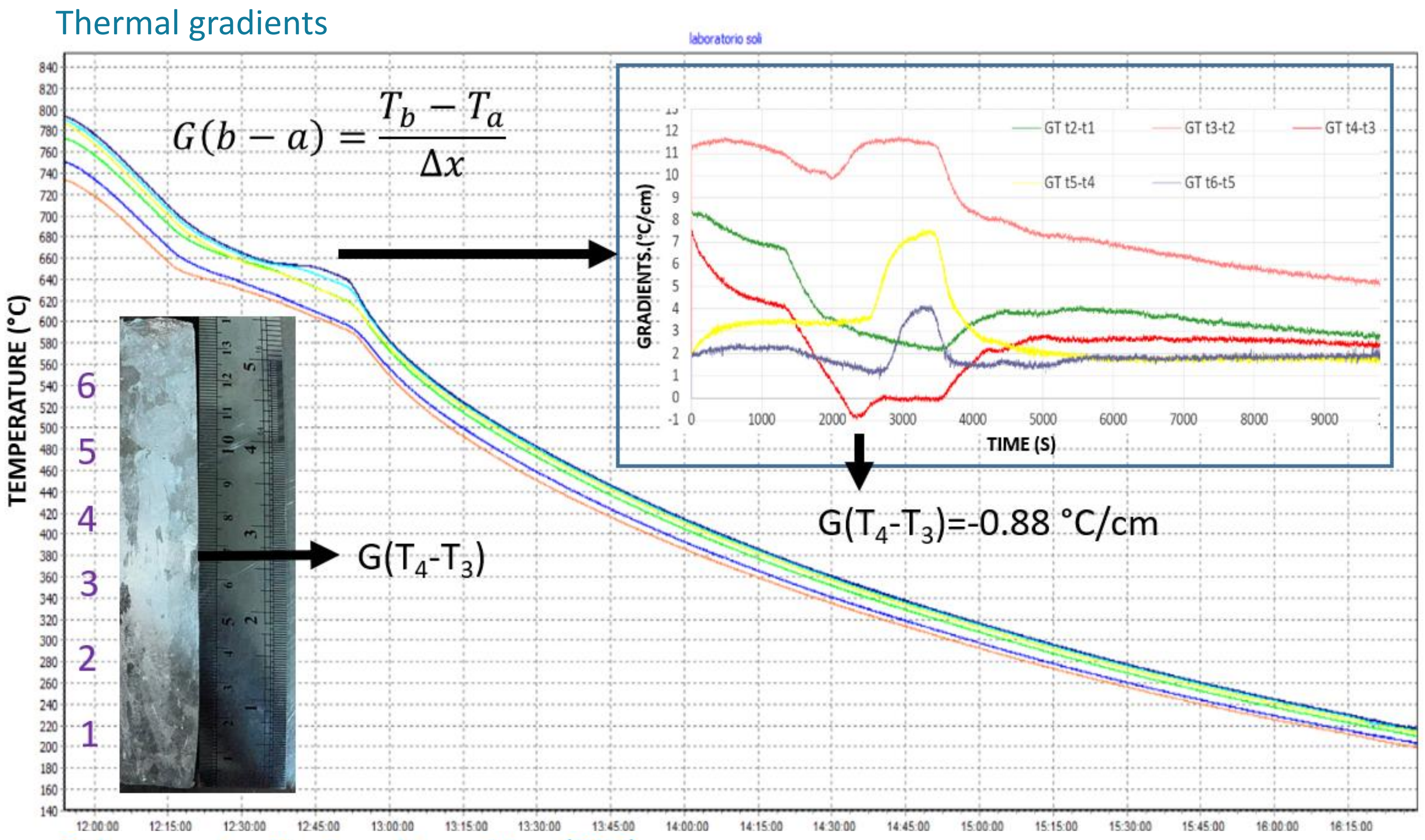
1) Data

Type of grains	Position (cm)	Thermocouple	*Liquidus* (°C)	*Solidus* (°C)	Liquidus cooling rate (°C/min)	Solidus cooling rate (°C/min)
Columnar	2	T_1	669.3	620.1	4.20	1.53
Columnar	4	T_2	669.3	620.1	3.03	1.72
Columnar	6	T_3	669.3	620.1	3.81	1.92
CET	8	T_4	669.3	620.1	3.75	2.49
CET	10	T_5	669.3	620.1	3.53	2.03
Equiaxed	12	T_6	669.3	620.1	3.39	2.02

2) Cooling rate



Thermal gradients



Columnar- to -Equiaxed transition (CET)

1) Position: 90°

Type of grains	Position (cm)	Thermocouple	Liquidus (°C)	Solidus (°C)	Liquidus cooling rate (°C/min)	Solidus cooling rate (°C/min)
Columnar	8	T_4	668.2	620.2	4.93	2.29
CET	10	T_5	668.2	620.2	4.30	2.69
Equiaxed	12	T_6	668.2	620.2	4.16	2.98

$G_T(T_6-T_5) = 0.13°C/cm$ ⇒ G_T at CET

2) Position: 45°

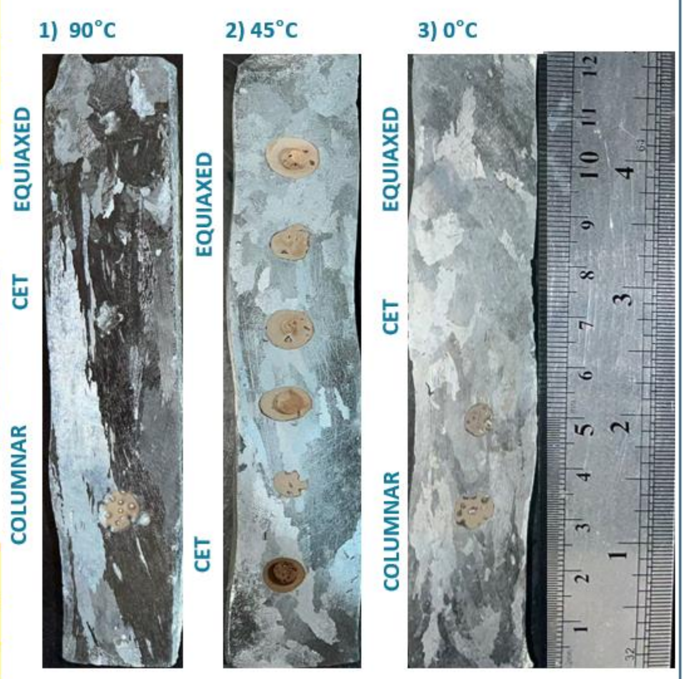
Type of grains	Position (cm)	Thermocouple	Liquidus (°C)	Solidus (°C)	Liquidus cooling rate (°C/min)	Solidus cooling rate (°C/min)
Columnar	4	T_3	665.9	614.1	3.89	2.03
CET	10	T_5	665.9	614.1	3.14	2.08
Equiaxed	12	T_6	665.9	614.1	3.10	2.10

$G_T(T_6-T_5) = -4.02°C/cm$ ⇒ G_T at CET

3) Position: 0°

Type of grains	Position (cm)	Thermocouple	Liquidus (°C)	Solidus (°C)	Liquidus cooling rate (°C/min)	Solidus cooling rate (°C/min)
Columnar	6	T_3	664.1	617.1	3.91	1.47
CET	8	T_4	664.1	617.1	3.44	1.36
Equiaxed	12	T_5	664.1	617.1	3.36	1.37

$G_T(T_4-T_3) = -1.83°C/cm$ ⇒ G_T at CET



CONCLUSION

- For commercial purity Al, average cooling rates of 2.21 °C/s at 90°, 2.05 °C/s at 45°, and 1.98 °C/s at 0° were obtained for each of the tests.
- For the Al-10wt. %Zn alloy, average cooling rates of 2.43 °C/s at 90°, 2.14 °C/s at 45°, and 1.99 °C/s at 0° are obtained, with a clear decrease in the cooling rate as the furnace tilt angle is varied.
- Similarly, when the CET occurs, the critical gradient value is -0.5 °C/cm for Al, 0.1 °C/cm for Zn, 1.4 °C/cm for Al-5wt. %Zn, and -1.2 °C/cm for Al-10wt. %Zn.
- On the other hand, when analyzing the behavior of Zn, it can be highlighted that the cooling rate values decrease significantly when compared with Al (both commercial grades) and with the Al-5wt. %Zn and Al-10wt. %Zn alloys.
- These data indicate that the alloy composition and the inclination of the solidification device influence the cooling rate and the thermal gradients.

FUTURE WORK / REFERENCES

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- Ares, A. E., & Gassa, L. M. (2012). Corrosion susceptibility of Zn–Al alloys with different grains and dendritic microstructures in NaCl solutions. *Corrosion Science*, *59*, 290-306.
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