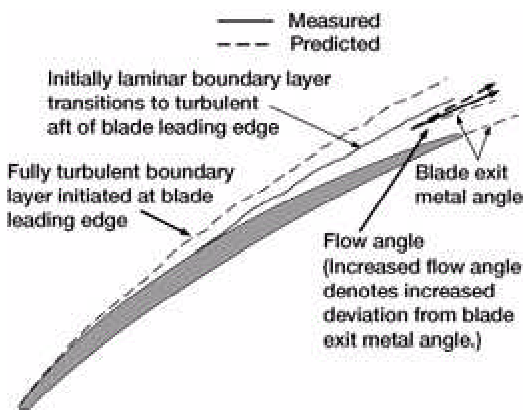
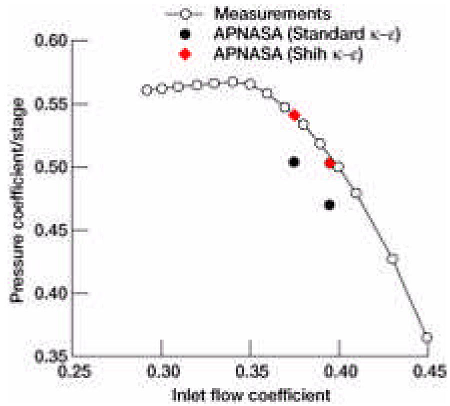
Multistage Turbomachinery Flows Simulated Numerically

At the NASA Lewis Research Center, a comprehensive assessment was made of the predictive capability of the average passage flow model as applied to multistage axial-flow compressors. This model, which describes the time-averaged flow field within a typical passage of a blade row embedded in a multistage configuration, is being widely used throughout U.S. aircraft industry as an integral part of their design systems.



Rotor flow-angle deviation.

In this work, detailed data taken within a four and one-half stage large low-speed compressor were used to assess the weaknesses and strengths of the predictive capabilities of the average passage flow model. The low-speed compressor blading is of modern design and employs stator end-bends. Measurements were made with slow- and high-response instrumentation. The high-response measurements revealed the velocity components of both the rotor and stator wakes. From the measured wake profiles, we found that the flow exiting the rotors deviated from the rotor exit metal angle to a lesser degree than was predicted by the average passage flow model (see the preceding illustration). This was found to be due to blade boundary layer transition, which recently has been shown to exist on multistage axial compressor rotor and stator blades (ref. 1), but was not accounted for in the average passage model. Consequently, a model that mimics the effects of blade boundary layer transition, Shih k-ε model, was incorporated into the average passage model. Simulations that incorporated this transition model showed a dramatic improvement in agreement with data (see the following graph). The altered model thus improved predictive capability for multistage axial-flow compressors, and this was verified by detailed experimental measurement. For more information, see references 2 and 3.



Overall pressure rise coefficient per stage.

References

1. Adamczyk, J.J., et al.: Numerical Simulation of Multistage Turbomachinery Flows. AGARD Propulsion and Energetics Panel. Tulous, France, May 1998.

2. Adamczyk, J.J., et al.: Numerical Simulation of Multistage Turbomachinery Flows. Unsteady Flows in Turbomachines, VKI-LS-1996-05, vol. 2, 1996.

3. Shih, T.-H., et al. New K-ε Eddy Viscosity Model for High Reynolds Number Turbulent Flows. Comp. Fluids, vol. 24, no. 3, 1995, pp. 227-238.

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