Mechanics/Machinery

Two-Stage Centrifugal Fan

Lyndon B. Johnson Space Center, Houston, Texas

Fan designs are often constrained by envelope, rotational speed, weight, and power. Aerodynamic performance and motor electrical performance are heavily influenced by rotational speed. The fan used in this work is at a practical limit for rotational speed due to motor performance characteristics, and there is no more space available in the packaging for a larger fan. The pressure rise requirements keep growing. The way to ordinarily accommodate a higher DP is to spin faster or grow the fan rotor diameter.

The invention is to put two radially oriented stages on a single disk. Flow enters the first stage from the center; energy is imparted to the flow in the first stage blades, the flow is redirected some amount opposite to the direction of rotation in the fixed stators, and more energy is imparted to the flow in the second-stage blades.

Without increasing either rotational speed or disk diameter, it is believed that as much as 50 percent more DP can be achieved with this design than with an ordinary, single-stage centrifugal design. This invention is useful primarily for fans having relatively low flow rates with relatively high pressure rise requirements.

This work was done by David Converse of Hamilton Sundstrand for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457(f)} to Hamilton Sundstrand. Inquiries concerning licenses for its commercial development should be addressed to:

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Refer to MSC-24881-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Combined Structural and Trajectory Control of Variable-Geometry Planetary Entry Systems

This technique can be applied for use in aircraft and underwater vehicles.

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Some of the key challenges of planetary entry are to dissipate the large kinetic energy of the entry vehicle and to land with precision. Past missions to Mars were based on unguided entry, where entry vehicles carried payloads of less than 0.6 T and landed within 100 km of the designated target. The Mars Science Laboratory (MSL) is expected to carry a mass of almost 1 T to within 20 km of the target site. Guided lifting entry is needed to meet these higher deceleration and targeting demands. If the aerodynamic characteristics of the decelerator are variable during flight, more trajectory options are possible, and can be tailored to specific mission requirements. In addition to the entry trajectory modulation, having variable aerodynamic properties will also favor maneuvering of the vehicle prior to descent. For proper supersonic parachute deployment, the vehicle needs to turn to a lower angle of attack.

One approach to entry trajectory improvement and angle of attack control is to embed a variable geometry decelerator in the design of the vehicle. Variation in geometry enables the vehicle to adjust its aerodynamic performance continuously without additional fuel cost because only electric power is needed for actuating the mechanisms that control the shape change. Novel structural and control concepts have been developed that enable the decelerator to undergo variation in geometry.

Changing the aerodynamic characteristics of a flight vehicle by active means can potentially provide a mechanically simple, affordable, and enabling solution for entry, descent, and landing across a wide range of mission types, sample capture and return, and reentry to Earth, Titan, Venus, or Mars. Unguided ballistic entry is not sufficient to meet this more stringent deceleration, heating, and targeting demands.

Two structural concepts for implementing the cone angle variation, a segmented shell, and a corrugated shell, have been presented. It is possible that a multi-parameter optimization approach will be necessary to fully explore the potential of the proposed solution. Since the shape of corrugated shell deviates from the conventional sphere-cone decelerator, the variation of aerodynamic characteristics with cone angle obtained is an approximation to that of the corrugated shell decelerator. A more precise numerical computation of the pressure distribution on the corrugated shell surface using panel method is currently underway. This numerical procedure will be incorporated into the trajectory simulation and the structural analysis. Further work will include tuning the current corrugated shell geometry using an energy-based optimization approach to minimize stress and actuation force, and exploring trajectory modulation with decelerators undergoing asymmetric variation in geometry.

Variations in cone angle for a decelerator with sphere-cone geometry have the effect of altering the trim angle of attack and the corresponding lift-to-drag ratio and ballistic coefficients during flight. This capability enables trajectory optimization with fewer aerodynamic constraints. A trajectory simulation with variable aerodynamic characteristics demonstrated a reduced deceleration peak and improved landing accuracy. The analytic expressions of the longitudinal aerodynamic coefficients were derived, and guidance laws that track reference heat flux, drag, and aerodynamic acceleration loads are also proposed. These guidance laws, based on dynamic inversion, have been tested in an integrated simulation environment, and the results indicate that use of variable geometry is feasible to track specific profiles of dynamic and heat load conditions during reentry.

The proposed concept of a decelerator system that is first deployed and then is able to adaptively change its geometry during operation is novel and is expected to lead to reductions of drag up to 20 percent and peak temperature by 20 percent, thus obviating the need for both expensive thermal protection systems and heavy expelled mass ballast to change the aerodynamic configuration of the vehicle.

This work was done by Marco B. Quadrelli, Sergio Pellegrino, and Kawai Kwok of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).NPO-47102

Pressure Regulator With Internal Ejector Circulation Pump, Flow and Pressure Measurement Porting, and Fuel Cell System Integration Options

Potential uses include regenerative and primary fuel cell power systems.

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An advanced reactant pressure regulator with an internal ejector reactant circulation pump has been developed to support NASA's future fuel cell power systems needs. These needs include reliable and safe operation in variable-gravity environments, and for exploration activities with both manned and unmanned vehicles. This product was developed for use in Proton Exchange Membrane Fuel Cell (PEMFC) power plant reactant circulation systems, but the design could also be applied to other fuel cell system types, (e.g., solid-oxide or alkaline) or for other gas pressure regulation and circulation needs. The regulator design includes porting for measurement of flow and pressure at key points in the system, and also includes several fuel cell system integration options.

NASA has recognized ejectors as a viable alternative to mechanical pumps for use in spacecraft fuel cell power systems. The ejector motive force is provided by a variable, high-pressure supply gas that travels through the ejector's jet nozzle, whereby the pressure energy of the fluid stream is converted to kinetic energy in the gas jet. The ejector can produce circulation-to-consumption-flow ratios that are relatively high (2-3 times), and this phenomenon can potentially (with proper consideration of the remainder of the fuel cell system's design) be used to provide completely for reactant pre-humidification and product water removal in a fuel cell system.

Specifically, a custom pressure regulator has been developed that includes: (1) an ejector reactant circulation pump (with interchangeable jet nozzles and mixer sections, gas-tight sliding and static seals in required locations, and internal fluid porting for pressure-sensing at the regulator's control elements) and (2) internal fluid porting to allow for flow rate and system pressure measurements. The fluid porting also allows for inclusion of purge, relief, and vacuum-breaker check valves on the regulator assembly. In addition, this regulator could also be used with NASA's advanced non-flow-through fuel cell power systems by simply incorporating a jet nozzle with an appropriate nozzle diameter.

For this advanced regulator and ejector concept, ejector flow and outlet pressure are controlled in a manner similar to an "external-sense" regulator. This control method senses the pressure downstream of the ejector mixer outlet, and uses that signal as the feedback to its internal control valve. As changes in ejector mixer outlet pressure occur as a result of consumption of gases in the fuel cell stack (or system), the regulator's control elements quickly respond with the variable supply of high-pressure gas to the inlet of the ejector jet nozzle to match the real-time flow needs of the fuel cell stack (or system).

In earlier tests of the regulator and ejector assembly at NASA's test facilities, purposefully selected geometry (ejector jet nozzle and mixer internal diameters), pressure, and flow ranges were tested to gather useful performance data to support the development of design guidelines for fuel cell systems utilizing ejectors for reactant circulation. The results of these tests (and with the particular ranges tested) showed that approximate 10:1 ejector-mixer-to-jet diameter ratios could produce performance (scalable over the range of fuel cell power output of 0.7 to 20 kW) that matched the presumed closed fuel cell circulation requirements of total-to-motive flow ratios of 2.5 to 4.5 at the higher motive flow ranges, and with pressure differences developed as high as about 2.5 psid (≈17.2 kPa) with reactant gas circulation.

This work was done by Arturo Vasquez of Johnson Space Center. Further information is contained in a TSP (see page 1).MSC-24731-1