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Effects of SiC_{nw}/Al_2O_3 composite powders on properties of Al_2O_3–SiC refractory castables

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CONTENTS

1.1 Background

With the fast global economic development and population growth, more than billions of tons of municipal solid waste are annually produced worldwide. Incineration is considered one of the most effective ways to deal with solid waste.

Service environment of waste incinerator	Performance requirements for refractories	Types of refractories for waste incineration
Erosion of gas phase	High wear resistance	Al_2O_3-Cr_2O_3
Particle wear	Good thermal shock resistance and slag resistance	MgO-Al_2O_3
Thermal shock		Al_2O_3-SiC

$Cr^{3+} \rightarrow Cr^{6+}$: harmful to the environment and human health; MgO: poor wear resistance

1.1 Background

Characteristics of SiC refractory castables

Good integrity

Easy construction and repair

Thermal shock resistance and wear resistance need to be improved

Enhancement strategies for refractory

Optimization formula

Modification of binder

Introduction of additives

Regulate the microstructure of matrix

Matrix is the weak binding area

Low dimensional ceramic phases, forming a binding network in the matrix

Problems

High cost, prone to agglomeration

Lack of commercial products

Method

Pre-synthesis composite powders containing low-dimensional components

Enhancing thermal shock resistance and wear resistance

2.1 Preparation of SiC_{nw}/Al_2O_3

Catalytic combustion synthesis of SiC_{nw}/Al_2O_3 in $Al\text{-}SiO_2\text{-}C$ system

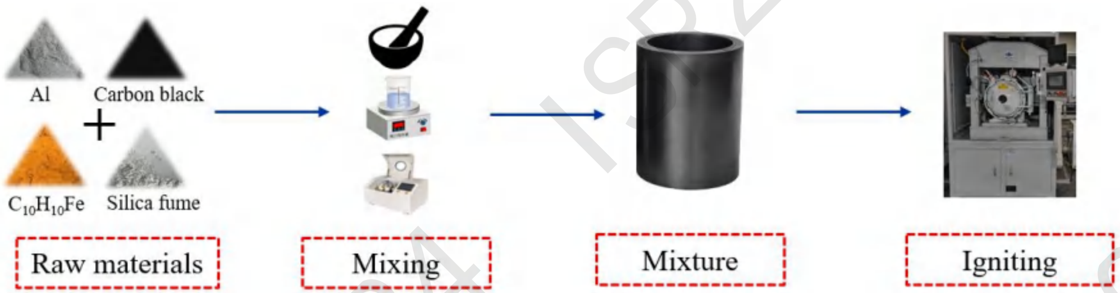

Fig. 2.1 Preparation of composite powder

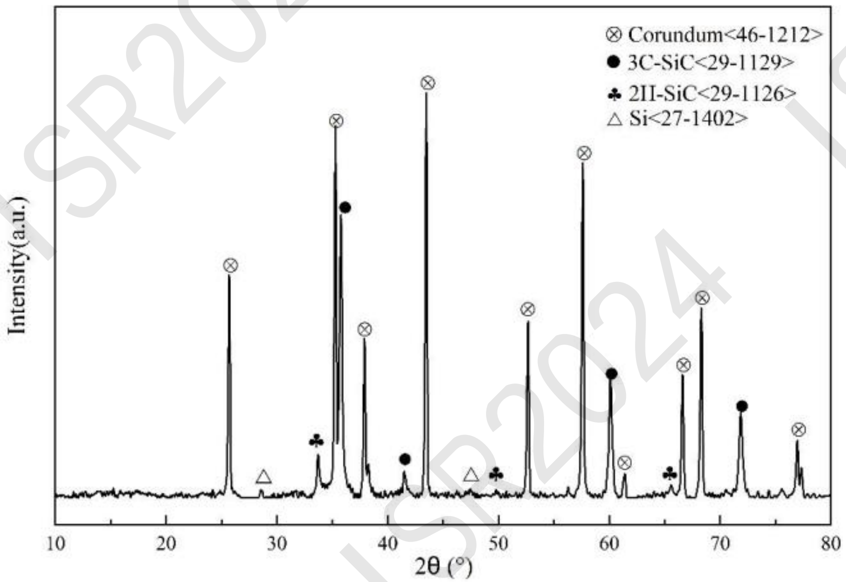

Fig. 2.2 XRD patterns of the synthesized powders

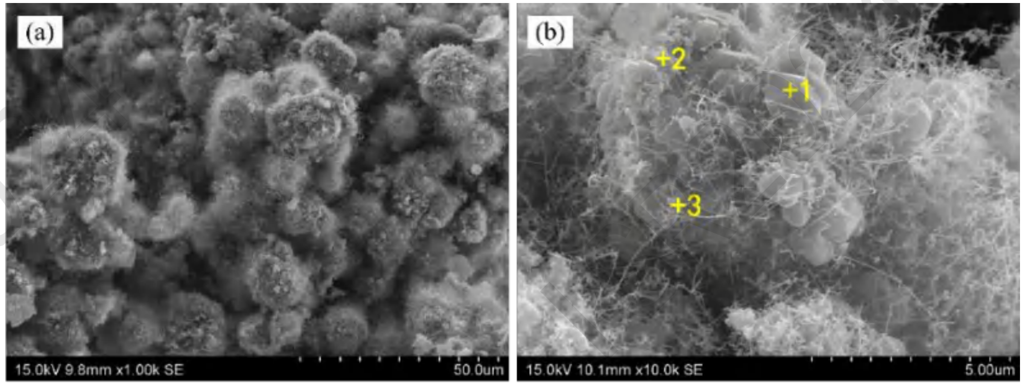

Fig. 2.3 SEM images of the synthesized powders

Table 2.1 EDS results of marked points in Fig. 2.3

Points	Al (at%)	Si (at%)	C (at%)	O (at%)
1	25.88	1.71	14.21	57.95
2	16.73	20.09	33.62	29.14
3	15.89	8.42	29.32	45.95

Preparation and characterization of Al_2O_3-SiC castables

Table 2.2 Formulations of the Al_2O_3–SiC refractory castables

Raw materials (wt.%)		Specimens				
		SA0	SA2	SA4	SA6	SA8
Tabular alumina	0–6 mm	66	66	66	66	66
	< 44 μm	6	4.8	3.6	2.4	1.2
Silicon carbide	< 74 μm	8	8	8	8	8
	< 44 μm	8	7.2	6.4	5.6	4.8
Activated alumina (CL370)		6	6	6	6	6
Silica powders		2	2	2	2	2
Silica fume		2	2	2	2	2
Secar71		2	2	2	2	2
SiC_{nw}/Al_2O_3		0	2	4	6	8
FS20		+0.2	+0.2	+0.2	+0.2	+0.2
Water		+5.2	+5.2	+5.2	+5.2	+5.2

Table 2.3 Characterization of castables

Properties	Methods
BD/AP	Archimedes
CMOR/HMOR	Three–point bending
CCS	Uniaxial compression
Thermal shock resistance	Water quenching, 3 cycles
Wear resistance	Hot wear
Slag resistance	Static crucible

Apparent porosity and bulk density

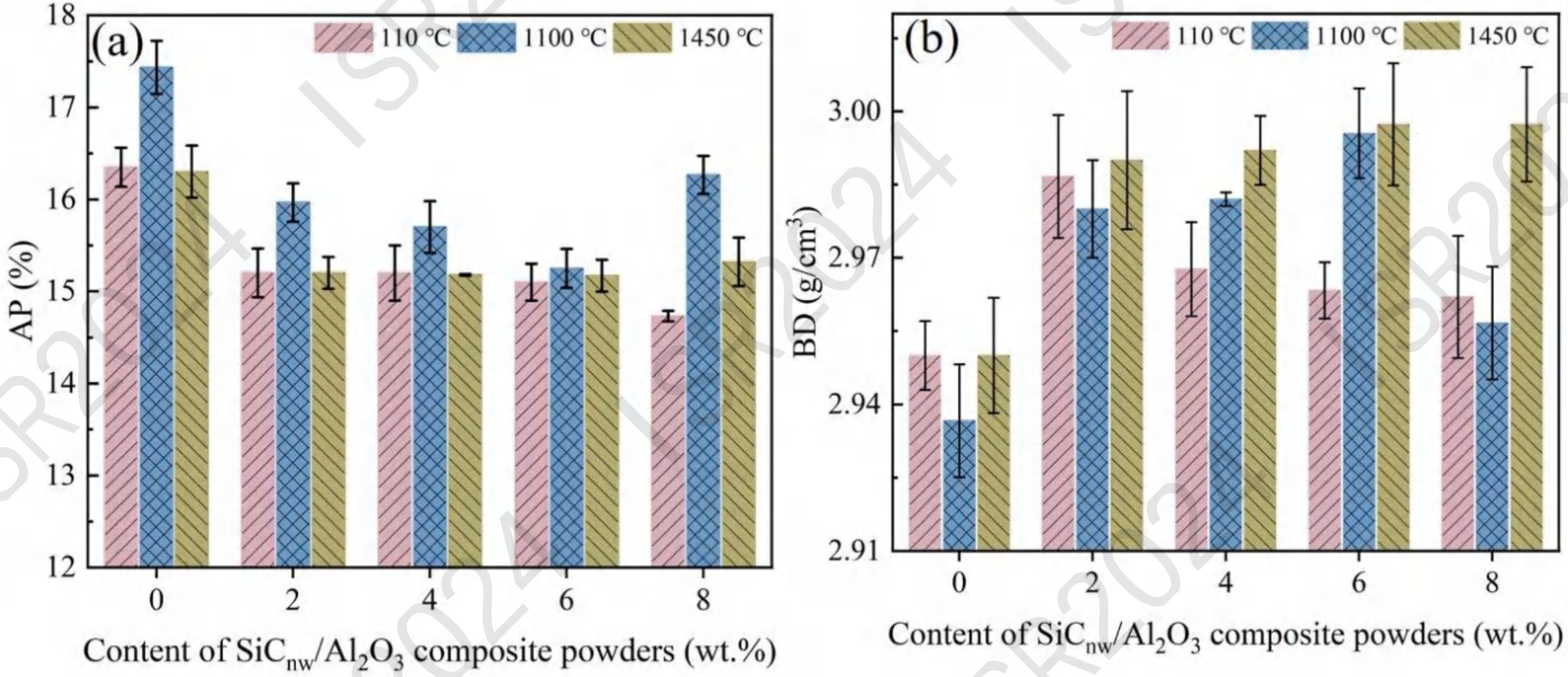

Fig. 3.1 AP and BD of castables

- After sintering at 1100 ℃ and 1450 ℃, SA6 shows the lowest AP of 15.25% and 15.17；the highest BD of 2.99 g/cm³ and 3.01 g/cm³%, respectively.

Cold modulus of rupture and cold crushing strength

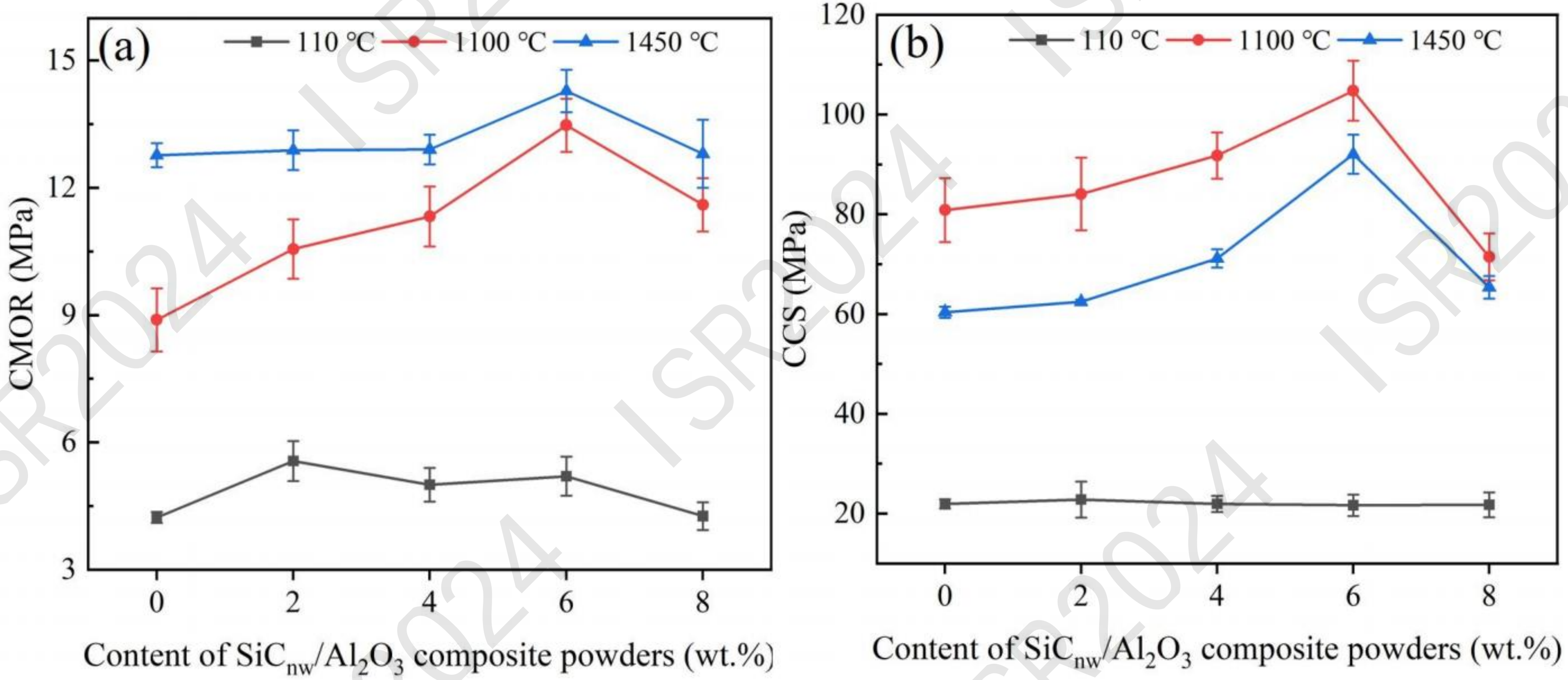

Fig. 3.2 CMOR and CCS of castables

- After sintering at 1100 °C and 1450 °C, the CMOR and CCS of the samples added with 6 wt.% SiC_{nw}/Al_2O_3 showed the maximum values.

Hot modulus of rupture（1450 °C）

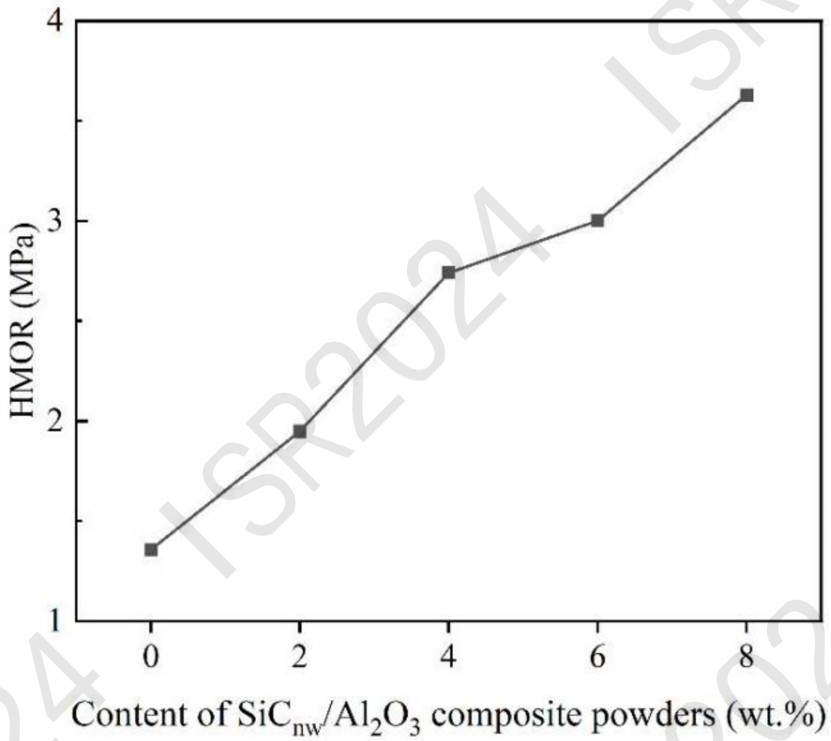

Fig. 3.3 HMOR of castables

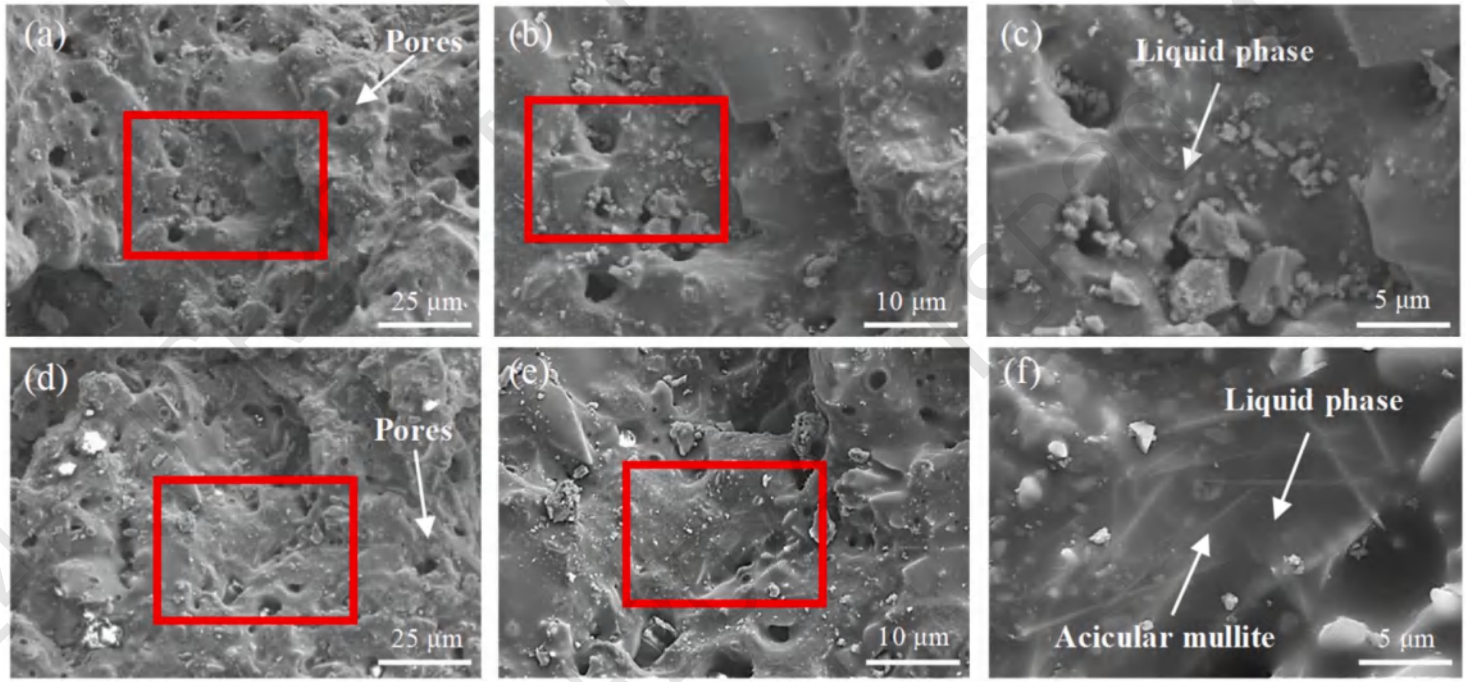

Fig. 3.4 SEM images of the samples after HMOR test: (a-c)SA0, (d-f) SA6

- SA8 shows the highest HMOR values of 3.63 MPa， which is 167% higher than that of SA0.

Hot modulus of rupture（1450 °C）

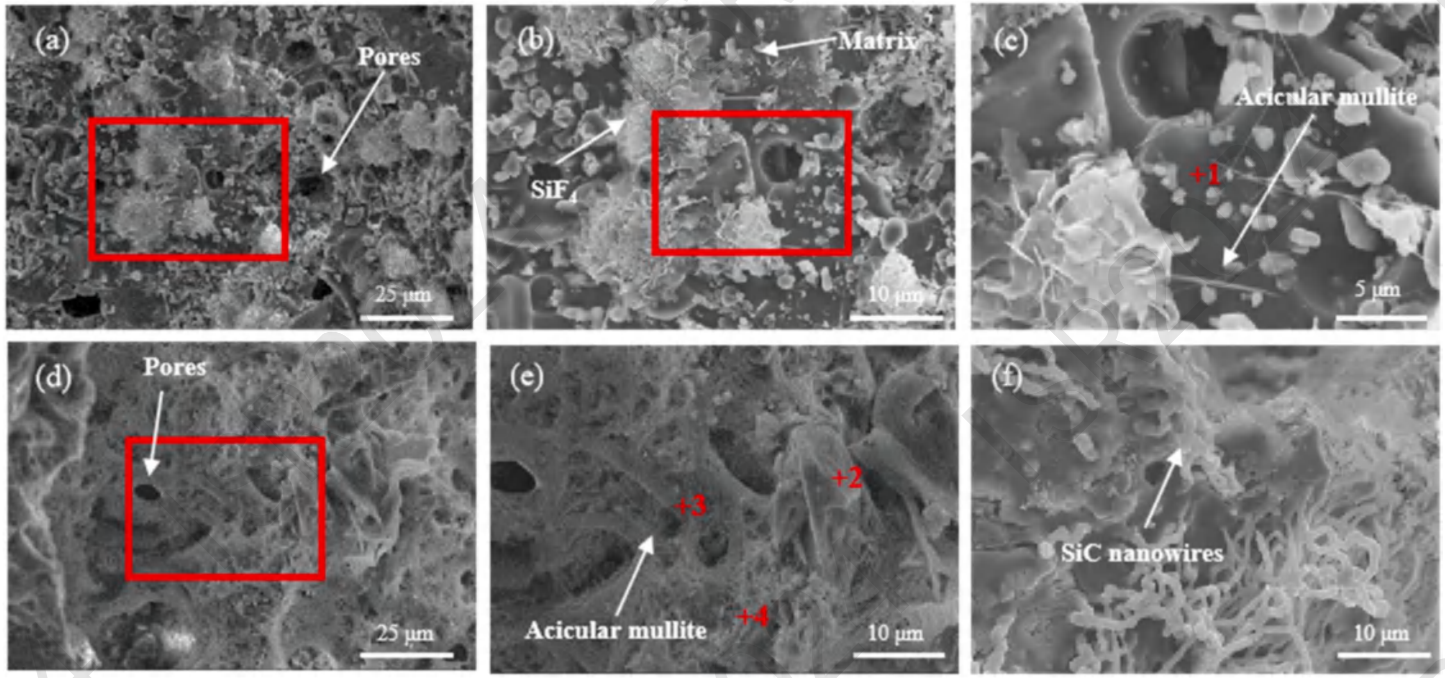

Fig. 3.5 SEM images of the samples after hydrofluoric acid pickling: (a-c) SA0, (d-f) SA6

Table 3.1 EDS results of the points marked in Fig. 3.5

Points	Al (at%)	Si (at%)	O (at%)	C (at%)
1	7.37	34.84	53.06	—
2	1.97	53.69	30.44	10.06
3	22.13	12.76	48.60	12.41
4	28.18	5.24	58.58	5.93

- The one-dimensional mullite and SiC nanowires in the SA6 synergistically improve the HMOR of SA6.

Thermal shock resistance（1100 °C, water quenching, 3 cycles）

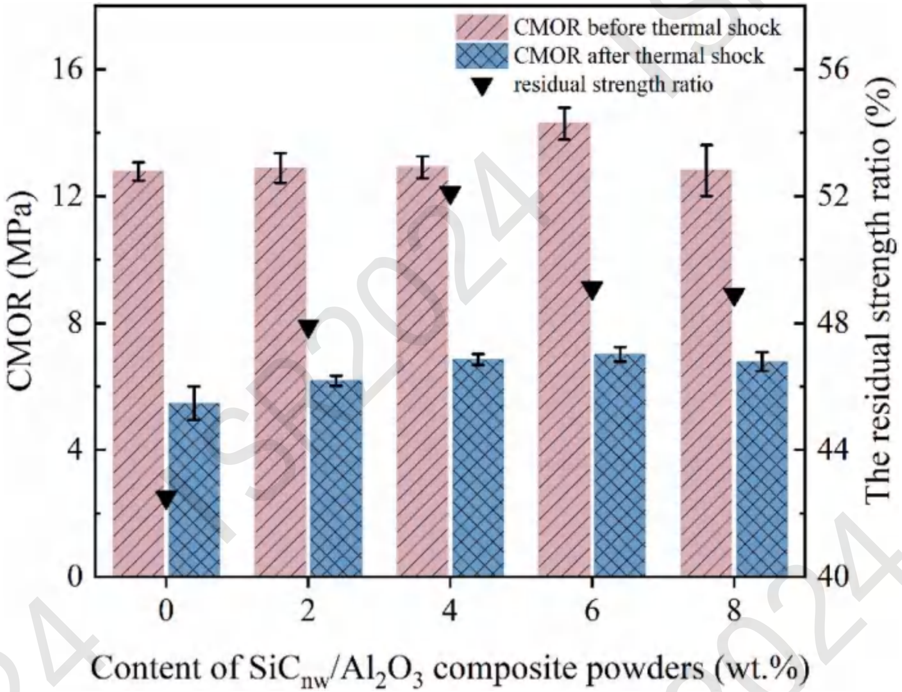

Fig. 3.6 CMOR before and after thermal shock and the residual strength ratio of castables

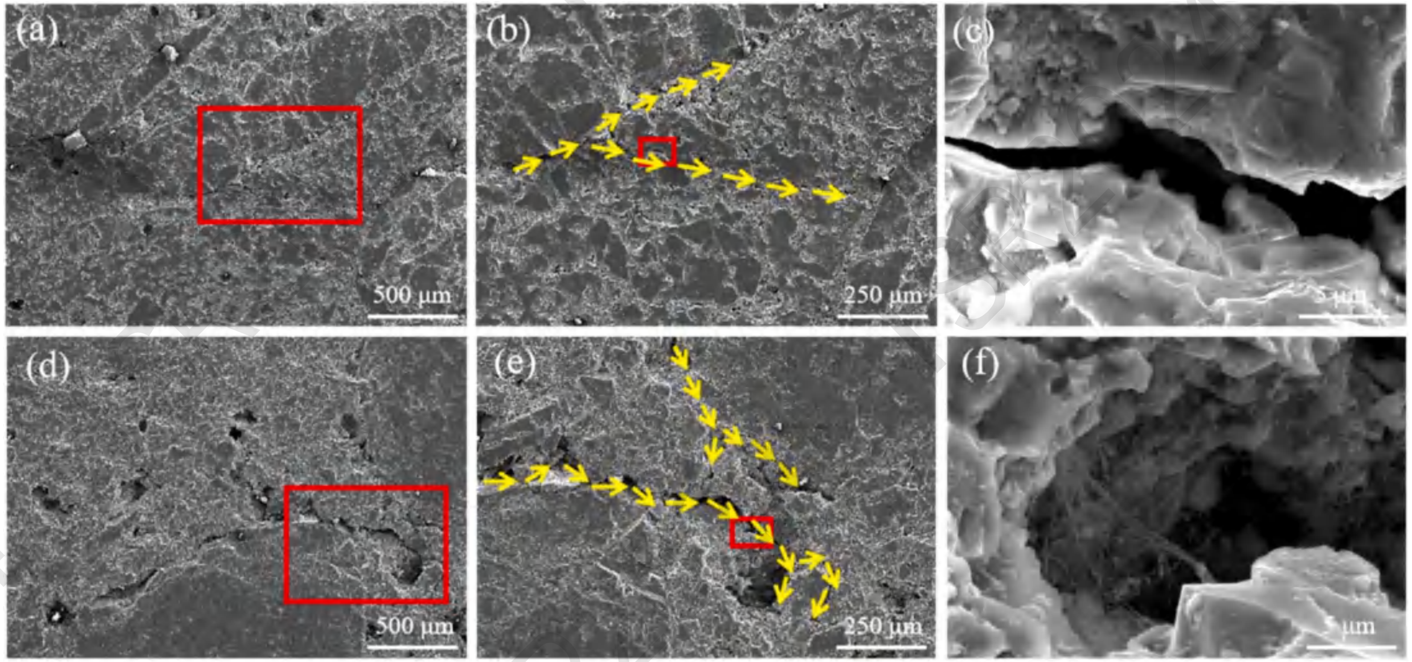

图3.7 SEM images of the samples after thermal shock: (a-c) SA0, (d-f) SA6

- SA6 shows the highest CMOR before and after shocking of 14.3 MPa and 7.0 MPa, and its residual strength ratio is 23% higher than that of 22.6%.

High temperature wear resistance（1100 °C, 30 min）

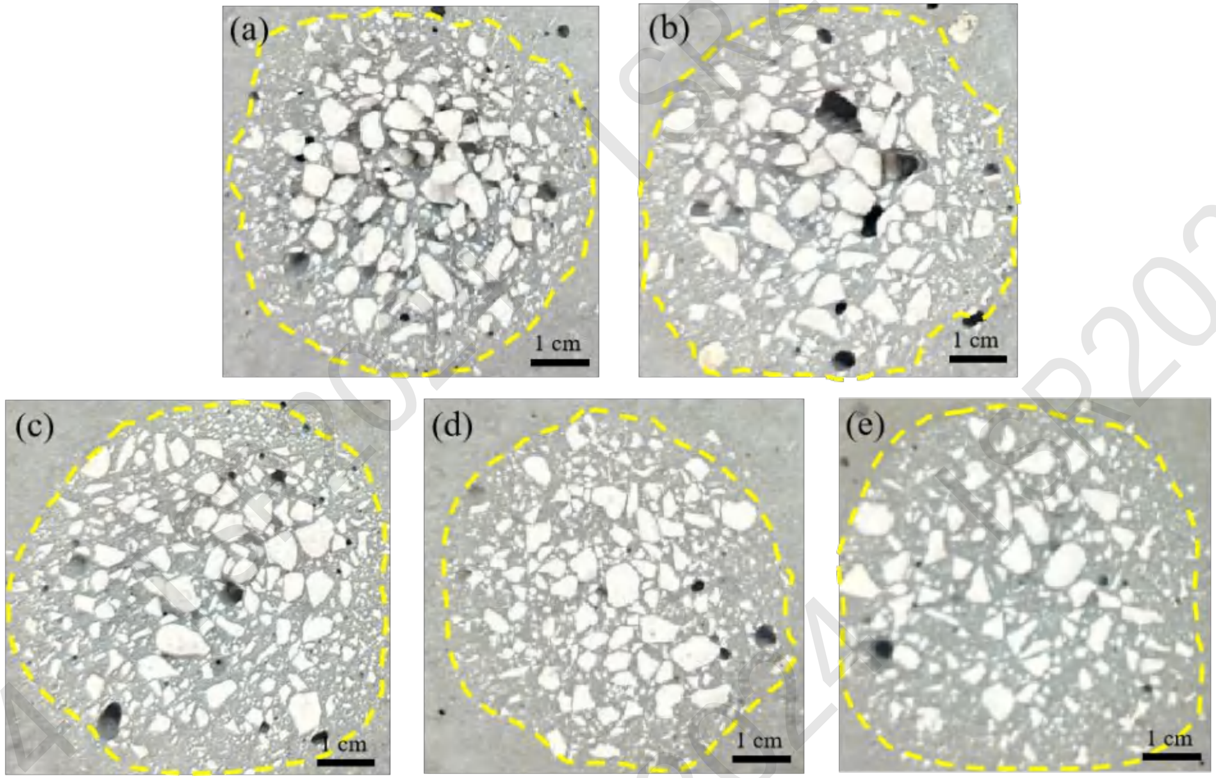

图3.8 Appearance of samples after high temperature wear test: (a) SA0, (b) SA2, (c) SA4, (d) SA6, and (e) SA8

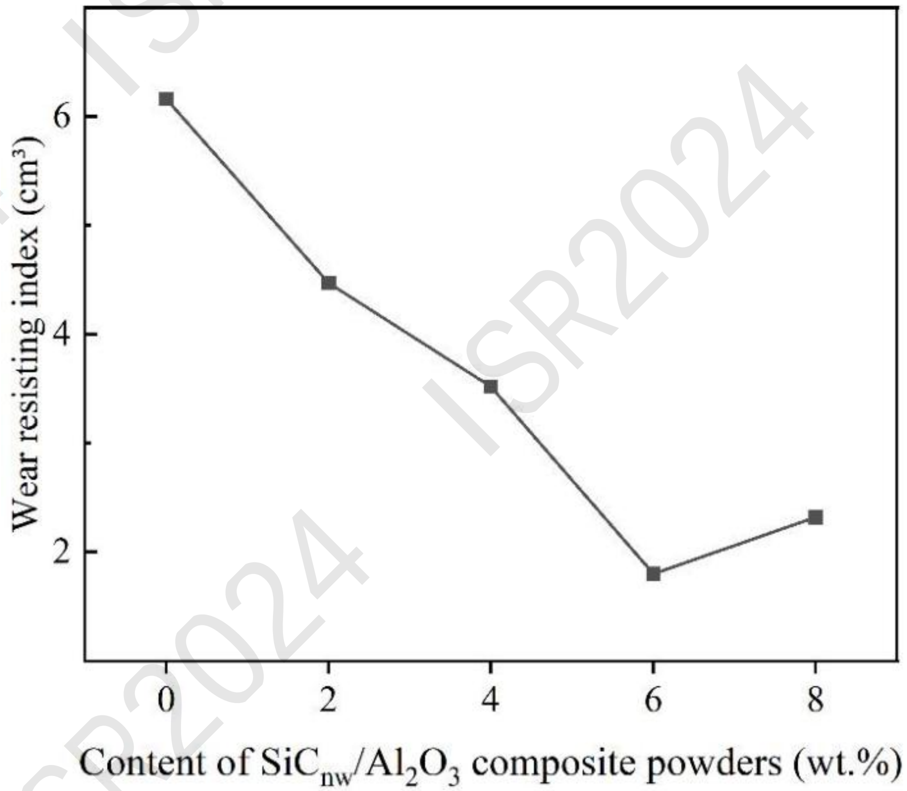

Fig. 3.9 Wear index values of castables

- The sample with 6 wt.% composite powders added shows the best wear resistance, with a wear index of 1.8cm³, which is 71% lower than that of the SA0.

High temperature wear resistance（1100 °C, 30 min）

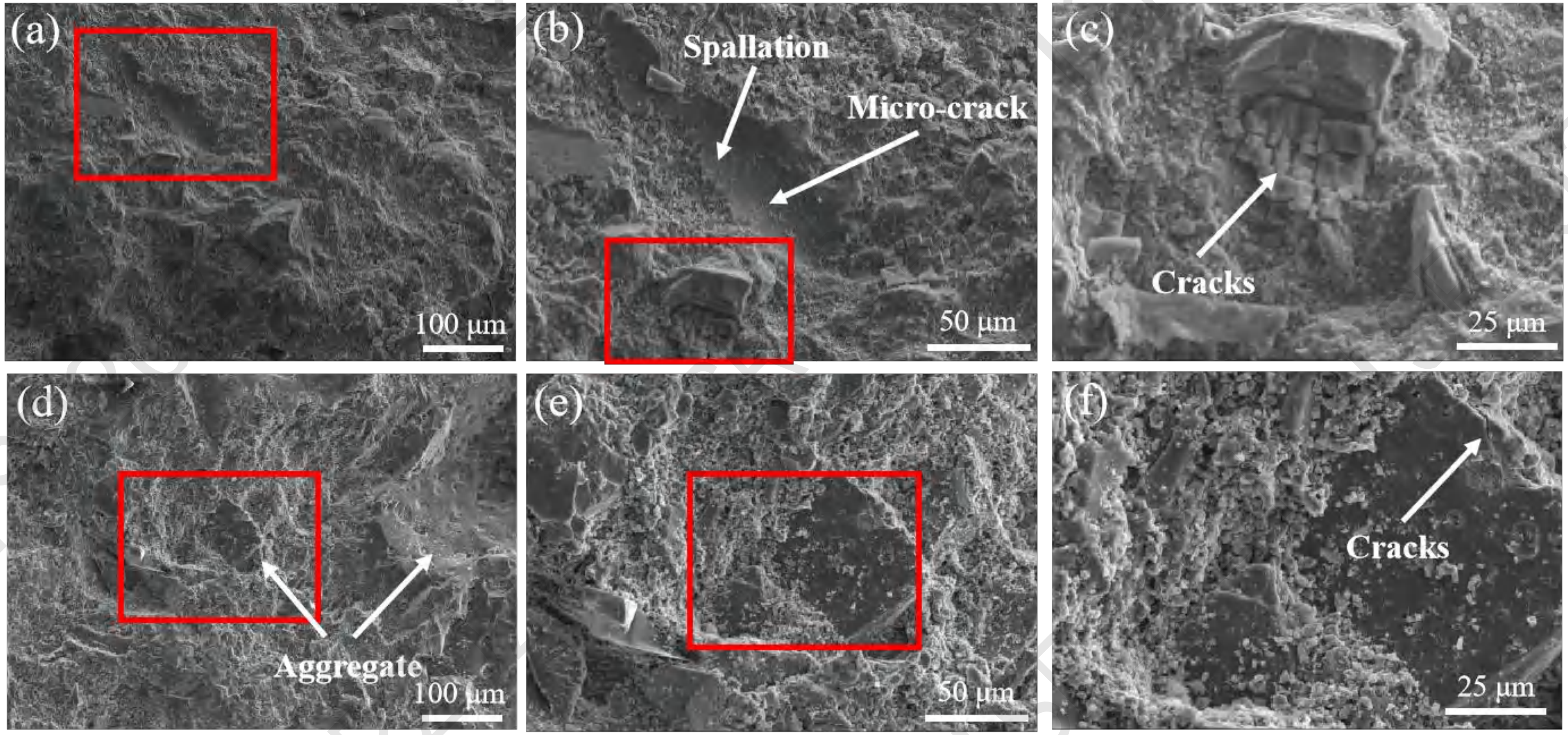

Fig. 3.10 SEM images of samples after high-temperature wear test: (a-c) SA0, (d-f) SA6

- The matrix in SA0 is prone to wear, and the aggregate is prone to detachment.
- The matrix in SA6 has a good bonding network, and the aggregate is wrapped by the matrix and is not easily detached.

Slag resistance （1600 °C，3 h）

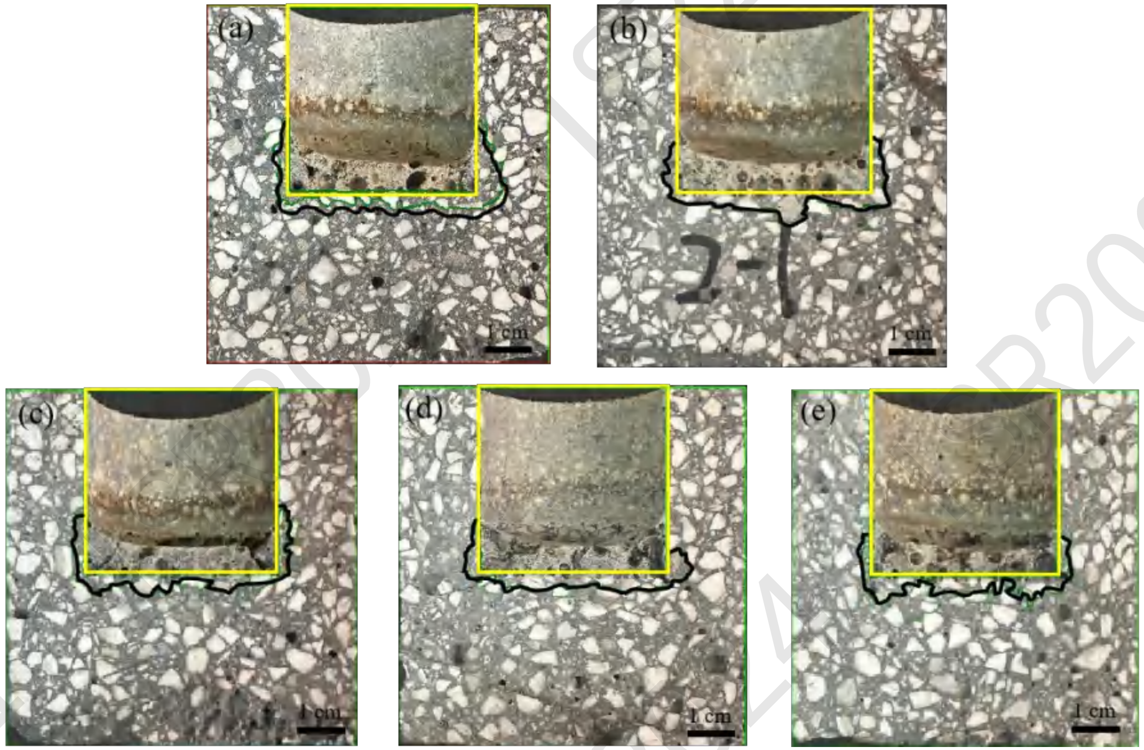

Fig. 3.11 Cross–sectional images of castables after the slag resistance test:
(a) SA0, (b) SA2, (c) SA4, (d) SA6, and (e) SA8.

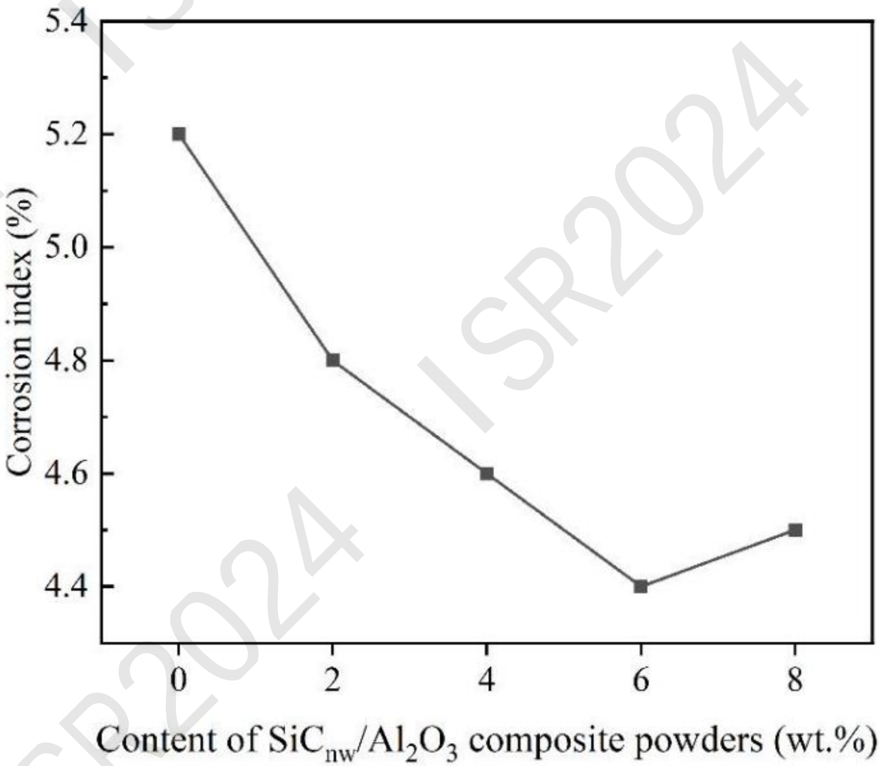

Fig. 3.12 Corrosion index of castable

- Compared to the SA0, the corrosion index of the SA6 decreased by 15.4%.

3.2 Conclutions

1 When 6 wt.% SiC_{nw}/Al_2O_3 composite powders was added, the residual strength ratio was improved from 43% to 49%; after the thermal shock test, the CMOR value increased by 28.2% to 7.0 MPa; the wear index value decreased by 71.0% to 1.8cm³; the HMOR value increased by 144% to 3.0 MPa; the corrosion index decreased from 5.2% to 4.4%.

2 The results indicate that the introduction of pre-synthesized low-dimensional nanocomposite powder can regulate the matrix microstructure, strengthen and toughen refractories, and improve the service performance of castables, especially in terms of high temperature wear resistance and thermal shock resistance.

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Achievements:

[1] Xiaochuan Chong, Guoqing Xiao, Donghai Ding, et al. Combustion synthesis of SiC/Al_2O_3 composite powders with SiC nanowires and their growth mechanism. ***Ceramics International,*** 2022, 48(2): 1778-1788. **https://doi.org/10.1016/j.ceramint.2021.09.258**

[2] Cankun Wang, Guoqing Xiao, Donghai Ding, Endong Jin, Xiaochuan Chong, Changkun Lei, Luyan Sun. Effects of SiC_{nw}/Al_2O_3 composite powders on properties of Al_2O_3–SiC refractory castables[J]. ***Ceramics International,*** 2024, 50(11): **https://doi.org/ 10.1016/j.ceramint.2024.03.007**

THANKS FOR YOUR ATTENTION