Injection of working fluid into a centrifugal compressor in the reverse tangent direction has been invented as a way of preventing flow instabilities (stall and surge) or restoring stability when stall or surge has already commenced. If not suppressed, such instabilities interrupt the smooth flow of the working fluid and, in severe cases of surge, give rise to pressure and flow oscillations that can be strong enough to damage the compressor and adjacent equipment.

The invention applies, in particular, to a centrifugal compressor, the diffuser of which contains vanes that divide the flow into channels oriented partly radially and partly tangentially. In reverse-tangent injection, a stream or jet of the working fluid (the fluid that is compressed) is injected into the vaneless annular region between the blades of the impeller and the vanes of the diffuser (see figure). As used here, “reverse” signifies that the injected flow opposes (and thereby reduces) the tangential component of the velocity of the impeller discharge. At the same time, the injected jet acts to increase the radial component of the velocity of the impeller discharge. The net effect is to turn the impeller discharge flow toward a more radial direction; in other words, to reduce the flow angle of fluid entering the vaned diffuser passage, thereby reducing diffusion ahead of the passage throat, reducing the pressure load and the incidence of flow on the leading edges of the vanes. The reduction of the flow angle also changes the dynamic coupling between the impeller and diffuser in such a way as to prevent the development of certain instability modes in the diffuser.

The number and distribution of reverse-tangent injectors can be tailored to match the expected stall/surge characteristics of the compressor and the space available for installation. Reverse-tangent injection can be implemented in any of three operating modes:
1. Continuous operation, in which the working fluid is injected continuously;
2. Open-loop operation, in which injection is initiated by on-off valves upon detection of compressor instability or conditions known to precede compressor instability and the injection is

Reverse-Tangent Injection in a Centrifugal Compressor
The compressor flow can be stabilized against stall and surge.

John H. Glenn Research Center, Cleveland, Ohio
Inertial Measurements for Aero-assisted Navigation (IMAN)

NASA's Jet Propulsion Laboratory, Pasadena, California

IMAN is a Python tool that provides inertial sensor-based estimates of spacecraft trajectories within an atmospheric influence. It provides Kalman filter-derived spacecraft state estimates based upon data collected onboard, and is shown to perform at a level comparable to the conventional methods of spacecraft navigation in terms of accuracy and at a higher level with regard to the availability of results immediately after completion of an atmospheric drag pass. A benefit of this architecture is that this technology is conducive to onboard data processing and estimation and thus can compute near real-time spacecraft state estimates making it suitable for autonomous operations and/or closed-loop guidance, navigation, and control strategies.

Currently, IMAN is being used in an experiment to demonstrate Inertial Measurement Unit (IMU)-based aerobraking navigation for the Mars Reconnaissance Orbiter (MRO). It also can be used in other operational missions such as those using the atmosphere for entry-descent-landing or solar sail missions that experience significant solar radiation pressure for propulsion.

This program was written by Moriba Jah, Michael Lisano, and George Hockney of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-43677.

Analysis of Complex Valve and Feed Systems

Stennis Space Center, Mississippi

A numerical framework for analysis of complex valve systems supports testing of propulsive systems by simulating key valve and control system components in the test loop. In particular, it is designed to enhance the analysis capability in terms of identifying system transients and quantifying the valve response to these transients. This system has analysis capability for simulating valve motion in complex systems operating in diverse flow regimes ranging from compressible gases to cryogenic liquids. A key feature is the hybrid, unstructured framework with sub-models for grid movement and phase change including cryogenic cavitations.

The multi-element unstructured framework has been evaluated for its ability to predict performance metrics like flow coefficient for cavitating venturi and valve coefficient curves, and could be a valuable tool in predicting and understanding anomalous behavior of system components at rocket propulsion testing and design sites.

This program was written by Vineet Ahuja, Ashvin Hosangadi, Jeremy Shipman, Peter Cavallo, and Sanford Dash of Combustion Research and Flow Technology (CRAFT), Inc. for Stennis Space Center.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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