Oxygen carrier derived from ferric sludge for chemical looping combustion of MSW syngas

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The production of drinking water results in the generation of a substantial amount of waste by-product known as water treatment sludge (WTS). Typically, WTS constitutes approximately 1 to 3% of the volume of raw water treated in these plants (Hidalgo et al., 2017). The conventional practice of directly sending WTS to landfills is not a sustainable long-term solution, given the finite nature of land resources and the associated high financial and environmental costs (Nguyen, Thomas, Surapaneni, Moon, & Milne, 2022). Thus, it is imperative to harness WTS, thereby mitigating the amount of WTS destined for landfills.

This research focuses on the utilization of WTS, specifically ferric sludge (FS), as an oxygen carrier (OC) for chemical looping combustion (CLC) of municipal solid waste (MSW) syngas in a bench scale fluidized bed. The choice of FS is motivated by its high Fe_2O_3 content, a suitable and promising compound for CLC (Lyngfelt, 2020). A comparative analysis of the CLC performance between FS and iron ore, employed as a benchmarked OC, reveals the superior syngas combustion efficiency of FS, as illustrated in Fig. 1.

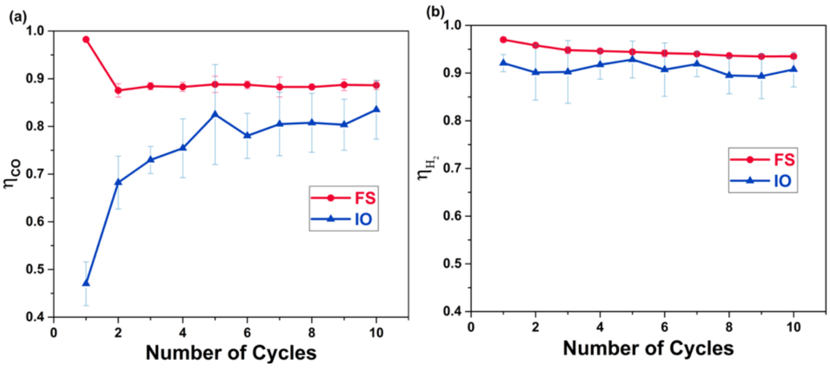

Fig. 1 (a) CO conversion efficiency comparison with FS and IO, (b) H_2 conversion efficiency comparison with FS and IO

To assess the viability of FS as an OC, extended CLC cycles (50 cycles) were conducted. However, challenges emerged, such as severe agglomeration leading to bed de-fluidization, hindering data collection. In response, modifications were introduced to refine FS as an OC. Two distinct methods were employed: first, the addition of adding inert α-Al_2O_3 support alongside FS to prevent agglomeration, resulting in significant reduction of agglomeration and sintering while achieving relatively high combustion efficiency, as depicted in Fig. 2.

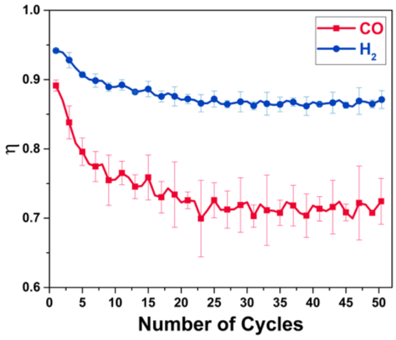

Fig. 2 CO and H_2 combustion efficiency of FS/Al_2O_3 for extended cycles CLC

Secondly, modification of FS involved the addition of high aluminate cement and CuO, with CuO enhancing the reactivity of the OC (Moed, Chiang, Ku, & Tseng, 2022) and the cement bolstering the stability and strength of the OC (Gu et al., 2015). Variation in CuO content, with a constant cement content, revealed that 10% substitution of CuO yielded the best combustion efficiency, as illustrated in Fig. 3. On top of the high CLC efficiency, this modified FS remained stable and successfully mitigated de-fluidization arising from agglomeration.

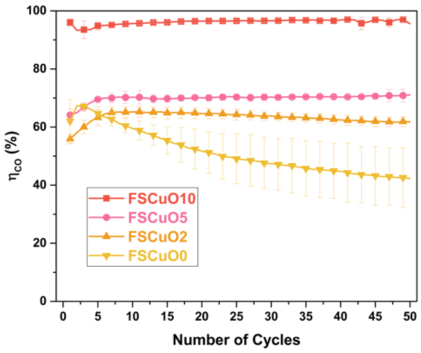

Fig. 3 CO conversion of modified OC with different substitution of CuO (2%, 5%, and 10%) for extended cycles CLC

In summary, the outcomes of this study highlight that with the implemented modifications, FS emerges as a novel, efficient, cost-effective, and environmentally friendly OC for CLC. The simultaneous utilization of waste-derived materials and waste derived syngas in CLC, presents an integrated solution that employs dual waste streams to enhance the sustainability of the CLC process.

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