Effects of Grain Size and Shape of alumina aggregates on the Sinterability and Thermal Shock Resistance of Refractory Materials

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Objectives :

The Concerted European Action on Sustainable Application of REFractories (CESAREF) is a consortium created to drive sustainable refractory materials and processes in steel production. This project which runs from 2022 - 2025 seeks to improve the microstructure for increased sustainability and thermo-mechanical performances of refractory castables.

In this work, different formulations of alumina-spinel refractory castables are considered. The main objective is to propose a new design for the microstructure of refractory materials with improved thermo-mechanical properties by considering :

- The nature of aggregates (chemistry, crystallinity, physical properties…)
- The arrangement of the calcium aluminate phases network (formation temperatures, unique formation mechanisms, location and morphology).

Properties of alumina aggregates :

The determination of the apparent densities, open porosities and water absorption of the alumina aggregates was done using the Archimedes method.

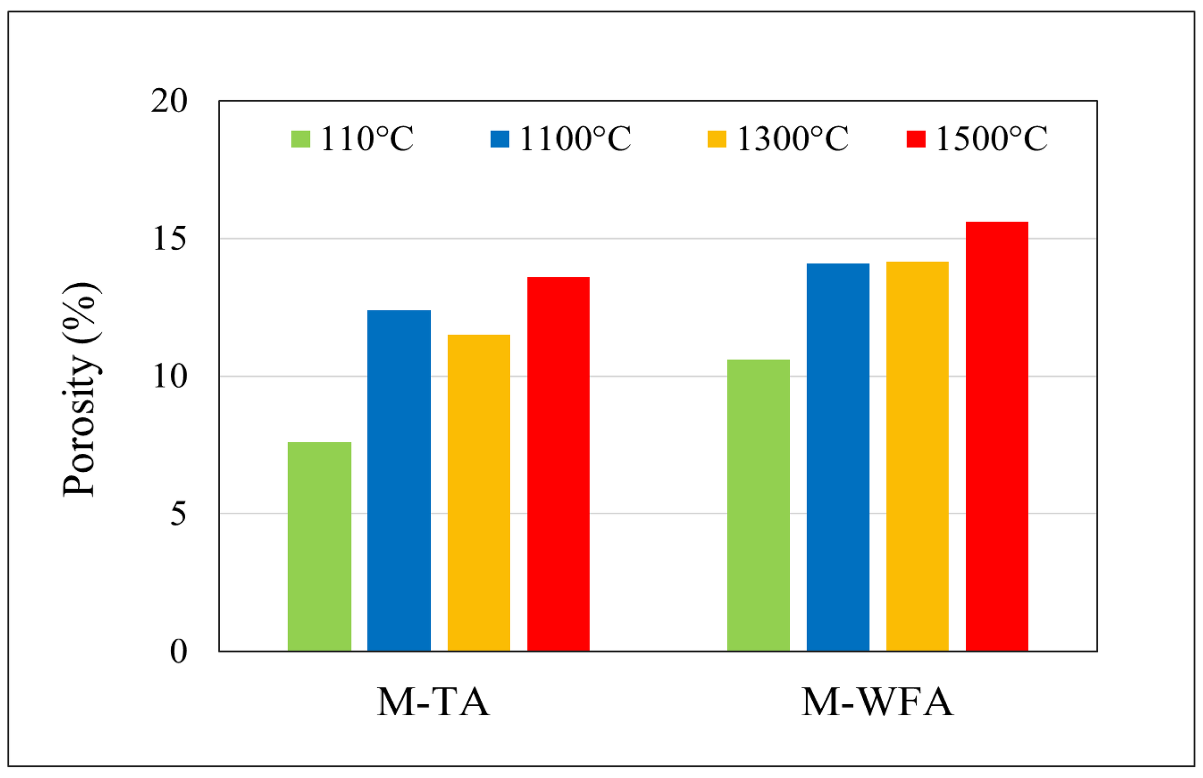
Physical Property	Tabular	White Fused
Apparent Density, g/cm3	3.6	3.5
Open Porosity, %	4.3	9.9
Water absorption, %	1.2	3.7
Shape	blocky	angular

Castable compositions :

	M-TA	M-WFA
Tabular Alumina 0-6 mm	60	-
White Fused Alumina 0-5 mm	-	60
Pre-formed spinel 0-1 mm	23	23
Reactive Alumina	11	11
CAC Secar 71	6	6
Peramin® PCE AL200	+ 0.1	+ 0.1
Water	+ 4.1	+ 4.1

Porosity In Castables :

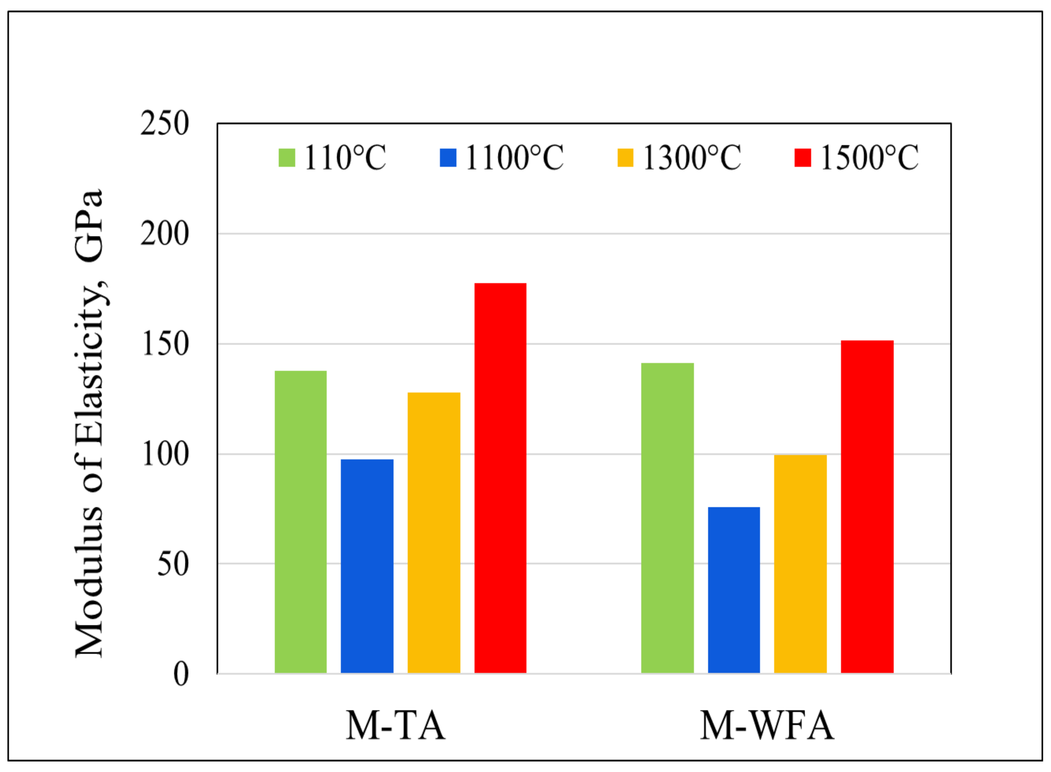
The apparent porosities in WFA are higher compared to TA castables. A part of this porosity could be attributed to the higher open porosity of WFA aggregates.



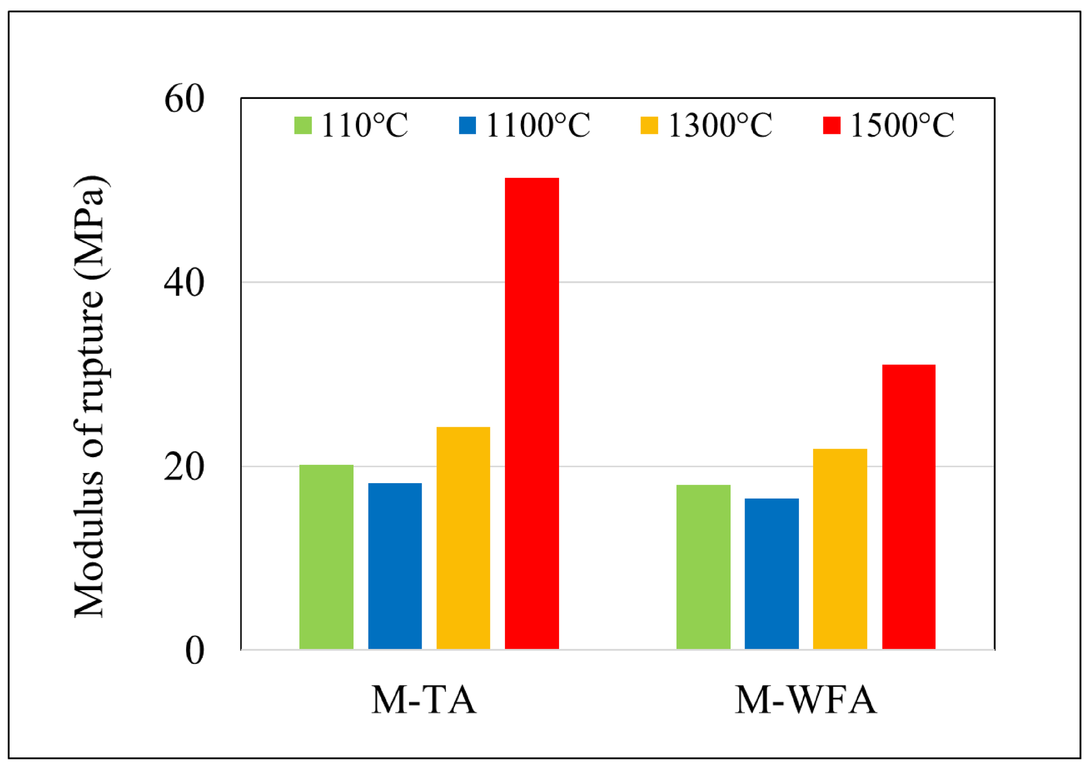
Apparent porosity of the tabular (M-TA) and white fused (M-WFA) alumina based castables at drying and firing temperatures.

Elastic and Mechanical Properties :

Quite equivalent elastic and mechanical properties except after firing at 1500°C where a drop is observed for M-WFA that could be attributed to a decohesion of the interface matrix/aggregates during cooling.



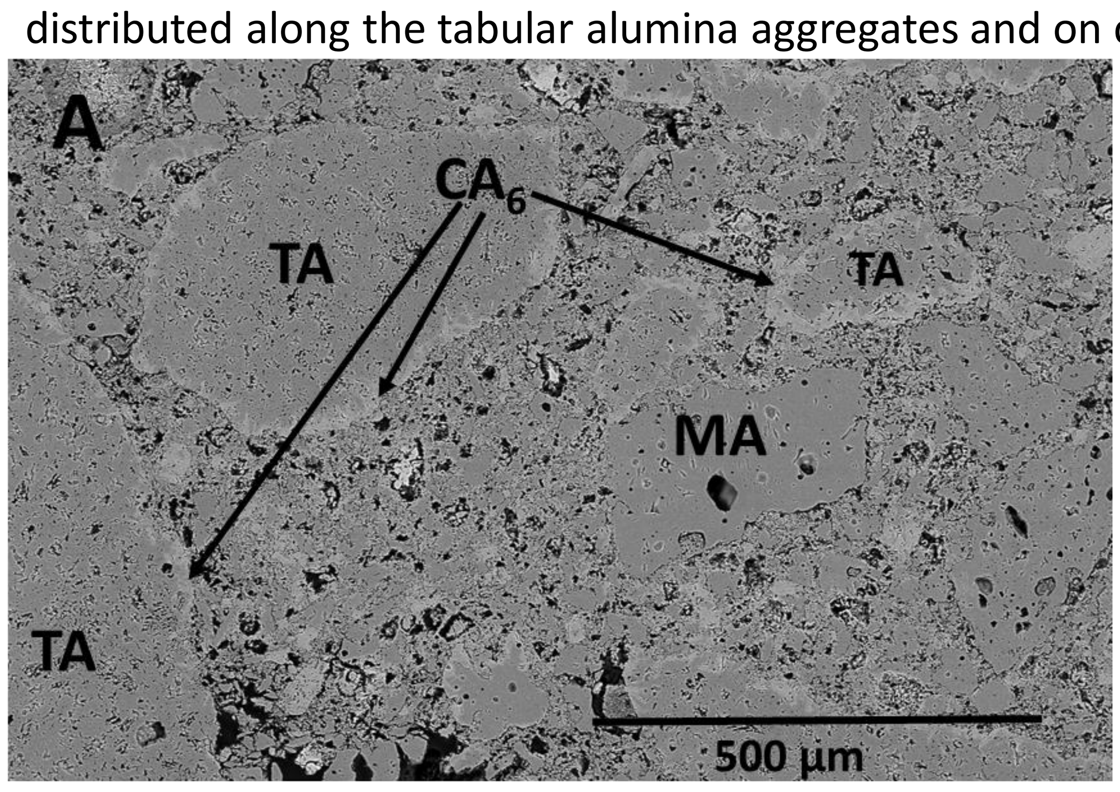
Modulus of Elasticity of the tabular (M-TA) and white fused (M-WFA) alumina based castables at drying and firing temperatures.

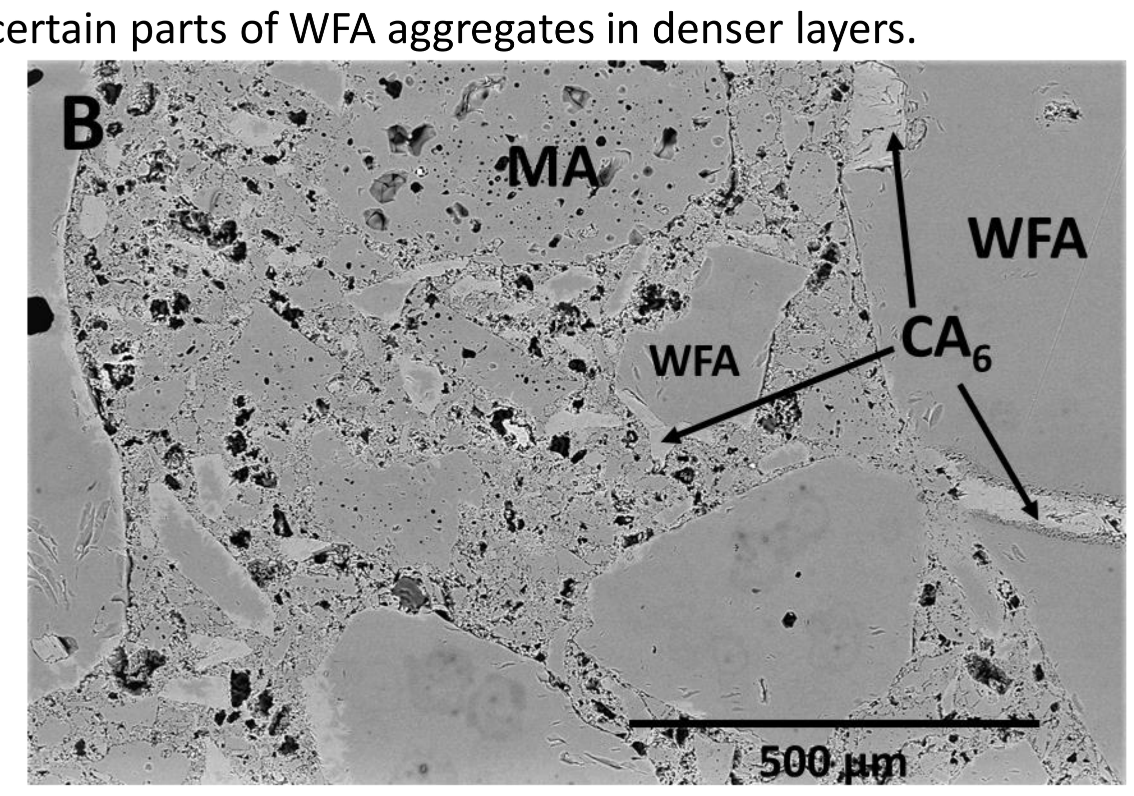


Modulus of Rupture of the tabular (M-TA) and white fused (M-WFA) alumina based castables at drying and firing temperatures.

SEM Images of tabular and white fused alumina-spinel castables :

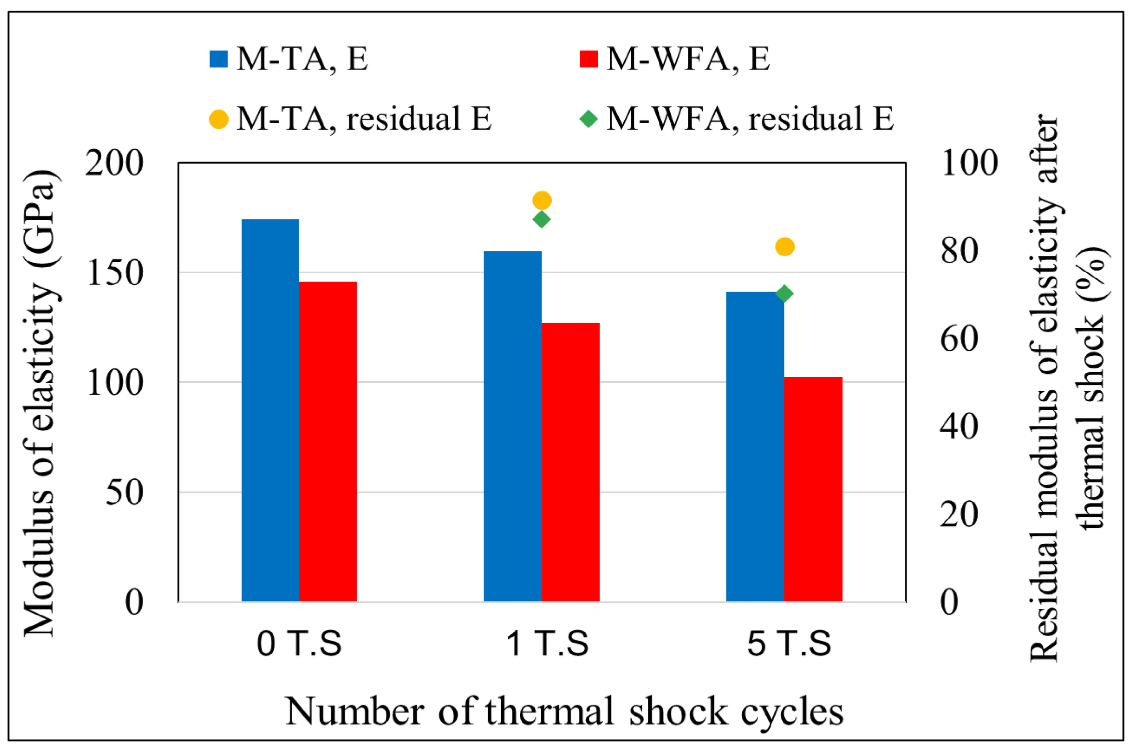
SEM images show the presence of CA_6 in both M-TA and M-WFA castables. However, CA_6 seems to be evenly distributed along the tabular alumina aggregates and on certain parts of WFA aggregates in denser layers.





SEM micrographs of A) tabular and B) white fused alumina-based spinel castables fired at 1500°C.

Thermal Shock Resistance :



Modulus of Elasticity of the tabular (M-TA) and white fused (M-WFA) alumina based castables after firing and thermal shock cycles.

Conclusion :

In summary, the influence of the different alumina aggregates on the castable properties at high temperatures is quite significant.

- Higher modulus of elasticity and rupture in M-TA castables could be related to their less porous microstructure.
- Residual modulus of elasticity after thermal shocking cycles are comparable for both M-TA and M-WFA castables regardless of original strengths after sintering.
- The morphology of the in-situ formed CA_6 at the interface to the aggregates is different for WFA vs tabular alumina and its impact on thermomechanics will be further investigated.

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Beneficiaries