Response Prediction of Compliant Structures in Hypersonic Flow

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Basic Investigations into Fluid-Thermal-Structural Interactions (FTSI) in Hypersonic Flow

STATUS QUO

Industry Treats Loads and Structural Responses Independent

- Compute load cases from operating points on a trajectory • Spot check @ discrete locations

Typical Research in FTSI

• Partially account for some load-response couplings • Demonstrated that FTSI impacts both fluid and structural responses

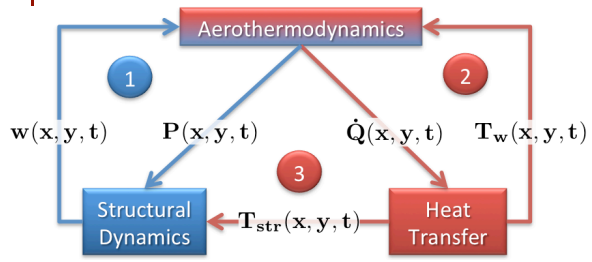
Current Options for More In-Depth FTSI study

• "Brute force" (expensive) • Coupling of a comprehensive set of simple models (gross losses of sub-discipline fidelity)

NEW INSIGHTS

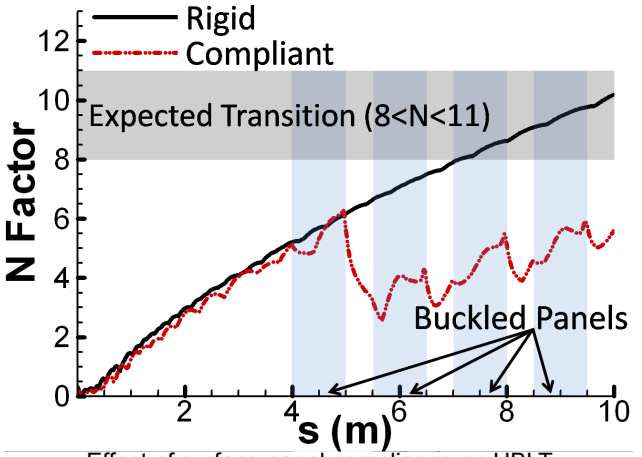
Technical Contribution

• Improved fundamental understanding of the levels of coupling and fidelity needed for reasonably accurate, long time record response prediction in hypersonic flow • Characterization of conditions where thermo-structural compliance is beneficial vs. detrimental vs. a non-issue.



Schematic of Fluid-Thermal-Structural-Interactions (FTSI)

MAIN ACHIEVEMENTS:



Effect of surface panel compliance on HBLT

- Development of simple, reduced-order, and full-order FTSI Models • Improved characterization of coupling between system loads and responses

APPROACH:

- Progressive leveraging of high-fidelity and SOA reduced order models • Identify and capture the applicable physics • Assess the system-level impact of uncertainties in our knowledge of the physics of hypersonic flight

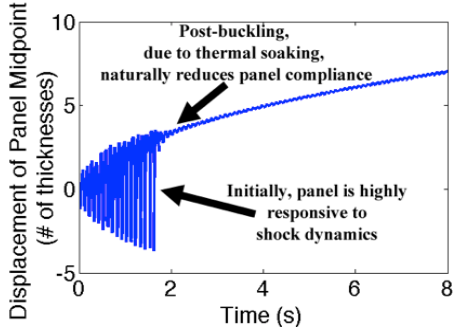
ASSUMPTIONS AND LIMITATIONS:

• Lack and challenge of obtaining experimental data for validation • Coupling makes problem too vast to draw broad conclusions • Obtaining a truly representative structure, without a priori knowledge of the fluid-thermal-structural behavior

IMPACT

Current Impact

• Observation of previously unseen, fluid & structural responses • Formulation of model/coupling reduction strategies to enable in-depth analysis



Center displacement of a compliant panel subject to SBLI

Planned Impact

• Improve our fundamental knowledge of the coupling and fidelity requirements for simulation of dynamic FTSI • Quantify system-level uncertainties using both experimental data and state-of-the-art computational tools• Enable both computation of FTSI over a trajectory, and propagation of uncertainties

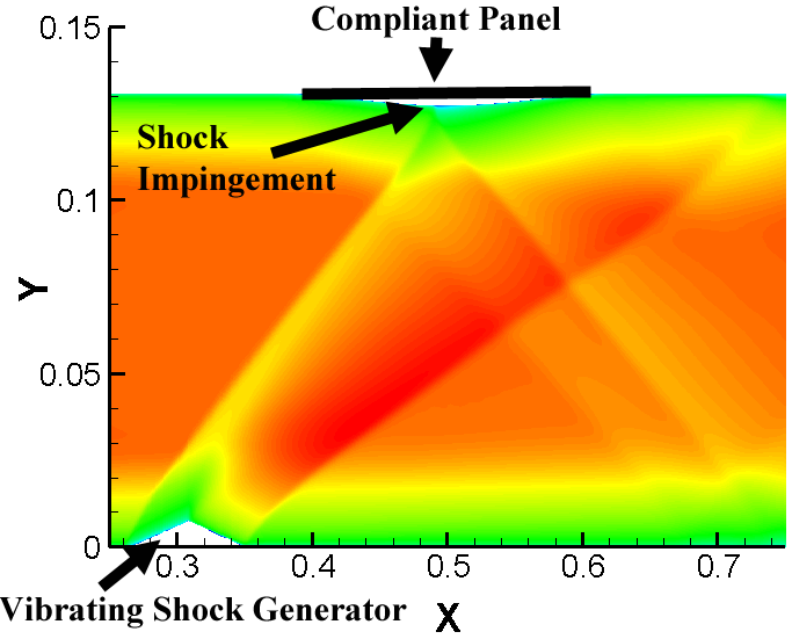
END-OF-PHASE GOAL

Research Goals

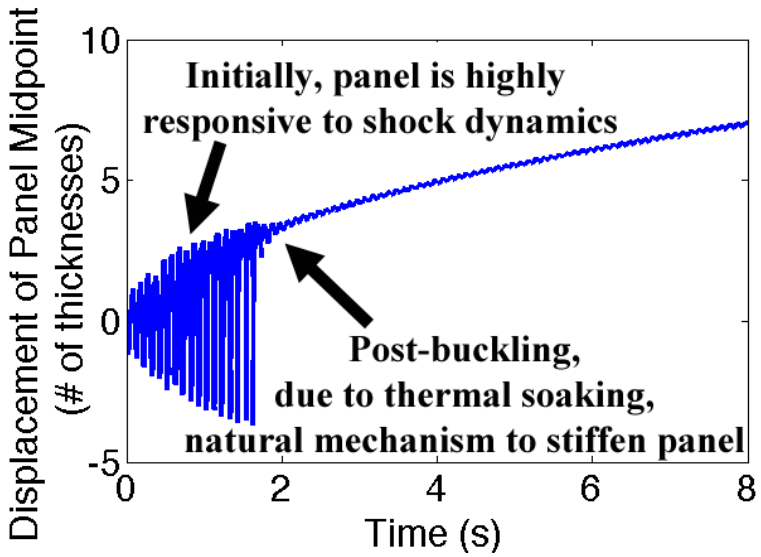
• Multi-scale time marching strategies for FTSI • Development of comprehensive reduced-order models • Impact of FTSI on HBLT • Incorporation of coupled turbulent boundary layer pressure loadings into FTSI analysis

Basic Research on FTSI Suggests Allowing Panel Compliance Improves Strength

Thermally buckled panels show resistance to SBLI[1]



- Lighter structures are more compliant to loads
- Thermal buckling a means to stiffen compliant panels



- Standard is to design away from buckling, which increases weight.

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• Mechanical & Aerospace Engineering
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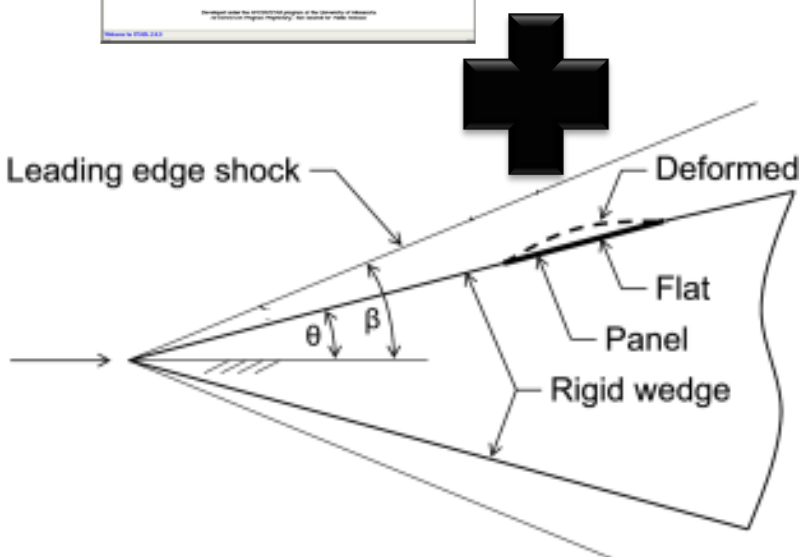
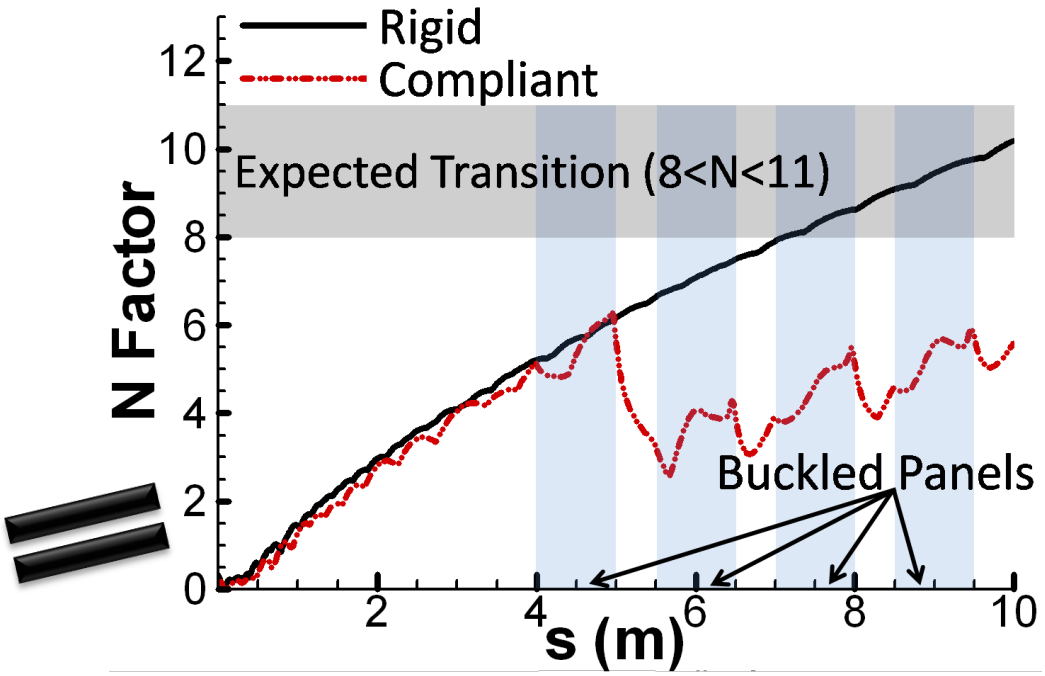
Consideration of Fluid-Thermal-Structural Interactions Enables Revolution

[1]Miller, Crowell, McNamara, "Modeling and Analysis of Shock Impingements on Thermo-Mechanically Compliant Surface Panels, AIAA-2012-1548.

Buckled Surface Panels May *Reduce* Aerodynamic Heating

First of a kind studies reveal a new strategy for simultaneously mitigating vehicle weight and aerodynamic heating





In recent studies, a series of buckled panels predicted to delay transition; which would reduce aerodynamic heating to the vehicle[2]

[2]Riley, Z., McNamara, J., and Johnson, H., "Hypersonic Boundary Layer Stability in the Presence of Thermo-Structural Compliance," AIAA-2012-

Heilmeier's Catechism

Your Highlight Should Answer *the Red* Questions – green (2nd priority) and black (3rd priority) questions are nice, but optional

by George H. Heilmeier, President and CEO of Bellcore

- What are you trying to do? Articulate your objectives using absolutely no jargon.
- How is it done today, and what are the limits of current practice?
- What's new in your approach and why do you think it will be successful?
- Who cares? If you're successful, what difference will it make?
- What are the risks and the payoffs?
- How much will it cost? How long will it take?
- What are the midterm and final "exams" to check for success?

Additionally…

- Does this work address the objectives of the portfolio to which it is being submitted?
- Are there opportunities to collaborate with other efforts – both internally and externally?