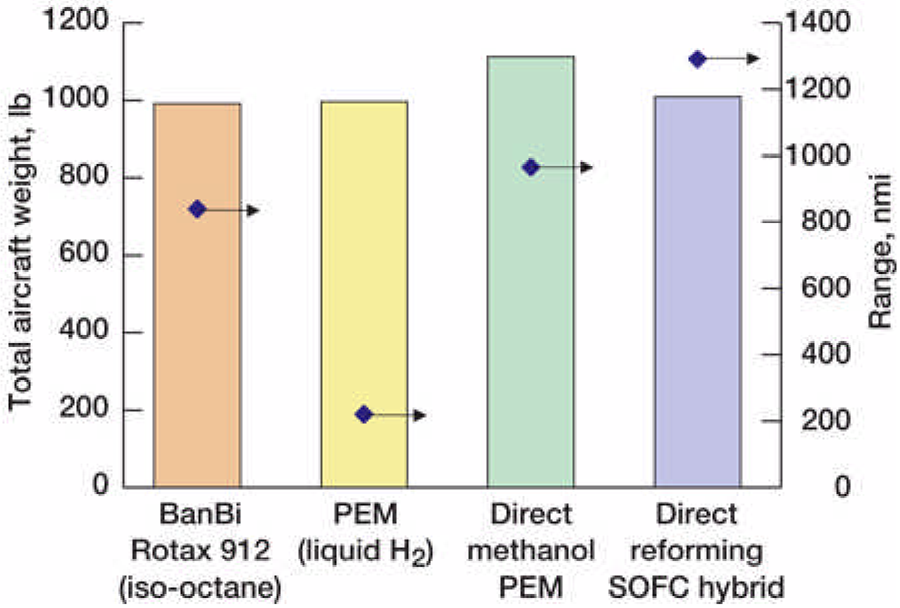
Systems Analysis Developed for All-Electric Aircraft Propulsion

There is a growing interest in the use of fuel cells as a power source for all-electric aircraft propulsion as a means to substantially reduce or eliminate environmentally harmful emissions. Among the technologies under consideration for these concepts are advanced proton exchange membrane (PEM) and solid oxide fuel cells (SOFCs), alternative fuels and fuel processing, and fuel storage. A multidisciplinary effort is underway at the NASA Glenn Research Center to develop and evaluate concepts for revolutionary, nontraditional fuel cell power and propulsion systems for aircraft applications. As part of this effort, system studies are being conducted to identify concepts with high payoff potential and associated technology areas for further development.

To support this effort, a suite of component models was developed to estimate the mass, volume, and performance for a given system architecture. These models include a hydrogen-air PEM fuel cell; an SOFC; balance-of-plant components (compressor, humidifier, separator, and heat exchangers); compressed gas, cryogenic, and liquid fuel storage tanks; and gas turbine/generator models for hybrid system applications.

First-order feasibility studies were completed for an all-electric personal air vehicle utilizing a fuel-cell-powered propulsion system. A representative aircraft with an internal combustion engine was chosen as a baseline to provide key parameters to the study, including engine power and subsystem mass, fuel storage volume and mass, and aircraft range. The engine, fuel tank, and associated ancillaries were then replaced with a fuel cell subsystem. Various configurations were considered including a PEM fuel cell with liquid hydrogen storage, a direct methanol PEM fuel cell, and a direct internal reforming SOFC/turbine hybrid system using liquid methane fuel. Each configuration was compared with the baseline case on a mass and range basis. A comparison of the study results is shown in the bar chart. On the basis of the study methodology, the SOFC-hybrid system appeared to offer the most potential in terms of achieving an acceptable takeoff weight and range. This was due to a number of factors, including the use of a hydrocarbon fuel, which is more volumetrically efficient than liquid hydrogen storage; direct internal reforming of the fuel, thus eliminating the need for an external fuel processor; and the ability to extract energy from the hot fuel cell exhaust streams by expanding the gas in a turbine.



Comparison of proton exchange membrane and solid oxide fuel cell/hybrid systems. Bar chart of total aircraft weight in poinds and range in nautical miles for BanBi Rotax 912 (iso-octane), PEM (liquid hydrogen), direct methanol PEM, and direct reforming SOFC hybrid.

Bibliography

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