



Steam reforming of the producer gas obtained from the gasification of beech wood: scale up from laboratory benches to full-size demonstrator

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This paper compiles the extensive collaborative work performed within the European FASTCARD project for the development of improved catalysts for steam reforming (SR) of producer gas from biomass gasification. The objective is the development of SR catalysts more resistant to deactivation by sulfur and tars. With this purpose, combined lab-scale testing with selected contaminant tar and sulfur molecules and concomitant pilot scale testing has led to insight in the total reforming of producer gas.. During lab-scale tests with target contaminants, sulfur was seen to cause more severe deactivation than tar molecules. Rh-based catalysts were found to perform better than Ni-based catalysts. Stable near-complete tar conversion was demonstrated for 100 hours operation with the selected Rh-mesoporous catalyst under real gasification conditions. To avoid deactivation of precious steam reforming catalyst during reforming of producer gas, upstream gas pre-treatment configurations are currently under development.

1. Scope

Europe today is facing major energy challenges and is therefore strongly focusing on increasing the utilization of biomass for the bio-based economy. To meet long term targets of European Energy Roadmap 2050 [1], an energy paradigm shift is needed for which biomass conversion into advanced biofuels is essential. Fluidized (indirect) bed gasification of biomass produces hydrocarbons (HC) (methane, C₂ and C₃ hydrocarbons and single/multi-ring aromatics) that represent 50% of the energy within the feedstock, which would be wasted if not converted to useful fuel. The full conversion of these HC to syngas and thus fuel is an important challenge for achieving the objectives of energy efficiency particularly where downstream Fischer-Tropsch (FT) processes require the conversion of all species including methane. Supported nickel catalysts that are widely used for conventional methane steam reforming deactivate rapidly when using a biomass feedstock due to sulfur poisoning and coking. In the present work, a summary of the extensive catalyst development work performed for improved steam reforming of hydrocarbons in producer gas from biomass gasification is presented. Both lab-scale and pilot-scale studies are included. Pilot-level runs use real producer gas directly obtained from a fluidized indirect bed gasifier (MILENA, ECN [2]).

2. Results and discussion

Developmental catalysts were firstly obtained from Johnson Matthey (JM) for benchmarking of state-of-the-art steam reforming catalysis with gasification producer gas. From data gained at lab-scale with feeds containing signature molecules (tars and H₂S), it was possible to feed kinetic models to identify the rate-controlling phenomena and their potential relation to catalyst performance. Sulfur was seen to cause more severe (reversible) deactivation than tar molecules. From these evaluations several potential new catalyst formulations were identified primarily based on either Ni or Rh as the key active component. Rh-based catalysts were found to perform better than Ni-based catalysts. A novel mesoporous Magnesium-Aluminum supported 0.35 Wt% Rh catalyst was selected for further pilot-scale studies with the producer gas under relevant gasification conditions (beech wood as biomass fuel, ~ 850°C, olivine as bed material), and

compared to an equivalent benchmark catalyst supplied by JM. Mesoporous supports were reported before to stabilize (precious) metal nano-particles in medium temperature catalytic reaction [3]. Moreover, the mesoporous (MgAl_2O_4 based) support is very robust and no apparent reaction with Rhodium to MgRh_2O_4 occurred. During a 100-hour test, the methane conversion was found to rapidly reduce from near complete conversion to ~60 % conversion and further decreased slowly to ~40%, Figure 1 (left). A very similar result was obtained with a benchmark catalyst. Tar conversion was nearly complete (98%) while benzene, toluene and C2-C5 hydrocarbons were converted to below detection limit. Pre-and post-test characterization of the catalytic materials involved XRD, HREM, XPS and Raman analysis. These results are currently compared with the total gas analysis of hydrocarbon and organosulfur compositions in the producer gas feed in order to understand the functionalities of the catalyst. So far, residual dust in the gas - after having passed cyclones - has been removed with a ceramic filter upstream the reformer. Reforming tests in the absence of the filter, i.e. with dusty producer gas, using monolith type of reactors are currently under preparation.

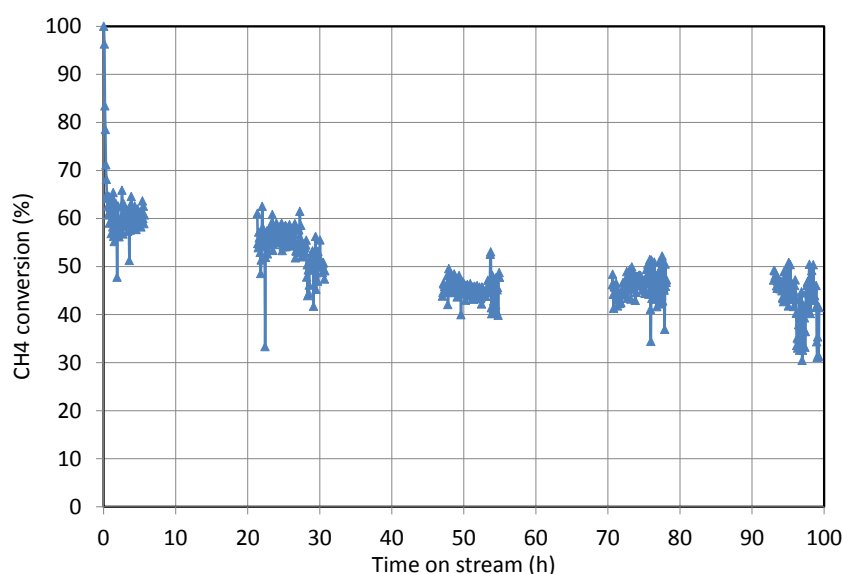


Figure 1. (left) CH_4 concentration in gas during dual bed duration test at 900°C , GHSV $\sim 5000 \text{ h}^{-1}$; (right) MILENA gasifier and catalyst reactors.

3. Conclusions

Combined lab-scale testing with selected contaminant tar and sulfur molecules and concomitant pilot scale testing has led to insight in the total reforming of producer gas in the absence of dust. During lab-scale tests with target contaminants, sulfur was seen to cause more severe deactivation than tar molecules. Rh-based catalysts were found to perform better than Ni-based catalysts. Stable near-complete tar conversion was demonstrated for 100 hours operation under real gasification conditions. To avoid deactivation of precious steam reforming catalyst during reforming of producer gas, upstream gas pre-treatment configurations are currently under development.

References

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