CO_2 UTILIZATION FOR THE PRODUCTION OF CARBONATE NANOPARTICLES IN A PILOT – SCALE ROTATING PACKED BED REACTOR

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ABSTRACT

Creating new value chains by CO_2 utilization will assist the wide proliferation of carbon capture and utilization technologies (CCU)[1, 2]. CO_2 waste streams can be utilized as raw material in the production of value-added nano-structured products like carbonate particles, i.e. precipitated calcium carbonate (nano-PCC) and hydromagnesite (nano-HM). Conventionally, PCC and HM are produced via reactive crystallization in bubble or continuous stirred reactors. However, a known bottleneck is the time-consuming batch methods currently applied. Intrinsic shortcomings of such setups include long processing times and poor controllability over product properties, while serious mass transfer limitations mandate large equipment sizes and harsh synthesis conditions[3, 4]. These challenges can be addressed with Rotating Packed Bed (RPB) reactors[5]. High gravity conditions of an RPB enable process intensification, resulting in significant reduction of equipment volumes, improved control over product properties and mild operating conditions[6].

In this work we demonstrate the production of nano-PCC and nano-HM via direct aqueous carbonation of $Ca(OH)_2$ and MgO slurries with pure CO_2 in a pilot plant, developed by our team. In both cases the carbonation was performed at very mild conditions. Precursors were suspended in water excluding other additives. A wide range of operating conditions was employed regarding solid concentration, gas and slurry flow rate, L/G ratio and rotating speed. The process performance was evaluated based on three key criteria; reaction time until complete conversion, particle size and CO_2 utilization efficiency.

We produced nano-PCC monodisperses of primary particle size as low as 181 nm and crystallite size 45 nm. Especially nano-HM was produced via a single-step route that was never reported before, resulting in sheet-like HM particles of thickness down to 31 nm. The utilization efficiency was exemplary under all applied conditions, reaching 99 % for PCC and 94 % for HM. In both cases, the RPB reactor enabled a serious reduction of processing times. In the case of PCC the reaction time was halved (-49 %) by adjusting the feed rates and rotating speed compared to the starting point. In the case of HM, the production rate was up to 30 times higher than in CSTRs, under the same process conditions.

KEYWORDS: Rotating Packed Beds, Nanoparticles, Reactive precipitation, Calcium carbonate, Hydromagnesite

REFERENCES

[1] IEA, “Transforming Industry through CCUS,” 2019.

[2] S. Kaiser, S. Gold, and S. Bringezu, "Environmental and economic assessment of CO_2-based value chains for a circular carbon use in consumer products," Resour. Conserv. Recycl., vol. 184, no. May, p. 106422, 2022.

[3] S. Stopic et al., "Synthesis of magnesium carbonate via carbonation under high pressure in an autoclave," Metals (Basel)., vol. 8, no. 12, 2018.

[4] P. J. Davies and B. Bubela, "The transformation of nesquehonite into hydromagnesite," Chem. Geol., vol. 12, no. 4, pp. 289–300, 1973.

[5] A. I. Papadopoulos and P. Seferlis, Process Systems and Materials for CO_2 Capture, 1st ed. John Wiley & Sons, Ltd, 2017.

[6] K. Neumann et al., "A guide on the industrial application of rotating packed beds," Chem. Eng. Res. Des., vol. 134, pp. 443–462, 2018