Fuel Processing for Fuel Cell Powered Vehicles

by

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January 1999

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A number of auto companies have announced plans to have fuel cell powered vehicles on the road by the year 2004. The low-temperature polymer electrolyte fuel cells to be used in these vehicles require high quality hydrogen. Without a hydrogen-refueling infrastructure, these vehicles need to convert the available hydrocarbon fuels into a hydrogen-rich gas on-board the vehicle. Earlier analysis has shown that fuel processors based on partial oxidation reforming are well suited to meet the size and weight targets and the other performance-related needs of on-board fuel processors for light-duty fuel cell vehicles (1).

The partial oxidation process can be represented by the idealized chemical reaction,

$$C_nH_m + x(O_2+3.76N_2) + (2n-2x)H_2O = nCO_2 + (2n-2x+m/2)H_2 + 3.76xN_2 \quad [1]$$

where the hydrocarbon (C_nH_m) reacts with oxygen from air and water to produce carbon dioxide and hydrogen, while the nitrogen passes through as an inert. The oxygen-to-fuel molar ratio is a critical control parameter because it determines the heat of reaction and the percentage of hydrogen in the product gas.

Even though any hydrocarbon fuel can be used to produce this hydrogen, the choice of fuel for these light-duty fuel cell vehicles will be determined by many factors, such as hydrogen yields, refueling infrastructure, well-to-wheel efficiency, energy density, cost of production, carbon dioxide emissions, and contaminants (e.g., sulfur). Considering that the existing refueling infrastructure is only for petroleum-derived fuels and represents a massive investment (2), an attractive strategy to market the fuel cell vehicles, at least for the near-term, is one based on gasoline or a similar fuel.

Given the uncertainty about the fuel and the fact that gasoline itself is a blend of many different types of hydrocarbons (paraffins, olefins, etc.), the partial oxidation process would be much more effective if a catalyst was developed that is effective with all variants of hydrocarbons. Further, fuel-cell systems analysis and hardware cost constraints indicated that a partial oxidation process at relatively low temperature (<800°C) would be most attractive.

Argonne National Laboratory has developed a novel new catalyst that has shown remarkable ability to convert a variety of hydrocarbon species into a hydrogen-rich gas. Micro-reactor studies using 2g of catalyst have shown (Table 1) that paraffins, olefins, aromatics, alcohols, etc., can be converted to produce high concentrations of hydrogen at temperatures below 800°C.

To verify the ability of this catalyst to convert gasoline to hydrogen, experiments were conducted in an engineering-scale reactor – a cylindrical reactor filled with 2-kg of catalyst pellets. With natural gas, the product gas contained 42% hydrogen. With retail gasoline, the product gas contained 38% H_2, 12% CO_2, 10% CO, 2% CH_4, and balance N_2, at temperatures less than 800°C (Figure 1). The 1.7 liters of catalyst pellets in the reactor produced over 40 L/min of hydrogen, which is sufficient to sustain a 3-kW fuel cell stack. A light-duty fuel cell vehicle will require a 40 to 50-kW fuel cell stack.

Table 1. The Argonne catalyst converted different hydrocarbons and alcohols to a H_2-rich gas. [*balance is methane].

	Temp., °C	Product Composition*, % (dry, N_2-free basis)		
		H_2	CO	CO_2
i-Octane	630	60	20	16
Toluene	655	50	42	8
2-Pentene	670	60	22	18
Ethanol	580	62	18	15
Methanol	450	60	20	18

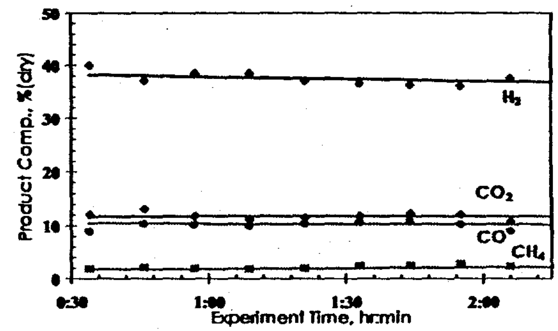

Figure 1. Product gas composition obtained from the partial oxidation reforming of retail gasoline in an engineering-scale reactor.

The Argonne reforming process has demonstrated the catalytic partial oxidation reforming of hydrocarbon fuels with a novel catalyst that works at hundreds of degrees cooler than uncatalyzed processes. This device is compact and lightweight and it is suitable for use on-board light-duty fuel cell vehicles slated for introduction in the next few years. This paper will discuss the fuel processing options in fuel cell vehicles and some principles of the partial oxidation process, and will present data on the development at Argonne National Laboratory.

Acknowledgments

This work was supported by the U.S. Department of Energy, Office of Advanced Automotive Technologies under Contract No. W-31-109-ENG-38.

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