STATUS OF LASER ANEMOMETRY IN TURBOMACHINERY RESEARCH AT THE LEWIS RESEARCH CENTER

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OPTICAL CONFIGURATION FOR FRINGE-TYPE
LASER ANEMOMETERS

Laser anemometer systems have been developed for a full-annular turbine stator cascade facility and for a compressor rotor facility; both are ambient temperature axial-flow facilities with a 20-inch tip diameter. The optical configurations of the two anemometers are similar single-component fringe-type backscatter systems with a probe volume diameter of 125 μm and length of about 2 mm. The effective f-number of the receiving optics is about f/5. A rhodamine 6G fluorescent dye aerosol, which fluoresces orange when excited by the 514 nm laser light, is used to allow rejection of unwanted scattered light from surfaces near the probe volume. Measurements can be made to within 1 mm of the hub. The estimated diameter of the particles actually measured is about 1.2 μm. For the rotor measurements the data are accepted continuously with the rotor position at the time of each measurement determined by a unique electronic shaft angle encoder.

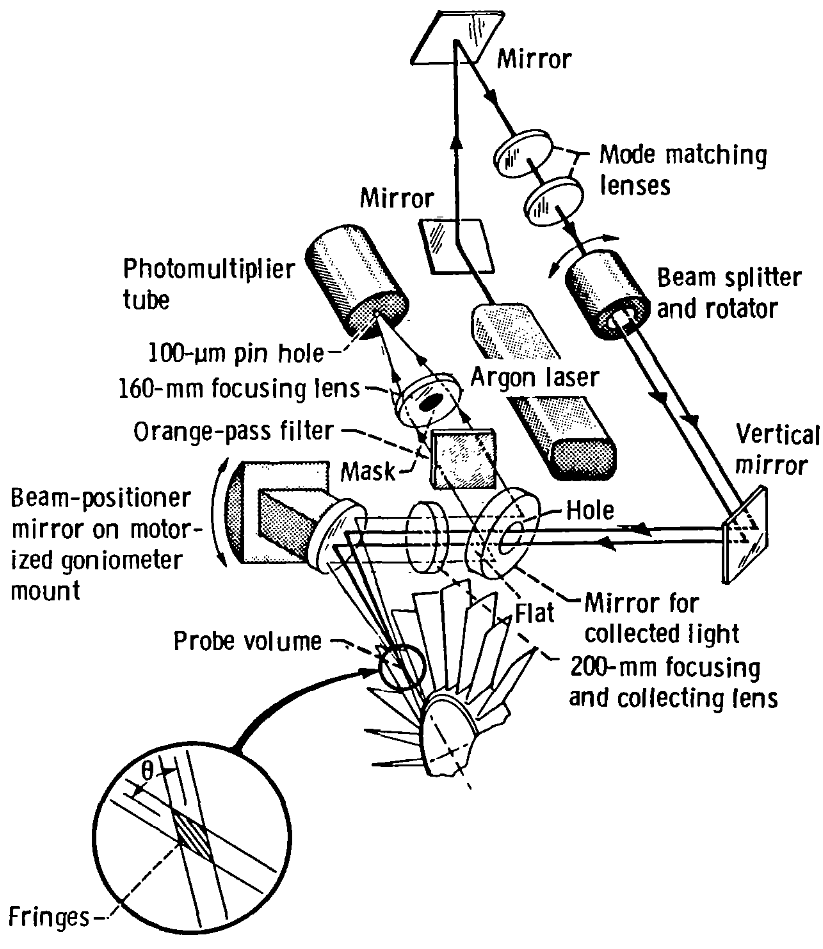
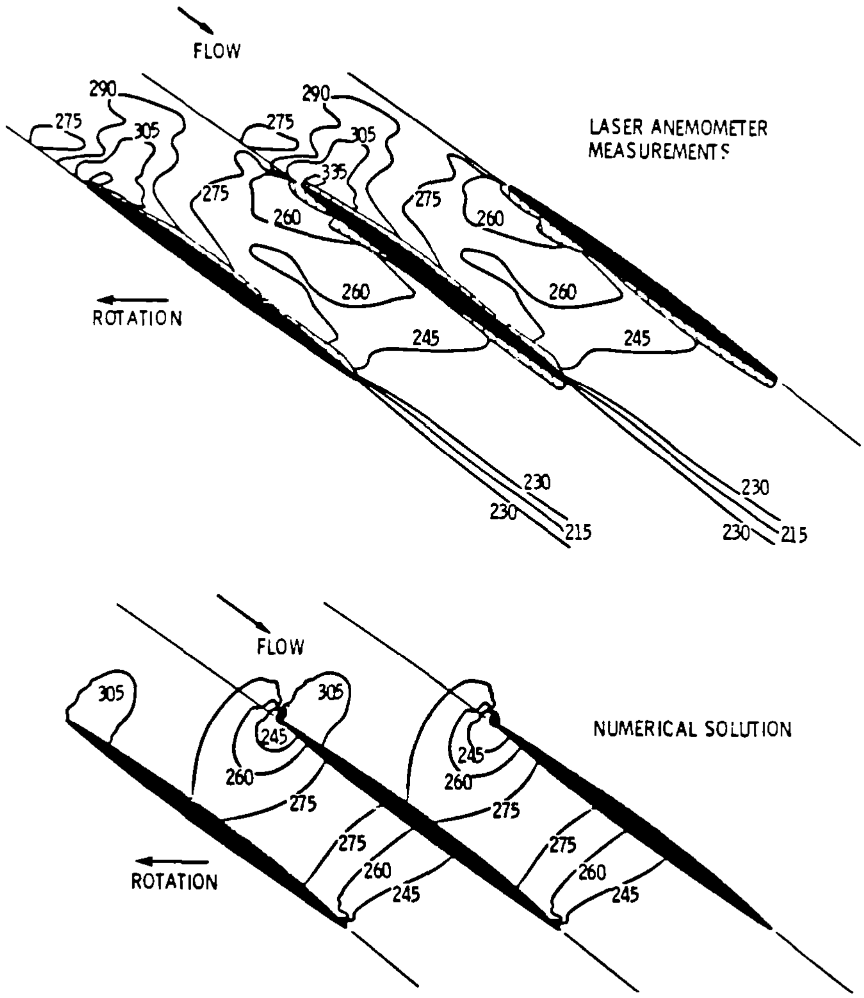


Figure 1

COMPARISON OF LASER ANEMOMETER MEASUREMENTS AND NUMERICAL SOLUTION FOR A TRANSONIC AXIAL-FLOW COMPRESSOR ROTOR

The results of an inviscid computer code are compared with laser anemometer measurements taken at mid-span. The operating point was 70 percent of design speed near maximum efficiency. The cross-hatched areas near the blade denote regions in which no measurements were obtained. The numerical and experimental results display reasonable agreement in the expansion region around the blade leading edge, but the LA measurements indicate less diffusion than predicted by the numerical solution near the pressure side of the blade passage in the rear portion of the passage.



RELATIVE VELOCITY

CONTOURS IN (M/SEC)

Figure 2

TURBINE STATOR TEST SECTION

The test section consists of a sector of four vanes, which are part of the full-annular ring of 36 vanes. The vanes, of constant profile from hub to tip, have a height of 1.5 inches and an axial chord of 1.5 inches. All measurements were taken at the design mean-radius exit critical velocity ratio of 0.78. A cutout in the test section outer vane ring provides optical access. The test vanes in this region have been machined to the vane tip radius to permit a cylindrical window to fit flush with the tip endwall. The 1/8-inch thick glass window was formed by sagging it, in a vacuum furnace, onto a machined graphite form. The form was designed so that the window area used for the measurements did not touch the form during the sagging process to avoid creating surface imperfections in the glass.

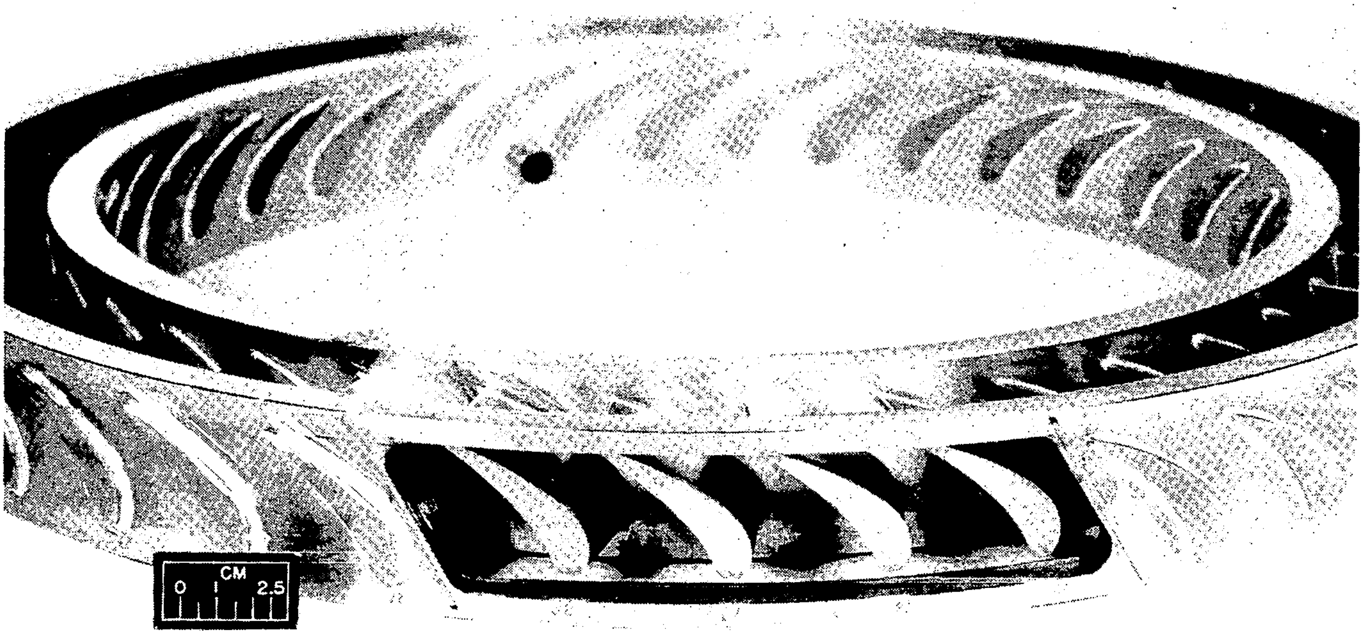
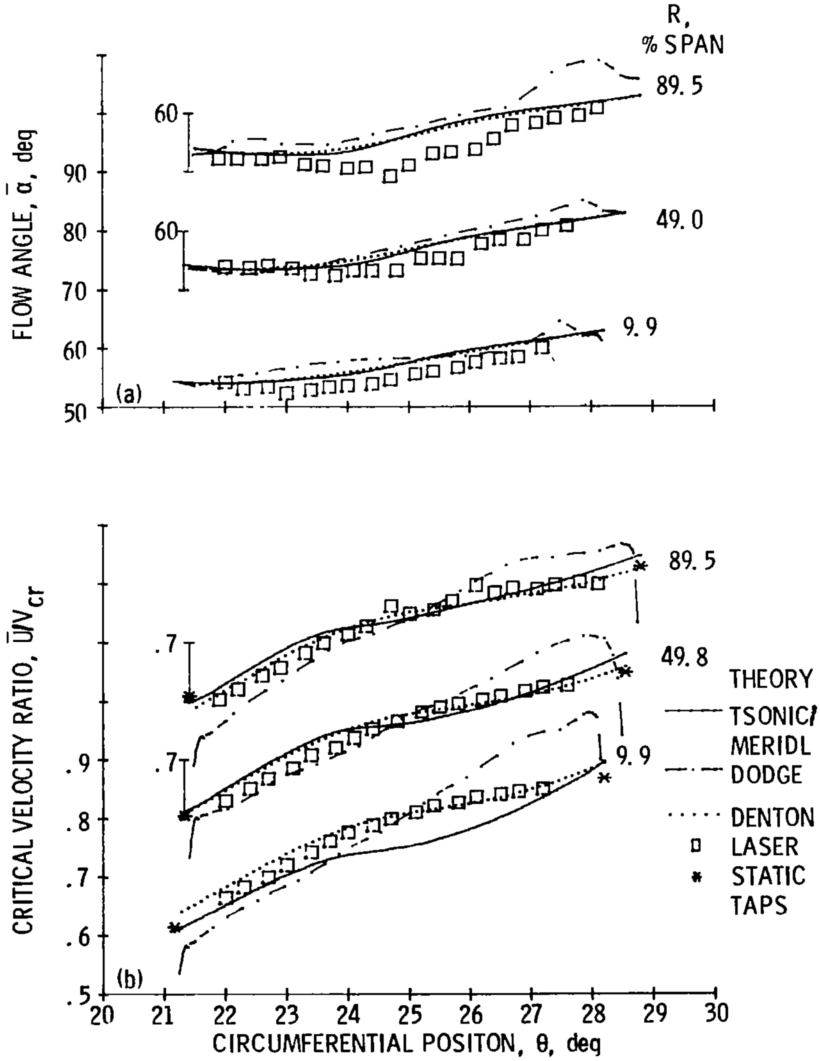


Figure 3

COMPARISON OF LASER ANEMOMETER MEASUREMENTS AND NUMERICAL SOLUTIONS FOR A TURBINE STATOR CASCADE

Typical laser anemometer measurements taken at 80 percent axial chord are shown compared with the results of three turbomachinery computer codes: a quasi three-dimensional inviscid code (Katsanis), a three-dimensional inviscid code (Denton), and a three-dimensional viscous code (Dodge). The agreement between the laser anemometer data and Denton code is considered good, while the comparison with the other two is only fair. The larger differences between the data and the Katsanis and Dodge codes at this axial location are felt to be caused by the modeling of the trailing edge region.



Flow angle.

Critical velocity ratio.

Figure 4

OPTICAL CONFIGURATION OF LASER ANEMOMETER USING FABRY-PEROT INTERFEROMETER FOR MEASUREMENT OF VELOCITY COMPONET ALONG OPTICAL AXIS

A laser anemometer based on a scanning confocal Fabry-Perot interferometer (2 GHz free spectral range) was built to measure the velocity component along the optical axis. This component, which corresponds to the radial component in axial flow turbomachinery, cannot be directly measured with fringe-type anemometers. The incident and scattered light propagation directions are symmetrically located off the optical axis to reduce the probe volume length while giving a Doppler shift frequency proportional only to the velocity component along the optical axis. A signal with an offset frequency generated by a Bragg cell is used as a reference for scan calibration and for a spectrum stabilization circuit that compensates for frequency drift of the laser. The system was tested in the annular turbine stator cascade previously mapped with the fringe-type anemometer. Because of the high acoustic noise level (105 dB), it was necessary to place the anemometer in an acoustic enclosure for this test to prevent excessive jitter of the laser frequency.

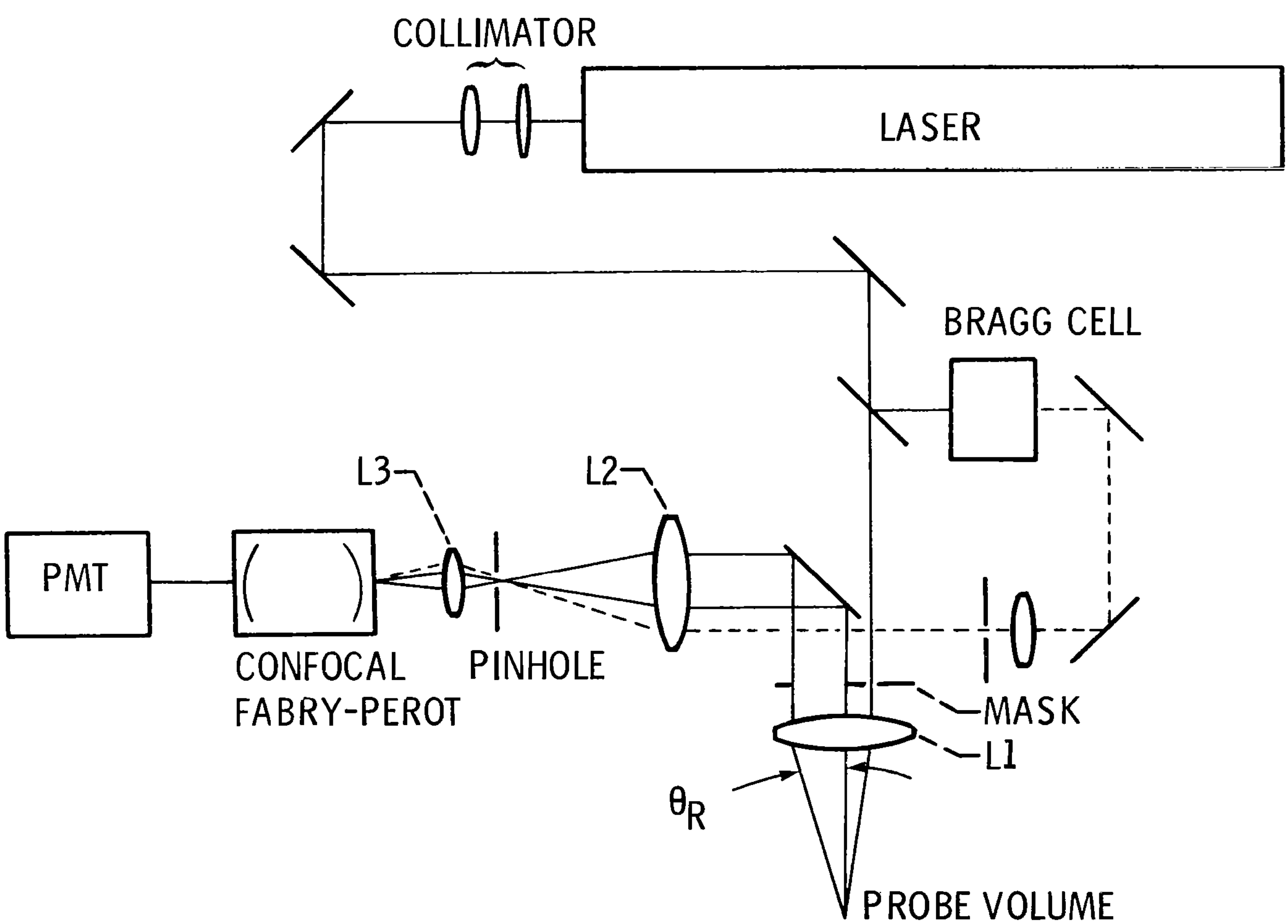
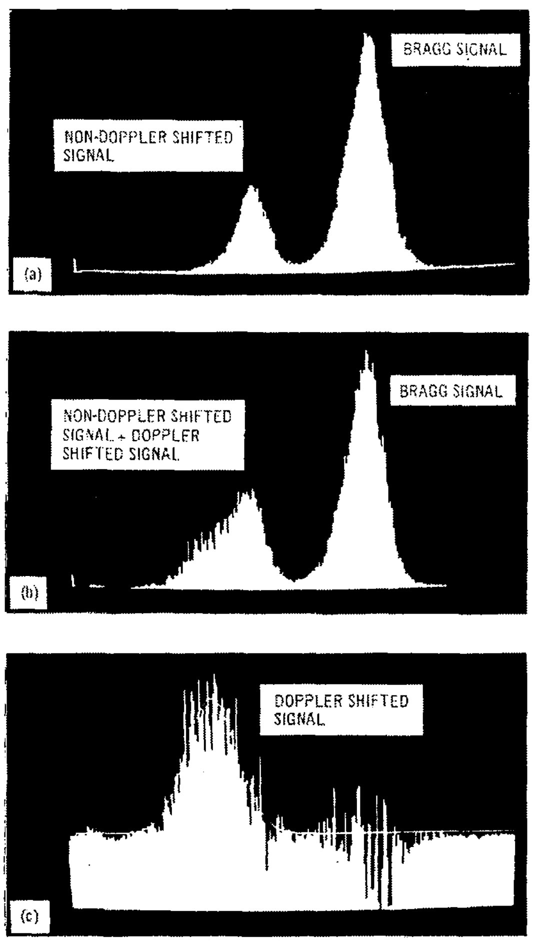


Figure 5

RADIAL VELOCITY COMPONENT IN ANNULAR TURBINE STATOR CASCADE MEASURED WITH FABRY-PEROT INTERFEROMETER

A procedure was developed to measure a small velocity component along the optical axis, where the Doppler shifted signal is masked by the unshifted signal due to light scattered from surfaces near the probe volume. To accomplish this, two multiple scan spectra were recorded using alternate scans of the Fabry-Perot with the flow being seeded for only one of the spectra. The Bragg signal, shifted by 77.7 MHz from the laser frequency, is recorded in each spectrum. Subtracting the unseeded spectrum from the seeded spectrum gives the signal due to just the seed particles. A least-squares fit of the unseeded spectrum to a double Gaussian gives the frequency span, which is used with a fit of the difference spectrum to a single Gaussian to calculate the mean Doppler shift. The width of the difference spectrum is also used to calculate the turbulence intensity. For this example (taken at 50% axial chord, 50% span, and 2.3 degrees from the vane suction surface), the mean radial velocity was 6.3 m/sec toward the hub. The turbulence intensity, relative to the mean velocity magnitude of 243 m/sec, was 2.4%.



- Measured spectra in annular cascade (a) unseeded flow (b) seeded flow (c) difference between seeded and unseeded flow.

Figure 6

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