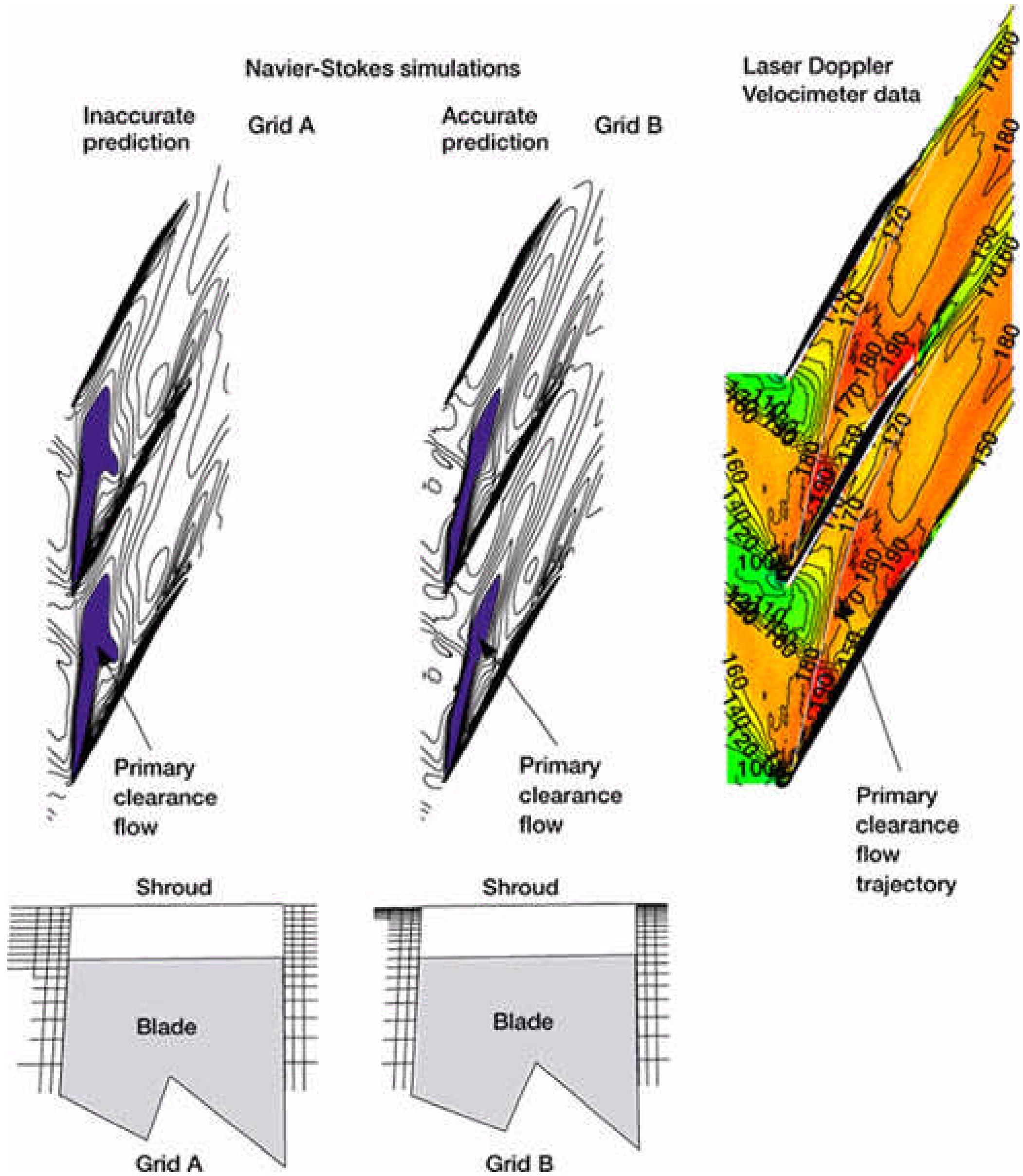
Accuracy of Numerical Simulations of Tip Clearance Flow in Transonic Compressor Rotors Improved Dramatically

The tip clearance flows of transonic compressor rotors have a significant impact on rotor and stage performance. Although numerical simulations of these flows are quite sophisticated, they are seldom verified through rigorous comparisons of numerical and measured data because, in high-speed machines, measurements acquired in sufficient detail to be useful are rare. Researchers at the NASA Glenn Research Center at Lewis Field compared measured tip clearance flow details (e.g., trajectory and radial extent) of the NASA Rotor 35 with results obtained from a numerical simulation. Previous investigations had focused on capturing the detailed development of the jetlike flow leaking through the clearance gap between the rotating blade tip and the stationary compressor shroud. However, we discovered that the simulation accuracy depends primarily on capturing the detailed development of a wall-bounded shear layer formed by the relative motion between the leakage jet and the shroud.

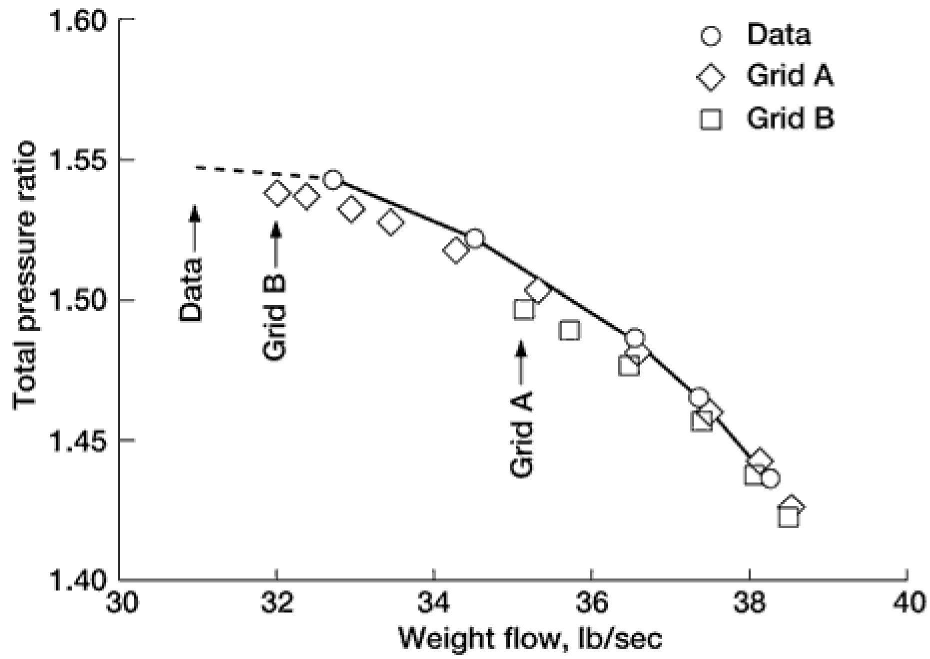


Predicted and measured rotor tip clearance flow in the blade tip plane of the NASA 35.

The preceding figure compares the Laser Doppler Velocimeter (LDV) measurements with the clearance flow on a plane at the blade tip as calculated with two different grids. We found that because the wall-bounded shear layer lies very close to the shroud it cannot be captured by standard grid topologies such as Grid A, which employs a uniformly spaced mesh with relatively few points in the clearance gap. In contrast, Grid B employs a stretched mesh to position points closer to the shroud wall with only a small increase in the total number of points in the clearance gap.

Differences in the predicted clearance flow result in significantly different rotor performance characteristics in the simulations. For example, the operating range for Rotor 35 (see the graph) will be greatly underestimated from a simulation using Grid A.

Simulations using the improved grid topology, Grid B, demonstrate dramatically better agreement with the data.



Predicted and measured rotor operating range

Additional rotor performance effects, a detailed explanation for the improved solution accuracy, and recommendations for a numerical simulation setup to obtain accurate results are discussed in reference 1.

References

1. Van Zante, D.E., et al.: Recommendations for Achieving Accurate Numerical Simulation of Tip Clearance Flows in Transonic Compressor Rotors. ASME Paper 99–GT–390, 1999.

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