

Evaluation of alternative structured catalytic reactors for gas phase endothermic reverse water gas shift reaction with selective inductive heating.

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Highlights

- Commercial catalyst wash-coated metallic foam strongly activated by magnetic field.
- Thermodynamic controlled conversion on fixed bed reactor by induction heating.
- Catalytic activation of FeCrAl foam by magnetic field application.

1. Introduction

In traditional chemical processes, conventional heating relies often on fossil fuel combustion generating significant axial and radial temperature gradients. These non-uniform thermal profiles reduce heat transfer efficiency, impacting the catalytic performance, particularly in endothermic reactions, while increasing energy consumption and environmental impact. Process electrification offers a promising alternative by enabling direct and selective heating of catalytic objects [1-2]. Approaches such as magnetic induction allow more controlled and localized heat generation, improving temperature uniformity and catalytic activity. This work evaluates the catalytic performance of various open-cell metallic foams wash-coated with a commercial CuO/ZnO/Al₂O₃ on the Reverse Water-Gas Shift (RWGS) reaction using induction heating.

2. Methods

Commercial Cu-based catalyst were used for RWGS catalytic test. The washcoating was prepared with a H₂O/CuO-ZnO-Al₂O₃ ratio of 2.7 w/w in acid solution. Catalytic test was operated using a fixed bed reactor located inside of inductor coil (100 kHz) alternating magnetic field in the range of 0–42 mT. The bed temperature was measured using a K-type thermocouple placed on top of the catalytic bed. For each experiment, Stainless Steel (SS), Nickel-Chromium (NiCr), and FeCrAl alloy (FeCrAl) foams were tested bare and washcoated with the Cu catalyst, in desired temperature and WHSV. The feed v/v ratio of H₂:CO₂ was fixed to 2:1 at atmospheric pressure. The reactants and products mixtures were analyzed using gas chromatography with a thermal conductivity detector.

3. Results and discussion

Firstly, a blank test with uncoated foams was realized. We observed a very low activity for the SS and NiCr uncoated foams with a maximum conversion of <1.5%. On the other hand, FeCrAl foam present significant activity around 400 °C (mid-temperature), reaching approximately 10% conversion under the operating conditions (Figure 1-A). The FeCrAl-mediated CO₂ conversion slope is similar to the thermodynamic equilibrium curve of the RWGS with a strong selectivity on CO product, while this material is not known to be active as a catalyst for RWGS reaction.

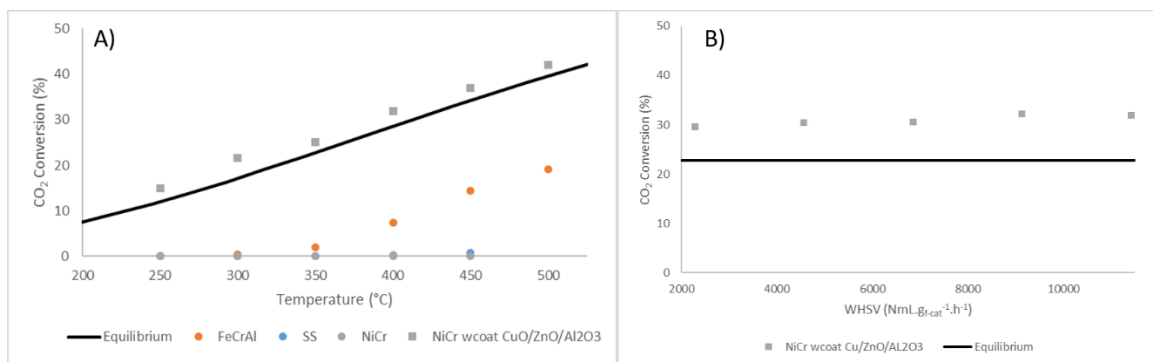


Figure 1. A) Effect of temperature sweep at WHSV = 3500 NmL.g_{cat}⁻¹.h⁻¹, and B) effect of WHSV at 350 °C. Both test at fixed H₂/CO₂ = 2, P = 1 bar.

In contrast, under identical operating conditions, the CuO/ZnO/Al₂O₃-coated NiCr achieves CO₂ conversion values closely to the thermodynamic equilibrium curve hence suggesting a higher catalytic activity compare with external heating in the literature [3]. The selectivity was toward CO until 400 °C with ~4% CH₄ selectivity. In addition, CO₂ conversion as function of gas flow rates (WHSV) at 350 °C showed a constant activity profile, instead of a parabolic decrease due to the reduced residence times (Figure 1–B). Works are still under progress to operate under kinetic control to evaluate kinetic parameters and possible mass and heat-transfer limitations; especially by comparison with classical thermal heating. In-situ measurement of temperature is still a main issue under induction heating, motivating specific methodological development that will be presented for the congress.

4. Conclusions

The present work showed that open cell metallic foams had activity with magnetic field application, which explores its potential in induction heated systems. Moreover, wash-coated Cu-based catalyst layer on structured support eliminated heat transfer limitations to the bed resulting in thermodynamic equilibrium. The latter also implies enhanced thermal management and more predictable catalytic performance. These findings highlight the potential of structured electrified catalysts as a viable pathway toward efficient and scalable electrified chemical processes.

References

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Keywords

Induction heating; FeCrAl; Catalysis; Open Foam.