EXPERIMENTAL STUDIES OF METHANE THERMAL PARTIAL OXIDATION WITHIN INERT POROUS MEDIA FOR THE DEVELOPMENT OF A NATURAL-GAS REFORMER FOR HYDROGEN PRODUCTION

Hydrogen production on-site from natural gas is widely regarded as a necessary step, which will support in the mid-term a wider market penetration of hydrogen based technologies and in particular of Fuel Cells. The three main processes used to reform hydrocarbons into hydrogen-rich gaseous mixtures (synthesis-gas) are steam reforming, partial oxidation and autothermal reforming. Among these, Thermal Partial Oxidation (TPOX), a particular case of partial oxidation, offers certain advantages especially in terms of fuelling High Temperature Fuel Cells. The currently presented work concerns experimental results obtained during the development of a natural-gas reformer on the basis of TPOX within inert porous media. The reformer was developed within the framework of the integrated European research project “FlameSOFC” for feeding a small-scale SOFC (Solid Oxide Fuel Cell) based micro-CHP unit.

Several characteristics of TPOX within inert porous media remain under investigation especially when it comes to the issue of soot particulate matter emissions. The later is a general problematic issue in all reforming technologies, even if the soot particulate matter emissions are extremely low, due to the degradation of subsequent sensitive components in a fuel cell system. For this purpose a detailed experimental study was conducted utilizing methane as primal fuel and focusing at the parameters, which effect soot formation in such a process. Packing material out of pure $\text{Al}_2\text{O}_3$ was utilized for creating the porous matrix within the reaction zone of the reformer. A Scanning Mobility Particle Sizer (SMPS) was used for measuring the size distributions and the concentrations of soot particles produced by the reactor. Prior to the particle measurements, the sampled gas had to be properly diluted (dilution ratios $\sim 10^4$) to minimize alterations on the particle size distributions caused by well-known aerosol processes such as coagulation, diffusion and thermophoresis. The changes in particle concentrations and size distributions were studied as a function of equivalence ratio $\phi$, thermal load, initial preheating of the unburned CH$_4$-air mixtures and sample dilution. In addition to particle size measurements, temperature profiles within the reaction region of the reformer were recorded and gas samples were analyzed by TCD and NDIR detectors, for concentrations of major species H$_2$, CO, CO$_2$, CH$_4$ and of the minor species C$_2$H$_2$. Part of
the results obtained for a thermal load of 1.10 W/mm², equivalence ratios ranging from \( \varphi = 2.00 \) up to \( \varphi = 2.50 \) and educts’ preheating temperature of 500°C, are presented in the following figures.

**Figure 1:** Soot size distributions obtained for three different equivalence ratios and for dilution ratio of 11280. Lognormal fits have been applied to the distributions and particle concentrations have been corrected for flame conditions.

**Figure 2:** Temperature profiles measured within the reaction zone of the examined reactor for three different equivalence ratios.

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