RAPID START FUEL REFORMING SYSTEMS AND TECHNIQUES

RELATED APPLICATION DATA

This is a divisional of U.S. patent application Ser. No. 12/816,280, filed Jun. 15, 2010 now U.S. Pat. No. 8,231,697, which is a divisional of U.S. patent application Ser. No. 10/551,516, filed Sep. 28, 2005 now U.S. Pat. No. 7,763,217, which is a §371 U.S. National Stage of International Application No. PCT/US2004/015402, filed May 17, 2004, which was published in English under PCT Article 21(2), which in turn claims the benefit of commonly owned U.S. Provisional Application No. 60/471,130 filed on May 16, 2003, U.S. Provisional Application No. 60/471,286 filed May 16, 2003, and U.S. Provisional Application No. 60/546,107 filed on Feb. 18, 2004. These applications are incorporated by reference in their entirety.

TECHNICAL FIELD

In one form, the present invention relates to fuel reforming systems for providing a hydrogen rich fuel stream to fuel cells, and more particularly to systems that are capable of rapid start up and efficient operation.

BACKGROUND

Fuel cells are devices that produce energy from the electrochemical reaction of a fuel and an oxidant, and they are considered attractive energy alternatives because of their high efficiency and relatively benign byproducts. Many fuel cells are being designed to use hydrogen as the fuel for the cell, but for many applications, such as use in vehicles or as portable generators, auxiliary power units (APU) or backup power supplies, it is currently impractical to procure and/or store large quantities of the needed hydrogen gas. To address this, systems are being developed to produce hydrogen on demand from more readily available or easily stored sources.

One such approach involves processing or reforming a hydrocarbon fuel into useable hydrogen. The advantages of such an approach are that a hydrocarbon fuel is generally easier to store, and significant distribution infrastructure already exists for several useful hydrocarbons, e.g. gasoline, diesel fuel, natural gas, etc. The major hydrocarbon reforming reactions typically employed require significant amounts of heat and/or elevated reaction temperatures to achieve suitable yields of hydrogen. These high temperatures and/or heat demands present challenges for system start up, such as the amount and rate of energy consumption during start up and the time delay before the fuel cell can begin producing useful energy from the produced hydrogen.

For example, the steam reforming reaction uses steam to oxidize hydrocarbons into carbon monoxide and hydrogen, typically in the presence of a catalyst. Steam reforming is strongly endothermic and is typically performed at high temperature in order to improve the kinetics and to improve equilibrium yield of hydrogen. A fuel processing system based on steam reforming has been developed by the present inventors for automotive applications (See *Progress on the Development of a Microchannel Steam Reformer for Automotive Applications*, G. A. Whyatt et at., 2002 AIChE Spring National Meeting). However this system has required on the order of 20 minutes to start-up from ambient temperatures to an operating temperature of around 650° C. where reasonable rates of steam reforming have been achieved. This hinders commercial practicality and fails to meet the start-up time

targets established by the U.S. Department Energy for on-board fuel processors of <1 minute by 2005 and <30 seconds by 2010. Accordingly, improvements are needed, and the present disclosure describes a fuel processing system based on steam reforming that is capable of dramatically reduced start up times.

However, while the present disclosure arose from efforts to reduce the start up time for Applicants' prior automotive steam reforming fuel processing system, it will be understood that the present invention is not so limited. For example, the present invention may be applied in connection with other types of fuel processors having significant heating demands and for a variety of energy production applications. Moreover, certain components and techniques useful in the fuel processors of the present invention are also useful in other fluid processing systems. Examples include a novel mixer for efficiently mixing two fluids and an improved header design for the distribution of a gas stream to a group of microchannels in a microchannel fluid processing device.

SUMMARY

The present invention provides systems and techniques for fuel processing as well as individual fluid processing components and techniques useful in a variety of applications. While the actual nature of the invention covered herein can only be determined with reference to the claims appended hereto, certain aspects of the invention that are characteristic of the embodiments disclosed herein are described briefly as follows.

According to one aspect, a method for operating a fuel cell involves providing a fuel cell system including a fuel reforming reactor and at least one blower for selectively conveying combustion gas through a heating side of the reforming reactor at different mass flow rates; starting-up the reforming reactor by heating a reforming side of the reactor with a combustion gas flowing through the heating side of the reactor; and then operating the reactor to produce a reformate stream by driving an endothermic reforming reaction on the reforming side with heat from a combustion gas flowing through the heating side. In one refinement, the mass flow rate of combustion gas through the heating side during the starting-up is at least about five times a mass flow rate of combustion gas through the heating side during the operating.

Accordingly to another aspect, a method comprises starting up a fuel reformer by heating the endothermic reaction channels of the fuel reformer with hot gas flowing through heating channels at a mass flow rate sufficient to raise the internal temperature of the channels from a starting temperature to an elevated operating temperature in less than about 30 seconds; wherein the starting temperature is less than about 50° C. and the elevated operating temperature is above about 600° C.

According to another aspect, a fuel cell system includes a fuel cell; a steam reformer operable to produce hydrogen for use by the fuel cell from steam and hydrocarbons; and a vaporizer for supplying the steam to the steam reformer; wherein the steam reformer is a panel defining a first face and a second face wherein the length and width of each face is substantially greater than the distance between the faces.

According to another aspect, a fuel cell system includes a fuel cell; a steam reformer for converting a gaseous inlet steam to a reformate outlet stream for use by the fuel cell; a vaporizer for providing superheated steam and having a heating side downstream from a heating side of the steam reformer, and a fuel injector between the vaporizer and the