Reactor Design Considerations for Reforming of Commercial Diesel

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Introduction

This paper is focused on an investigation regarding reformer design and catalyst development intended for a mobile auxiliary power unit (APU) system using commercial diesel fuel. The generation of hydrogen from a commercial diesel fuel is challenging, given that diesel is a complex mixture of different compounds as well as containing substances which are poisonous to the catalyst. Reforming high-molecular weight hydrocarbons could also give rise to coking and thereby deactivate the catalyst.

The most efficient process, when it comes to achieving high hydrogen concentrations, is steam reforming. However, the big drawback for using this process in automotive applications is its endothermicity that leads to a slow process and bulky reactors. A way to circumvent this problem is to supply small amounts of air and thereby achieve a temperature increase. Hence, an autothermal process where heat is supplied to the catalytic surface by oxidizing a part of the fuel with oxygen will provide a more compact and dynamic system. However, when using air in the feed the product gas will be diluted by nitrogen and thus decreasing the partial pressure of hydrogen.

Materials and Methods

The catalyst samples were prepared using primarily nitrate salts. Rh was used as active material and the washcoat consisted of γ-alumina and ceria with various promoters. After impregnation of active materials, the washcoat was deposited onto either a cordierite or a metallic monolith with subsequent drying and calcination. The cell density of the cordierite monoliths was 400 cpsi, which corresponds to a channel diameter of ca 1 mm. The metallic monoliths were of various cell densities. Commercial diesel fuel was used in the experiments with a sulfur content of less than 10 ppm(w). The product gas from the autothermal reforming experiments was analyzed using two on-line gas chromatographs, a Varian CP-3800 and a Varian 3400CX. The first GC is equipped with a thermal conductivity detector (TCD) and a flame ionization detector (FID) and two packed columns, a Porapak Q and a MS 5A. The latter GC is used for analysis of the high molecular-weight hydrocarbons with two capillary columns, a VF-1ms and a GS-Q and using two FIDs.

Results and Discussion

Hydrogen concentrations greater than 35 vol% have been obtained using various monolithic Rh-based catalysts. A key question for successful reforming of diesel is the method used for the injection and evaporation of liquid fuel in the reformer. The influence of reactant mixing on reformer performance, has also been studied as well as the effect of the homogeneous reactions in the mixing zone on the inlet temperature of the catalyst. Evaporation of diesel fuel and reactant mixing can be improved by using various types of arrangements for increasing swirl and for decreasing droplet size of the injected fuel. The influence of operating parameters on catalyst activity, selectivity and catalyst coking has also been investigated, where oxygen-to-carbon-ratio and steam-to carbon ratio have been identified as the most important factors. The geometric design of the reactor and fuel-gas mixing zone has also been shown to significantly influence the quality of the reforming process (see Figure 1).

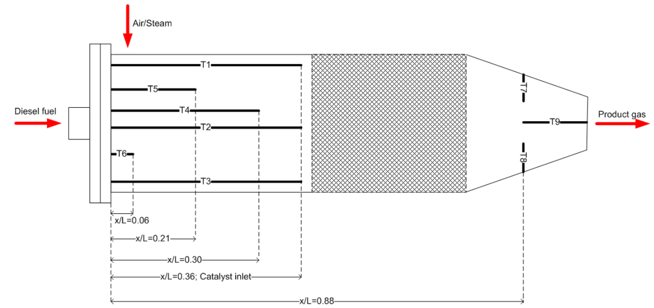

Figure 1. A schematic figure of the KTH diesel reformer

Significance

APU systems could drastically decrease emissions of NO_x, hydrocarbons and CO during idling and also improve fuel economy and thereby reduce CO_2 emissions. It is likely that APU systems for trucks and marine applications will be the first area where fuel cells will reach high market penetration (see Figure 2).

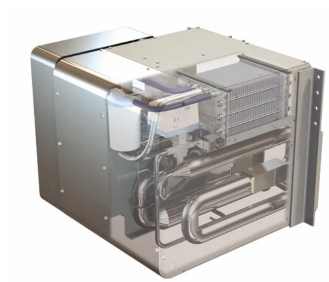

Figure 2. PowerCell fuel cell-APU

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