Passive Acoustic Tomography Tested for Measuring Gas Temperatures

The requirements of higher performance, better fuel economy, and lower emissions place an increasing premium on knowing the internal operating parameters of jet engines. One of the most important is the gas temperature in the post combustor section of the engine. Typically the gas temperature is measured with a thermocouple probe or by some optical technique such as Rayleigh scattering.

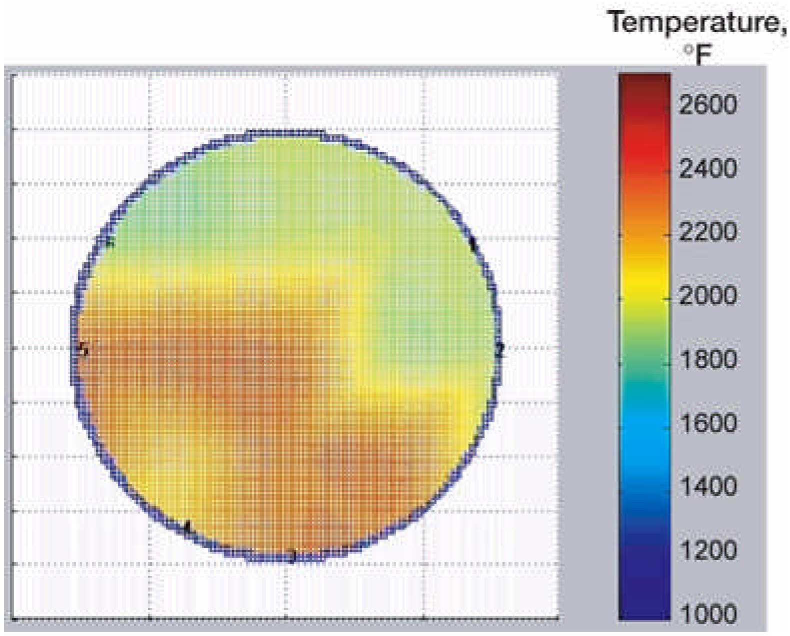
Probes, while providing valuable information, have several limitations. The probe signal must be corrected for radiation and conduction losses, probes provide only a point measurement, and probes must be constructed of materials whose melting points are lower than the temperature of the environment into which they are inserted.

Some of the disadvantages of probes are overcome by various optical techniques. Nothing needs to be inserted into the flow, and the temperature can be directly related to the signal by known physical laws. However, optical techniques require optical access (i.e., a window) and a light source (such as a laser), and they are very sensitive to the presence of particles in the flow.

To overcome these problems, researchers from the NASA Glenn Research Center and The University of Nevada are developing a technique that uses sound instead of light to measure gas temperature. Like optical techniques, it is nonintrusive--no probe need be exposed to the combustion environment--and the temperature is directly related to a measured quantity--the speed of sound, which is proportional to the square root of the absolute temperature.

The temperature profile inside the engine is constructed from the differences in arrival time between correlated signals from an array of microphones placed around the circumference of the engine. In much the same way as a complete picture of the inside of your body can be constructed from an array of x-ray photographs taken at different angles, the temperature profile in the engine is constructed from the angular array of microphones. It is tomography by sound waves.

Active acoustic tomography, in which a sound pulse is injected into the flow and the time delays between members of an array of microphones are used to construct the temperature field has been used successfully in the stacks of power plants. However, the flow field inside a jet engine is much too noisy for it to be possible to detect an externally injected sound pulse. Instead we are developing passive acoustic tomography, which uses the sound already present in the flow.



Temperature distribution inside Glenn's High Pressure Burner Rig, as measured using passive acoustic tomography.

The figure shows the temperature distribution inside Glenn's High Pressure Burner Rig. The data were taken from an array of six microphones spaced roughly equally around the circumference of the ~8-in.-diameter duct. The data were reduced using a new frequency domain algorithm that we expect will provide the temperature distribution in real time, making passive acoustic tomography a candidate control sensor for both the combustor operating point and the burner pattern factor. These expectations are reinforced by the fact that, during the course of testing, it was discovered that the frequency content of the signal was correlated with the rig fuel air ratio. Further development of passive acoustic tomography includes plans to reduce the burner factor data taken last year in a burner rig at Rolls-Royce U.S. and to test an engine during calendar year 2004 or 2005.

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