# Castability and inclusions in a low sulphur Ca-treated peritectic steel for two deoxidation techniques

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# Introduction

**Question: How to minimize clogging formation in continuous casting nozzles?**

**Caused by $Al_2O_3$ and $MgAl_2O_4$ solid solution inclusions**

**Solution: optimize deoxidation process and calcium treatment to improve castability and inclusion modification**

# Introduction

**Goal: Minimize clogging tendency in a Brazilian Steelwork**

**Material: Low sulfur Al-killed calcium treated peritectic steel**

**Proposed changes on steel refining process with help of computational thermodynamics and inclusion characterization**

# Introduction

| Process before modifications | Process after modifications |
| --- | --- |
| Fully Al killed | Si killed with FeSi<br>-20wt% of Al content on deoxidation |
| Calcium treated | Calcium treated (no changes) |
| Slag:<br>53wt% CaO, 39wt% $Al_2O_3$, 8wt% $SiO_2$ | Slag:<br>56wt% CaO, 32wt% $Al_2O_3$, 12wt% $SiO_2$ |

# Methodology

**Industrial trials with production route:**

**LD converter – ladle furnace – continuous casting of slabs**

**10 steel samples from tundish**

**Five before: 1 - 5**

**Five after: A - E**

**Lollipop samples (no deoxidizer) quenched**

**Elemental composition of steel in wt%**

**Tundish temperature**

**Total oxygen content**

# Methodology

**“Castability windows”**

**FactSage 7.1**

**Equilibrium module**

**FTmisc and FToxid**

**Input data**

**Composition of each trial in wt%**

**Total oxygen in steel sample in ppm**

**Tundish temperature**

**0-70ppm Ca and 0-1000ppm Al**

# Methodology

**Inclusion characterization**

**SEM-EDS**
**Backscattered electrons**

**Quantification by manual mode**

**Acceleration voltage of 20kV**

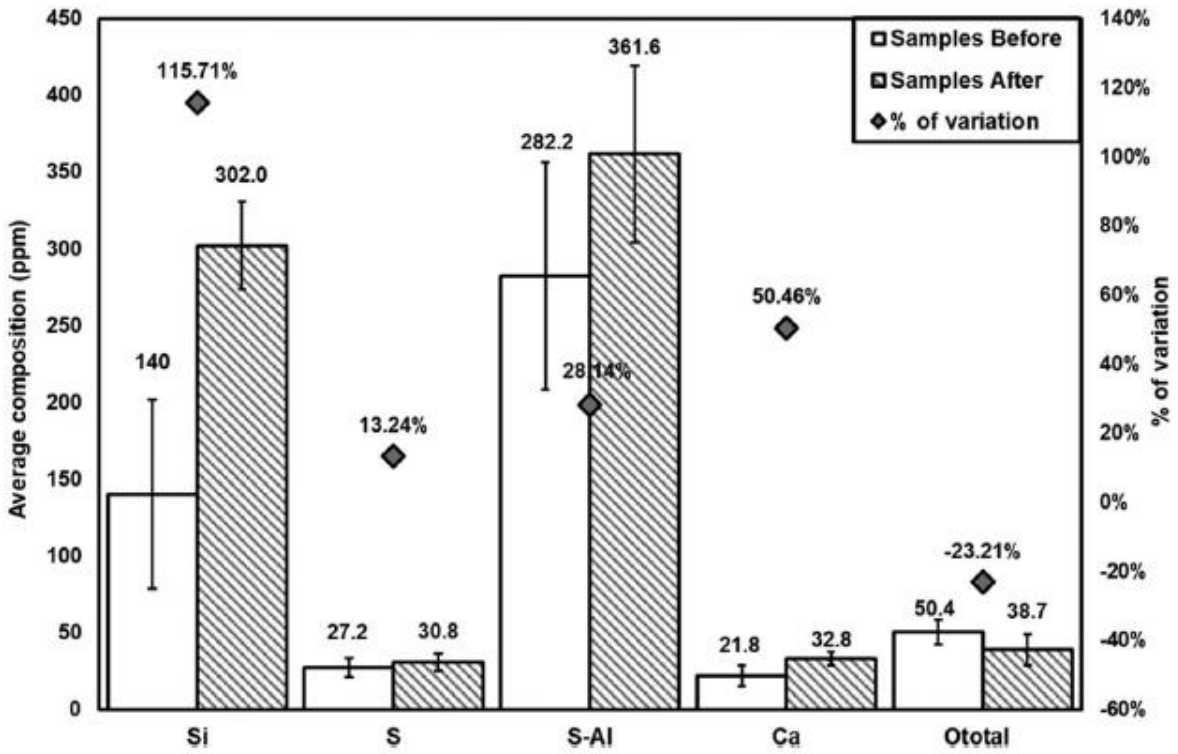
**Sample preparation**

**Cutting, sanding and**
**Polishing with diamond paste**

**No etching was applied**

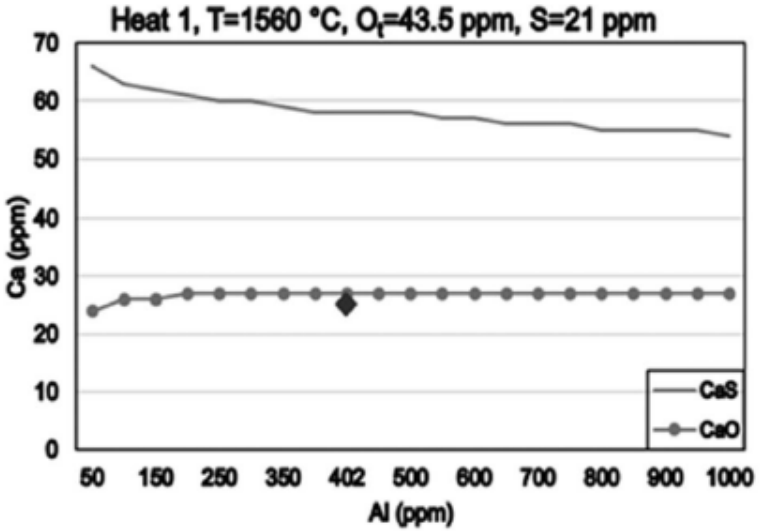
**75mm$^2$ area analyzed**

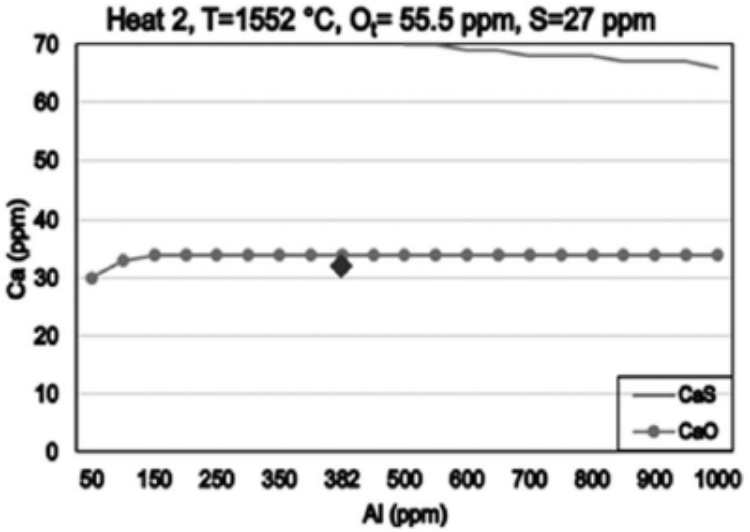
# Steel elemental composition



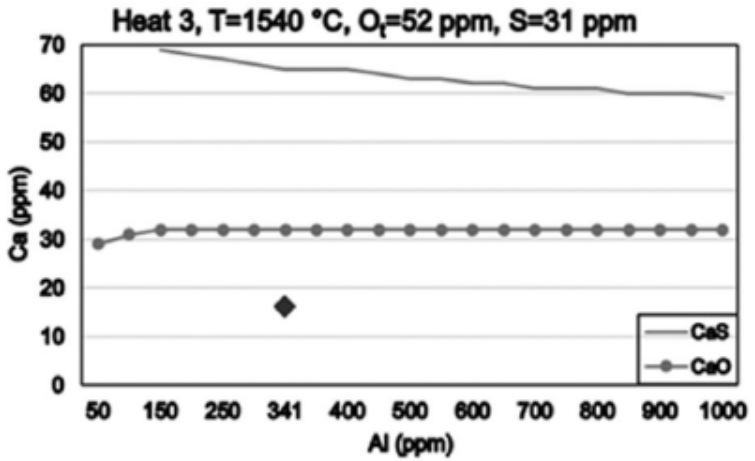

Average content of Si, S, soluble-Al, Ca e $O_{total}$ for the steel before and after the process changes.

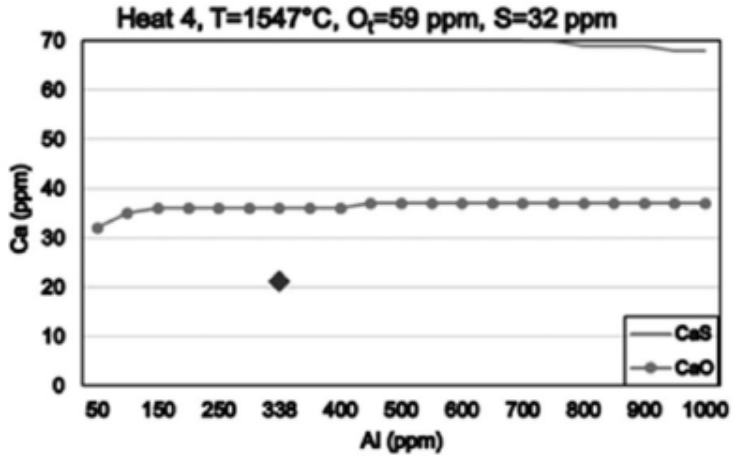
# Castability windows before process changes

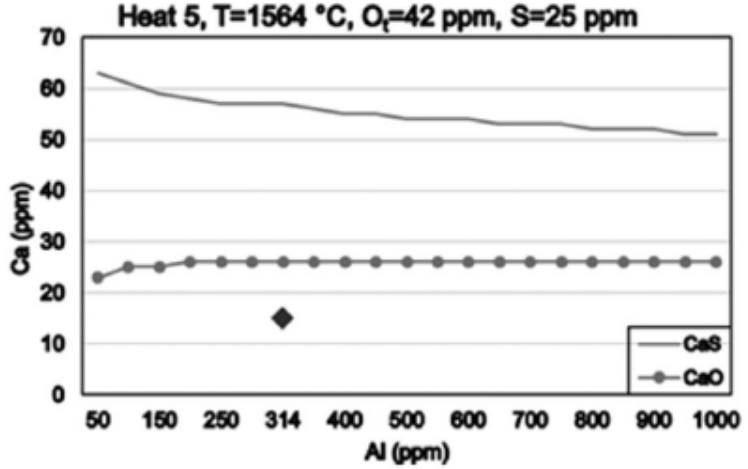


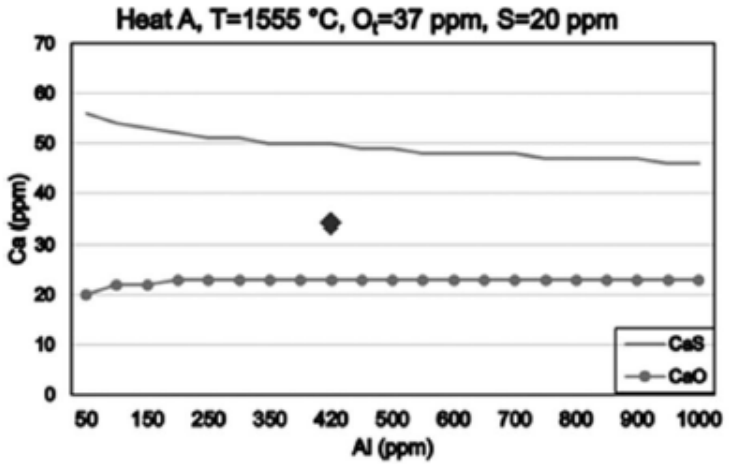

Castability windows for samples 1–5 (before industrial process change) calculated using FactSage 7.1 with the databases FToxid e FTmisc.

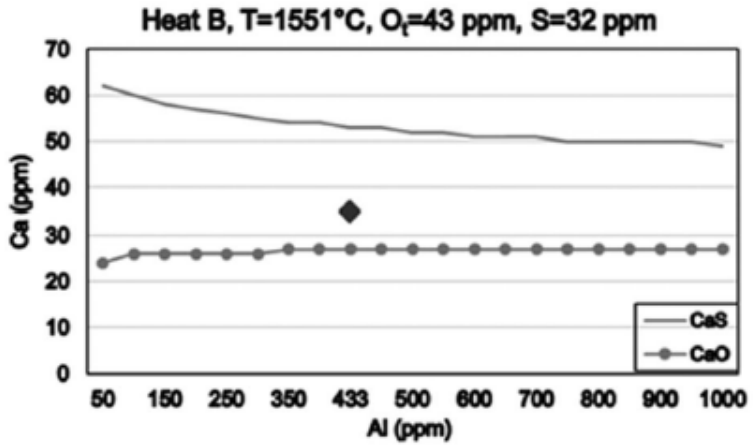


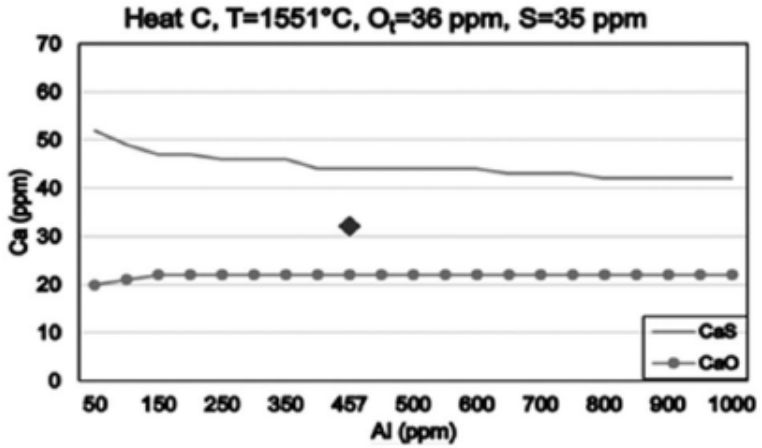



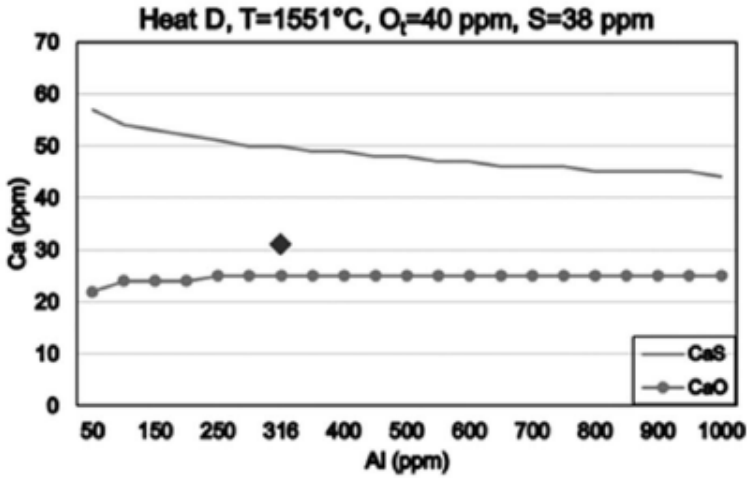



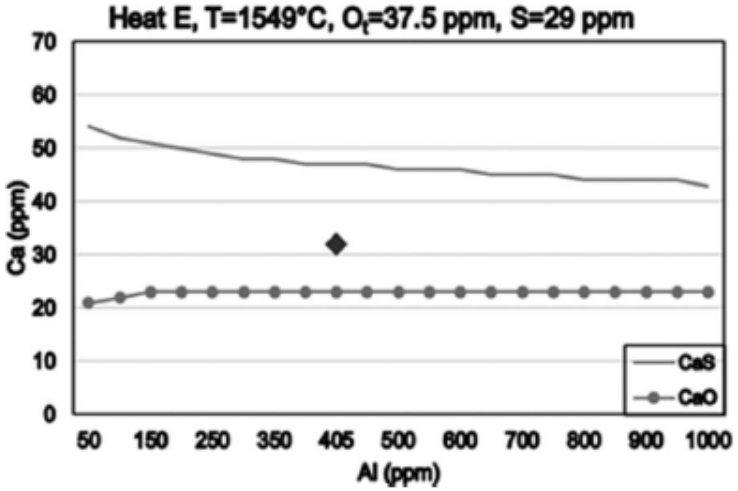
# Castability windows after process changes



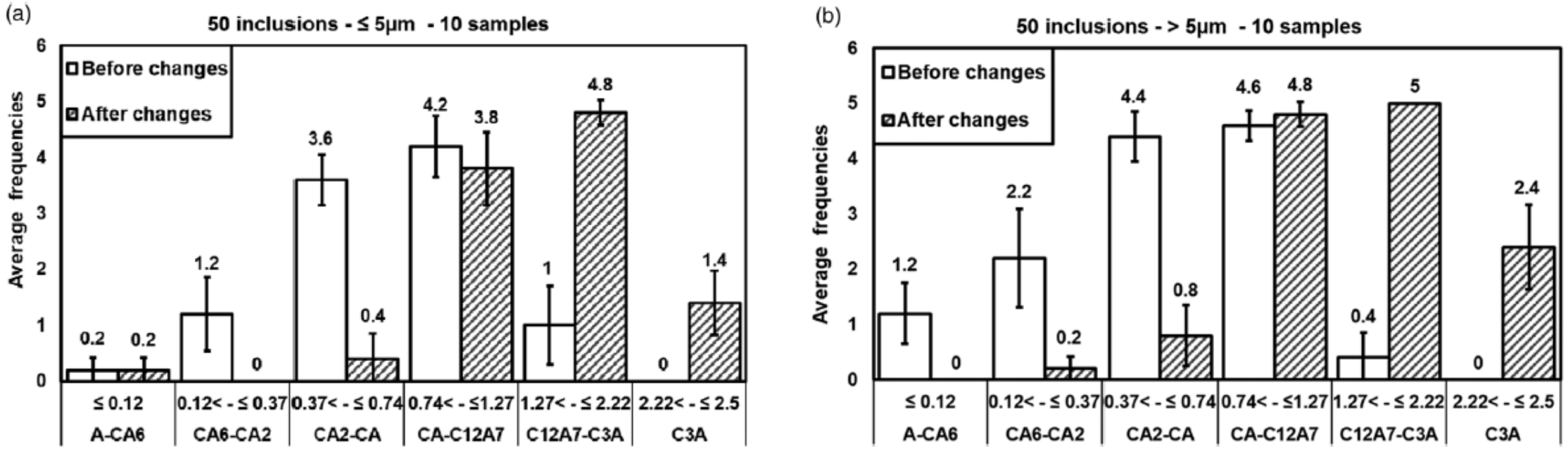



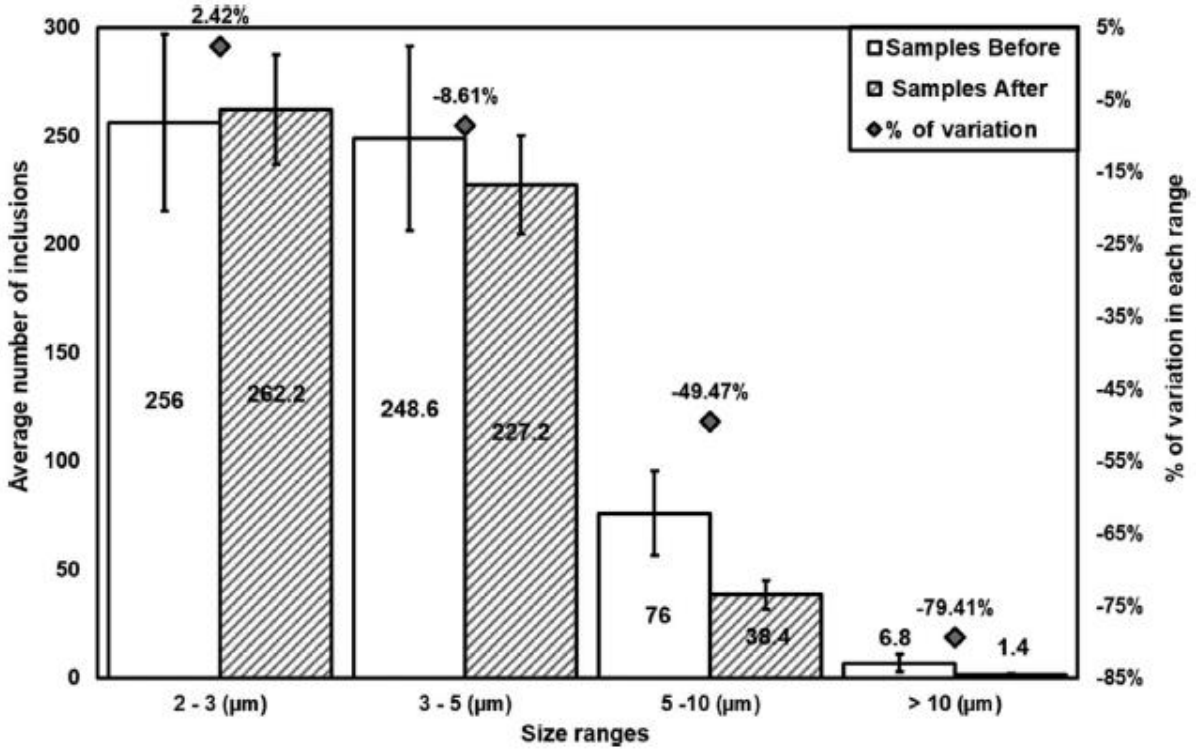

Castability windows for samples A–E (after industrial process change) calculated using FactSage 7.1 with the databases FToxid e FTmisc.

# Inclusions Characteristics



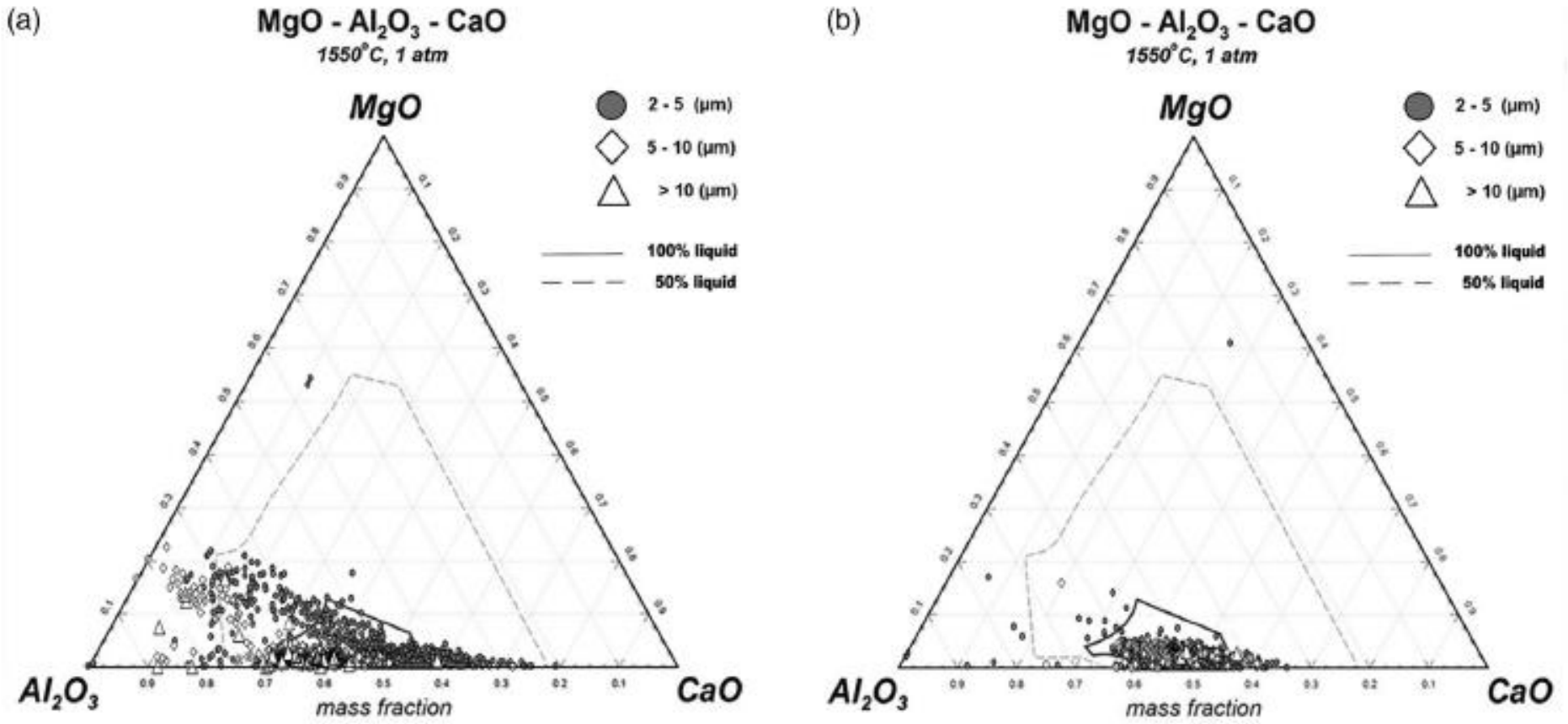

Average frequencies for calcium aluminate inclusions layers determined using SEM-EDS line scan, before and after the industrial process changes.
a) Inclusions less than or equal to 5 µm.
b) Inclusions larger than 5 µm.

# Inclusions characteristics



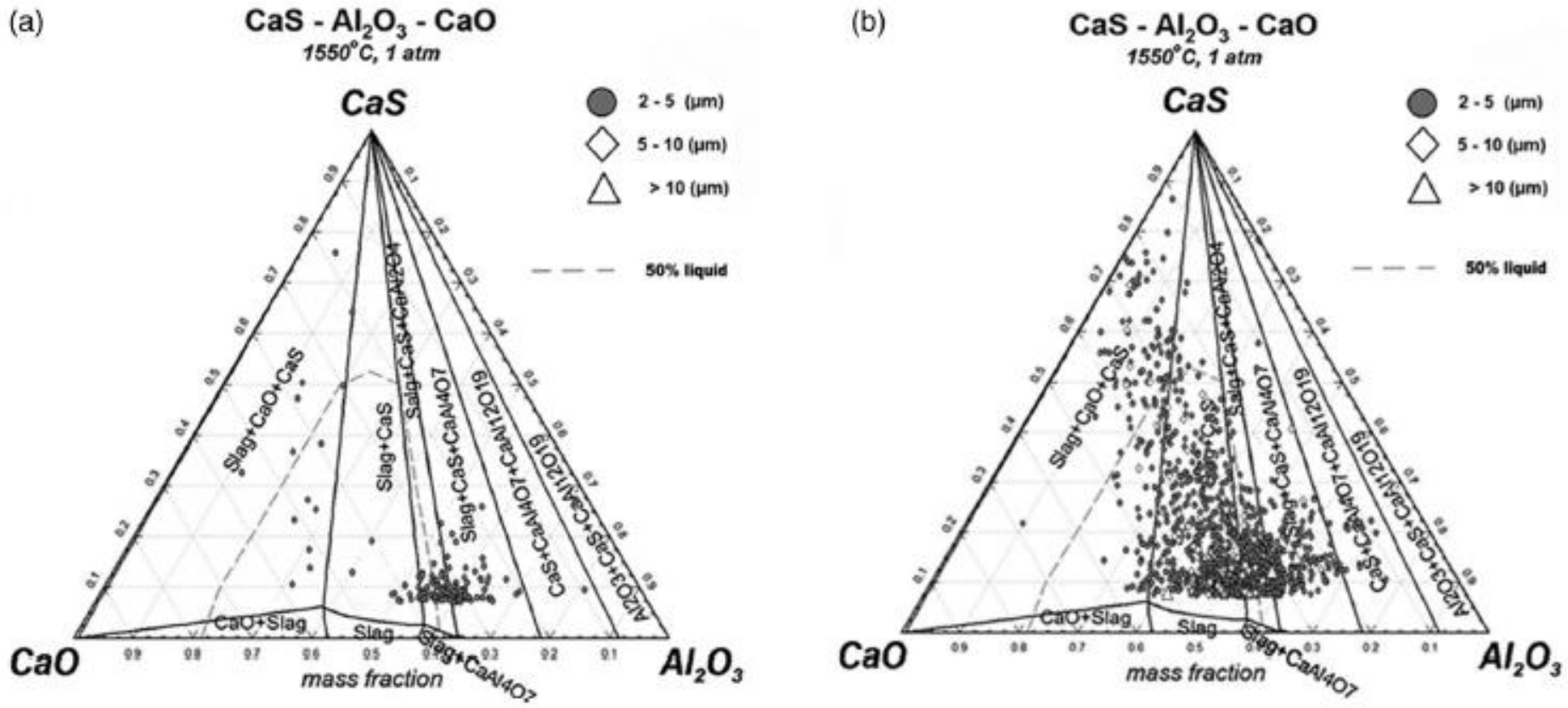

Inclusion size distribution, before and after the industrial process changes.

# Inclusions characteristics




Elemental chemical composition of inclusions detected by SEM-EDS plotted in ternary diagrams for the $MgO–Al_2O_3–CaO$ system.
a) Before the industrial process changes (2800 inclusions).
b) After the industrial process changes (1470 inclusions).

# Inclusions characteristics




Elemental chemical composition of inclusions detected by SEM-EDS plotted in ternary diagrams for the CaS–$Al_2O_3$–CaO system. The number of CaS-bearing inclusions dramatically increased.

a) Before the industrial process changes (137 inclusions).

b) After the industrial process changes (1176 inclusions).

# Conclusions

**Considering the industrial case study, which was performed in this work, for the analyzed low sulfur Ca-treated peritectic steel, nozzle clogging occurrences were controlled.**

**The castability windows show that the amount of calcium dissolved in liquid steel was too low before the process changes, and this fact explain the blockage of the tundish nozzles, which was observed at steelworks, due to deposition of high-melting point spinel inclusions.**

# Conclusions

**Inclusion characterization showed high frequency of the liquid calcium aluminates after the process changes, which is coherent with the calculated castability windows.**

**Before the changes, the inclusion modification was not complete because the core of the inclusions was polygonal solid spinel.**

**After the changes, the inclusions became homogeneous (completely modified); few ones presented CaS ring around the globular inclusion.**



# Thank You!

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