HOT SECTION LASER ANEMOMETRY

by

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The Lewis Research Center is sponsoring an in-house and grant program to develop a laser anemometry system for hot section applications. The goal of this program is to be able to map the flow profiles through the vanes, between the vanes and blades, and between the rotating blades of a turbine. We are specifically aiming at developing a system for the Lewis High Pressure Turbine (HPT).

In-house work on laser anemometry at Lewis has been under way since about 1973. All the work has been in cold axial flow cascades and in single-stage axial flow compressor facilities. Under these conditions we have found that the fringe-type, single axis system has worked well for axial and circumferential flow component measurements. The radial component has been quite a bit more difficult to measure since we never have more than a minimum size window to access the rig. In addition, we never have the option of putting the optical axis more than a few degrees from the radial direction of the machine to measure the radial component because the view is always blocked by the blades or vanes. This led us to the development of a laser anemometer system which measures the Doppler shift directly along the optical axis. This is particularly difficult because the radial component is not only a very small fraction of the perpendicular components but is also a very small absolute velocity which causes very little Doppler shift. A paper has just been published on this topic.[1]

All the problems we have had so far are expected to be much worse when we face the hot, high pressure flows in the HOST program. The velocity profiles which will be measured will include all three components--axial, circumferential, and radial. Our experience with the radial component in cascades warns us that this will be the most difficult component to obtain under the limited optical access conditions under which we are forced to work. We plan to measure the mean flows and angles, the turbulence parameters, the Reynolds stresses, and the power spectra.

Because running the HPT is very expensive, we are going to develop the system as much as possible in lower cost rigs and move up in phases until we finally get to HPT. We just can't afford to be doing much hardware or software debugging while HPT is running.

The first step, which is currently getting under way, is to solve as many problems as possible in a small bench top combustor facility. This is an open jet burner operating at one atmosphere. Here we will investigate various seeding materials and techniques. Windows with various thicknesses, geometries, temperature gradients, and stresses will be tried to determine whether we can make the laser beams behave properly under these conditions of nonuniform refractive index. Here also we will try various signal processing techniques to extract the signal from the background noise radiation and the reflections from nearby surfaces. A computer is being installed here which is identical to the one we would put in HPT so that all of the interfacing, control, and data gathering, handling, and processing software will be as complete as possible before moving to the more expensive facilities. We will even simulate the rotation of the stage here so that the synchronization software and hardware that we developed for compressor stages can be incorporated into the system.

The next step up will be to put an almost identical system into the Lewis Warm Turbine Facility. Here we can get all of the conditions of HPT except the pressure and temperature. All the desired flow mapping can be done here. This alone would be very valuable data even if we never made it to HPT. In the meantime, the system that was installed on the open jet bench top rig will remain operational so that continued development can be done there. Problems encountered on the Warm Turbine also can be attacked on this little rig.

As can be seen from the schedule, the timetable on this program calls for fixing the design for the Warm Turbine Facility by fall of 1983 so that we can be running in that facility throughout 1985 and then in HPT in 1986. So far we are doing pretty well on this schedule and have high hopes of staying on it.

A continuing problem which plagues laser anemometry systems used in high operating cost facilities is getting a sufficient data rate so that the flow maps can be obtained without a phenomenal amount of running. The way to get the data rate up is to carefully optimize seeding, beam geometries, signal processing, and data reduction. These problems are being addressed in a grant that we are funding at Case-Western Reserve University. The next speaker, Professor Robert V. Edwards, will present some of the results of his study.

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[1]Seasholtz, Richard G. and Goldman, Louis J., "Laser Anemometer Using a Fabry-Perot Interferometer for Measuring Mean Velocity and Turbulence Intensity Along the Optical Axis in Turbomachinery," NASA TM 82841

HOST LASER ANEMOMETRY

GOAL:

CHARACTERIZE VELOCITY FIELD IN HIGH PRESSURE TURBINE

- THREE SPATIAL COMPONENTS
- INTER AND INTRA BLADE
- MEAN AND TURBULENT PARAMETERS

SEQUENCE:

1. START WITH SYSTEMS DEVELOPED FOR LOW TEMPERATURE CASCADES AND ROTATING BLADE ROWS
2. APPLY THESE SYSTEMS (MODIFIED) TO BENCH TOP COMBUSTOR FACILITY
3. COMPLETE DESIGN FOR HIGH TEMPERATURE FACILITIES
4. INSTALL SYSTEM IN WARM TURBINE FACILITY
5. INSTALL SYSTEM IN HIGH PRESSURE/TEMPERATURE TURBINE FACILITY

HOST LASER ANEMOMETRY SCHEDULE