ferred to subsequent projects by use of simple cut-and-paste routines.

BAT includes a library of temperature-dependent cryogenic bearing-material properties for use in the mathematical models. BAT implements algorithms that (1) enable the user to select combinations of design and/or operating-condition parameters, and then (2) automatically optimize the design by performing trade studies over all of the parameter combinations. This feature enables optimization over a large trade space in a fraction of the time taken when using prior bearing-model software.

This program was written by James D. Moore, Jr., and Ed Troy of SRS Technologies for Marshall Space Flight Center. Further information is contained in a TSP (see page 1). MFS-31864-1.

Reverse-Tangent Injection in a Centrifugal Compressor

The compressor flow can be stabilized against stall and surge.

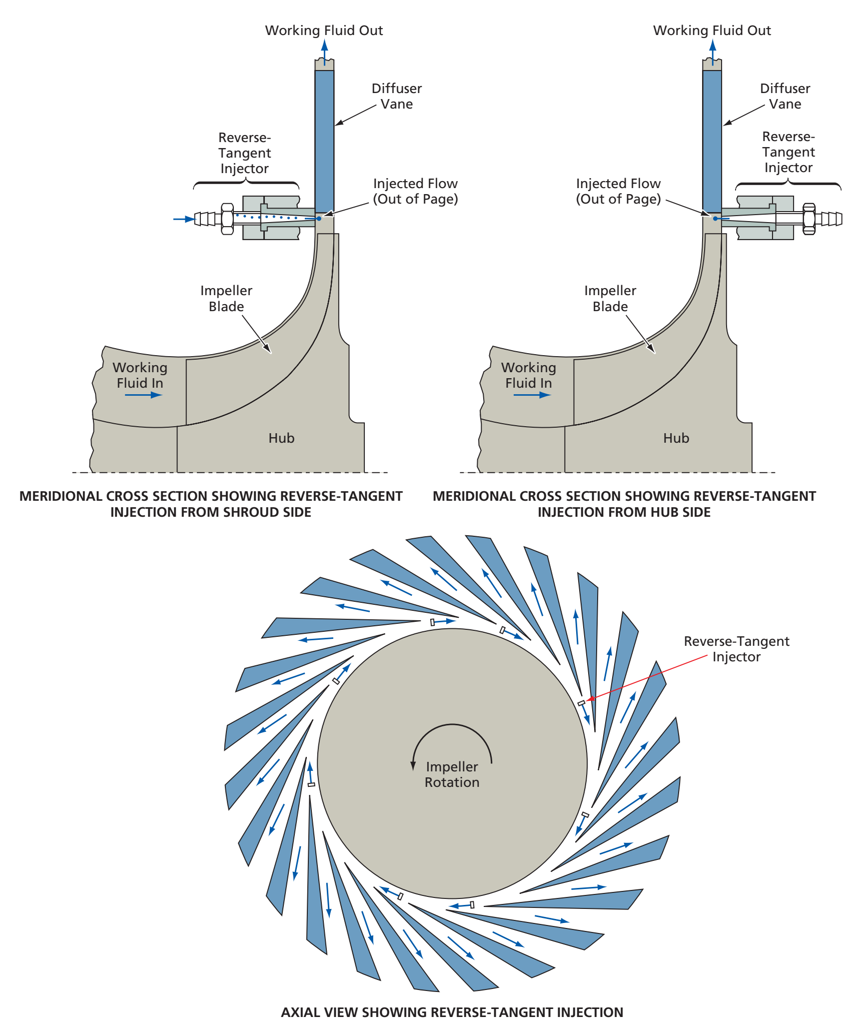
John H. Glenn Research Center, Cleveland, Ohio

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



Working Fluid Is Injected in the direction opposing the tangential component of impeller discharge velocity at multiple points (eight in this example) in the vaneless region between the impeller blades and the diffuser vanes.

terminated when stable compressor operation returns; or

3. Closed-loop or feedback-controlled operation, in which compressor stability is monitored and the number of active injectors and the injection rate are continually adjusted, using a dynamic control model and controlled valves.

In each of these operating modes, the injected working fluid can be supplied from an external source or from a downstream compressor stage where the total pressure is sufficient to produce the injected stream(s).

This work was done by Gary J. Skoch of the U.S. Army Research Laboratory for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17560-1.

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.

This tool can be used to reliably predict subsequent periapsis times and locations over all aerobraking regimes. It also yields accurate peak dynamic pressure and heating rates, which are critical for a successful corridor control strategy. These data are comparable to radiometric-based navigation team reconstructed values. IMAN also provides the first instance of the use of the Unscented Kalman Filter (UKF) for the purpose of estimating an actual spacecraft trajectory arc about another planet. A significant advantage to the implementation of this type of filter is that the UKF is a non-linear filter and thus accurate to at least second order. It provides more meaningful and realistic covariances and has been shown to be robust in the presence of sparse data sets.

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 offers improved predictions of valve performance characteristics under steady conditions for structurally complex valves such as pressure regulator valve. Unsteady simulations of valve motion using this computational approach have been carried out for various valves in operation at Stennis Space Center such as the split-body valve and the 10-in. (≈25.4-cm) LOX (liquid oxygen) valve and the 4-in. (≈10 cm) Y-pattern valve (liquid nitrogen). Such simulations make use of variable grid topologies, thereby permitting solution accuracy and resolving important flow physics in the seat region of the moving valve.

An advantage to this software includes possible reduction in testing costs incurred due to disruptions relating to unexpected flow transients or functioning of valve/flow control systems. Prediction of the flow anomalies leading to system vibrations, flow resonance, and valve stall can help in valve scheduling and significantly reduce the need for activation tests. This framework has been evaluated for its ability to predict performance metrics like flow coefficient for cavitating venturis 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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