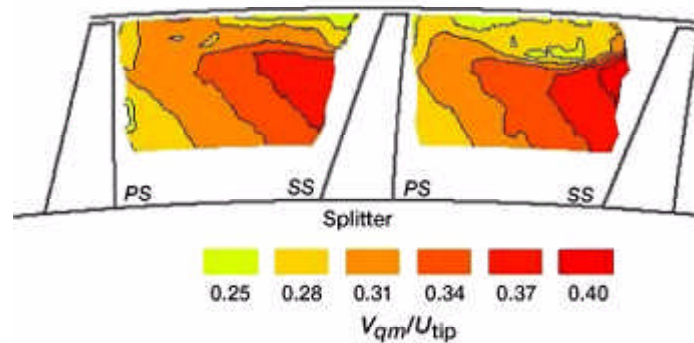


Optical Flow-Field Techniques Used for Measurements in High-Speed Centrifugal Compressors

The overall performance of a centrifugal compressor depends on the performance of the impeller and diffuser as well as on the interactions occurring between these components. Accurate measurements of the flow fields in each component are needed to develop computational models that can be used in compressor design codes. These measurements must be made simultaneously over an area that covers both components so that researchers can understand the interactions occurring between the two components.

Optical measurement techniques are being used at the NASA Lewis Research Center to measure the velocity fields present in both the impeller and diffuser of a 4:1 pressure ratio centrifugal compressor operating at several conditions ranging from design flow to surge. Laser Doppler Velocimetry (LDV) was used to measure the intrablade flows present in the impeller, and the results were compared with analyses obtained from two three-dimensional viscous codes. The development of a region of low throughflow velocity fluid within this high-speed impeller was examined and compared with a similar region first observed in a large low-speed centrifugal impeller at Lewis.

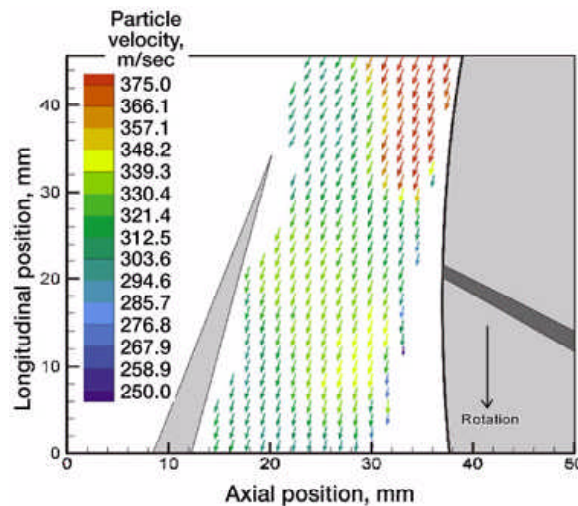


Contours of impeller throughflow velocity from LDV measurements at 70 percent of the blade chord, where V_{qm} is the quasi-meridional, or throughflow, velocity; U_{tip} is the blade tip speed at the impeller discharge; PS is the impeller blade pressure surface; and SS is the suction surface.

Particle Image Velocimetry (PIV) is a relatively new technique that has been applied to measuring the diffuser flow fields. PIV can collect data rapidly in the diffuser while avoiding the light-reflection problems that are often encountered when LDV is used. The Particle Image Velocimeter employs a sheet of pulsed laser light that is introduced into the diffuser in a quasi-radial direction through an optical probe inserted near the diffuser discharge. The light sheet is positioned such that its centerline is parallel to the hub and shroud surfaces and such that it is parallel to the diffuser vane, thereby avoiding reflections

from the solid surfaces. Seed particles small enough to follow the diffuser flow are introduced into the compressor at an upstream location. A high-speed charge-coupled discharge (CCD) camera is synchronized to the laser pulse rate; this allows it to capture images of seed particle position that are separated by a small increment in time. A cross-correlation of a particle's position in two consecutive images provides an estimate of flow velocity and direction. Multiple image pairs obtained in rapid succession at a particular flow condition provide enough measurements for statistical significance. PIV provides simultaneous velocity measurements over the entire plane that is illuminated by the light sheet instead of at a single point, as is the case when LDV is used.

PIV has a further advantage in that the laser light pulse can be triggered by an external source such as a high-response pressure transducer. This feature will allow PIV to synchronize flow imaging to physical phenomena such as rotating stall or stall precursor waves. We hope that this technique can be used to obtain images of the flow field during and just prior to stall.



Diffuser absolute velocity field at 88 percent of the passage height obtained using Particle Image Velocimetry.

Bibliography

Skoch, G.J., et al.: Laser Anemometer Measurements of the Flow Field in a 4:1 Pressure Ratio Centrifugal Impeller. ASME Paper 97-GT-342, 1997.

Hathaway, M.D., et al.: Experimental and Computational Investigation of the NASA Low-Speed Centrifugal Compressor Flow Field. ASME J. Turbomachinery (ASME Paper 92-GT-216), vol. 115, no. 3, July 1993, pp. 527-541.

Wernet, M.P.: Digital PIV Measurements in the Diffuser of a High Speed Centrifugal Compressor. AIAA Paper 98-2777, 1998.

Lewis contacts: Gary J. Skoch, (216) 433-3396, Gary.J.Skoch@grc.nasa.gov; and Dr. Mark P. Wernet, (216) 433-3752, Mark.P.Wernet@grc.nasa.gov

Author: Gary J. Skoch

Headquarters program office: OAT

Programs/Projects: Propulsion Systems R&T, P&PM