

## Cool flame evaporation for diesel reforming technology

Lutz Hartmann, Chistian Mengel,  
Klaus Lucka, Heinrich Köhne,  
Oel-Wärme-Institut Aachen,  
Kaiserstraße 100, 52134 Herzogenrath, Germany  
www.owi-aachen.de

The separation of the evaporation from the high temperature reaction zone is crucial for the reforming process. Unfavourable mixtures of liquid fuels, water and air lead to degradation by local hot spots in the sensitive catalysts and to formation of unwanted by-products in the reformer. Furthermore the vaporiser has to work with dynamic changes in the heat transfer, residence times and educt compositions. By using exothermal pre-reactions in the form of cool flames it is possible to realise a complete and residue-free evaporation of liquid hydrocarbon mixtures. The conditions whether cool flames can be stabilised or not is related to the heat release of the pre-reactions in comparison to the heat losses of the system (Fig. 1).

The reaction mechanism of cool flames is nearly temperature-limited. A shift in the value of heat loss leads to a marginal change in the stabilisation temperature  $T_s$ . For this reason a reduction in the preheating of the air has only a small effect on the final temperature of the cool flame. In Fig. 2 the educt conversion and products yields for CO, CO<sub>2</sub> and HC are given in respect to the air inlet temperature for *n*-heptane. The cool flame reaction starts at temperatures of 330 °C. The hydrocarbon and oxygen conversion decreases significantly with an increase in the air preheating. As a result of oxidation and decay reactions, it is mainly long hydrocarbon chains that react to form short molecules during this process. Also a noticeable conversion into carbon monoxide and carbon dioxide can be verified in the cool flame product.

The designed liquid fuel reformer is based on two process stages, the vaporiser and the catalytic reforming zone (Fig. 3). The homogeneous mixture of liquid fuel air and contingent water is produced in the first reaction chamber using exothermic cool flame pre-reactions. With a temperature of 400 °C to 480 °C the mixture is transferred into the second stage of the fuel processor to be converted by catalytic partial oxidation (CPO) or by autothermal reforming (ATR) if water vapour is supplied. In all described processes the hydrocarbon reforms catalytically at around 800 °C to form hydrogen and carbon monoxide. Due to the low purity demands on the feed gases the SOFC-technology no further carbon monoxide conversion of the reformer gas is necessary.

Generally the reforming efficiency increases with decreasing air ratios while sufficient water takes place in the reforming reaction. For pure partial oxidation without water vapour reforming efficiencies of 75 % can be expected. Through water supply this value can be raised to 82 %. The measured yields of hydrogen and carbon monoxide, given in Fig. 4, agree with the equilibrium values. Moreover the type of catalyst material both the expensive noble metal and nickel seem to have no effect on the hydrocarbon conversion. In both cases the measured hydrocarbon concentration is strictly below 0.5 % independently from the value of SCR and degradation cannot be observed even under 500 h operations.

