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Low carbon, green, high quality refractories

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Effect of Microporous Corundum Aggregates on Thermal Shock Resistance of Corundum Spinel Castables for Setting Block

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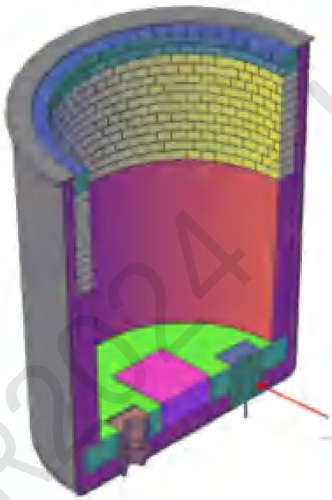
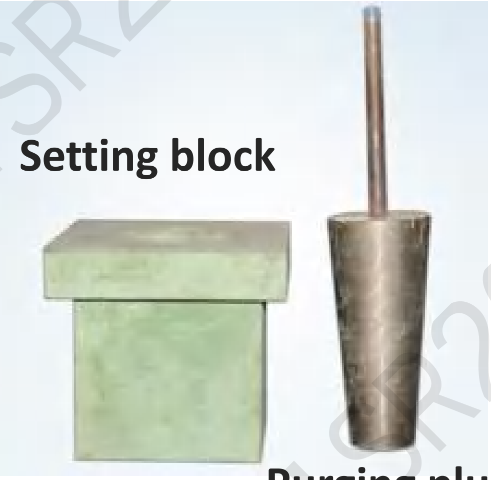
1. Introduction

High temperature

Long time refining

Harsh service environment

Ladle refractory general contracting mode →

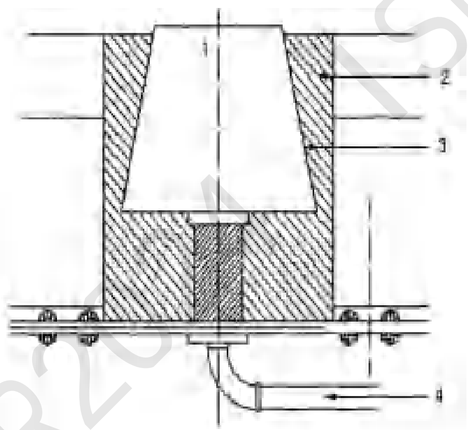
Long service life

High security

Eco-friendly

1. Introduction

Setting block



1.Purging plug
2. Setting block

Service environment

- 1650°C～1680°C high temperature steel erosion
- Frequent thermal shocks
- Ferro-static pressure in dynamic condition
- Expansion stress from the bottom of the ladle

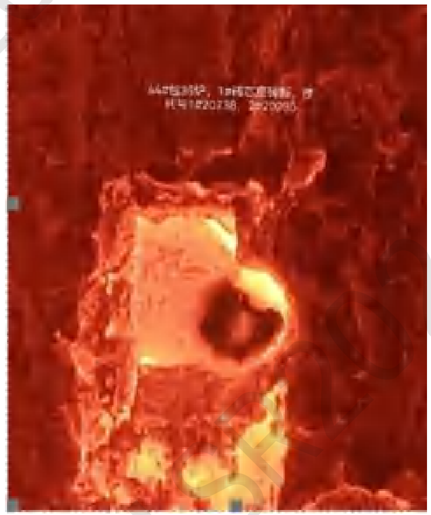
Thermal shock | **Mechanical erosion** | **Chemical corrosion**

Harsh service environment ➡ good comprehensive performance

1. Introduction

Damage of setting block

Enlarged hole caused by wear and erosion



cracking and spalling

Broken and fracture

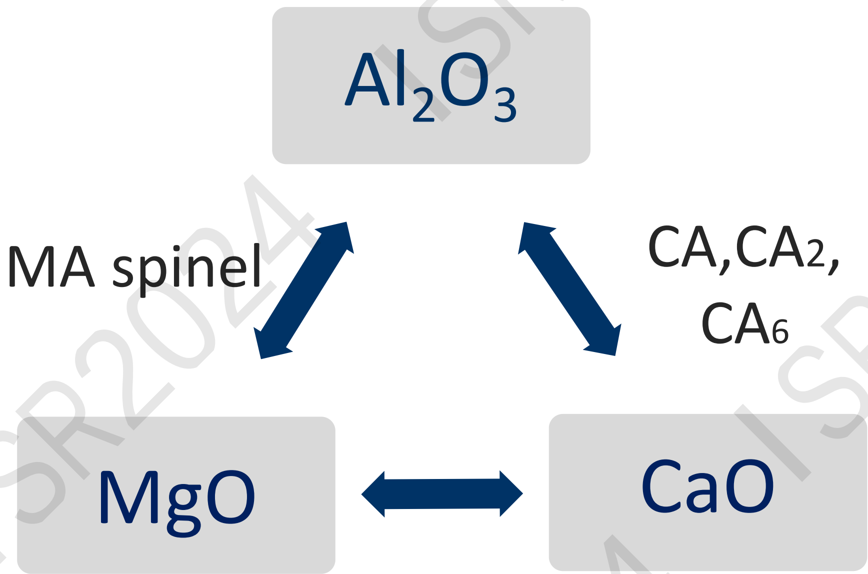
Materials of setting block →

- √ Thermal shock resistance
- √ Volume stability
- √ Mechanical strength
- √ Slag resistance

→ **Castables of Al_2O_3-MgO-CaO system**

1. Introduction

Al_2O_3-MgO-CaO system



- High refractoriness under load
- Excellent corrosion resistance in steel/slag environments
- High oxidation resistance and chemical stability
- Relatively low fracture energy and unsatisfactory thermal shock performance

Problem: thermal shock resistance

Measures to improve thermal shock resistance

1. Increase the thermal conductivity of the material and reduce the thermal expansion coefficient of the material	2. Improve the strength of the material, while reducing the elastic modulus of the material, so that G/E is increased	3. Control the micro-structure of the materials
• Add non-oxide, B_4C, SiC, Sialon, etc	• Appropriately improve the porosity of the material, add fiber	• Micropores and micro-cracks are introduced , control the grain size
• Problem: High cost, introduction of impurities	• Problem: Difficult to control	• Problem: Difficult to control

How to improve thermal shock resistance on the premise of ensuring strength and slag resistance?

Microporous corundum aggregate is introduced

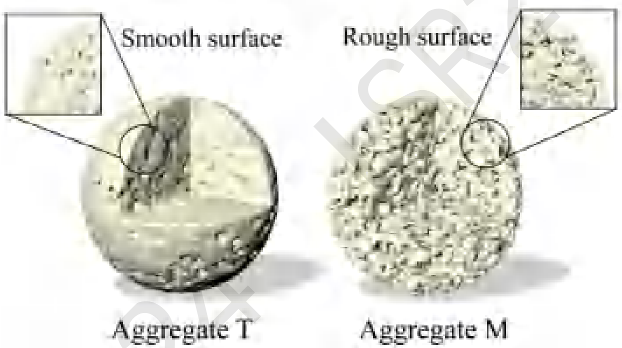
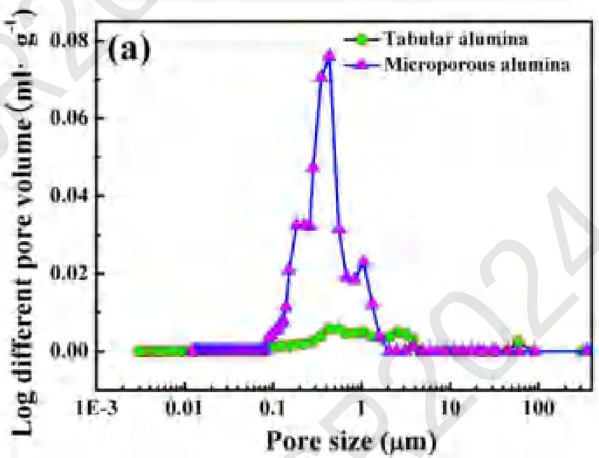


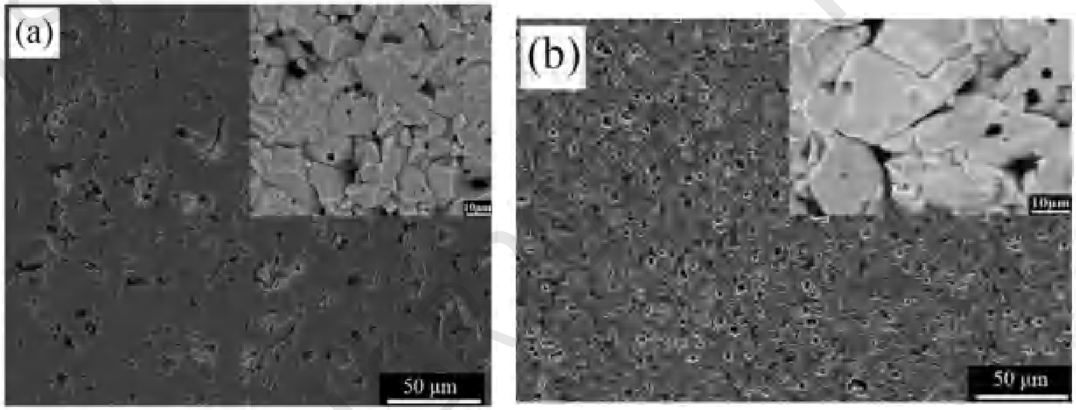
Diagram of different corundum aggregates

Physical indexes of different aggregates

	AP(%)	BD(g/cm³)	PSD(μm)
Tabular alumina	6.2	3.54	9.77
Microporous alumina	25.7	2.82	4.20



Pore size distribution of different corundum aggregates



Microstructure of different corundum aggregates

Zhe Chen, Wen Yan. Journal of the American Ceramic Society[J]. 2020. 103(8).
Lvping Fu, Ao Huang. Ceramics International[J]. 2016. 42.

1. Introduction

Application of microporous corundum aggregate in castable

Properties of two alumina–magnesia castables.

	Permanent linear change (%)		Apparent porosity (%)			Bulk density (g cm^{-3})		
	1000 °C	1500 °C	110 °C	1000 °C	1500 °C	110 °C	1000 °C	1500 °C
Common alumina–magnesia castable	−0.055	+0.934	19.8	22	21.8	2.94	2.92	2.92
Lightweight alumina–magnesia castable	−0.025	+0.325	21.2	24.7	22.7	2.89	2.83	2.82

Strengths of two alumina–magnesia castables.

	Cold modulus of rupture (MPa)			Cold crushing strength (MPa)		
	110 °C	1000 °C	1500 °C	110 °C	1000 °C	1500 °C
Common alumina–magnesia castable	2.8	3.8	13.5	14.4	18.19	74.38
Lightweight alumina–magnesia castable	4.01	5.64	15.5	28.58	36.58	78.75

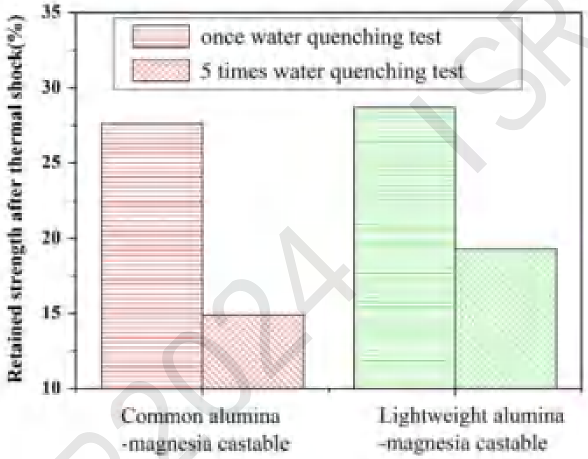
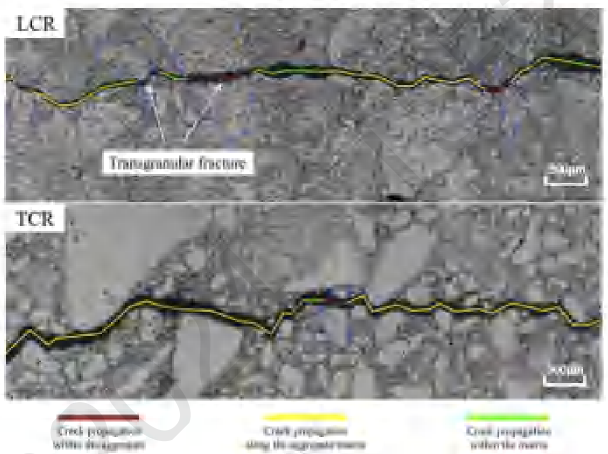


Fig. 4. Retained strength after thermal shock of different castables.

- Good volume stability
- High strength
- Proper porosity
- High thermal shock resistance

Lvping Fu, Hauzhi Gu. Ceramics International[J]. 2015. 41.

Application mechanism of microporous corundum aggregate



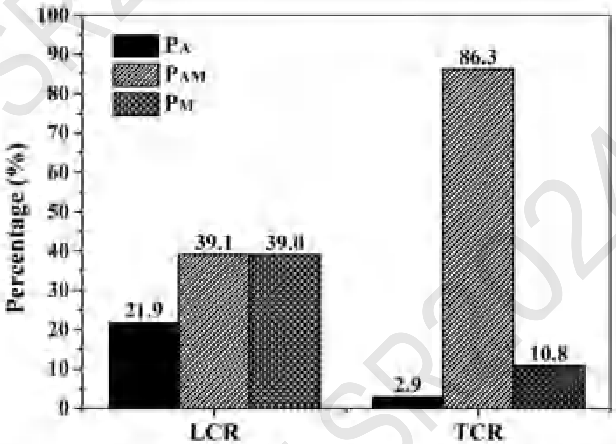
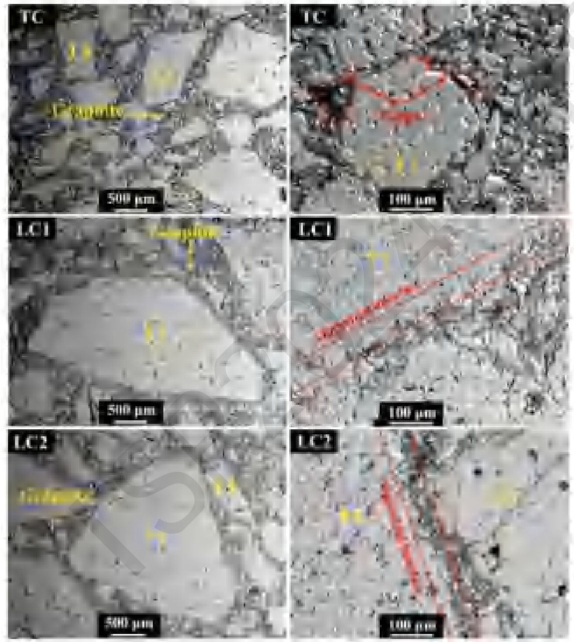


Fig. 9. Percentages of the three crack propagation mechanisms in the LCR and TCR specimens during three-point bending test.

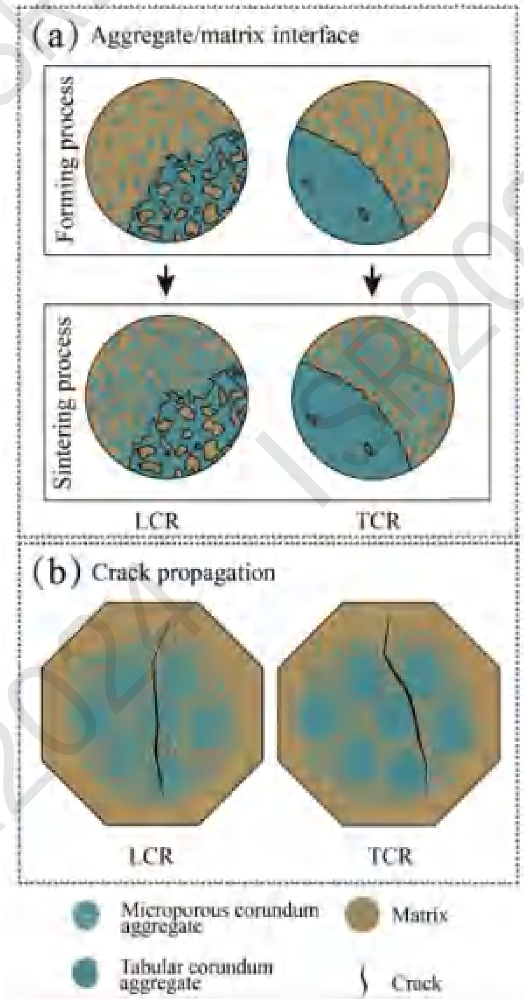


Tight bonding between the aggregate and matrix

Intergranular fracture

↓

Transgranular fracture



Qi long Chen, Tianqing Li. Ceramics International[J]. 2023. 49.
Zhe Chen, Wen Yan. Ceramics International[J]. 2019. 45.

1. Introduction

Potential risk

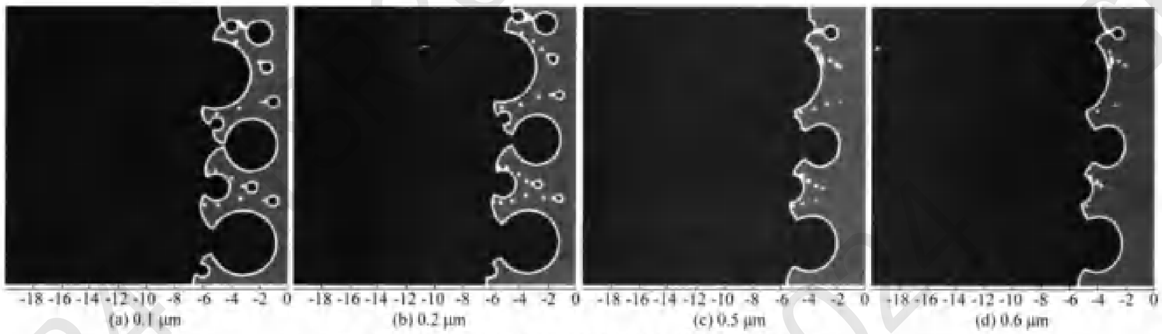
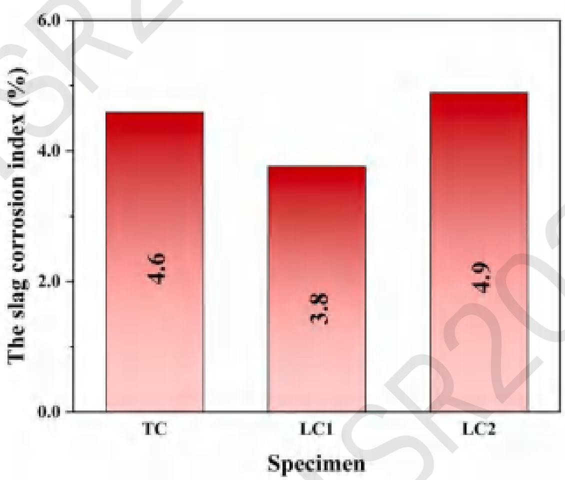


图 1 熔渣对不同孔径骨料的耐火材料的渗透情况

Fig. 1 Penetration results of slag to refractories with different aggregates

Slag resistance?



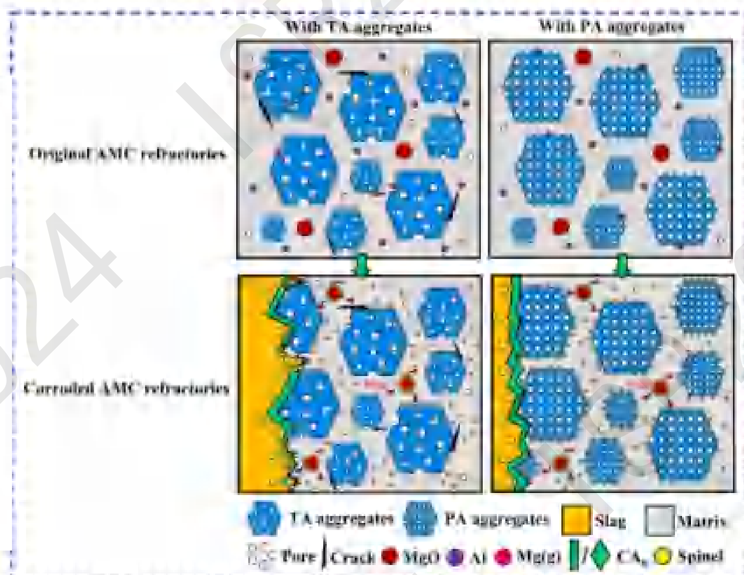


Fig. 13. The schematic diagram of original and corroded AMC refractories.

Interfacial cracks and matrix pores decreased

The hot surface forms a dense and continuous CA_6 isolation layer

Qi long Chen, Tianqing Li. Ceramics International[J]. 2023. 49.

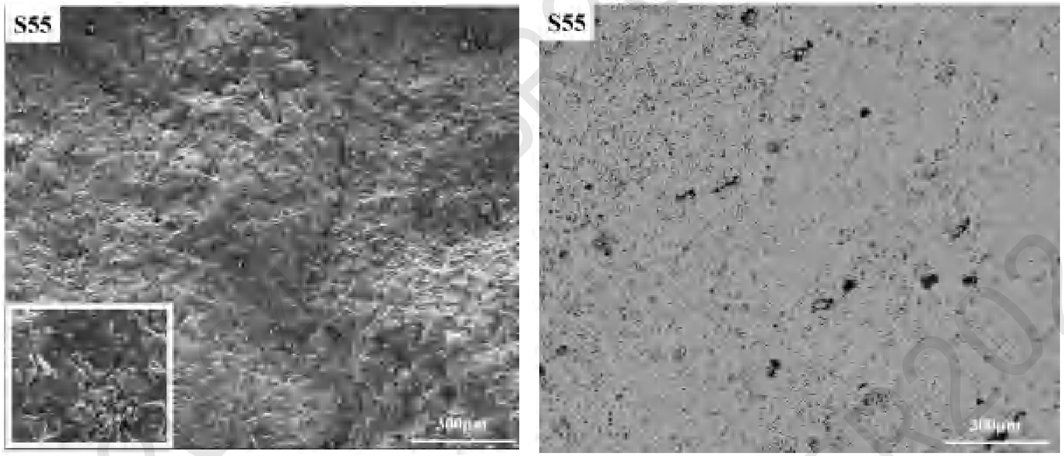
1. Introduction

Feasibility of application of microporous corundum aggregate in setting block

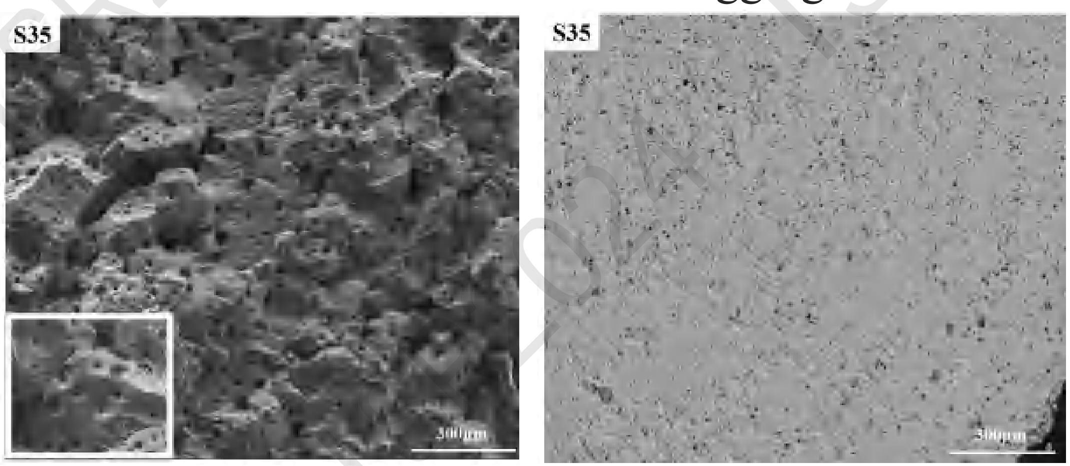
- Ensure the basic performance of castable
- Improve thermal shock stability of materials
- Reduce raw material costs

2. Experimental Procedures

Comparison of corundum aggregate



Fracture surface of different aggregates



Polished surface of different aggregates

Physical properties of different aggregates

	Bulk density (g/cm³)	Apparent porosity (%)	Water absorption (%)	True density (g/cm³)
S55	3.60	3.7	1.0	3.90
S35	3.40	7.6	2.2	3.87

S35

- Lower bulk density
- Higher AP and water absorption
- Rougher surface with sharp edges
- More homodispersed smaller pores

2. Experimental Procedures

Experiment

Batches composition of castables

		Ref	MPA1	MPA2	MPA3	MPA4
S55	5~3mm	35	35	35		
	3~1mm	15	15		15	
	1~0mm	20		20	20	
S35	5~3mm				**35**	**35**
	3~1mm			**15**		**15**
	1~0mm		**20**			**20**
S55	320mesh	14				
Spinel		6				
AMA20		5				
Secar 71		5				
Additive		+ 0.4				

Curing(25°C)
Drying(110°C)
Firing(1100 °C,1600 °C)




3. Results and Discussions

Conventional performance

Properties of specimens treated at different temperatures

	Ref	MPA1	MPA2	MPA3	MPA4
Water(wt%)	4.25	4.6	4.65	4.8	5.0
Fluidity(mm)	240	245	240	230	245
110°C					
PLC(%)	-0.14	-0.01	-0.06	0.00	-0.04
AP(%)	7.7	10.9	10.7	11.1	10.6
BD(g/cm³)	3.24	3.21	3.22	3.22	3.08
CMOR(MPa)	15.8	16.6	16.2	14.1	15.4
CCS(MPa)	109.2	102.3	103.5	96.1	92.3
1100°C					
PLC(%)	0.06	0.09	0.10	0.00	0.05
AP(%)	14.4	14.9	14.5	15.0	17.4
BD(g/cm³)	3.15	3.13	3.14	3.13	3.02
CMOR(MPa)	15.9	14.6	13.6	13.2	15.8
CCS(MPa)	106.1	94.8	84.9	87.0	89.2

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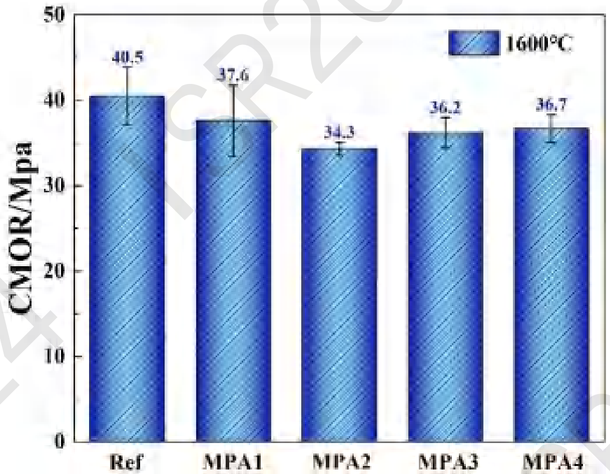
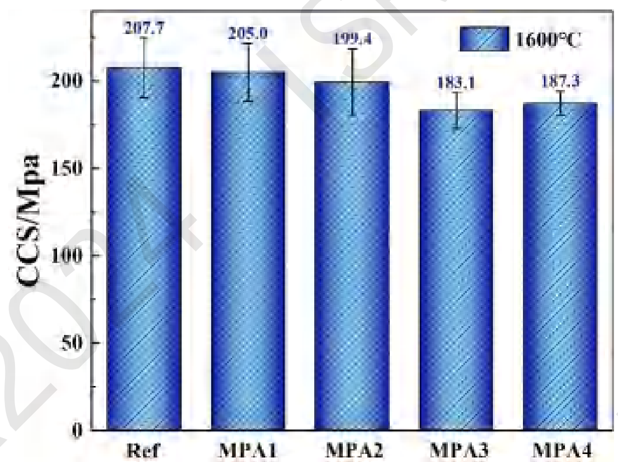
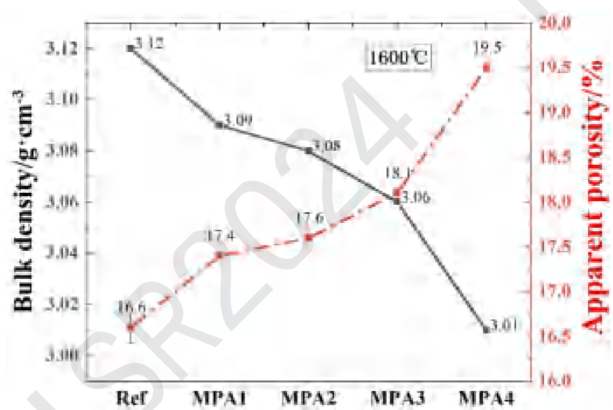
3. Results and Discussions

Conventional performance

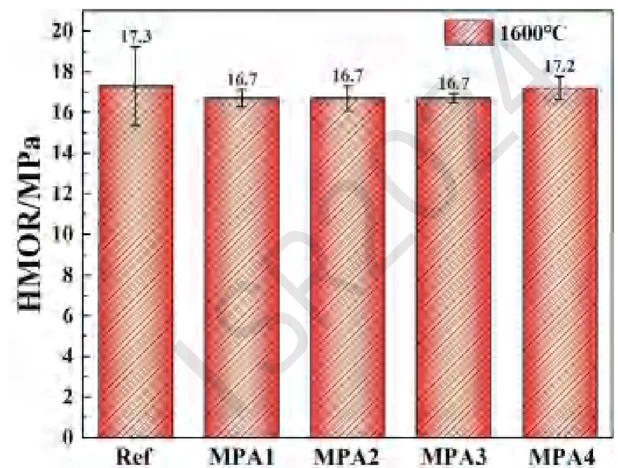




CMOR and CCS of specimens treated at 1600°C



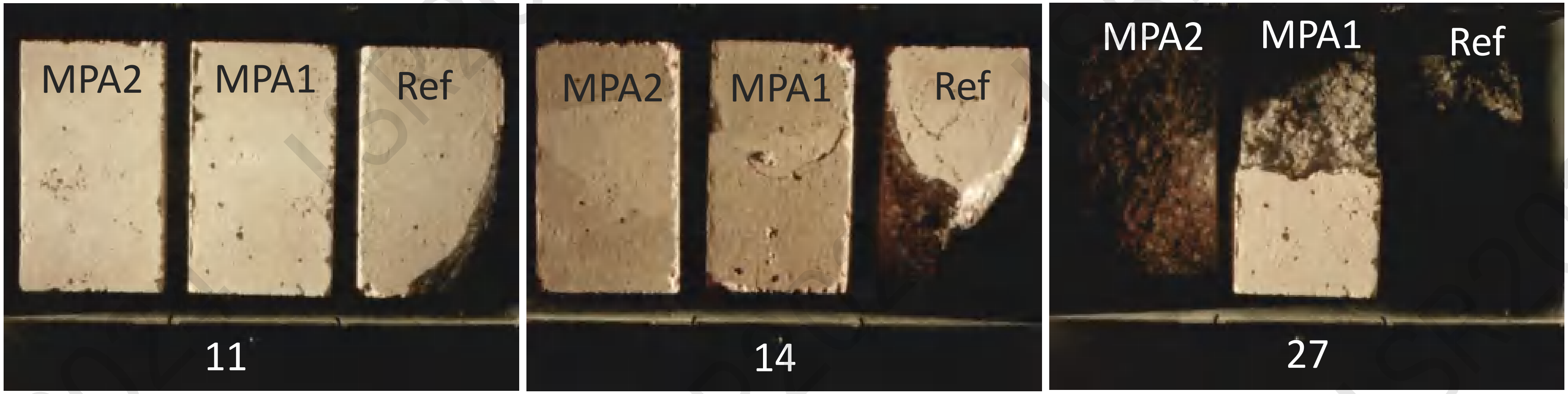
BD and AP of specimens treated at 1600°C



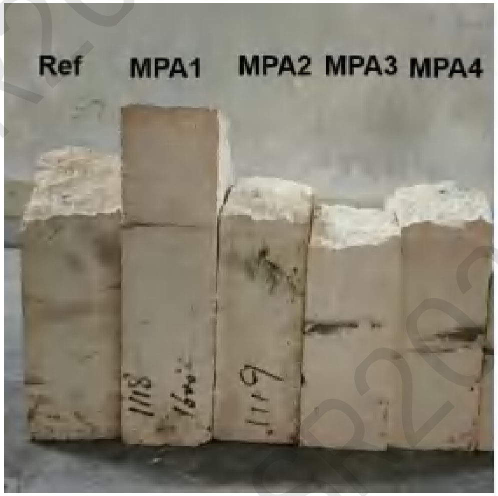
HMOR(1500°C×0.5h) of specimens treated at 1600°C

3. Results and Discussions

Thermal shock test



Images during thermal shock test



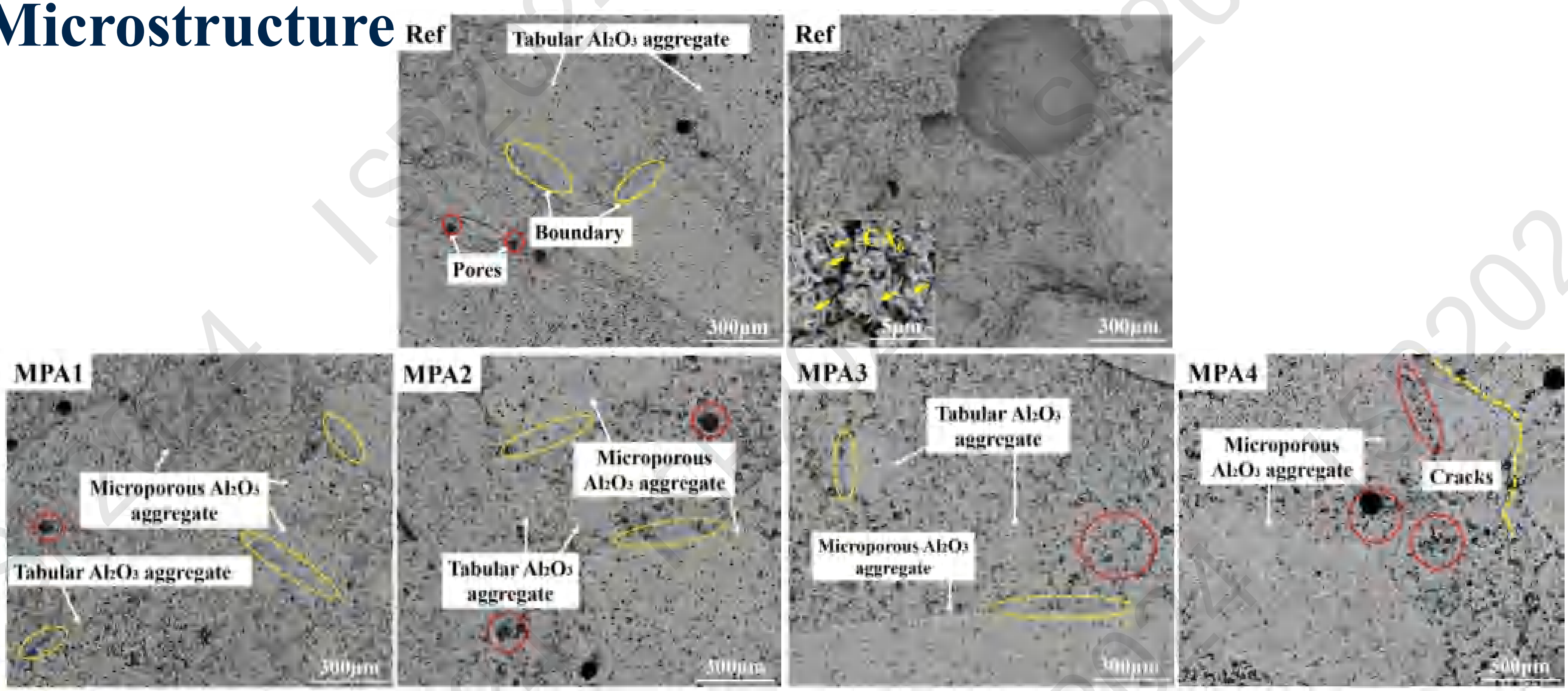
Images after thermal shock test

Thermal shock times of different specimens

	Ref	MPA1	MPA2	MPA3	MPA4
Times	18	27	24	20	16

3. Results and Discussions

Microstructure



The SEM images of specimens fired at 1600°C

MPA

Rough surface

→ **able to hang the slurry and better combine with the matrix**

Porous structure

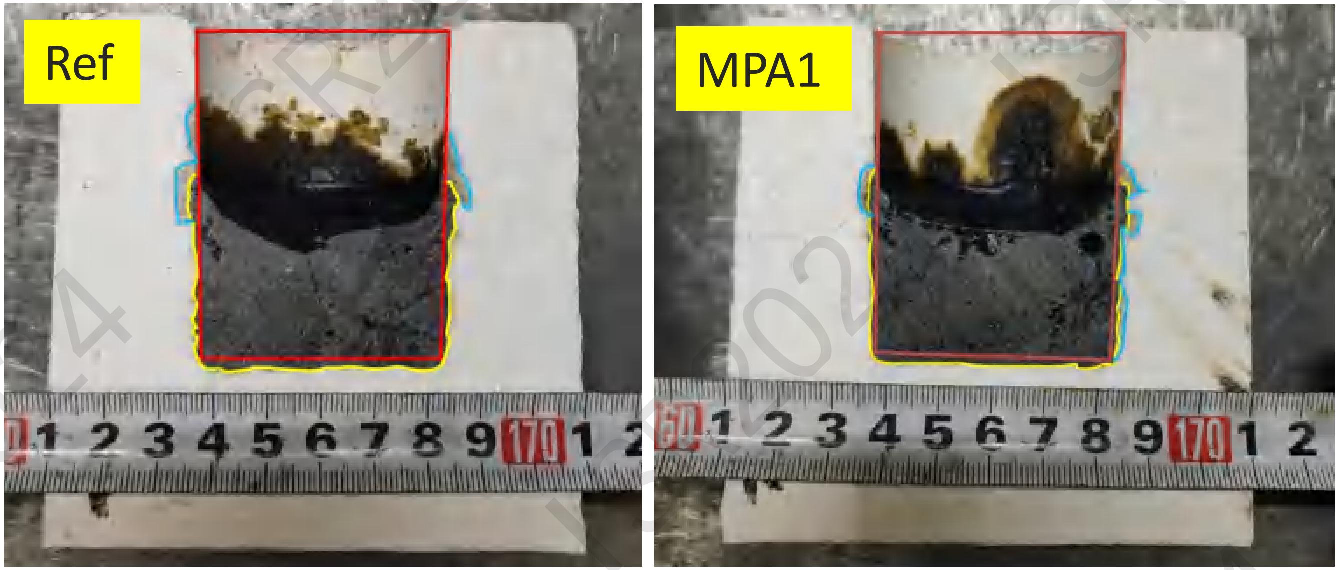
→ **leading to more space to release the thermal stress**

Strength

Thermal shock resistance

3. Results and Discussions

Slag resistance



Cross-sections of Ref and MPA1 after slag corrosion test

Corrosion and penetration index of Ref and MPA1 after slag corrosion test

	Ref	MPA1
Corrosion index/%	3.92	4.10
Penetration index/%	1.72	1.56

No obvious difference

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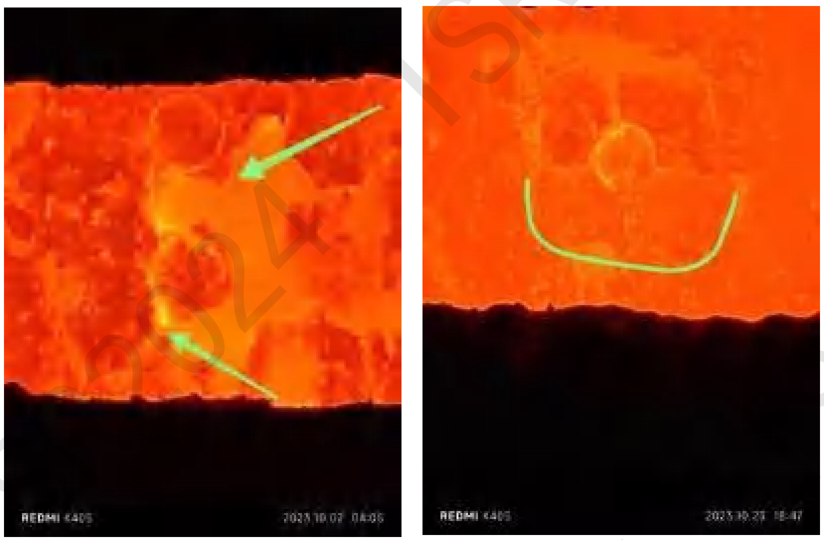
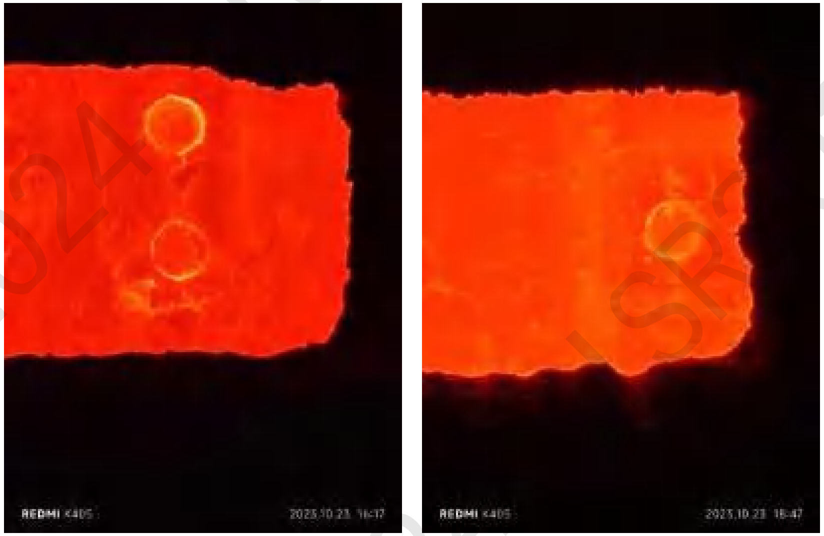
3. Results and Discussions

Industrial application

XX steel factory



Before（serious spalling ）



After substitution of 10% 1-0mm microporous corundum aggregate

The spalling and fracture of setting block have been decreased

4. Conclusions

The experimental results show that when the 1-0mm aggregate particles are completely replaced by microporous corundum aggregate, the specimens show best comprehensive performance, and the thermal shock resistance is increased by 50%. This is owing to the following reasons:

1. The rough surface of microporous aggregate can better combine with matrix, forming a dense bonding and improve the strength of castable.

2. The structure of microporous corundum aggregate and its higher water absorption increase the water requirement of castable and improve the porosity inside material, as a result the material has more space to accommodate and release the thermal stress in the state of dramatic temperature changes, thus improve their thermal shock resistance.

The use of microporous corundum aggregate is expected to solve the problem of fracture and spalling of setting block, it is of great significance for improvement of the lifetime for steel ladle, and bring out cost decreasing and benefit increasing.

Thanks for Your Attention!