Development of Catalyst Bed Concepts for Induction Heating for Emission Control

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Significance and Relevance

Greenhouse gas emissions (GHGs) rise at alarming rates, making it crucial to address this issue. While 15% of the total emissions are accounted for by the transport sector, 60% come from the energy and chemical industry.[1] As the chemical industry moves toward electrification, traditional emission control technologies must be adapted to align with these emerging trends. This work demonstrates that electromagnetic induction heating technology can be applied to provide highly dynamic heating, e.g. for accommodating spontaneous emissions. Further, this technology supports industrial electrification by alternative heating of catalytic processes.

Preferred and 2nd choice for the topic: Catalysis to electrify the chemical production, automotive and stationary emission control
Preferred presentation: Poster

Introduction and Motivations

Electromagnetic induction heating is a promising candidate for achieving controlled, dynamic, and immediate heat regulation, which may contribute to industrial electrification when being coupled with chemical processes.[2] In the induction heating process, energy is converted into radiofrequency electromagnetic waves while susceptors release heat when they are immersed in an alternating magnetic field.[3] Modifying the active phase to serve as a susceptor for induction heating with specific magnetic susceptibility poses a challenge for emission control applications. However, effective heat dissipation near the active phase is expected to be similarly efficient for the chemical reaction. In a simplified approach, the catalyst bed can be adapted for induction heating using a physical mixture of susceptors and catalysts (Figure 1).

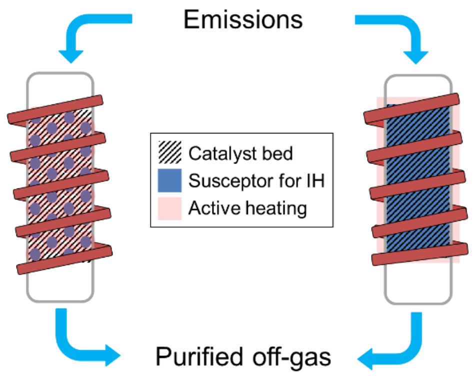

Figure 1. Schematic illustration of different catalyst bed concepts for emission control applications using induction heating (IH). Left – stainless steel beads as susceptors, right – powder of susceptor as part of the catalyst bed.

Materials and Methods

In this work, different catalyst bed concepts were developed by using a variety of susceptors for induction heating. On the one side, commercially available stainless steel beads (SS316) sized between 1 and 5 mm were utilized as susceptors. Aside from these bulk susceptors, mixed metal iron oxides (ferrites) containing cobalt and nickel were synthesized using co-precipitation, hydrothermal, or surfactant-free methods, resulting in various particle sizes and magnetic properties.[4, 5] Additionally, Pt/Al_2O_3 is decorated with iron carbide nanoparticles (ICNP) via organometallic approach.[6] Susceptors with different size fractions were physically mixed with the Pt/Al_2O_3 to modify the catalyst bed and allow for emission control testing. In addition to induction heating studies, susceptors were thoroughly characterized and material properties were correlated with the bed temperature during induction heating. Here, magnetic characterisation of the susceptors becomes particularly important and has been conducted using X-ray Diffraction (XRD), Transmission Electron Microscopy (TEM), Raman Spectroscopy, Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES), magnetometry, and specific absorption rate (SAR) measurements.

Results and Discussion

The temperature in the catalyst bed can be adjusted by the supplied power, the ratio of catalyst-susceptor-SiC, the mixing homogeneity, size fractions, and other parameters. Overall, induction heating has demonstrated itself as a rapid and controllable technique, achieving an isothermal bed within 5-10 minutes, depending on the target temperature and materials used. Regarding the susceptors, nickel ferrites outperformed cobalt ferrites due to their lower coercivity. Meanwhile, large stainless and carbon steel beads demonstrated a faster heating, but performance degradation over time. Iron carbide decorated Pt/Al_2O_3 was found to have a faster magnetic response and owing to their smaller particle size they have shown a superparamagnetic induction heating behaviour. The herein presented preparative work provides a basis for currently running activity tests for the oxidation of CO as the first model reaction using induction heating.

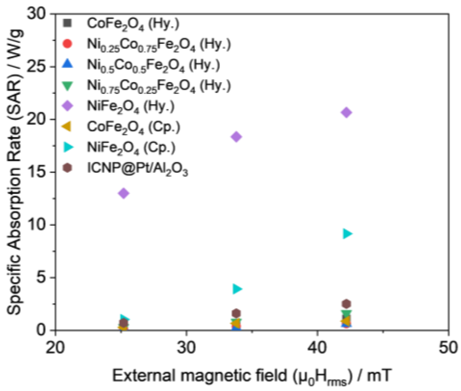

Figure 2 Specific absorption rates of synthesized susceptors.

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