Temperature mapping of fixed-bed reactor in microwave-assisted catalytic dry-reforming of methane over SiC-based catalysts

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Significance and Relevance

Ni/SiC catalysts can be rapidly and efficiently heated at high temperature under microwaves. The catalysts exhibit good performances for the DR of methane. However, the specificity of microwave heating can lead to large temperature gradients in a fixed-bed reactor. This work shows that catalyst shaping is very important to obtain uniform heating of the catalytic bed.

Preferred topic: Catalysis to electrify the chemical production; 2nd choice topic: green H_2 production
Preferred presentation: Oral preferred or Short Oral

Introduction and Motivations

Catalytic dry reforming (DR) of methane allows converting two greenhouse gases (CH_4 and CO_2) into syngas (H_2 + CO), which is a potential source of methanol, synthetic hydrocarbons and hydrogen. The reaction is highly endothermic and requires high temperatures, while catalyst deactivation due to coking and sintering can be an important issue that limits its industrial applications. The use of microwave (MW) heating could help overcome part of these limitations by providing a new and more energy-efficient way to heat the solid catalyst directly, avoiding heat transfer limitations[1].
In this study, an innovative reactor using MW heating and a MW-susceptible DR catalyst have been developed.

Materials and Methods

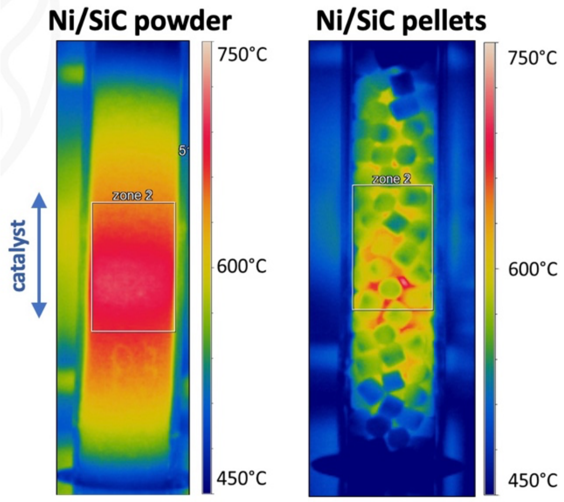
A porous SiC under the form of powder (100-200 mm) or pellets (2x2 mm) was impregnated with nickel nitrate and calcined in air to obtain a Ni loading of 5 wt.%. The catalyst was reduced under H_2 at 650°C before the catalytic tests. Microwave-assisted catalysis was carried out in a tubular quartz reactor housed in the cavity of a single mode MW generator (SAIREM GMP G3, 2 kW) operating at 2.45 GHz, equipped with an optical pyrometer for temperature control and an IR camera for temperature mapping of the catalytic bed. The DR reaction was carried out between 700 and 900°C with a mixture of CO_2:CH_4:(N_2+He) of composition 0.6:0.2:0.2. Quantitative online gas analysis of gases (CH_4, CO, CO_2, H_2, light HCs) was performed with a micro-GC using He as internal standard.

Results and Discussion

The most challenging task during MW heating of a solid catalyst is the catalyst temperature control. It is not possible, as with an electric furnace, to place metallic thermocouples along the catalyst bed since metals deflect the electromagnetic field and can cause arcing. Achieving a homogeneous absorption of MW along the catalyst bed is difficult, especially since the reaction is highly endothermic, which can lead to temperature gradients while the microwave absorption properties of the material also vary with temperature.

Fig. 1 compares the temperature profiles recorded in the catalyst bed under the same MW power, for the Ni/SiC catalysts under powder or pellets form. The Ni/SiC powder displays a homogeneous temperature profile along the catalyst bed, whereas the Ni/SiC pellets bed shows an uneven temperature within the pellets and large temperature gradients between the core and the surface of the pellets, as well as at the contact points between the pellets.

Fig. 2 shows the effect of catalyst shaping on the performances for dry reforming of methane, at the same temperature of 750°C controlled and regulated on the basis of the pyrometer temperature reading. Clearly, the performances of the Ni/SiC pellets catalyst are impaired by the poor and uneven temperature distribution and the presence of some very hot spots does not compensate for the drop of catalytic activity at the colder spots.



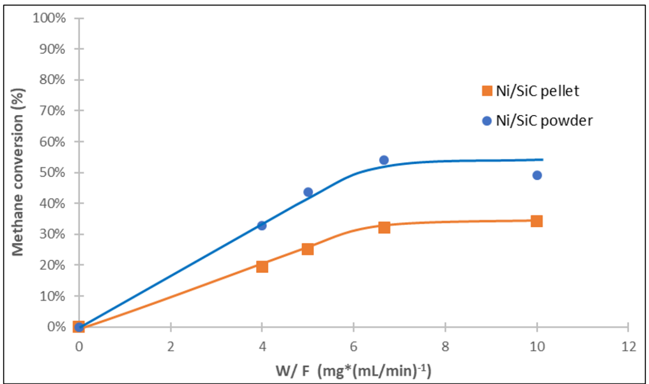


Figure 1. Temperature profiles in the catalyst bed recorded with the IR camera	**Figure 2.** Performance of Ni/SiC powder and pellets catalysts for DR of CH_4 at 750°C (pyrometer reading) as a function of W/F.

Conclusion

Microwaves can efficiently and rapidly heat suitable catalysts to the high temperatures required for DR of methane. However, the catalyst shaping must be adapted to this specific heating method, notably in the perspective of industrial applications, and the catalyst bed temperature must be carefully controlled.

References

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Acknowledgements

The authors gratefully acknowledge the funding of the European Commission (eQATOR project, Grant agreement n° 101058293).