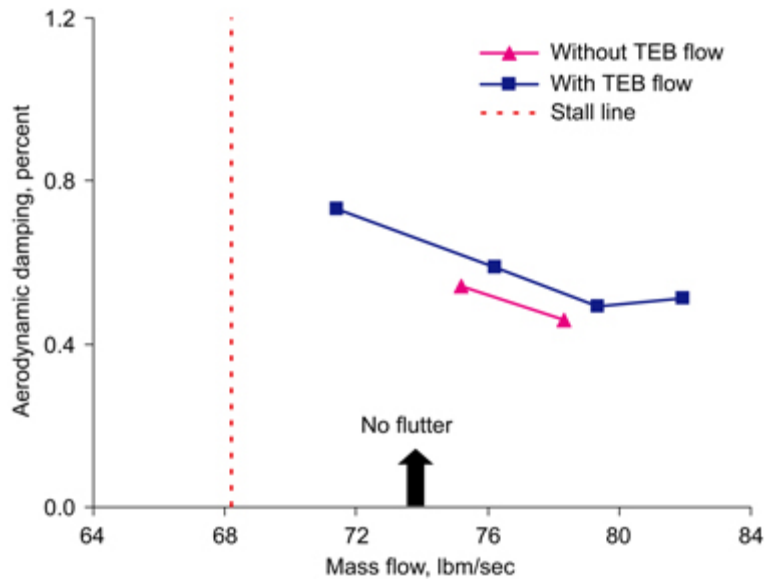


Flutter Stability Verified for the Trailing Edge Blowing Fan

The TURBO-AE aeroelastic code has been used to verify the flutter stability of the trailing edge blowing (TEB) fan, which is a unique technology demonstrator being designed and fabricated at the NASA Glenn Research Center for testing in Glenn's 9- by 15-Foot Low-Speed Wind Tunnel. Air can be blown out of slots near the trailing edges of the TEB fan blades to fill in the wakes downstream of the rotating blades, which reduces the rotor-stator interaction (tone) noise caused by the interaction of wakes with the downstream stators. The TEB fan will demonstrate a 1.6-EPNdB reduction in tone noise through wake filling. Furthermore, the reduced blade-row interaction will decrease the possibility of forced-response vibrations and enable closer spacing of blade rows, thus reducing engine length and weight. The detailed aeroelastic analysis capability of the three-dimensional Navier-Stokes TURBO-AE code was used to check the TEB fan rotor blades for flutter stability. Flutter calculations were first performed with no TEB flow; then select calculations were repeated with TEB flow turned on.

The TEB flow, prescribed as a spanwise variation of flow properties at the trailing edge of the blade, was interpolated onto the TURBO-AE grid. Then, a special-purpose preprocessor was used to convert the flow to source terms. A steady flowfield was computed with TEB flow, using the steady flowfield without TEB flow as the initial guess. A comparison of the flowfields with and without TEB flow showed, as expected, significant differences in the wake region downstream of the trailing edge. With TEB flow, the velocity magnitude was significantly increased in the wake region and the angle of the flow was moderately changed. There was no significant change in either magnitude or flow direction upstream of the trailing edge of the blade.

The blade vibration modeling capability of the TURBO-AE code was used to carry out unsteady flow computations with TEB flow, starting from the steady flowfield calculated as described previously. The aerodynamic damping was calculated when the unsteady flowfield converged to periodicity in time. The graph shows the aerodynamic damping calculated for the two-nodal-diameter pattern bending vibration mode at the takeoff condition. The aerodynamic damping shows a modest increase with TEB flow turned on. The aerodynamic damping is larger than 0.4 percent and shows an increasing trend as the stall line is approached. Thus, for the analyzed takeoff condition and vibration mode, flutter would not be expected. More importantly, the influence of TEB flow on aerodynamic damping and flutter stability was found to be small and stabilizing. Additional flutter calculations need to be carried out to verify that the flutter characteristics are not adversely affected when the TEB flow is turned on for other nodal diameter patterns, vibration modes, and part speed conditions.



Aerodynamic damping for the trailing edge blowing (TEB) fan calculated with the TURBO-AE aeroelastic analysis code.

Long description of figure. The variation of aerodynamic damping with mass flow is shown with and without trailing edge blowing (TEB) flow. With TEB flow, the aerodynamic damping increased by less than 0.1 percent for the conditions analyzed. The stall line is also shown.

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