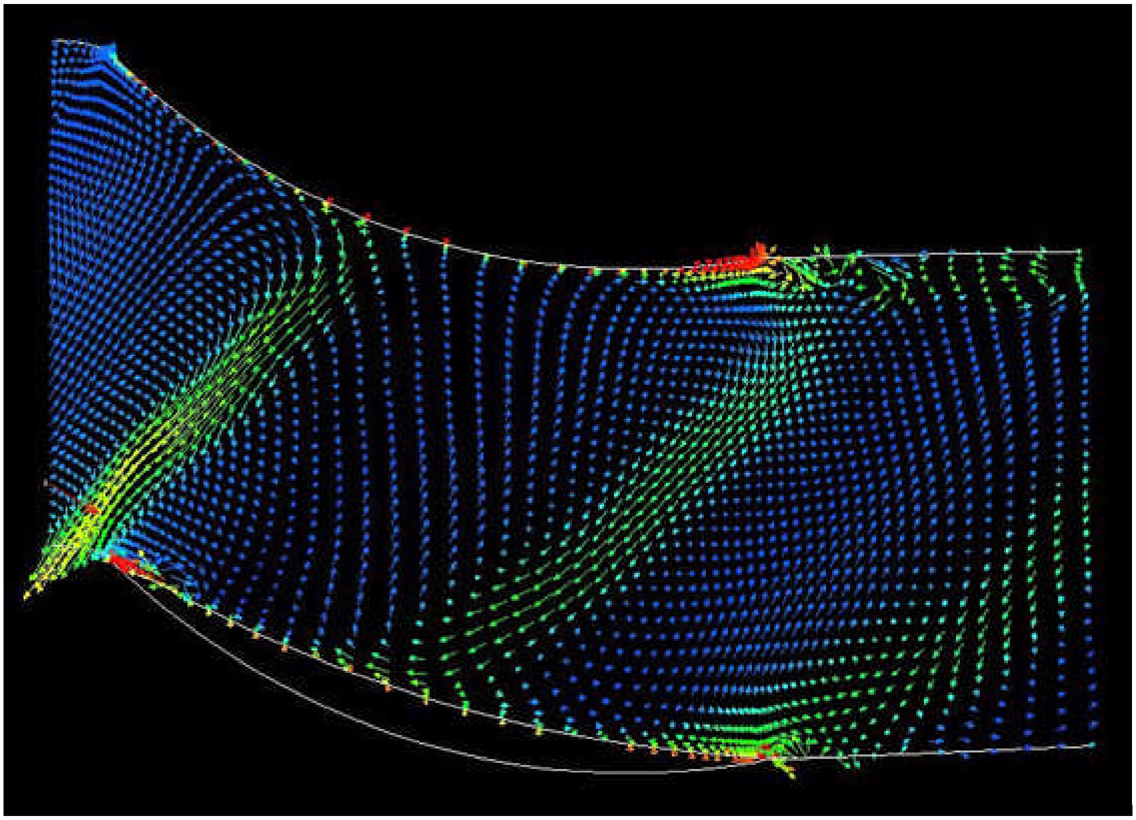
Significance of Compressor Blade Row Interactions on Loss Production Investigated

The performance of compressors and the sophistication of analysis tools have reached a level such that less well understood flow mechanisms are gaining importance to designers. In current design systems, the effect on performance of many of these mechanisms, such as blade row interactions, is not typically addressed rigorously. A detailed set of Laser Doppler Velocimetry data was used to confirm the fidelity of an unsteady model of a transonic compressor stage (rotor-stator) simulated with the TURBO unsteady multistage turbomachinery solver. The kinematics of the velocity field were accurately simulated, and the unsteady simulation was then used to assess changes in loss production due to unsteady blade-row-interaction mechanisms. This work was done at the NASA Glenn Research Center in support of the Ultra-Efficient Engine Technology Program.



Disturbance velocity field of the stator at an instant in time. Velocity vectors are colored by entropy.

The interaction of the upstream rotor wakes with the downstream stator leading edge and boundary layers is an example of a blade row interaction loss. The figure shows a snapshot of the stator flow field from the unsteady simulation at one instant in time. The vectors show the magnitude and direction of the disturbance velocity (instantaneous velocity minus time mean velocity). The vectors are colored by entropy. The rotor wakes appear as regions of high entropy and large disturbance velocity. The vectors show the "negative jet" effect of the rotor wakes on the stator boundary layers. That is, the rotor wakes transport high-entropy stator suction surface boundary layer fluid out into the core flow, and the high-entropy rotor wake fluid accumulates on the stator pressure surface. Also, the large change in incidence angle onto the stator blade as the rotor wake is chopped can cause additional loss over what would be seen in a steady simulation.

The unsteady simulations were analyzed in detail for effects of the stator on the rotor loss production and the impact of the rotor wakes on stator loss production. The overall conclusions follow. Rotor loss production is not significantly affected by the back-pressure variations generated by the presence of the stator. However, it is not known if loss production in an embedded stator is affected by downstream static pressure variations. Time average stator loss is increased because of the rotor wake/stator leading edge interaction and the rotor wake/stator boundary layer interaction. The distribution of losses in the stator is changed significantly, with losses increasing in the pressure surface boundary layer and core flow.

Reference

1. Van Zante, Dale E.; To, Wai-Ming; and Chen, Jen-Ping: Blade Row Interaction Effects on the Performance of a Moderately Loaded NASA Transonic Compressor Stage. ASME Paper GT-2002-30575, 2002.

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