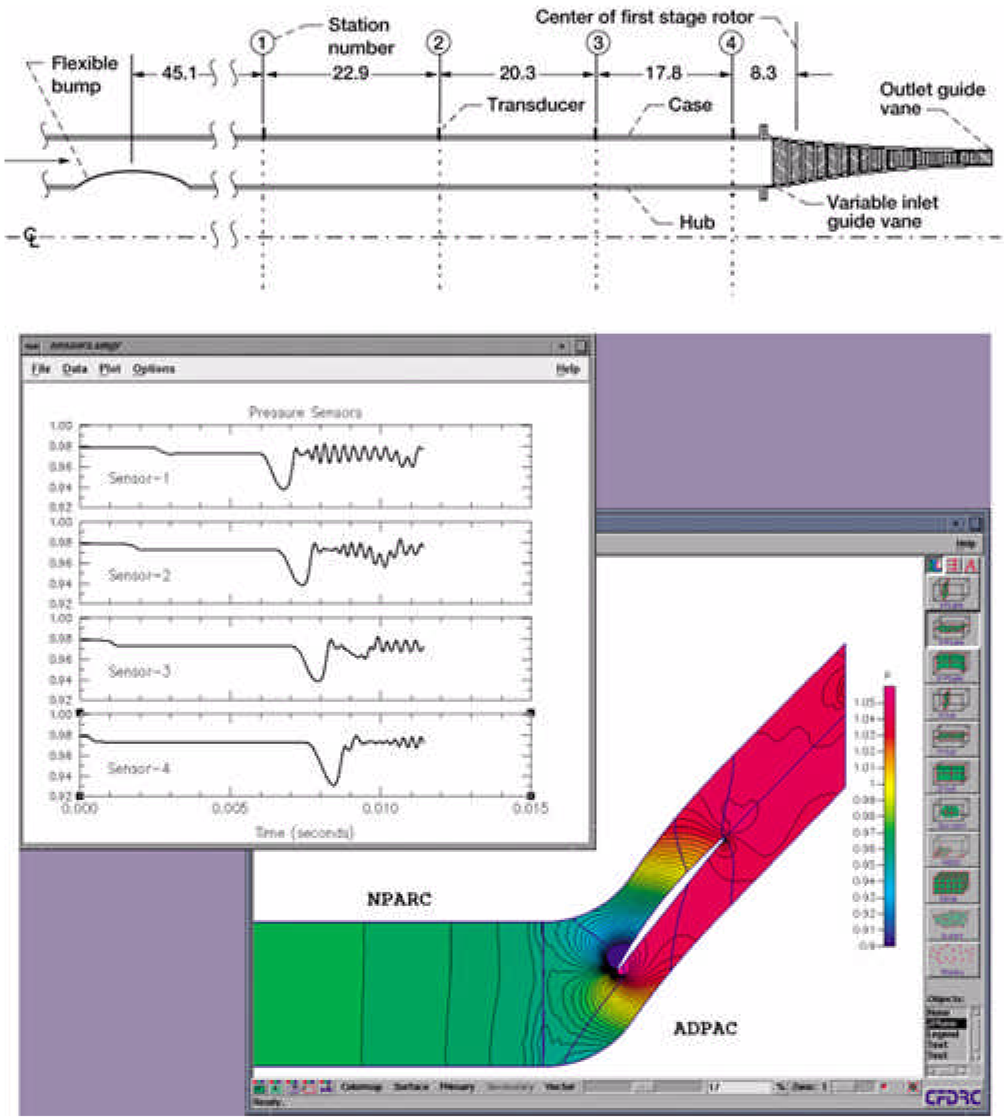
Inlet-Compressor Analysis Performed Using Coupled Computational Fluid Dynamics Codes

A thorough understanding of dynamic interactions between inlets and compressors is extremely important to the design and development of propulsion control systems, particularly for supersonic aircraft such as the High-Speed Civil Transport (HSCT). Computational fluid dynamics (CFD) codes are routinely used to analyze individual propulsion components. By coupling the appropriate CFD component codes, it is possible to investigate inlet-compressor interactions. The objectives of this work were to gain a better understanding of inlet-compressor interaction physics, formulate a more realistic compressor-face boundary condition for time-accurate CFD simulations of inlets, and to take a first step toward the CFD simulation of an entire engine by coupling multidimensional component codes. This work was conducted at the NASA Lewis Research Center by a team of civil servants and support service contractors as part of the High Performance Computing and Communications Program (HPCCP).

An inlet-compressor experiment (ref. 1) conducted at the University of Cincinnati was chosen as the application for this CFD analysis because of the availability of experimental data for validation. A schematic of the experiment is shown in the figure. It consists of a constant-area annular inlet coupled to a GE T–58 engine (General Electric) that was modified for cold operation. The collapse of a flexible bump on the hub of the inlet produced a well-defined acoustic pulse that traveled downstream and interacted with the engine. Static-pressure time histories were measured at the four axial locations shown in the figure. NPARC, a general-purpose CFD code, was used to simulate the inlet portion of the experiment. The engine was approximated by the first-stage rotor and was simulated with ADPAC, a turbomachinery code. Details concerning the code coupling approach and the issues involved are given in reference 2.



Snapshot of (partial) NPARC-ADPAC pressure contour plots and pressure time histories at sensor locations during simulation of the University of Cincinnati experiment. All dimensions in diagram at top are in centimeters.

The NPARC domain was solved using a single grid block, whereas the ADPAC domain was divided into multiple blocks, with all the blocks computed in parallel to achieve faster execution. Simulation of the experiment for a 10.4-msec transient took about 32.5 hours for a seven-block ADPAC case and 12 hours for a 21-block case. A snapshot in time of flow-field pressure contour plots and the four pressure-sensor time histories are shown in the figure. (Only part of the NPARC domain is shown.) Although not shown in the figure, the computed pressure time histories were found to give reasonable agreement with the experimental data.

The investigation indicates that coupling inlet and turbomachinery CFD codes is a feasible approach to studying inlet-engine interaction problems. Additional investigation of cold coupling issues and the means for reducing execution time is planned. This approach offers the possibility of including other specialized codes (e.g., combustor) to provide a full engine simulation. The coupled NPARC-ADPAC codes could also serve as a testbed for exploring other flow perturbations of interest and for validating simplified boundary conditions.

References

1. Freund, D.; and Sajben, M.: Reflection of Large Amplitude Acoustic Pulses From an Axial Flow Compressor. AIAA Paper 97-2879, 1997.

2. Suresh, A., et al.: Analysis of Compressor-Inlet Acoustic Interactions Using Coupled Component Codes. AIAA Paper 99-0749, 1999.

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