Integrated 10kWe Hydrodesulfurizer-Microchannel Steam Reformer for Fuel Cell Power from JP-8 and Road Diesel

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Introduction

The development of fuel cell power systems supplied by liquid hydrocarbon fuels such as jet fuel (JP-8) or diesel has continued to be challenged by the difficulty in cleanly reforming these fuels without catalyst deterioration. One of the major sources of catalyst deterioration and resulting low conversion activity has been the presence of sulfur in these fuels. Various approaches to deal with sulfur have been investigated, including development of sulfur-tolerant catalysts [1]; use of sulfur specific and regenerable adsorbents [2]; selective oxidation of sulfur species followed by their adsorptive removal [3]; and removal by catalytic hydrodesulfurization (HDS). All have their challenges when applied to small and potentially portable fuel cell systems. The only commercially proven technology is hydrodesulfurization, which has generally been considered impractical for operation in small scale applications. Moreover, the requirement for available high pressure hydrogen has provided a major hurdle.

Small scale hydrodesulfurization is indeed possible when coupled with a steam reformer operating at 15-20 atm. Rather than requiring hydrogen, steam reformate can be utilized for the HDS unit. A fraction of the total reformate is diverted to the HDS unit, with the remainder treated as needed and provided to the fuel cell. We have previously described tests showing that sub-ppm levels of organic sulfur can be achieved with full JP-8 operating with synthetic steam reformate [4]. Here we describe extended tests integrating the HDS unit with a microchannel steam reformer, in which actual steam reformate feeds the HDS unit and the clean fuel as processed by the HDS unit is fed to the reformer. In addition, we will describe recent work in extending the HDS-reformer concept to ultra-low-sulfur road diesel.

Materials and Methods

Hydrodesulfurization was carried out using a packed bed containing pre-sulfurized Ni-Mo/Al_2O_3 catalyst. HDS optimization with JP-8 fuel (550 ppm) and diesel desulfurization studies (4 ppm) utilized approximately 100 cc of 40-80 mesh catalyst (0.5 kWe). Integrated studies with the steam reformer (10 kWe) using JP-8 fuel employed three 1560 cc beds of catalyst in extrudate form. The HDS liquid product was purged with air to remove residual dissolved H_2S and analyzed using an Agilent model 6890 gas chromatograph equipped with a sulfur chemiluminescent detector. Microchannel steam reformers developed in our laboratory have been described previously [5], and the unit employed for this work comprised channels fabricated from Inconel 625 and contained a proprietary precious metal catalyst. Typical operation was approximately 20 bar and 380^{o}C for the HDS unit and 750^{o}C for the reformer. The steam reformate was subsequently sent to a water gas shift reactor to increase H_2 content and also decrease H_2O content, which facilitated operation of the HDS unit. Typical gas composition (by volume) fed to the HDS unit was 43.8%H_2, 35.4%H_2O, 15.1%CO_2, 1.5%CO and 3.7%CH_4. The operation of the HDS unit was targeted to ensure less than 500 ppbw residual organic sulfur in the fuel fed to the reformer.

Results and Discussion

HDS of the JP-8 fuel to less than 500 ppbw was successfully achieved during an integrated test of 300 hours, operated during several cycles of start-up and shut down. During continuous operation, the desulfurization performance was steady, but some time was required on startup to stabilize the HDS catalyst before achieving optimal performance. Typical HDS analysis is shown in Figure 1. A modest but acceptable decrease in HDS catalyst performance was observed over the duration of the 300 hour test. This was compensated for by reducing the liquid flow rate. Analysis is underway to determine possible causes for the deactivation. For the steam reformer, a modest excess of catalyst was utilized over that required for sulfur-free fuel in anticipation of possible catalyst deactivation even at 500 ppbw S. With that modification, the steam reformer maintained target performance over the course of 300 hours. For HDS of road diesel, 0.8 ppmw S has been achieved, starting with 4ppmw in the fuel. We believe that with implementation of improved catalysts, less than 0.5 ppmw S is achievable.

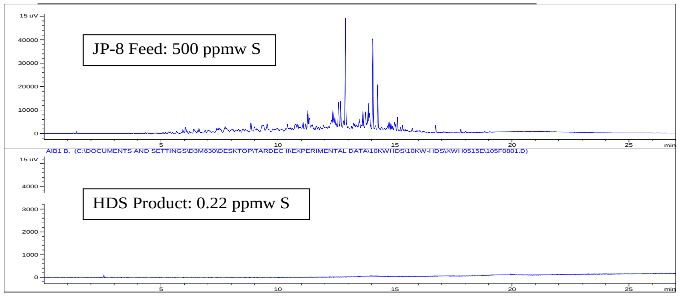

Figure 1. SCD GC traces before and after reformate-based HDS of JP-8 fuel. Conditions: 380^{o}C, 270 psig (H_2 partial pressure 102 psig), LHSV = 0.47, reformate/JP-8 (molar) = 12.9

Significance

The production of clean hydrogen or syngas for portable fuel cell systems operating on JP-8 fuel is possible when employing an integrated HDS/steam reformer system. Extension to non-military applications, including road diesel fuel, also appears possible. This provides a large step forward in enabling fuel cells to operate with a range of heavy hydrocarbon fuels.

References

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