Effect of SO_2 and steam on CO_2 capture performance of biomass-templated calcium aluminate pellets

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Calcium looping (CaL)

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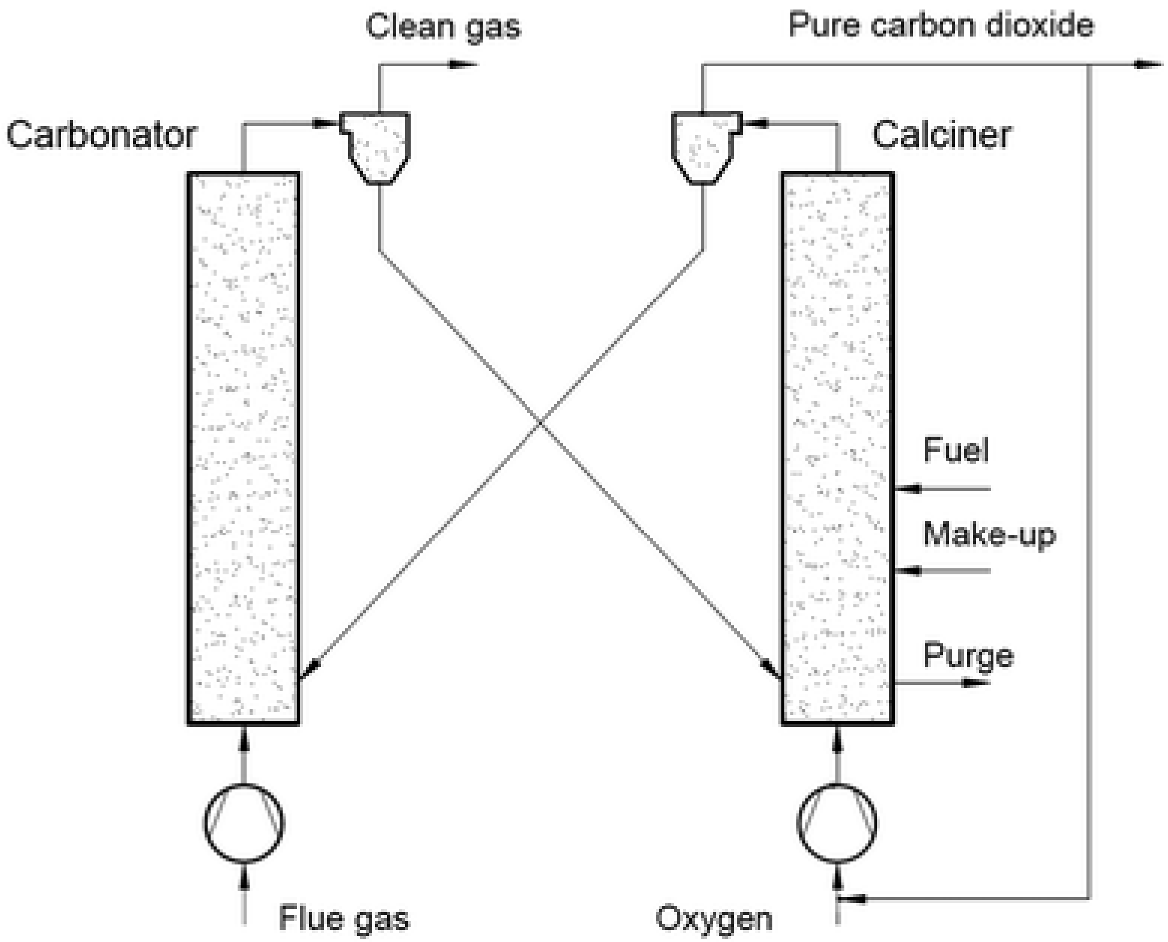

Figure 1: Schematic of CaL

Challenges in CaL sorbents

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- The effect of the number of carbonation/calcination cycles in the reactivity caused mainly by sintering
- The attrition of the sorbent in both fluidized beds
- Effects of SO_2 concentration in the flue gas causes sorbent poisoning

Pelletised sorbents

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- Possibility of incorporating inert material
- Higher attrition resistance
- Cheap method
- Easy to scale-up
- Less reactivity decay than natural materials

Biomass-templating of sorbents

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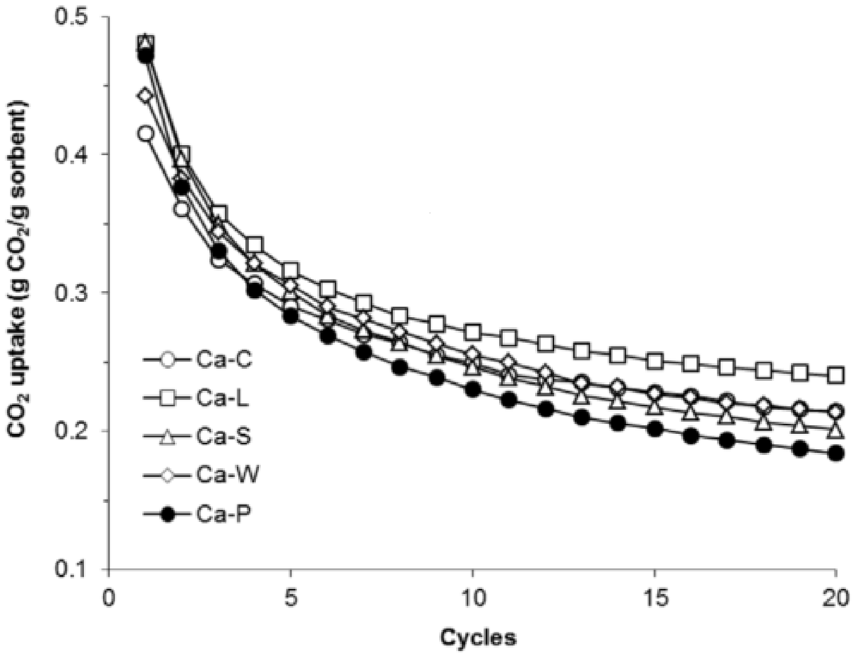
- Inexpensive material to increase porosity of pelletized sorbents
- TGA testing demonstrated 33.3% higher CO_2 uptake than normal calcium aluminate pellets



Ca-C: Pellets with cardboard
Ca-L: Pellets with leaves
Ca-S: Pellets with date seeds
Ca-W: Pellets with wood
Ca-P: Biomass-free pellets

Figure 2: Effect of 10% biomass on CO_2 uptake (Carbonation: 20 min 15% CO_2 650 °C; calcination: 5 min 100% air at 850 °C) [1]

Production of pellets

Figure 4: Pelletized material

Figure 5: Spraying system

Figure 3: TMG 1/4 Granulator

Preparation of sorbents

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Sample type	Lime (wt %)	Calcium aluminate cement (wt %)	Flour (wt %)	Type of water used
LC	90	10	0	Deionized
LF	90	0	10	Deionized
LCF	80	10	10	Deionized
LCFSW	80	10	10	Sea water

Methodology

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- Calcination of limestone
- Mixing the desired materials in the pelletization vessel
- Add water (700 ml approximately) with agitator speed to 500 rpm and chopper speed to 2500 rpm
- Once the pellets have been formed, sieve the particles to the desired size range
- Air drying for 2 hours and storing in nitrogen to avoid reactions with air

Elementary analysis of the samples

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Component (wt %)	Limestone	LC	LF	LCF	LCFSW
Al_2O_3	0.082	5.63	0.218	4.73	5.22
BaO	0.007	0.007	0.007	0.005	0.015
CaO	53.9	58.4	58.2	52.4	57.3
Fe_2O_3	0.015	0.033	0.040	0.027	0.030
K_2O	0.007	0.006	0.037	0.023	0.051
MgO	0.185	0.208	0.210	0.197	0.335
MnO_2	0.008	0.008	0.009	0.008	0.010
Na_2O	0.053	0.071	0.052	0.056	0.806
P_2O_5	0.007	0.011	0.035	0.022	0.012
SO_3	0.034	0.039	0.122	0.055	0.234
SiO_2	0.701	1.20	0.770	0.267	0.292
SrO	0.017	0.018	0.018	0.017	0.018
TiO_2	0.006	0.015	0.013	0.006	0.007
Total oxides	55.1	65.7	59.7	57.8	64.4
TOC+TIC +CO_2	42.7	12.8	28.1	25.6	15.4
Water at 105°C	0.10	0.10	0.10	0.10	0.10
Water at 950°C	0.10	22.3	15.9	20.5	23.1
Total	98.0	100.8	103.8	103.9	102.9

SEM

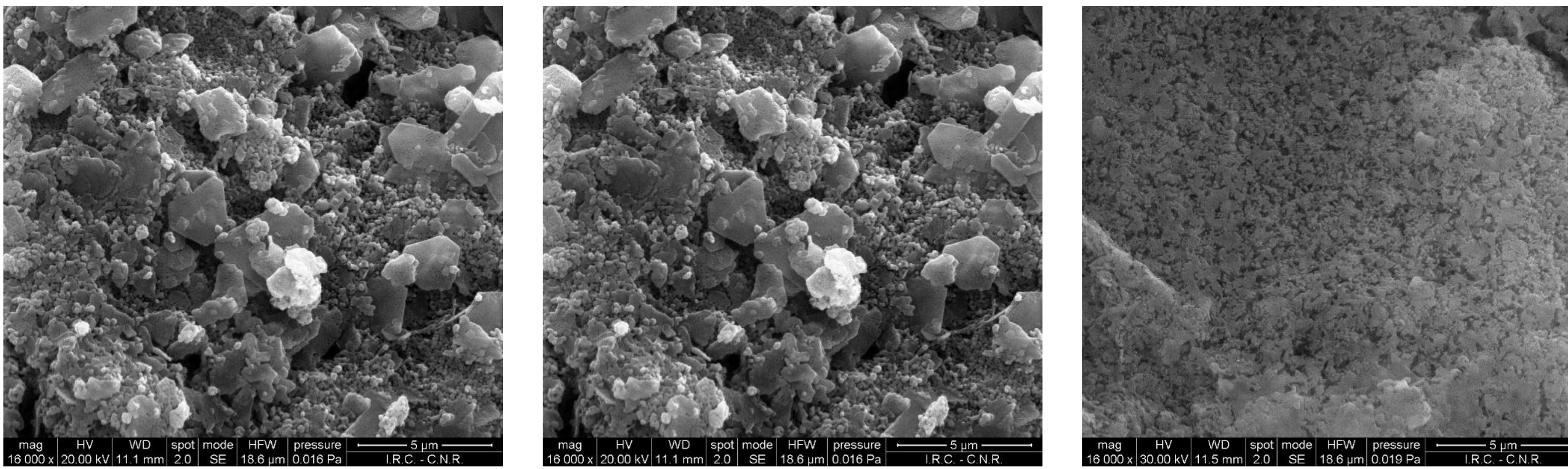

Figure 6: SEM image of LC, LF and LCF respectively

Crushing strength

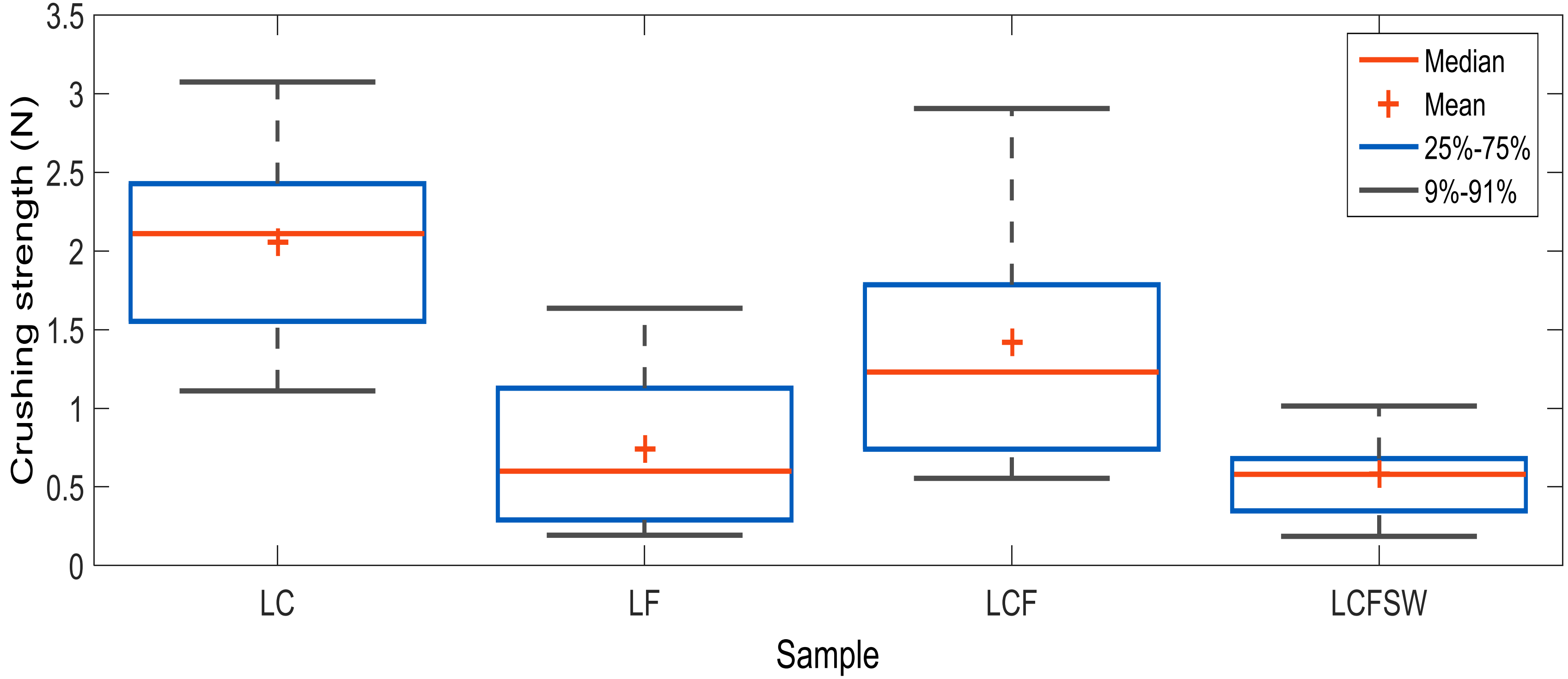

Figure 7: Crushing strength of non-calcined samples

TGA results

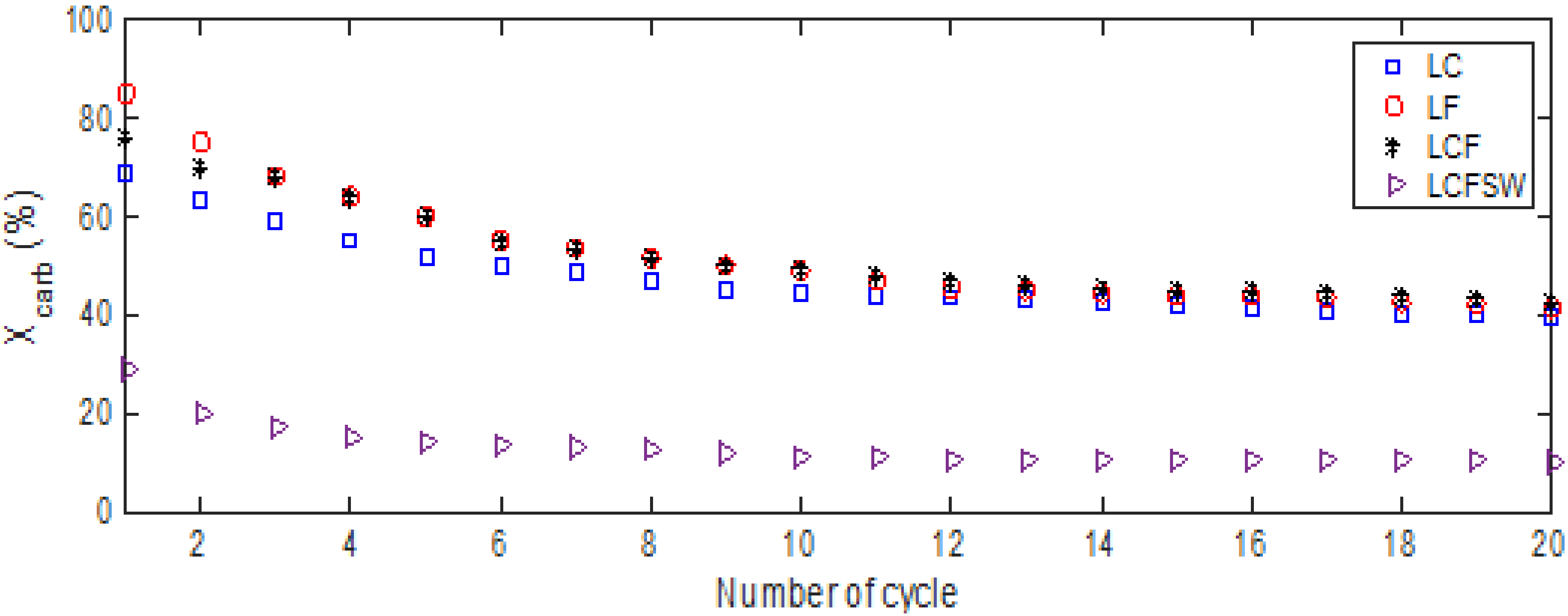

Figure 8: TGA results: carbonation at 650°C 15% vol CO_2 (20 min), calcination 950°C at 100% vol CO_2 (10 min)

BFB

-68 mm ID

-100 g of sorbent in 1.5 kg of silica sand

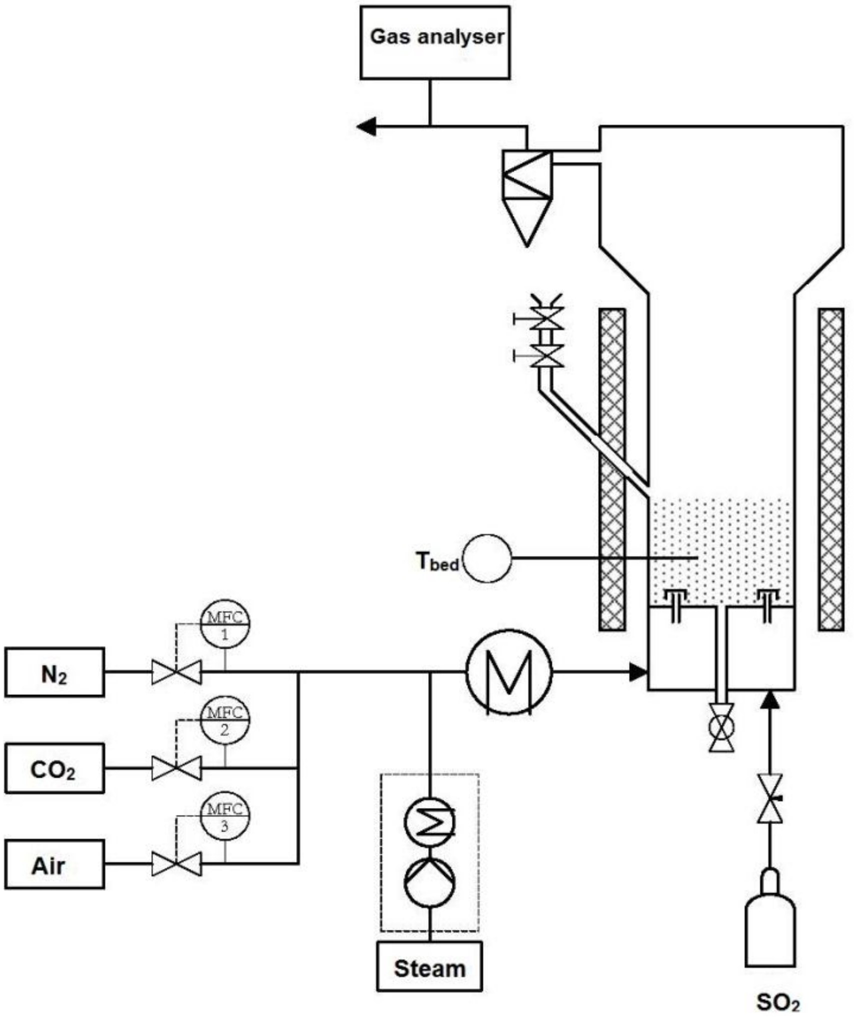

Figure 9: Schematic of BFB utilised in the experiments

Conditions of BFB experiments

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- Normal condition experiment

Carbonation and calcination isothermal at 850°C with 90% vol. CO_2 during the carbonation and 20% vol. Duration of both calcination and carbonation was 15 min.

- High-sulphur experiment

Carbonation and calcination isothermal at 850°C with 90% vol. CO_2 during the carbonation and 20% vol. Duration of both calcination and carbonation was 15 min. 1500 ppm of SO_2 during carbonation and calcination.

- Steam experiment

Carbonation and calcination isothermal at 850°C with 90% vol. CO2 during the carbonation and 20% vol. Duration of both calcination and carbonation was 15 min. 15% vol in both carbonation and calcination.

BFB results

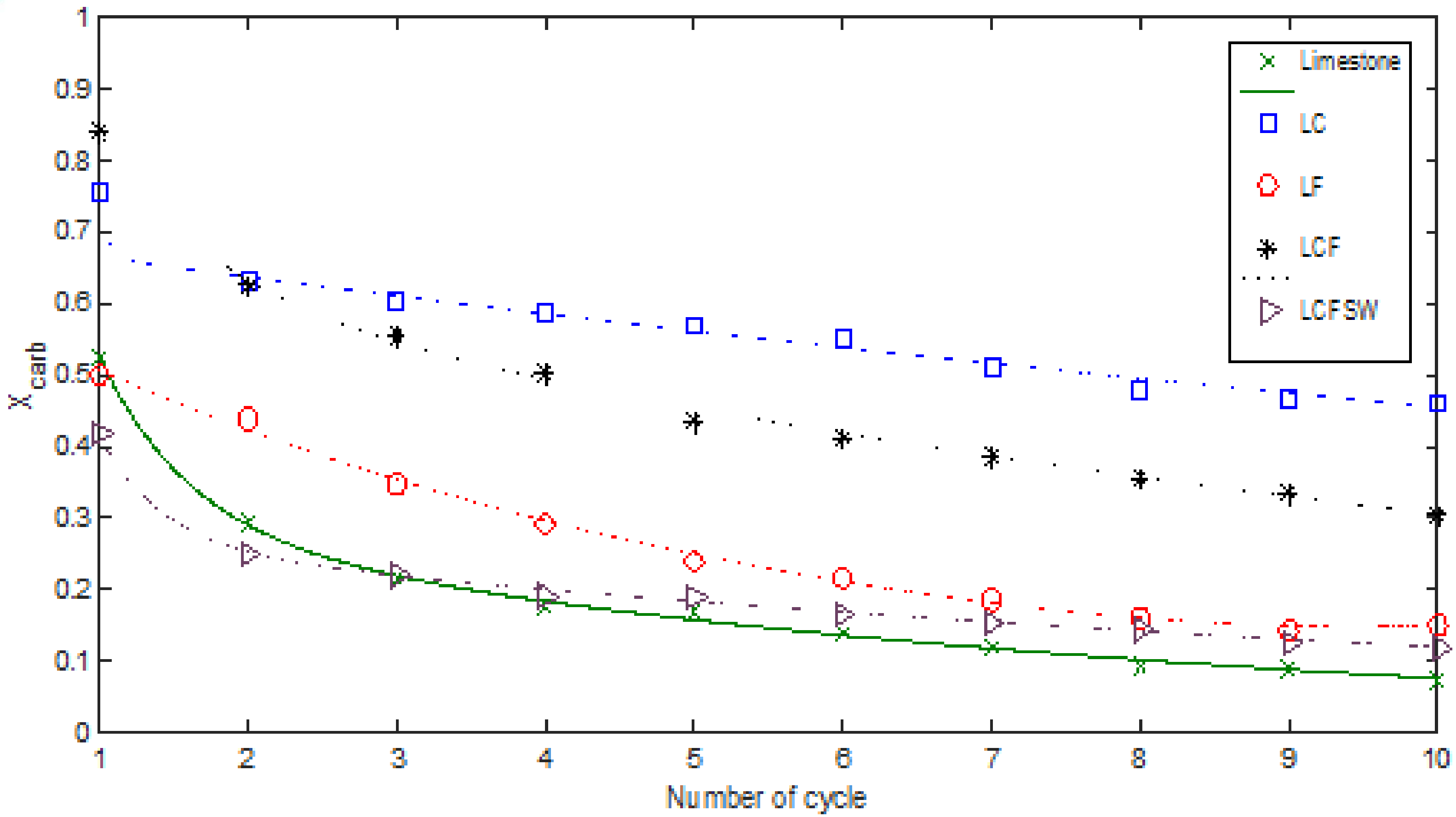

Figure 10: Carbonation degree in BFB under normal conditions during 10 cycles

BFB results (II)

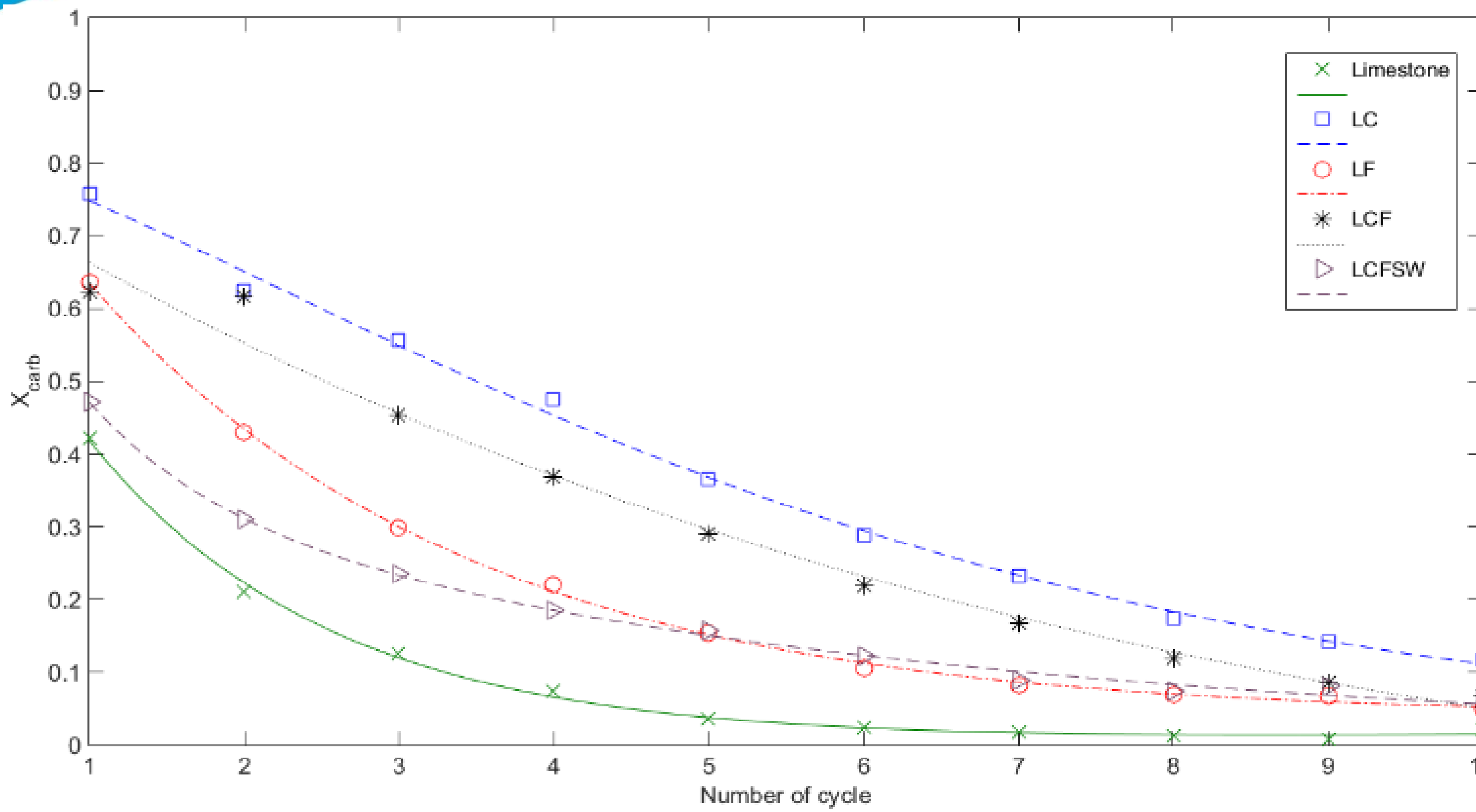

Figure 11: Carbonation degree in BFB under high sulphur during 10 cycles

BFB results (III)

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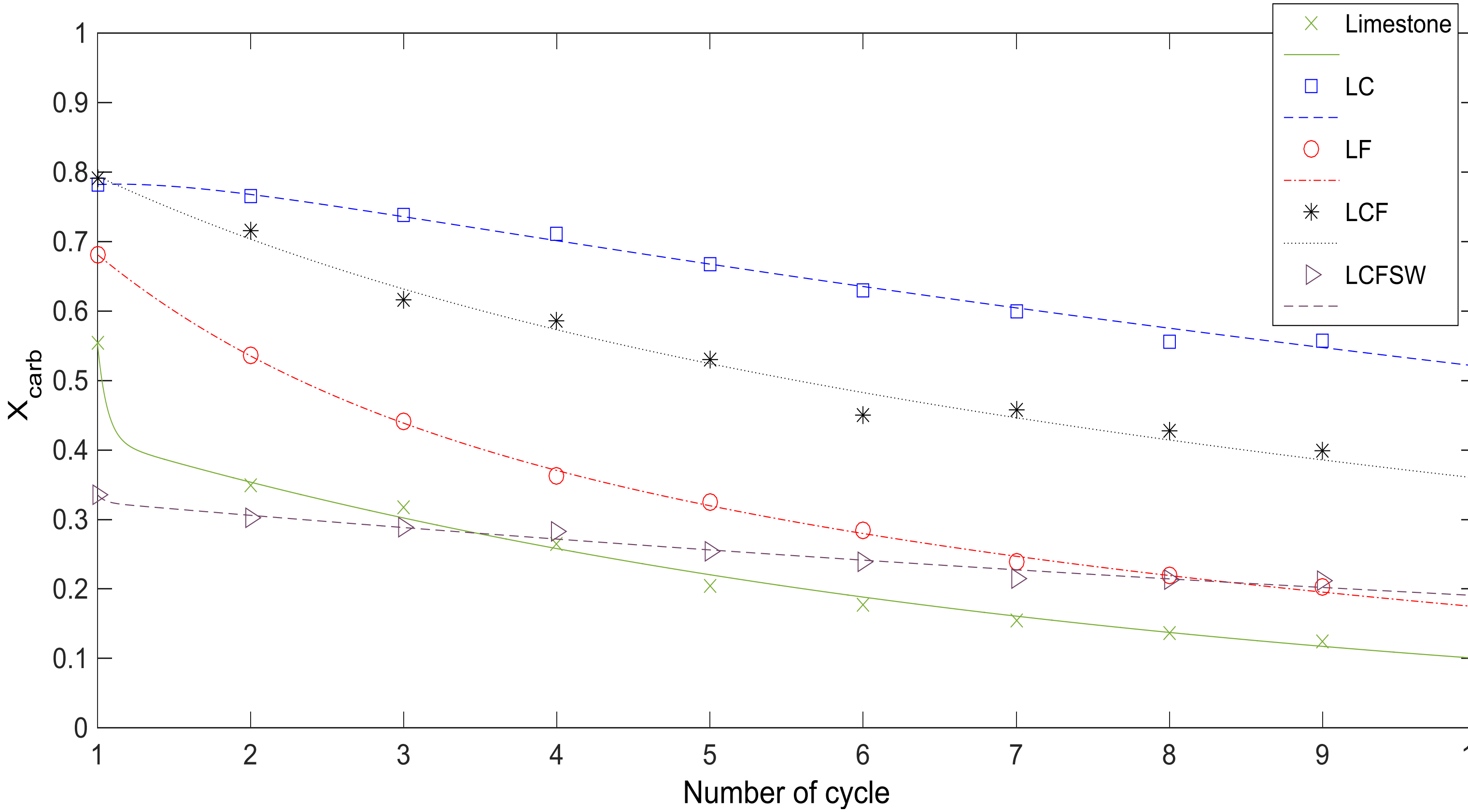

Figure 12: Carbonation degree in BFB with 15% vol steam during 10 cycles

Conclusions

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- All synthetic sorbents performed better than limestone when tested in BFB under all conditions

- LCF performed better in TGA, but LC performed better in BFB

- Attrition is believed to be higher in the materials with pore forming components (biomass-templated)

References

[1] Ridha FN, Wu Y, Manovic V, Macchi A, Anthony EJ. Enhanced CO_2 capture by biomass-templated $Ca(OH)_2$-based pellets. Chem Eng J 2015;274:69–75. doi:10.1016/j.cej.2015.03.041.

All the results included in this presentation can be found in:

M. Erans, T. Beisheim, V. Manovic, M. Jeremias, K. Patchigolla, H. Dieter, L. Duan and E.J. Anthony, Faraday Discuss., 2016, DOI: 10.1039/C6FD00027D.

Acknowledgement

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Q&A

Any questions?