Interaction of a Mach 2.25 turbulent boundary layer with elastic panels using direct numerical simulation

ABSTRACT
The interaction between thin metallic panels and a Mach 2.25 turbulent boundary layer is investigated using a direct numerical simulation approach for coupled fluid-structure problems; one panel is "thin" and undergoes flutter while a thicker panel does not. The solid solution is found by integrating the finite-strain, finite-deformation equations of elasticity using a non-linear 3D finite element solver, while the direct numerical simulation of the boundary layer uses a finite-difference compressible Navier-Stokes solver. The initially laminar boundary layer contains low amplitude unstable eigenmodes that grow in time and excite traveling bending waves in both panels. As the boundary layer transitions to a fully turbulent state, with momentum thickness-based Reynolds number of approximately 1200, the thinner-panel's bending waves coalesce into a standing wave pattern exhibiting flutter with a final amplitude approximately 20 times the panel thickness. The corresponding panel deflection is roughly 25 wall units and reaches across the sonic line in the boundary layer profile. Once it reaches a limit cycle state, the fluttering panel/boundary layer system is examined in detail where it is found that turbulence statistics, especially the main Reynolds stress \langle u' v' \rangle, appear to be modified by the presence of the compliant panel, the effect of which is forgotten within one turbulence integral length downstream of the panel. These results suggest that RANS models may need to be modified when used for fluid predictions on forthcoming flexible vehicle structures. Future directions needed to enhance our understanding of turbulence-panel interactions will also be given.

BIO
Daniel J. Bodony is the Blue Waters Associate Professor in the Department of Aerospace Engineering at the University of Illinois. He received his Ph.D. in Aeronautics & Astronautics from Stanford University in 2005 and subsequently work with the NASA Ames/Stanford Center for Turbulence Research. He received an NSF CAREER award in 2012 in fluid dynamics. Professor Bodony is a National Defense Science and Engineering Graduate fellow, an AFRL summer graduate fellow, an ARCS fellow, an associate fellow of the AIAA, and is a member of the American Physical Society. He holds courtesy appointments in the Mechanical Sciences & Engineering department, the Parallel Computing Institute, and at NCSA.

Refreshments will be served at 3:45 p.m.
Hosted by Rodney Bowersox